The Seeds of a Crisis: A Theory of Bank Liquidity and Risk-Taking over the Business Cycle[1]

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Abstract

We examine how the banking sector may ignite the formation of asset price bubbles when there is access to abundant liquidity. Inside banks, to induce effort, loan officers are compensated based on the volume of loans. Volume-based compensation also induces greater risk-taking; however, due to lack of commitment, loan officers are penalized ex post *only if* banks suffer a high enough liquidity shortfall. Outside banks, when there is heightened macroeconomic risk, investors reduce direct investment and hold more bank deposits. This 'flight to quality' leaves banks flush with liquidity, lowering the sensitivity of bankers' payoffs to downside risks and inducing excessive credit volume and asset price bubbles. The seeds of a crisis are thus sown.

JEL Classifications: E32, G21
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1 Introduction

In the period leading up to the global financial crisis of 2007-2009, credit and asset prices were growing at a ferocious pace.[1] In the United States, for example, in the five-year period from 2002 to 2007, the ratio of debt to national income went up from 3.75 to one, to 4.75 to one. During this same period, house prices grew at an unprecedented rate of 11% per year while there was no evidence of appreciating borrower quality. The median house price divided by rent in the United States[2] over the 1975 to 2003 period varied within a relatively tight band around its long-run mean. Yet starting in late 2003, this ratio increased at an alarming rate. This rapid rise in asset volume and prices met with a precipitous fall. In mid 2006, for instance, the ratio of house price to rent in the United States flattened and kept falling sharply until 2009 (See Figure 1).

What caused this tremendous asset growth and the subsequent puncture is likely to intrigue economists for years. Some have argued that the global economy was in a relatively benign low-volatility environment in the decade leading up to the ongoing crisis (the so-called "Great Moderation", see Stock and Watson, 2002). Others argue that it is likely not a coincidence that the phase of remarkable asset growth described above started at the turn of the global recession of 2001–2002. In response to the unprecedented rate of corporate defaults, a period of abundant availability of liquidity to the financial sector ensued, large bank balance-sheets grew two-fold within four years, and when the "bubble burst", a number of agency problems within banks in those years came to the fore. Such problems were primarily concentrated in centers that were in charge of underwriting loans and positions in securitized assets. Loan officers and risk-takers received huge bonuses based on the volume of assets they originated and purchased rather than on (long-term) profits these assets generated.[3] Reinhart and Rogoff (2008,

[1] The series of facts to follow are borrowed from Acharya and Richardson (2009a).

[2] In particular, this is the ratio of the Office of Federal Housing Enterprise Oversight (OFHEO) repeat-sale house price index to the Bureau of Labor Statistics (BLS) shelter index (i.e., gross rent plus utilities components of the CPI).

[3] See Rajan (2005, 2008) for a discussion of bank-level principal-agent problem – the

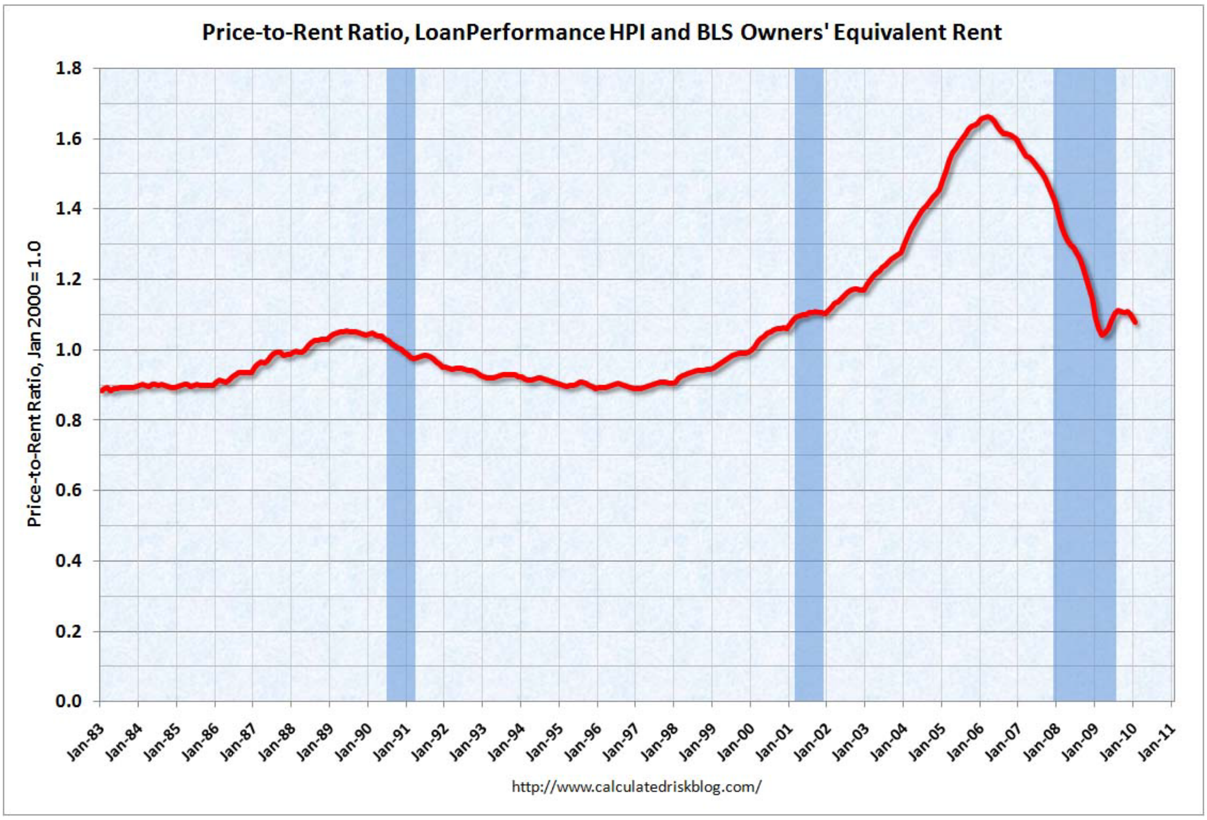

Figure 1: House Price to Rent Ratio. The Figure graphs the value of the ratio of the Office of Federal Housing Enterprise Oversight (OFHEO) repeat-sale house price index to the Bureau of Labor Statistics (BLS) shelter index (i.e., gross rent plus utilities components of the CPI).

2009) document that this lending boom and bust cycle is in fact typical since several centuries, usually (but not always) associated with real estate lending by banks and also often coincident with a surge in capital inflows.

In this paper, we develop a theoretical model that explains why access to abundant liquidity aggravates the risk-taking moral hazard at banks, giving rise to excessive lending and asset price bubbles. We show that this is more likely to happen when the macroeconomic risk is high and investors in the economy switch from direct investments to savings in the form of bank deposits.[4] As banks become flush with liquidity they relax lending standards fueling credit booms and asset price bubbles and sowing seeds of the next crisis.

After providing an informal description of our model in Section 2.1, we develop a benchmark model in Section 2.2 wherein the representative bank collects deposits from investors and then allocates a fraction of these deposits to investment projects. The bank faces random deposit withdrawals and in case of liquidity shortfalls suffers a penalty cost. The penalty cost could be interpreted as the cost of fire sales or alternatively the cost of raising external finance from markets. In order to avoid such costs the bank has an incentive to set aside some reserves (cash and marketable assets or other forms of ready liquidity). The rest of the deposits are invested in projects (e.g. houses) depending on the demand for loans (e.g. mortgages). The bank chooses the optimal lending rate that maximizes its expected profits subject to the depositors' participation constraint. We show in this benchmark model that the bank lending rate appropriately reflects the underlying risk of projects.

In Section 2.3 we enrich the model to study how agency problems within the bank affect the pricing of loans. In practice, bankers and loan officers ("bank managers") often have incentives to give out excessive loans since

"fake alpha" problem when performance is measured based on short-term returns but risks are long-term or in other words in the "tail" – and the role that this problem played in causing the financial crisis of 2007–2009.

[4] In the context of a global economy, this could correspond to heightened precautionary levels of reserves lent by surplus countries to deficit countries, or equivalently through their demand of "safe assets" (Caballero (2010)).

their payoffs are proportional to the amount of loans advanced.[5] We show that such incentives can arise as part of an optimal contracting outcome of a principal-agent problem when managerial action or effort is unobservable. To induce effort, compensation is tied to the volume of loans. This, however, induces incentives to take excessive risks. We assume the principal can conduct a costly audit *ex post* to verify whether or not the manager had acted over-aggressively by lowering the lending rate and sanctioning excessive loans. In particular, subsequent to an audit, if it is inferred that the manager had indeed acted over-aggressively, the manager can be penalized a fraction (or possibly all) of the penalty costs incurred by the bank arising from liquidity shortfalls. We show that even though the principal may want to commit ex ante to a tough audit policy, the costs of the audit imply that it is ex-post optimal for the bank to conduct an audit only if the liquidity shortfall suffered by the bank is large enough.

To summarize, the optimal managerial compensation is increasing in the volume of loans in order to induce effort, but if the manager underprices the risk of the investments (in order to sanction an excessive volume of loans), then he faces the risk of a penalty whenever the bank suffers a significant liquidity shortfall. Hence, when the bank is awash with liquidity, the manager rationally anticipates a lax audit policy and attaches little weight to the scenario where the bank might ex post face liquidity shortfalls. In other words, excessive liquidity encourages managers to disregard downside risk, akin to the moral hazard from insurance of risk, and, in turn, managers increase loan volume and underprice the risk of projects.

We then show in Section 3 that such behavior ultimately has an impact on asset prices. We assume that the demand for loans arises from investments by bank borrowers (the household sector) in underlying assets (houses). We first define "fundamental" asset prices as those that arise in the absence of any agency frictions within banks. We then construct the op-

[5] The Bureau of Labor Statistics reports that "Most (loan officers) are paid a commission based on the number of loans they originate." (See the Bureau of Labor Statistics' Occupational Outlook Handbook, 2008-09 Edition available at http://www.bls.gov/oco/ocos018.htm#earnings.)

timal demand function for assets by bank borrowers and then solve for the asset price given the market clearing condition that the aggregate demand for assets should equal their supply. If the bank lending rate underprices risks, then there is an increase in aggregate borrowing from banks. This in turn fuels an excessive demand for assets by bank borrowers which leads to prices rising above their fundamental values. We interpret this asset price inflation as a "bubble". Importantly, such bubbles are formed only when bank liquidity is high enough as only then do bank managers underprice risk while making loans.

Next, in Section 4 we study under which conditions bank liquidity is likely to be high and thus asset price bubbles most likely to be formed. We show that this is the case when the macroeconomic risk in the economy is high. When macroeconomic risk increases, depositors (more generally, investors) avoid direct risky investments as they cannot contain well the increased corporate or entrepreneurial moral hazard, and prefer to save their money in bank deposits which are perceived to be safer. Gatev and Strahan (2006) offer direct empirical evidence consistent with this effect. They find that banks experience deposit inflows when spreads in the commercial paper market, which proxy for risks of direct investments, widen. They further find evidence that the growth rate of bank loans increases following an increase in market spreads. In our model, such "flight to quality" results in excessive bank liquidity, which induces bank managers to engage in excessive lending, leading to the formation of a bubble and sowing the seeds of a crisis.

In Section 5 we discuss the related literature. Section 6 concludes.

2 The model

2.1 Informal description

Our overall economy consists of several sectors, namely, banking sector, savers, borrowers (both savers and borrowers are referred to as households, for simplicity), and the entrepreneurial sector (corporations, for simplicity).[6]

[6] We do not introduce all interactions across these sectors at once. Instead for pedagogical reasons and clarity of exposition, we introduce them serially, augmenting the current

We start with the banking sector receiving deposits from the savers and determining its loan decisions. We then introduce the borrowers who demand assets (houses) based on borrowing from the bank (mortgages). Given the demand and supply of assets we determine asset prices. Finally, we introduce the corporate sector that can raise direct financing from the savers, and the extent of corporate sector's risk determines what level of bank deposits the savers choose.

In terms of asset-side outcomes, bank liquidity in our model is endogenously chosen by the bank in the form of the optimal level of reserves. However, its primary determinant in our model is the level of bank deposits, D, received by the bank. Hence, instead of referring to the endogenous outcome (i.e. level of reserves) as bank liquidity, we refer to its driver (i.e. level of deposits) as bank liquidity. In the first half of the paper, we take bank liquidity, D, as given. Nevertheless, in Section 4 we endogenize it by considering the risks faced by investors when they make direct entrepreneurial investments as opposed to depositing their endowments in banks.

2.2 Bank lending: Base case

We consider a three-date model of a bank that at $t = 0$ receives deposits D from risk-neutral investors (savers of the economy). For now, D is given. Each investor deposits 1 unit of his endowment in the bank. The reservation utility of depositors is given by $\bar{u}$. Hence in order to secure deposits the bank needs to set the rate of return on deposits, r_D, such that the depositors earn an expected payoff of at least $\bar{u}$.[7]

After receiving deposits the bank makes investments in projects ("loans") while holding a fraction of the deposits as liquid reserves, R. The bank-funded projects either succeed or fail at $t = 2$. The probability of success

model at each step or adding the missing pieces not analyzed till that step.

[7] The reason why banks are "special" in our model is that they can circumvent entrepreneurial moral hazard via monitoring akin to the delegated monitoring argument of Diamond (1984). We assume this for now, but in Section 4 we model dispersed investors who are subject to entrepreneurial moral hazard when they make direct entrepreneurial investments.

of bank projects is given by θ and in the event the project is successful it pays off at $t = 2$. The project is illiquid in the sense that if it were to be liquidated prematurely at $t = 1$, the bank faces a penalty or a liquidation cost. The bank observes θ after receiving deposits and sets r_L which is the (gross) rate of return on loans. When choosing the lending rate, the bank takes into account the demand function for loans (by the households that are borrowers) which is given by $L(r_L)$ where $L'(r_L) < 0$. Bank reserves are the residual after the bank meets the loan demand:

$$R = D - L(r_L).$$

The bank may experience withdrawals at $t = 1$. We assume that the fraction of depositors who experience a liquidity shock and withdraw is a random variable given by $\tilde{x}$, where $x \in [0, 1]$.[8] The cumulative distribution function of $\tilde{x}$ is given by $F(x)$ while the probability distribution function is denoted by $f(x)$. Each depositor who withdraws early receives 1 unit of his endowment back at $t = 1$.[9] Thus the total amount of withdrawals at $t = 1$ is given by $\tilde{x}D$. If the realization of $\tilde{x}D$ is greater than R, then the bank faces a liquidity shortage, and it incurs a penalty, given by $r_p(xD - R)$, which is proportional to the liquidity shortage, where $r_p > r_L > 1$.

The penalty can be justified in a number of ways. The bank may be forced to cover the shortfall in a costly manner by selling some of its assets prematurely at fire-sale prices. This is particularly likely when firms in

[8] As in Allen and Gale (1998) and Naqvi (2007) we could have assumed that $\tilde{x}$ is correlated with asset quality news in the sense that depositors receive a noisy signal of θ on which they base their decision on whether or not to run. While this is more realistic, it does not affect our qualitative results but highly complicates the analysis. Hence similar to Diamond and Dybvig (1983) and Prisman, Slovin and Sushka (1986) we assume that $\tilde{x}$ is random.

[9] More generally, we can assume that an impatient depositor recieves r_1 if he withdraws early since our results are not dependent on r_1 being specifically equal to 1. For tractability, we do not endogenize r_1. It could be thought of as being pinned down to a level (in our case, one) due to a regulatory restriction on "demand deposit" rates or due to government savings scheme rates. Also, in practice when banks fail, depositors are only owed their principal amounts, since the rate r_D adjusts accordingly.

other industries are also facing difficulties.[10] Alternatively the bank can raise external financing via capital markets. However, this is also privately costly because raising equity leads to dilution of existing shareholders due to the debt overhang problem (Myers, 1977). Furthermore, raising external finance may entail a price impact due to the adverse selection problem a la Myers and Majluf (1984). Capital raising can also entail deadweight costs related to monitoring that the new financiers must undertake. Finally, if the bank attempts to cover the shortfall by emergency borrowing from the central bank, this can also be costly as the central bank may charge a penalty rate. And, apart from pecuniary costs, the bank may also suffer non-pecuniary costs such as a reputational cost, e.g., the stigma associated with borrowing from the central bank's emergency facilities.

Reverting to the model, if the projects financed by bank borrowings are successful, then the bank is solvent and is able to repay the patient depositors the promised rate of return of r_D at $t = 2$, whilst the equityholders consume the residual returns. However, in case of the failure of bank-funded projects, the surplus reserves, $R - \tilde{x}D$, if any, are divided amongst the patient depositors whilst the equityholders consume zero. The sequence of events is summarized in the timeline depicted in Figure 2.

Given this setup, the bank owners' problem is as follows:

$$\max_{r_L, r_D, R} \Pi \equiv \pi - r_p E\left[\max\left(\tilde{x}D - R, 0\right)\right] \tag{1}$$

subject to

$$E\left(\tilde{x}\right) + \left(1 - E\left(\tilde{x}\right)\right)\left[\theta r_D + (1-\theta)\frac{E\left[\max\left(R - \tilde{x}D, 0\right)\right]}{\left(1 - E\left(\tilde{x}\right)\right)D}\right] \geq \bar{u}, \tag{2}$$

and

$$L\left(r_L\right) + R = D, \tag{3}$$

[10] Shleifer and Vishny (1992) argue that the price that distressed firms receive for their assets is based on industry conditions. In particular, the distressed firm is forced to sell assets for less than full value to industry outsiders when other industry firms are also experiencing difficulties. There is strong empirical support for this idea in the corporate-finance literature, as shown, for example, by Berger, Ofek, and Swary (1996), Pulvino (1998), Stromberg (2000), and Acharya, Bharath, and Srinivasan (2007). James (1991) provides evidence of such specificity for banks and financial institutions.

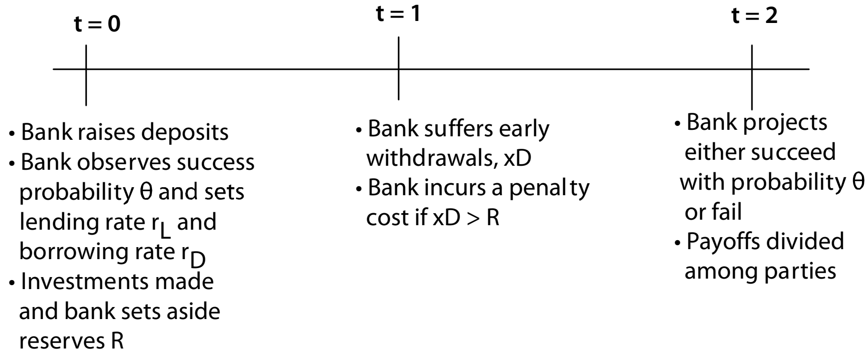

Figure 2: Benchmark model: Timeline of events

where $E(\cdot)$ is the expectations operator over the distribution of $\tilde{x}$, and π is given by

$$\pi = \theta \left\{ r_L L(r_L) - r_D D (1 - E(\tilde{x})) + E\left[\max(R - \tilde{x}D, 0)\right] \right\}. \qquad (4)$$

The above program says that the bank chooses deposit and lending rates as well as the level of bank reserves so as to maximize its expected profits, π, net of any penalty incurred in case of liquidity shortage and subject to the participation constraint of the depositors given by expression (2) and the budget constraint given by (3). A depositor withdraws his funds early with a probability of $E(\tilde{x})$ in which case he receives a payoff of 1. With a probability of $(1 - E(\tilde{x}))$ the depositor does not experience a liquidity shock in which case he receives a promised payment of r_D if the bank projects succeed (which is with probability θ). In case of the failure of bank investments (which happens with probability $1-\theta$), any surplus bank reserves are divided amongst the patient depositors. Thus expression (2) states that the depositors must on average receive at least their reservation utility. Equation (3) represents the budget constraint of the bank which simply says that the sum of loan volume and bank reserves equal the total deposits received by the bank. Equation (4) represents the expected profit of the bank exclusive of the penalty costs. With probability $(1 - \theta)$ bank profits are zero since the bank-funded projects fail. With probability θ the projects succeed in which case the bank's expected profit is given by the expected return from the loans ($r_L L(r_L)$) minus the expected cost of deposits ($r_D D[1 - E(\tilde{x})]$) plus the expected value of net reserve holdings at the end of the period (which is given by the last term of the equation).[11]

We solve the bank's optimization problem and derive the first-best lending rate, deposit rate, and level of bank reserves. The results are summarized in Proposition 1.

Proposition 1 *1. The optimal gross lending rate is given by*

$$r_L^* = \frac{1 + (r_p - 1)\Pr(\tilde{x}D \geq R^*)}{\theta\left(1 - \frac{1}{\eta_L}\right)} \tag{5}$$

where $\eta_L = -r_L L'(r_L)/L > 0$ *is the elasticity of the demand for loans. The optimal gross deposit rate is given by*

$$r_D^* = \frac{(\bar{u} - E(\tilde{x}))D - (1-\theta)E[\max(R^* - \tilde{x}D, 0)]}{\theta(1 - E(\tilde{x}))D}. \tag{6}$$

And, the optimal level of reserves is given by

$$R^* = D - L(r_L^*).$$

2. *(Risk effect)* $\frac{\partial r_L^*}{\partial \theta} < 0$, *i.e., an increase in risk* $(1-\theta)$*, ceteris paribus, increases the equilibrium lending rate.*

3. *(Liquidity effect)* $\frac{\partial r_L^*}{\partial D} < 0$, *i.e., an increase in bank liquidity, ceteris paribus, decreases the equilibrium lending rate.*

It is interesting to note that as the elasticity of demand for loans decreases, the lending rate increases and hence the spread between the loan

[11] Note that for simplicity we have considered a setup with a given penalty cost. In the online appendix, we consider a setup wherein the penalty costs are explicitly calculated in an environment where the bank finances the shortfall by selling its assets at an interim date at fire-sale prices. We show that in this three-period environment, the objective function of the bank is analogous to equation (1) and is given by π minus a cost term which is proportional to the bank's liquidity shortfall. Since our qualitative results remain unchanged, we use the simpler setup given its parsimony and tractability.

rate and deposit rate increases. This result is consistent with the Monti-Klein (Klein, 1971 and Monti, 1972) model. The second and third parts of the proposition are also intuitive. The lending rate prices both project risk and bank liquidity. An increase in liquidity lowers the expected penalty cost of liquidity shortage and the bank passes some of this benefit to the borrowers via a lower loan rate.

2.3 Agency problem at banks and over-lending

2.3.1 Setting of the problem

We now consider agency issues between the bank owners and the bank manager. A study by OCC (1988) found that "Management-driven weaknesses played a significant role in the decline of 90 percent of the failed and problem banks the OCC evaluated... directors' or managements' overly aggressive behavior resulted in imprudent lending practices and excessive loan growth." They also found that 73% of the failed banks had indulged in over-lending. This suggests that principal-agent problems within banks have been one of the key reasons for bank failures and that bank managers often tend to engage in 'overly aggressive risk-taking behavior'.[12] Similar evidence is presented by the financial crisis of 2007-2009 which has revealed that in the period preceding the crisis, mortgage lenders, traders and large profit/risk centers at a number of financial institutions received substantial bonuses based on the size of their risky positions rather than their long-run profitability. Moreover, in many cases, it was a conscious choice of senior management to silence the risk management groups that had spotted weaknesses in the portfolio of building risks.[13]

[12] The OCC's study is based on an analysis of banks that failed, became problems and recovered, or remained healthy during the period 1979-1987. The study analysed 171 failed banks to identify characteristics and conditions present when the banks deteriorated.

[13] See Chapter 8 of Acharya and Richardson (2009b), which contains a detailed account of governance and management failures at a number of financial institutions. The most detailed evidence is for UBS based on its "Shareholder Report on UBS's Write Downs" prepared in 2008 for the Swiss Federal Banking Commission. Ellul and Yerramilli (2010) provide empirical evidence that the worst-performing bank-holding companies during 2007-08 had the weakest internal risk controls.

To study how managerial agency problems can have an effect on bank lending policies, we model the agency problem within banks explicitly. Let e denote the unobservable effort level of the manager, such that $e \in \{e_L, e_H\}$. We assume that although the loans are affected by effort, they are not fully determined by it. The stochastic relationship is necessary to ensure that effort level remains unobservable. We assume that the distribution of loan demand $L(r_L)$ conditional on e_H first-order stochastically dominates the distribution conditional on e_L. In other words, for a given level of lending rate, the manager on average makes a higher volume of loans when he exerts high effort relative to the case where he exerts lower effort, i.e., $\dot{E}[L(r_L)|e_H] > \dot{E}[L(r_L)|e_L]$, where $\dot{E}(\cdot)$ represents the expectations operator over the range of values of L.

As is standard in the literature, it is easy to show that if the principal wants to implement low effort then it would offer a fixed wage to the manager such that the wage satisfies the managers' participation constraint. This will be optimal only if the gains from the lower wage costs of inducing low effort outweigh the costs associated with lower profits. However, as discussed in footnote 5, data from the Bureau of Labor Statistics indicates that most loan officers are paid a commission based on the number of loans they originate. In other words loan officers are given an incentive to exert high effort to sell loans. Thus, henceforth we will focus on the case where it is in the interest of the principal to implement high effort.

The manager earns an income, b, which can be interpreted as bonuses but he faces a penalty, ψ, if the principal conducts an audit and it is revealed that the manager had acted over-aggressively to increase loan volume by setting a loan rate lower than the one that maximizes the principal's expected profits. The managerial penalty is some proportion, γ, of the penalty cost incurred by the bank due to liquidity shortfalls. However, given limited liability the maximum penalty that can be imposed on the manager is given by $\bar{\psi}$. In other words the managerial penalty is given by $\psi = \min\left(\bar{\psi}, \gamma r_p S\right)$, where $S = \max(xD - R, 0)$ represents the liquidity shortfall, if any, and $\gamma \in (0, 1]$.[14] Thus the net wage earned by the manager is given by $w = b - \psi$.

[14]More simply we can just assume that $\psi = \min\left(\bar{\psi}, r_p S\right)$, i.e., the manager bears the

Audits are costly and the cost of an audit is given by z. The audit probability is given by ϕ. While the incentive pay or bonuses can be contractually committed at $t = 0$ (else principal would never pay ex post), the principal cannot commit to conduct an audit in all states of the world and thus the audit policy is set in a time-consistent or subgame-perfect fashion based on the realization of the liquidity shortfall at $t = 1$. Tirole (2006) refers to this as the *topsy-turvy* problem of corporate governance (which our audit policy can be interpreted more generally as): The principal would like to commit to a tough audit policy but since implementing the audit policy is costly, it will do so ex post only if it is desirable at that point of time.

Finally, the manager is an expected utility maximizer with a Bernoulli utility function $u(w, e)$ over his net wages w, and effort e, where $u_w(w, e) > 0$, $u_{ww}(w, e) < 0$, and $u_e(w, \psi, e) < 0$ (the subscripts denote the partial derivatives). This implies that the manager prefers more wealth to less, is risk averse, and dislikes high effort. More specifically we assume that $u(w, e) \equiv v(w) - e$, where $v'(w) > 0$, $v''(w) < 0$. The manager's reservation utility is given by u^o.

2.3.2 Symmetric-information problem

As a benchmark, assume principal has same information as the manager. In this symmetric information case, the possibility of manager being penalized for over-lending implies that there is no agency problem and the bank's problem is analogous to that of Section 2.2 with the bank maximizing[15]

$$\Pi = \pi - r_p \hat{E}\left[\max\left(\tilde{x}D - R, 0\right) | e = e_H\right] \tag{7}$$

entire penalty if he is punished subject to a limited liability constraint. This will not alter any of our results.

[15]It should be noted that maximizing Π as given by (7) is equivalent to maximizing $\Pi - w$ as long as w is a constant. It is straightforward to show that under symmetric-information the optimal wages offered to the manager are such that the wages are constant so as to ensure that the risk-averse manager does not bear any risk. Thus to make the problem directly comparable to that in Section 2.2 we write the maximand as in (7).

subject to the following participation constraint

$$\hat{E}(\tilde{x})+\left(1-\hat{E}(\tilde{x})\right)\left[\theta r_D+(1-\theta)\frac{\hat{E}\left[\max\left(R-\tilde{x}D,0\right)|e=e_H\right]}{\left(1-\hat{E}(\tilde{x})\right)D}\right]\geq\bar{u},\quad (8)$$

and the following budget constraint

$$L(r_L)+R=D, \qquad (9)$$

where π is given by

$$\pi=\theta\left\{r_L\hat{E}\left[L(r_L)|e_H\right]-r_D D\left(1-\hat{E}(\tilde{x})\right)+\hat{E}\left[\max\left(R-\tilde{x}D,0\right)|e=e_H\right]\right\}, \qquad (10)$$

and $\hat{E}(\cdot)$ represents the expectations operator over the range of values of x and L.[16] The first-best lending rate analogous to equation (5) is given by

$$r_L^f=\frac{1+(r_p-1)\Pr\left[(\tilde{x}D\geq R)|e=e_H\right]}{\theta\left(1-\frac{1}{\bar{\eta}_L}\right)} \qquad (11)$$

where $\bar{\eta}_L=-r_L\frac{\hat{E}[L(r_L)|e_H]/\partial r_L}{\hat{E}[L(r_L)|e_H]}>0$.

2.3.3 Contractual problem under asymmetric information

Next, we allow for asymmetric information which introduces the agency problem. The manager can observe the quality of the project, θ, and also the specific level of bank deposits, D, at the time of setting the loan rate. However, this information is not available to the principal at the time of setting the contract. Hence, the principal cannot 'infer' whether or not the manager had acted over-aggressively by setting a loan rate lower than the

[16] Note that $\hat{E}(x)=\int\limits_L\int\limits_x xf(x)\,g(L)\,dxdL=\int\limits_x xf(x)\,dx=E(x)$,where $g(L)$ is the pdf of L. The second equality holds since x and L are independent and since $\int\limits_L g(L)\,dL=1$. Thus $E(x)=\hat{E}(x)$. Similarly we can write $\dot{E}(L)=\hat{E}(L)$. In other words since both the expectations operators, E and $\dot{E}$, are subsumed by $\hat{E}$, for consistency of notation we write the entire problem in terms of $\hat{E}$.

one that maximizes its expected profits (unless the principal conducts an audit at $t = 1$).

Let the distribution of bank deposits be given by $H(D)$. We assume that the principal does not observe project quality (θ), does observe the distribution of bank deposits ($H(D)$) (rather than its exact level), and that liquidity also is non-verifiable ex post. This is plausible given that in reality liquidity can take several forms and managers have great flexibility in where to "park" liquidity. For example, bank liquidity may be lent out to other banks via the interbank market or conversely it may be the excess liquidity of other banks that makes its way to the bank in question. It is also particularly difficult to verify off-balance sheet liquidity which may take the form of unused loan commitments or repurchase agreements or exposure to recourse from special purpose vehicles.

Thus, the time line is as depicted in Figure 3. The chronology of events at $t = 0$ is as follows: Principal offers contract to manager (such that e_H is chosen); manager chooses effort; manager receives deposits, D, and observes project risk θ; and finally, manager sets the loan rate, r_L, and the deposit rate, r_D. At $t = 0.5$, for a given level of r_L the volume of loans $L(r_L)$ will be realized, investments are made and reserves are set aside. As before, at $t = 1$ there may be early withdrawals which can lead to a liquidity shortfall and penalty for the bank. The principal then decides whether or not to conduct an audit. If an audit is conducted the manager may be penalized depending on the inference obtained from the audit outcome. Finally, the payoffs are realized at $t = 2$ and divided between the parties given the contractual terms. It should be noted that at the time of contracting the manager has not yet received deposits and that he sets the lending rate only *after* deposits have been received and *after* observing project risk. This implies that when setting the lending rate the manager takes into account the level of bank liquidity, D, and project risk, θ. However, this information is not available to the principal at the time of contracting and hence the principal cannot enforce the optimal lending rate via an incentive compatibility condition.

In this asymmetric information setting, the contract that the principal offers the manager specifies the compensation of the manager in the form of

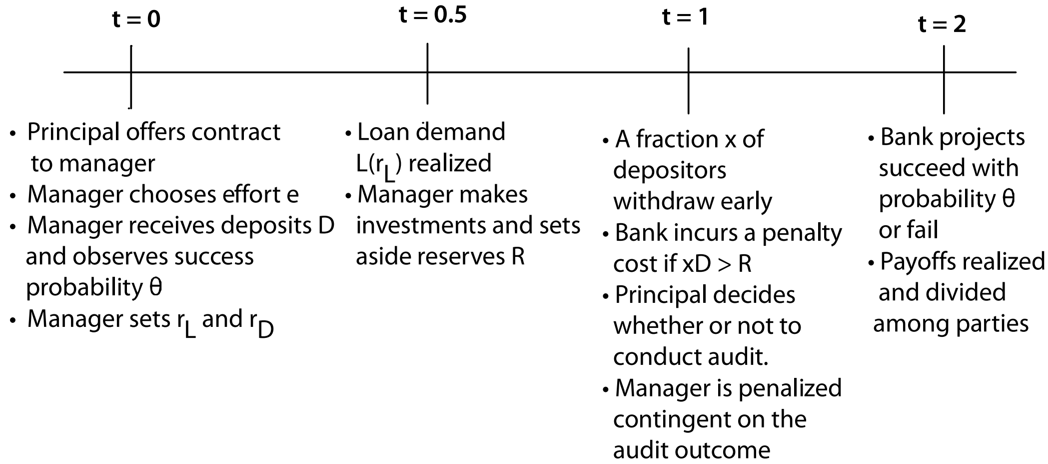

Figure 3: Timeline of events under asymmetric information.

bonuses, b, penalties, ψ, as well as the "audit policy", ϕ. The audit policy is the likelihood with which the principal audits at $t = 1$ and under which scenarios. As stressed above, since audit is costly, we consider time-consistent audit policies only. Furthermore, when computing the optimal compensation scheme the principal anticipates outcomes over different realizations of liquidity levels, D. After characterizing the optimal compensation scheme below we then study the impact of the different realizations of liquidity levels on managerial lending and asset prices.

More specifically, the principal needs to solve the following program:

$$\max_{b,\psi,\phi} \Pi - \bar{E}\left(b - \psi\right) - \bar{E}\left(z\right) \tag{12}$$

subject to

$$\bar{E}\left[v\left(b - \psi\right)\right] - e \geq u^{o}, \tag{13}$$

$$\bar{E}\left[u|e_H\right] \geq \bar{E}\left[u|e_L\right], \tag{14}$$

$$\psi \leq \min\left(\bar{\psi}, \gamma r_p S\right), \tag{15}$$

and

$$\phi \in \left[0, 1\right], \tag{16}$$

where $\bar{E}(\cdot)$ represents the expectations operator over the range of values of x, L, and D. The above program says that the principal chooses a compensation schedule so as to maximize his expected profits minus the expected compensation of the manager and minus the expected audit costs subject to a number of constraints. Constraint (13) is the participation constraint which says that the manager's expected utility must be at least equal to his reservation utility. Constraint (14) is the incentive compatibility constraint for inducing high managerial effort. Constraint (15) says that the managerial penalty cannot exceed $\min\left(\bar{\psi}, \gamma r_p S\right)$. In fact this constraint will hold with equality. Finally, constraint (16) imposes the condition that the probability of an audit lies between zero and one. We can then prove the following proposition.

Proposition 2 *The managerial compensation contract is such that bonuses, b, are increasing in loan volume, L. Furthermore, the principal conducts an audit at $t = 1$ if and only if the liquidity shortfall suffered by the bank exceeds some threshold S^*. In other words, the optimal audit policy conditional on the realization of liquidity shortfall S is given by*[17]

$$\phi|S = \begin{cases} 1 & \text{if } S > S^* \\ 0 & \text{otherwise} \end{cases}.$$

The intuition is straightforward. Managerial bonuses are increasing in loan volume because the manager needs to be incentivized for exerting effort. By verifying whether or not the agent had acted over-aggressively when liquidity shortfalls are substantial ($S > S^*$) and punishing him with the maximum penalty if it is inferred that he had underpriced risk, the principal discourages the agent from setting a suboptimal loan rate. Importantly, if there are no liquidity shortfalls or liquidity shortfalls are minimal ($S < S^*$), then that sends a signal to the principal that the manager was less likely to have acted over-aggressively and to have reserved sufficient liquidity. Thus, in the absence of liquidity shortfalls there is not adequate "return" to the

[17] One can interpret $\phi|S$ as the 'ex post audit probability', i.e., conditional on the realization of S: the audit probability is equal to 1 if $S > S^*$ and zero otherwise. This implies that the 'ex ante audit probability' at $t = 0$ is given by $\Pr(S > S^*)$.

principal from incurring the cost of an audit. More generally, hence, there is no incentive ex post to conduct an audit unless liquidity shortfalls are sufficiently large.

The presence of a penalty upon audit creates a trade-off for the manager. The manager can increase his payoffs by setting a low loan rate and increasing the loan volume. But, an increase in loan volume can trigger a liquidity shortfall and subsequently the manager faces the risk of being audited and penalized. We exploit this trade-off below in Proposition 4 where we show that once the manager receives deposits, the threat of being penalized ex post implies that the manager will take into account the level of bank liquidity when deciding whether to under-price loan risk. In particular, we show the manager will under-price loan risk only when bank liquidity is sufficiently high so that he is "insured" against the downside risk of loans.

2.3.4 Optimal loan rate under asymmetric information

Note that in the presence of asymmetric information, if the manager does not act over-aggressively and consequently acts in the interest of the principal then he solves the following problem for a given realization of D:

$$\max_{r_L^{na}} \pi - r_p \hat{E}\left[\max\left(\tilde{x}D - R, 0\right)|e = e_H\right] - \hat{E}\left[b + z|e = e_H\right] \tag{17}$$

subject to the participation constraint

$$\hat{E}\left(\tilde{x}\right) + \left(1 - \hat{E}\left(\tilde{x}\right)\right)\left[\theta r_D + (1-\theta)\frac{\hat{E}\left[\max\left(R - \tilde{x}D, 0\right)|e = e_H\right]}{\left(1 - \hat{E}\left(\tilde{x}\right)\right)D}\right] \geq \bar{u}$$

and the budget constraint

$$L\left(r_L^{na}\right) + R = D,$$

where π is given by equation (10). In other words a manager acting in the interests of the principal chooses a loan rate so as to maximize the gross profit of the bank net of the expected penalty costs associated with liquidity shortfalls, and net of the expected wage and audit costs faced by the principal, and subject to the depositors' participation constraint and the bank's budget constraint. Note that if the manager is not acting over-aggressively he does not incur any penalty costs subsequent to an audit and thus the expected managerial penalty cost is zero conditional on the manager not acting over-aggressively.

The optimal loan rate under asymmetric information is then given by the following proposition.

Proposition 3 *In the presence of asymmetric information if the manager does not act over-aggressively and hence there is no agency problem then he chooses a lending rate, r_L^{na}, such that (for a given D)*

$$r_L^{na} = r_L^f + \frac{\frac{\partial \hat{E}[b+z|e=e_H]}{\partial r_L}}{\theta \frac{\partial \hat{E}[L|e=e_H]}{\partial r_L}} \tag{18}$$

where r_L^f, the first-best rate, is given by expression (11) so that $r_L^{na} > r_L^f$.

Note that the lending rate set by the manager in the presence of asymmetric information but in the absence of agency problems is higher than the first-best rate. This is because both wage and audit costs are decreasing in the loan rate. An increase in the loan rate lowers the loan volume and thus lowers the wage costs given that managerial bonuses are increasing in loan volume. Furthermore a reduction in loan volume lowers the probability of liquidity shortfalls and thus decreases the expected audit costs. Consequently a manager acting in the interests of the principal will set a loan rate, r_L^{na}, which is higher than the first-best rate. In other words, in the presence of asymmetric information, the optimal loan rate that maximizes the principal's expected profits is given by the second-best rate, r_L^{na}, which is higher than the first-best rate.

2.3.5 Liquidity-induced agency problem

Reverting to the asymmetric information case with agency problem, we analyze when the manager will engage in "overly-aggressive behavior". More specifically, we define "overly-aggressive behavior" on the part of the manager as follows.

Definition 1 *A bank manager is said to engage in "overly-aggressive behavior" when he sets a loan rate, r_L^a, such that $r_L^a < r_L^{na}$ where r_L^{na} is the optimal loan rate that maximizes the principal's expected profits in the presence of asymmetric information.*

Given the results that optimal wages are increasing in loan volume and that an audit is triggered only when liquidity shortfall is sufficiently high, we can then prove the following proposition.

Proposition 4 *The manager will engage in overly-aggressive behavior if and only if bank liquidity, D, is sufficiently high.*[18]

This proposition says that for high enough bank liquidity the manager has an incentive to sanction excessive loans by setting a loan rate lower than the one that maximizes the principal's expected profits. In other words, the agency problem is only actuated when bank liquidity or level of deposits (D) is high enough. This is because even though the manager bears a proportion of the penalty costs, in the presence of excessive liquidity, the probability of experiencing a liquidity shortage is low. As argued above (Proposition 2), with low or no liquidity shortage, it is not ex post efficient for the principal to incur the costs of an audit. This encourages the manager to engage in excessive lending. Put another way high liquidity has an 'insurance effect' on the manager: the manager's compensation becomes more sensitive to loan volume - and less sensitive to the liquidity risk of loans - when liquidity is high, incentivizing him to lend below r_L^{na} to make more loans. In contrast, for low enough liquidity the agency problem is not actuated and the manager does not sanction excessive loans for fear of incurring a penalty in the event of a liquidity shortfall which is now more likely.[19]

[18] It can also be shown that if bank liquidity, D, is high enough the loan rate that the manager sets will not only be below r_L^{na} but also below the first-best rate r_L^f. More specifically, if D^* is the liquidity level above which the manager sets a loan rate below r_L^{na}, then there exists a liquidity level D^{**} above which $r_L^a < r_L^f$, where $D^{**} > D^*$.

[19] As discussed in Section 2.1, in our model the level of deposits is interpreted as bank liquidity. However, another notion of bank liquidity is the ease with which banks can sell their assets. This notion of 'asset market liquidity' can be captured by the penalty

Note that due to the manager's limited liability there is an upper bound on the penalty that can be imposed on the manager. For any finite level of penalty the agency problem is actuated if bank liquidity is sufficiently high. More precisely, as shown in the proof to Proposition 4, for any finite ψ there exists a level of bank liquidity, D, above which the agency problem is actuated. If there were no upper bound on the managerial penalty the principal could implement the optimal loan rate by imposing an arbitrarily large penalty if it was inferred that the manager had acted over-aggressively. However, limited liability on the part of the manager implies that such extreme punishments cannot plausibly be implemented and consequently agency problems will arise for high enough levels of bank liquidity.[20]

3 Asset pricing and bubbles

Next we introduce an asset market to the model and consider the asset pricing implications of our results. We define the fundamental asset price as the price that would arise in the absence of any distortions created by

cost incurred by the bank when it attempts to meet its short-term obligations. The lower this penalty cost, the more liquid would be the bank's assets. Recall that the bank's penalty cost is given by $r_p (xD - R) = r_p [L - D(1-x)]$ since $R = D - L$. Then note that the higher the level of bank deposits, D, the lower are the penalty costs incurred by the bank and hence the higher is the asset market liquidity. Hence our definition of bank liquidity is also consistent with the notion of asset market liquidity. Furthermore, it is not difficult to show that the lower is the penalty cost parameter, r_p, the lower is the cost of liquidity shortfalls and hence the more likely it is the case that the manager will act over-aggressively. Hence, even if we solely focus on the measure of asset market liquidity as captured by r_p we would get the similar result that an increase in (asset market) liquidity increases the likelihood that the manager will act over-aggressively.

[20] For tractability, we assumed that the audit technology is perfect as in Townsend (1979) and Gale and Hellwig (1985). In the presence of an imperfect audit technology, the manager could be penalized even if he had not acted over-aggressively. Under this scenario if the managerial penalty were extremely large it would fail to satisfy the manager's participation constraint since the risk-averse manager would face the risk of being penalized heavily even if he had not acted over-aggressively. Thus extremely high managerial penalties are in general not feasible either due to manager's limited liability and/or because they violate the manager's participation constraint.

agency problems. We then compare the fundamental asset price with the actual asset price which may or may not be distorted depending on whether or not agency problems have been actuated within the banking system. To facilitate this comparison we first model the asset demand by bank borrowers which was so far taken as given.

We assume that there exists a continuum of risk-neutral borrowers (e.g., home-owners or households) who have no wealth and hence need to borrow in order to finance assets (homes, cars, etc.). We analyze the behavior of a representative borrower. This implies that the equilibrium is symmetric and that all borrowers choose the same portfolio. This also implies that the bank cannot discriminate between borrowers by conditioning the terms of the loan on the amount borrowed or any other characteristic. Hence, borrowers can borrow as much as they like at the going rate of interest.

The asset returns a cash flow (or cash flow equivalent of consumption) of C per unit with a probability of θ, where as defined earlier in section 2.2, θ is the success probability of projects. We make the usual assumption that the cash flow, C, is sufficiently high so that the borrower earns a positive payoff net of any investment costs conditional on the success of the project. Let P denote the price of one unit of the asset. Let X_d denote the number of units of the asset demanded by the representative borrower and $\tilde{X}_s(P)$ denote the total supply of the risky asset. The supply of the asset, $\tilde{X}_s(P)$, is stochastic. Furthermore, $X'_s(P) > 0$ for any realization $X_s(P)$. In words, if house prices are high for instance, there is greater construction of homes and hence the supply of houses increases. As in Allen and Gale (2000) we assume the borrowers face a non-pecuniary cost of investing in the risky asset $b(X_d)$ which satisfies the usual neoclassical properties: $b(0) = b'(0)$, $b'(X_d) > 0$ and $b''(X_d) > 0$ for all $X_d > 0$. The purpose of the investment cost is to restrict the size of the individual portfolios and to ensure the concavity of the borrower's objective function. Risk aversion on part of borrowers would lead to similar results.

The optimization problem faced by the representative borrower is to choose the amount of borrowing so as to maximize expected profits:

$$\max_{X_d} \theta \left[C X_d - r_L P X_d \right] - b\left(X_d\right). \tag{19}$$

Note that the borrower has to pay an interest of r_L on its borrowing as offered by the bank at $t = 0$. The market-clearing condition for the asset is:

$$X_d = X_s. \tag{20}$$

The first-order condition of the problem (19) is as follows:

$$\theta \left[C - r_L P \right] - b'\left(X_d\right) = 0 \tag{21}$$

Solving for P, we obtain that

$$P = \frac{\theta C - b'\left(X_d\right)}{\theta r_L}. \tag{22}$$

Finally, setting $X_d = X_s$ and letting $\tau\left(X_d\right) = b'\left(X_d\right)$ denote the marginal investment cost, the equilibrium unit asset price is given by the fixed-point condition:

$$P^* = \frac{\theta C - \tau\left(X_s\left(P^*\right)\right)}{\theta r_L}. \tag{23}$$

As expected, the asset price is the discounted value of the expected cash flows net of the investment cost. Also, there is a one-to-one mapping from the (gross) lending rate, r_L, to the asset price, P. To see this, take the derivative of the equilibrium asset price with respect to the loan rate:

$$\frac{dP^*}{dr_L} = -\frac{C}{r_L^2} + \frac{\tau\left(X_s\left(P^*\right)\right)}{\theta r_L^2} - \frac{\tau'\left(X_s\left(P^*\right)\right) X_s'\left(P\right)}{\theta r_L} \frac{dP^*}{dr_L}.$$

Therefore,

$$\frac{dP^*}{dr_L} \left[1 + \frac{\tau'\left(X_s\left(P^*\right)\right) X_s'\left(P\right)}{\theta r_L} \right] = -\frac{P^*}{r_L}.$$

Since $b''(\cdot) = \tau'(\cdot) > 0$, $X_s'(\cdot) > 0$ and $P^* \geq 0$, it follows that $\frac{dP^*}{dr_L} < 0$. In turn, $\frac{dX_s(P^*)}{dr_L} < 0$. Note that market-clearing implies a demand function, $X_d\left(r_L\right)$ for any realization $X_s\left(P\right)$, which is given by $X_d\left(r_L\right) = X_s\left(P^*\left(r_L\right)\right)$ and is decreasing in r_L.

Let r_L^{na} denote the fundamental (gross) lending rate which is the rate obtained in the absence of any agency problems. Recall that r_L^{na} is given by expression (18). Then the fundamental asset price is given by the fixed-point condition:

$$\bar{P} = \frac{\theta C - \tau\left(X_s\left(\bar{P}\right)\right)}{\theta r_L^{na}}. \tag{24}$$

Having derived the fundamental asset price we can next define an asset price bubble. An asset price *bubble* is formed whenever $P^* > \bar{P}$ since the asset is overpriced. Note that $P^* > \bar{P}$ as long as $r_L < r_L^{na}$. A lending rate lower than the fundamental rate creates a high demand for the asset which leads to an increase in asset prices over and above the fundamental values.

From Proposition 4 we know that for high enough bank liquidity ($D > D^*$) an agency problem is actuated and as a result the loan rate set by the manager is lower than the fundamental rate. Thus, we immediately have the following corollary to Proposition 4.

Corollary 1 *In the presence of an agency problem between the bank manager and the equityholders, an asset price bubble is formed for high enough bank liquidity.*

To better understand the mechanics behind the formation of a bubble, the four-quadrant diagram in Figure 4 is useful. Quadrant I in the figure depicts the relationship between the risk of project failure, $(1-\theta)$, and the loan rate, r_L, charged by the bank. In general the higher this risk the higher would be the equilibrium lending rate as is captured by the line AA. The loan rate in turn determines the demand for loans and the volume of credit in the economy. For any generic loan rate, r_L, set by the bank manager the expected volume of bank loans is given by $\hat{E}\left[L\left(r_L\right)|e_H\right]$. We know that an increase in the loan rate lowers the expected loan volume of the bank and vice versa. This inverse relationship between the loan rate and expected investment in the economy is captured by the line NN in quadrant II. An increase in investment pushes up asset demand which in turn pushes up asset prices and conversely, a reduction in investment reduces asset prices. This positive relationship between expected investment and asset prices as captured by the line YY in quadrant III. Finally quadrant IV shows the relationship between asset price and risk. The equilibrium relationship between asset price and risk is derived by tracing the effect of risk on the loan rate, which in turn has an effect on the amount of investment which subsequently determines the asset price.

For instance, if the risk of the project is given by $1 - \theta^o$, then as shown by quadrant I, in the absence of any agency problems the manager will set a loan rate r_L^o. The expected investment corresponding to a loan rate of r_L^o is given by N^o in quadrant II while the corresponding asset price is given by P^o in quadrant III. This relationship between risk and asset price is captured by the line ZZ in quadrant IV. In general, the higher is the underlying risk the lower is the asset price and vice versa. The line ZZ depicts this negative relationship.

Now, let the line AA represent the fundamental relationship between risk and the bank loan rate, the relationship that would be obtained in the absence of agency issues. Then for any given level of risk, the fundamental asset price would be represented by the line ZZ. However, as we showed in Proposition 4, an agency problem is actuated for sufficiently high bank liquidity levels whereby the bank loan rate is lowered for any given level of risk. Hence if bank liquidity is high enough the line AA shifts from AA to A^1A^1, and for the same level of risk the manager charges a loan rate r_L^1 that is lower than the fundamental rate r_L^o, where r_L^1 corresponds to the agency loan rate, r_L^a, while r_L^o corresponds to the no-agency loan rate, r_L^{na}. From quadrant II we know that the expected volume of credit in the economy increases following lower loan rates. Consequently asset prices increase as is shown in quadrant III.

The final relationship between asset prices and risk shown in quadrant IV implies that the actuation of the principal-agent problem shifts the ZZ line to Z^1Z^1. As shown in the figure if the underlying risk is given by $1-\theta^o$ and the loan rate charged by the manager is given by r_L^1 rather than r_L^o then the asset price increases from P^o to P^1, where P^o corresponds to the fundamental rate $\bar{P}$. In other words, once the agency problem is actuated,

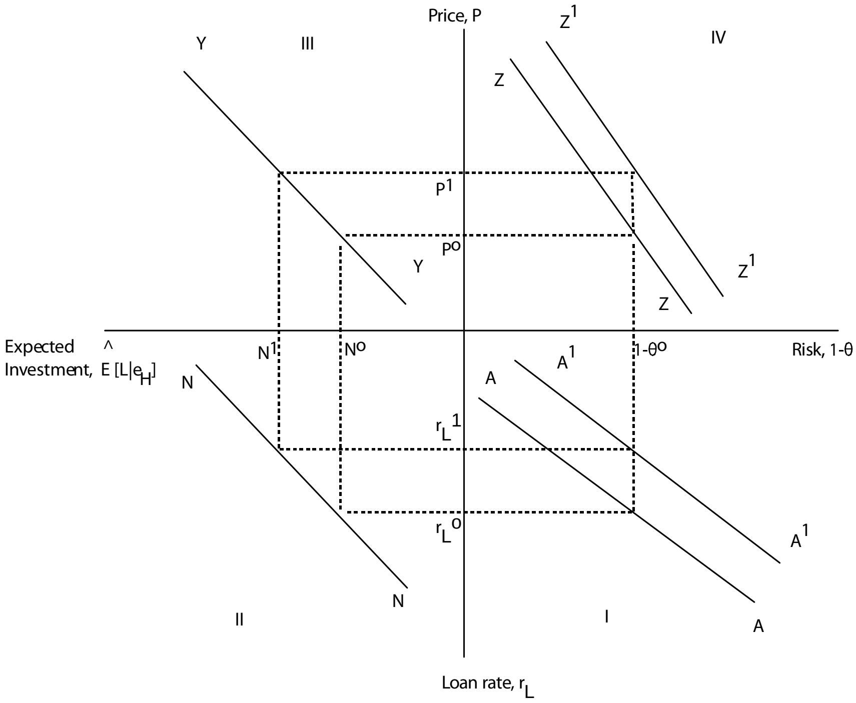

Figure 4: The mechanics of the formation of asset price bubbles.

an asset-price bubble is formed.[21] If we ignored the role of the banking sector, then we would be reducing our attention to quadrant IV alone in relating risk to asset price missing the full picture of how the banking sector contributes to equilibrium investment demand and asset prices.

4 When are bubbles likely to be formed?

Given asset price bubbles are formed when bank liquidity is substantially high, the question that arises is when are banks most likely to be flushed

[21] It is also interesting to note that our model implies that the size of the bubble is monotonic in the leverage of bank borrowers. This is because bank borrowers in the model borrow more the lower the lending rates offered by the banks. The greater the severity of the bank agency problem, the lower are the lending rates, and the higher is the borrower leverage and asset price.

with liquidity. In an empirical study, Gatev and Strahan (2006) find that as spreads in the commercial paper market increase, bank deposits increase and bank asset (loan) growth also increases. The spreads on commercial paper are often considered a measure of the investors' perception of risk in the real economy. Intuitively, when investors are apprehensive of the risk in the corporate sector they are more likely to deposit their investments in banks rather than make direct investments.[22]

To formalize the above intuition we integrate with the model an entrepreneurial or the corporate sector that can raise direct external financing from investors, endogenize the decision of investors to fund the corporate sector (e.g., through commercial paper debt) or to save in bank deposits, and show that bank deposits will increase at a time when the risk of the entrepreneurial sector increases.

Consider an economy where entrepreneurs have access to projects that yield a terminal cash flow C^e if it succeeds and 0 otherwise.[23] As before, the macroeconomic risk is given by $1 - \theta$. The probability of success depends partly on the realization of the state variable, $\tilde{\theta}$, and partly on the entrepreneurs' effort decision, ϵ, which identifies whether the entrepreneur is diligent ($\epsilon = 1$) or shirks ($\epsilon = 0$) in which case, entrepreneurs extract a private benefit of B. If the entrepreneur is diligent, the probability of success as before is given by θ but in the presence of shirking the probability of success is $\varphi\theta$, where $\varphi \in (0, 1)$.

[22] The flight of depositors to banks may be due to banks having greater expertise in screening borrowers during stress times, inducing a natural negative correlation between the usage of lines of credit and deposit withdrawals as argued by Kashyap, Rajan and Stein (2002). Alternatively, the flight may simply be due to the fact that bank deposits are insured (up to a threshold), e.g., by the Federal Deposit Insurance Corporation (FDIC) in the United States, whereas commercial paper and money market funds were uninsured, at least until the extraordinary actions taken by the Federal Reserve during 2008 and 2009. Pennacchi (2006) finds evidence supportive of the insurance hypothesis by examining deposit growth and lending at banks during crises prior to the creation of the FDIC.

[23] With some additional complexity arising from joint bank-lending and direct investments in equilibrium, we can consider entrepreneurial projects to be the same as bank borrower projects. See, for example, Bolton and Freixas (2000) for such a bank-cum-bond-market equilibrium.

Entrepreneurs promise to pay the risk-neutral investors who invest directly in their projects a face value of y. To ensure the concavity of the entrepreneur's objective function we assume that there exists a non-pecuniary financing cost, $m(y)$, which satisfies the standard neoclassical conditions: $m'(y) > 0$ and $m''(y) > 0$. We can then write the entrepreneur's problem as maximizing the expected return

$$\max_{y} \theta (C^e - y) - m(y) \tag{25}$$

subject to the constraints

$$\theta y \geq \bar{u}, \tag{26}$$

and

$$\theta (1 - \varphi)(C^e - y) \geq B. \tag{27}$$

Constraint (26) is the investor rationality constraint which says that the expected return to the investor must at least equal the investor's reservation utility. Constraint (27) is the incentive compatibility constraint which says that the expected entrepreneurial return conditional on the entrepreneur being diligent exceeds his expected return from shirking.[24]

We can then prove the following proposition.

Proposition 5 *There exists a θ^c such that for $\theta < \theta^c$, the entrepreneur's incentive compatibility constraint is not satisfied and the expected return to the investor fails to satisfy the investor rationality constraint.*

The above proposition says that for high enough macroeconomic risk the contract offered by the entrepreneur to investors is not incentive compatible. Intuitively, if macroeconomic risk is sufficiently high, the probability of success is low and thus the entrepreneur has little incentive to exert effort and is better off by shirking and consuming his private benefit.

However, if the entrepreneurial projects are financed by banks rather than dispersed investors then such moral hazard can be alleviated via monitoring. Formally, in the presence of bank borrowing entrepreneurs suffer a

[24] More formally, this implies the following: $\theta (C^e - y) \geq \varphi \theta (C^e - y) + B$. Simplifying this inequality we get (27).

cost from shirking, say κ. As long as $\kappa \geq B$ the entrepreneur will have no incentive to shirk. In other words, if the banks impose a high enough cost on the entrepreneurs when they shirk, then due to the presence of monitoring the entrepreneurs will have no incentive to engage in shirking since there are no private benefits net of the shirking costs. This is consistent with the delegated monitoring argument of Diamond (1984) who argues that there are times when bank-based intermediation cannot be substituted by market-financing since investors face duplication of monitoring costs and cannot control the entrepreneurial moral hazard problem in a cost-effective manner. As put succinctly by Diamond (1996), "the cost of monitoring and enforcing debt contracts issued directly to investors (widely held debt) is a reason that raising funds through an intermediary can be superior."

Since investors earn on average $\bar{u}$ from bank investments, in the presence of entrepreneurial moral hazard investors will be better off by depositing their endowments in banks. On the other hand, if $\theta \geq \theta^c$, entrepreneurs can attract investors by offering them an expected return slightly above $\bar{u}$. In summary, if investors observe θ identically, then all investments will be channeled directly into entrepreneurial projects if $\theta \geq \theta^c$, and into banks if $\theta < \theta^c$.

To obtain a more realistic distribution of investments as macroeconomic risk varies, we assume each investor receives an imperfect signal, s, on the basis of which they decide how to allocate their endowments. A signal $s_j = g$ received by investor j is a good signal which implies that $\theta \geq \theta^c$; a signal $s_j = b$ is a bad signal which would be an indication to the investor that $\theta < \theta^c$. The probability distribution of the signals is assumed to be identical and independent across depositors and given as:

$$\Pr(s = g) = \nu\theta, \text{ so that } \Pr(s = b) = 1 - \nu\theta$$

where $\nu \in (0, 1)$. Investors only observe their own signals and are not aware of the probability distribution of the signals. This formulation implies that a proportion $\nu\tilde{\theta}$ of the investors will allocate their endowments to entrepreneurial projects while a proportion $1 - \nu\tilde{\theta}$ will allocate their endowments to bank deposits. Note that as the macroeconomic state, θ, improves the amount of direct entrepreneurial investment increases. Conversely, a deterioration of the macroeconomic state results in a flight to bank deposits.

The resulting relationship between bank liquidity and macroeconomic risk is illustrated by the liquidity-risk curve DD in Figure 5. Figure 5 illustrates that as macroeconomic risk increases there is a flight to quality whereby bank deposits increase. In the figure, D^* is the liquidity threshold above which bank agency problems are actuated and asset price bubbles are formed. When macroeconomic risk increases above a critical level, $(1-\theta^*)$, to say $\left(1-\theta^1\right)$, bank liquidity crosses the threshold D^* to D^1 leading to the formation of a bubble. We can then prove the following proposition.

Proposition 6 *A bubble is formed in the economy when the macroeconomic risk is high enough. More formally, there exists a threshold θ^* such that $P^* > \bar{P}$ if $\theta < \theta^*$ where $\theta^* \in [\underline{\theta}, 1]$.*

That is, as macroeconomic risk increases, there is a flight to quality whereby investors prefer to invest in bank deposits rather than engage in direct lending. Banks find themselves flushed with liquidity during such times when spreads in the commercial paper market (i.e., the direct costs to entrepreneurs of financing from investors) are high. This excessive liquidity encourages bank managers to increase the volume of credit in the economy by mispricing downside risk. And, this in turn fuels a bubble in asset prices.

5 Related Literature

While Jensen and Meckling (1976) showed that leverage induces equityholders to prefer excessive risk, our point is concerned with risk-taking incentives inside banks as a function of liquidity. On this front, our paper is similar to Myers and Rajan (1998) wherein access to liquidity allows financial firms to switch to riskier assets more readily, and its anticipation renders them illiquid ex ante. The channel in our model is somewhat different in that when banks are flush with liquidity, managers are hedged from the downside risks they undertake, and this induces risk-taking incentives.

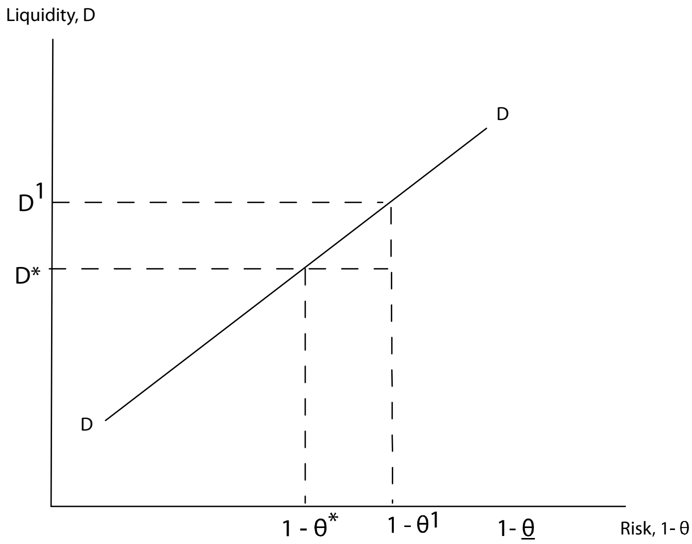

Figure 5: The interplay between bank liquidity and macroeconomic risk.

Allen and Gale (2000) explain the formation of a bubble via an agency relationship in the banking sector. In their paper there is an agency problem between the bank and the bank borrowers. On the one hand, bank borrowers have limited liability and hence they default if the value of their portfolio is insufficient to service the debt. On the other hand, in good states of the world the borrowers being the residual claimants capture the entire upside from the asset payoffs. This non-convexity coupled with the inability of banks to observe the riskiness of the projects generates a risk-shifting problem. In their model the risky projects have a fixed supply. Due to the risk-shifting problem the borrowers bid up the price of the risky asset which fosters an asset price bubble.

Our paper also explains how an agency problem in financial intermediation can lead to bubbles in asset prices. However, the nature of the agency problem is different from Allen and Gale (2000). Whilst in their paper there is an agency problem between the bank and the borrowers, in our paper there is an agency problem *within* banks between the bank managers and the owners. In our paper, excessive bank liquidity triggers overinvestment on the part of the bank manager which leads to bubbles. In their paper, it is the risk-shifting on part of bank borrowers which results in overinvestment leading to asset price bubbles.

Barlevy (2008) also develops a model where an agency problem is conducive to the formation of a bubble. In his model there are some borrowers who invest in the risky asset for speculative reasons. However, creditors cannot distinguish between speculators and non-speculators. As in Allen and Gale (2000) a bubble arises since the agents use borrowed money to invest in the risky assets and have limited liability. Barlevy (2008) also studies how various policies (e.g., restricting the use of certain contractual arrangements between lenders and borrowers) give rise to or eliminate the possibility of bubbles. In contrast to Barlevy (2008), the focus in our paper is not on the strategic behavior of borrowers but rather on the behavior of bank managers who may or may not act over-aggressively depending on the volume of deposits received by the bank.

A number of recent empirical papers find evidence directly in support of our theory. Adrian and Shin (2009) show that the aggregate balance-sheet of financial intermediaries grows more rapidly in times of asset price booms. They argue that growth in financial sector balance-sheets might be the relevant measure of liquidity to rein in the pro-cyclicality of its risk choices. Berger and Bouwman (2010) test our theory and in confirmation of its results find that high liquidity creation is accompanied by a high likelihood of the occurrence of a crisis. In a recent paper, Rajan and Ramcharan (2011) examine the rise (and fall) of land prices in the United States in the early twentieth century and find that the availability of easy credit played a significant role (over and above any change in fundamentals) in exacerbating the farm land price boom and the subsequent spate of bank failures.[25]

Finally, we note that there are several alternative theories of bank lending over the cycle that are not directly related to liquidity inflows. Rajan (1994) argues that it is easier for loan officers to share blame in bad times and

[25] In an earlier contribution, Mei and Saunders (1997) show that the real-estate lending of U.S. financial institutions exhibits a "trend-chasing" pattern, lending more when real estate returns are expected to be low and vice-versa.

this leads to herding and delay of loan-loss recognitions in good times. He also provides supporting empirical evidence based on the real-estate banking crisis in Massachusetts, USA of the early 90's. Ruckes (2004) shows that in expansions banks reduce their screening activity which results in loans being extended to lower quality borrowers, but that in economic downturns banks tighten credit standards. Thakor (2005) argues that bank over-lending is due to banks permitting higher loan commitments and not invoking the revocation clause during booms given reputational concerns. Dell'Ariccia and Marquez (2006) show that as banks obtain private information about borrowers and information asymmetries across banks decrease, banks may loosen their lending standards resulting in lower profits and expanded aggregate credit, which makes banks more vulnerable to economic downturns. Matsuyama (2007) analyses how a movement in borrower net worth causes the composition of the credit to switch between investment projects with different productivity levels, resulting in credit cycles (fluctuations in net worth) and credit traps (low borrower net worth). Acharya and Yorulmazer (2008) show that the collective limited liability of banks induces herding since when banks fail, they impose a negative externality on each other through information contagion, an effect that is stronger in downturns. The channel for over-lending by banks provided by our paper is complementary to these explanations.

6 Conclusion

We develop a theory of bank lending explaining how the seeds of a crisis may be sown when banks are flush with liquidity. The main empirical implication of our model is that excessive liquidity induces risk-taking behavior on the part of bank managers. In summary, we obtain the following results: (a) bank managers behave in an overly-aggressive manner by mispricing downside risk when bank liquidity is sufficiently high; (b) asset price bubbles are formed for high enough bank liquidity; and finally, (c) bubbles are more likely to be formed when the underlying macroeconomic risk is high as it induces investors to save with banks rather than make direct investments.

One can also argue that an expansionary monetary policy adopted by the central bank can increase the likelihood of the formation of a bubble by increasing the liquidity base of banks. Historical evidence supports this. For instance, in the late 1980's a property bubble was formed in Finland and Sweden following a steady credit expansion by the authorities. In Japan the real estate bubble was formed subsequent to a loose monetary policy adopted by the Bank of Japan in 1986. In the United States the Federal Reserve lowered the federal funds rate to 1% in 2003 - a level that at that time was last seen only in 1958. Subsequently banks seem to have mispriced downside risk and engaged in over-lending which culminated in the subprime crisis. Our model suggests that a central bank should follow a "leaning against liquidity" approach, i.e., it should adopt a contractionary monetary policy at times when banks are awash with liquidity so as to draw out their reserves. Nevertheless, a full modeling of these issues is outside the scope of this paper and we leave this to future research.

Finally, it should be noted that an increase in global macroeconomic risk can also increase bank liquidity in some economies due to "global imbalances". For instance, Caballero (2009) and Jagannathan et al. (2009) argue that as a result of the South East Asian crisis and the NASDAQ crash there was an increased global demand for safe securities and the U.S. financial system catered to this demand by creating collateralized debt obligations (CDOs). This resulted in an influx of liquidity in the U.S. financial system from emerging economies, increasing the liquidity of the U.S. banking system. Such capital flows can leave banks flooded with liquidity and actuate agency problems resulting in a mispricing of downside risk and bubble formation. We aim to explore these linkages in future work.

Appendix A: Extension of the model with competitive banks

So far we have considered the case of monopolistic credit markets where one bank acts as a price-setting monopolist. In this extension we analyze the case of competitive credit markets where there are many banks competing to invest in the risky assets. We show that our results are also relevant to a setting with a perfectly competitive banking system.

As in the main body of the paper, the bank hires a risk-averse manager and offers a contract so as to minimize the expected wage and audit costs subject to manager's participation constraint, incentive constraint, limited liability constraint and the constraint that the audit probability lies between zero and one. More specifically, the principal solves:

$$\min_{b,\psi,\phi} \bar{E}(w) + \bar{E}(z)$$

subject to

$$\bar{E}[v(w)] - e \geq u^o,$$

$$\bar{E}[u|e_H] \geq \bar{E}[u|e_L],$$

$$\psi \leq \min\left(\bar{\psi}, \gamma r_p S\right),$$

and

$$\phi \in [0,1]$$

where $w = b - \psi$. As shown in the proof to Proposition 2, the managerial bonuses are increasing in loan volume and the principal conducts an audit when the liquidity shortfalls exceed a certain threshold.

As in Besanko and Thakor (1987) as long as there are no agency problems competition for loans results in every borrower being offered a contract that maximizes its expected utility subject to the additional constraint that the bank breaks even. Thus if the hired manager does not act over-aggressively and acts in the interest of the principal then he solves the following problem:

$$\max_{r_L^c, r_D^c, R^c} \left\{ \left[\theta\left[CX_d - r_L P X_d\right] - b\left(X_d\right)\right] | e = e_H \right\} \tag{28}$$

subject to

$$\hat{E}(\tilde{x}) + \left(1 - \hat{E}(\tilde{x})\right)\left[\theta r_D + (1-\theta)\frac{\hat{E}\left[\max\left(R - \tilde{x}D, 0\right)|e = e_H\right]}{\left(1 - \hat{E}(\tilde{x})\right)D}\right] \geq \bar{u}, \tag{29}$$

$$L\left(r_L^c\right) + R = D, \tag{30}$$

and

$$\pi - r_p \hat{E}\left[\max\left(\tilde{x}D - R, 0\right)|e = e_H\right] - \hat{E}\left(w + z|e = e_H\right) = 0 \tag{31}$$

where w is the wage cost.

Expression (28) represents the expected utility of the borrower conditional on high effort exerted by the manager. Since credit markets are competitive a manager acting in the interest of the bank maximizes the expected utility of the borrower subject to the constraints faced by the bank. The first two constraints are the same as before whilst constraint (31) represents a competitive bank's zero profit condition, i.e., the bank's profit net of the expected penalty costs, managerial wage and audit costs should be zero. Thus the bank maximizes the expected utility of the borrower (28) subject to the depositors' participation constraint (29), the bank's budget constraint (30) and the bank's zero profit condition (31). It should be noted that in the above problem $\psi = 0$ and thus $w = b$ (where as before b denotes managerial income gross of any penalties (e.g. bonuses)) since if the manager is acting in the interests of the principal then he will not be penalized if an audit is conducted by the principal.

As before the participation constraint (29) also binds from which we can solve for r_D^c. From the budget constraint (30) we know that $R = D - L\left(r_L^c\right)$. In order to solve for r_L^c we substitute r_D^c, R and $w = b$ in the zero profit condition (31). Then under asymmetric information the loan rate in the absence of agency problems, r_L^c, is given by the solution to:

$$\max_{r_L^c} \left\{\left[\theta\left[CX_d - r_L PX_d\right] - b\left(X_d\right)\right]|e = e_H\right\}$$

subject to

$$\pi\left(r_D^c\right) - r_p \hat{E}\left[\max\left(\tilde{x}D - R, 0\right)|e = e_H\right] - \hat{E}\left(b + z|e = e_H\right) = 0$$

However, if the manager acts over-aggressively he sets a lending rate $r_L^a < r_L^c$ in order to boost his bonuses. But, in this case he faces the risk of a penalty ($\psi > 0$) in the event of an audit. Using the same line of reasoning as in the main body of the paper one obtains the result in Proposition 4 whereby the manager acts over-aggressively if and only if bank liquidity, D, is sufficiently high.[26] We then also get the same corollary to Proposition 4 whereby a bubble is formed if bank liquidity is sufficiently high. Hence the qualitative results of our model with a monopolistic bank are also obtained in a competitive setting.

Appendix B: Proofs

Proof of Proposition 1. The participation constraint of the bank will be binding because otherwise the bank can increase its expected profits by slightly reducing r_D. Thus, r_D^* is given by the solution to the following:

$$E(\tilde{x}) + (1 - E(\tilde{x}))\left[\theta r_D + (1-\theta)\frac{E[\max(R - \tilde{x}D, 0)]}{D}\right] = \bar{u}$$

Solving for r_D^* we get (6).

We can then substitute r_D^* in the bank's objective function and hence r_L^* will be the solution to the following unconstrained maximization problem:

$$\begin{aligned}\max_{r_L^*} \Pi &= \theta\{r_L L(r_L) - r_D^* D(1 - E(\tilde{x})) + E[\max(R - \tilde{x}D, 0)]\} \\ &\quad -r_p E[\max(\tilde{x}D - R, 0)].\end{aligned}$$

Assuming that Π is quasi-concave in r_L and substituting the budget constraint (3), $R = D - L(r_L)$, into the bank's objective function, the maximum is characterized by the following first order condition:

$$\frac{\partial \Pi}{\partial r_L} = \theta L(r_L) - \theta \Pr[\tilde{x}D < R] L'(r_L) + \theta r_L L'(r_L)$$

$$-r_p \Pr[\tilde{x}D \geq R] L'(r_L) - \theta D(1 - E(\tilde{x}))\frac{\partial r_D^*}{\partial r_L} = 0. \tag{32}$$

Noting that $\partial r_D^*/\partial r_L = (1-\theta)\Pr[\tilde{x}D < R] L'(r_L)/\theta D(1 - E(\tilde{x}))$ and solving for r_L after some simplification we get (5). Thus the optimal reserve level is given by $R^* = D - L(r_L^*)$ which proves the first part of the proposition.

[26] The proof is exactly the same as the proof to Proposition 4 with the difference being that under competition the manager is penalized subsequent to an audit if he had set a loan rate lower than r_L^c whereas in the earlier case the manager was penalized following an audit if he had set a loan rate lower than r_L^{na}.

From the FOC (32), if we solve for r_L^* directly without exploiting the definition of η_L we get the following expression for the return on loans:

$$r_L^* = \frac{1}{\theta} - \frac{L}{L'} + \frac{(r_p - 1)\Pr(\tilde{x}D \geq R^*)}{\theta} \tag{33}$$

Taking the partial derivative of the above expression w.r.t. θ we get:

$$\frac{\partial r_L^*}{\partial \theta} = -\frac{1 + (r_p - 1)\Pr(\tilde{x}D \geq R^*)}{\theta^2} < 0 \tag{34}$$

since $r_p > r_L > 1$, which proves the second part of the proposition.

Next note that $\partial \Pr(\tilde{x}D \geq R)/\partial D < 0$, i.e. an increase in bank liquidity (deposits) lowers the probability of liquidity shortfalls since $R = D - L$. Then taking the partial derivative of (33) w.r.t. $1 - F(R) = \Pr(\tilde{x}D \geq R)$ we get:

$$\frac{\partial r_L^*}{\partial [1 - F(R)]} = \frac{r_p - 1}{\theta} > 0 \tag{35}$$

Hence $\frac{\partial r_L^*}{\partial D} = \frac{\partial r_L^*}{\partial [1-F(R)]} \frac{\partial [1-F(R)]}{\partial D} < 0$, which proves the third part of the proposition. Q.E.D.

Proof of Proposition 2. Let μ_1, μ_2, μ_3 denote the Lagrange multipliers for constraints (13), (14), (15). Taking the FOC w.r.t. b the following condition is satisfied at every L:

$$\frac{1}{\int\limits_D \int\limits_x [(1-\phi) v'(b) + \phi v'(b - \psi)] f(x) h(D) \, dx dD} = \mu_1 + \mu_2 \left[1 - \frac{g(L(r_L)|e_L)}{g(L(r_L)|e_H)}\right] \tag{36}$$

where $g(L(r_L)|e) > 0$ is the density function of loans conditional on effort and $h(D)$ is the density function of bank liquidity, D. As is common in the literature, we then invoke the monotone likelihood ratio property (MLRP), i.e. $[g(L(r_L)|e_L)/g(L(r_L)|e_H)]$ is decreasing in L. In words, this means that as bank loans increase, the likelihood of getting a given level of loans and profits if effort is e_H, relative to the likelihood if effort is e_L must increase. Hence an increase in L increases the RHS of (36). It follows that the LHS is increasing in L and hence the denominator of the LHS is decreasing in L. The denominator of LHS will be decreasing in L if and only if $v'(\cdot)$ is decreasing in L. Note, however, that $\psi = \min\left(\bar{\psi}, \gamma r_p S\right)$ is increasing in L, since $S = \max\left[L - (1-x) D, 0\right]$. Given that $v'' < 0$, it follows that the denominator of the LHS is decreasing in L if and only if managerial bonuses, b, are monotonically increasing in L.

Next, taking the FOC w.r.t. ψ the following condition is satisfied for every L:

$$\int\limits_D \int\limits_x \left[1 - \mu_1 v'(b-\psi) - \mu_2 v'(b-\psi)\left(1 - \frac{g\left(L\left(r_L\right)|e_L\right)}{g\left(L\left(r_L\right)|e_H\right)}\right)\right] \phi g\left(L\left(r_L\right)|e\right) f(x) h(D)\, dx dD = \mu_3$$

Since constraint (15) is binding it follows that $\mu_3 > 0$. Thus the following condition is satisfied:

$$\left[1 - \mu_1 v'(\cdot) - \mu_2 v'(\cdot)\left(1 - \frac{g\left(L\left(r_L\right)|e_L\right)}{g\left(L\left(r_L\right)|e_H\right)}\right)\right] > 0. \tag{37}$$

Finally, taking the FOC w.r.t. ϕ the following condition is satisfied for every L:

$$\begin{aligned}
&\int\limits_D \int\limits_x \psi g\left(L\left(r_L\right)|e_H\right) f(x) h(D)\, dx dD - z \\
&+\mu_1 \int\limits_D \int\limits_x \left[-v(b) + v(b-\psi)\right] g\left(L\left(r_L\right)|e_H\right) f(x) h(D)\, dx dD \\
&+\mu_2 \int\limits_D \int\limits_x \left[-v(b) + v(b-\psi)\right]\left[g\left(L\left(r_L\right)|e_H\right) - g\left(L\left(r_L\right)|e_L\right)\right] f(x) h(D)\, dx dD + (\mu_4 - \mu_5) = 0
\end{aligned}$$

where μ_4 and μ_5 correspond to the Lagrange multipliers for the constraints $\phi \geq 0$ and $\phi \leq 1$ respectively. An audit will take place if and only if

$$\begin{aligned}
k(S) \;=\; &\int\limits_D \int\limits_x \psi g\left(L\left(r_L\right)|e_H\right) f(x) h(D)\, dx dD - z \\
&+\mu_1 \int\limits_D \int\limits_x \left[-v(b) + v(b-\psi)\right] g\left(L\left(r_L\right)|e_H\right) f(x) h(D)\, dx dD \\
&+\mu_2 \int\limits_D \int\limits_x \left[-v(b) + v(b-\psi)\right]\left[g\left(L\left(r_L\right)|e_H\right) - g\left(L\left(r_L\right)|e_L\right)\right] f(x) h(D)\, dx dD > 0.
\end{aligned}$$

This is because if $k(S) > 0$ it implies that that $\mu_5 > \mu_4$. But $\mu_5 > \mu_4$ if and only if the constraint $\phi \leq 1$ is binding as a binding constraint implies that $\mu_5 > 0$ but $\mu_4 = 0$. This would be the case if and only if $\phi = 1$. It follows that $\phi = 1$ if $k(S) > 0$ and $\phi = 0$ otherwise. Let S^* denote the threshold such that $k(S^*) = 0$. In order to prove that it is optimal to audit if and only if $S > S^*$, it would suffice to show that $k'(S)$ is strictly increasing in S.

Taking the derivative of $k(S)$ with respect to S after some simplification we get

$$k'(S) = \int_D \int_x \left[1 - \mu_1 v'(b-\psi) - \mu_2 v'(b-\psi)\left(1 - \frac{g(L(r_L)|e_L)}{g(L(r_L)|e_H)}\right)\right] g(L(r_L)|e_H)\,\psi'(S)\,dFdH.$$

where F and H represent the distribution functions of x and D respectively. Since $\psi'(S) > 0$ and given condition (37) it follows that $k'(S) > 0$.

Proof of Proposition 3. As before the participation constraint is binding from which we can solve for r_D^*. Also from the budget constraint, we have $R = D - L$. Substituting r_D^* and R in π we need to solve for an unconstrained maximization problem. Taking the FOC with respect to r_L and solving for r_L^{na} we get

$$r_L^{na} = \frac{1 + (r_p - 1)\Pr\left[(\tilde{x}Dr_1 \geq R)|e = e_H\right]}{\theta\left(1 - \frac{1}{\bar{\eta}_L}\right)} + \frac{\frac{\partial \hat{E}[b+z|e=e_H]}{\partial r_L}}{\theta \frac{\partial \hat{E}[L|e=e_H]}{\partial r_L}}.$$

where $\bar{\eta}_L = -r_L \frac{\partial \hat{E}[L(r_L)|e_H]/\partial r_L}{\hat{E}[L(r_L)|e_H]}$. Noting that the first term on the RHS is r_L^f we get expression (18). Next note that

$$\frac{\partial \hat{E}[b + z|e = e_H]}{\partial r_L} = \frac{\partial \hat{E}[b + z|e = e_H]}{\partial L}\frac{\partial L}{\partial r_L} < 0$$

since bonuses (b) are increasing in loan volume; audit costs (z) are increasing in loan volume since an increase in loan volume increases the probability of liquidity shortfalls thereby increasing the expected audit costs (z); while $\partial L/\partial r_L < 0$. Finally noting that $\partial \hat{E}[L|e = e_H]/\partial r_L < 0$ it follows that the second term on the RHS of (18) is positive and thus $r_L^{na} > r_L^f$. Q.E.D.

Proof of Proposition 4. If the manager engages in overly-aggressive behavior, his expected utility is given by the following expression:

$$\Pi_m^a = \int\limits_L \int\limits_x v\left(b\left(L\left(r_L^a\right)\right) - \tilde{\psi}|e = e_H\right) f\left(x\right) g\left(L|e = e_H\right) dxdL - e_H$$

where r_L^a denotes the lending rate set by the manager when he acts over-aggressively. Thus in the agency world the manager faces the following problem:

$$\max_{r_L^a} \ \Pi_m^a$$

The first order condition is given by:

$$\int\limits_L \int\limits_x v'\left(\cdot\right)\left[b'\left(L\right) L'\left(r_L^{a*}\right) - \frac{\partial\tilde{\psi}}{\partial r_L^a}\right] f\left(x\right) g\left(L|e = e_H\right) dxdL = 0. \tag{38}$$

The above condition can be rewritten as:

$$\int\limits_L \int\limits_x v'\left(\cdot\right)\left[b'\left(L\right) L'\left(r_L^{a*}\right)\right] f\left(x\right) g\left(L|e = e_H\right) dxdL = \int\limits_L \int\limits_x v'\left(\cdot\right)\left[\frac{\partial\tilde{\psi}}{\partial r_L^a}\right] f\left(x\right) g\left(L|e = e_H\right) dxdL$$

which implies that at the optimum the marginal benefit of setting a lower lending rate (in terms of higher bonuses) just equals the marginal cost (in terms of a higher expected managerial penalty).

The manager will behave over-aggressively if and only if his expected utility from acting over-aggressively exceeds his expected utility from not acting over-aggressively. More formally this will be true if and only if the following expression is positive:

$$\Delta\Pi_m = \int\limits_L \int\limits_x v\left(b\left(L^a\right) - \tilde{\psi}|e = e_H\right) f\left(x\right) g\left(L|e = e_H\right) dxdL - \int\limits_L v\left(b\left(L^{na}\right)|e = e_H\right) g\left(L|e = e_H\right) dL \tag{39}$$

where L^a denotes the loan volume when the manager acts over-aggressively, L^{na} denotes the loan volume when the manager does not act over-aggressively by setting the optimal loan rate, r_L^{na} under asymmetric information and $\Delta\Pi_m$ denotes the expected utility of the manager from acting over-aggressively minus the expected utility from not acting over-aggressively conditional on high effort.

Adding and Subtracting $\int_L v\left(b\left(L^a\right)|e=e_H\right) g\left(L|e=e_H\right) dL$ to expression (39) we get

$$\Delta\Pi_m = \left[\int\limits_L v\left(b\left(L^a\right)|e=e_H\right) g\left(L|e=e_H\right) dL - \int\limits_L v\left(b\left(L^{na}\right)|e=e_H\right) g\left(L|e=e_H\right) dL\right] - c \tag{40}$$

where

$$c \equiv \int\limits_L v\left(b\left(L^a\right)|e=e_H\right) g\left(L|e=e_H\right) dL - \int\limits_L \int\limits_x v\left(b\left(L^a\right) - \tilde{\psi}|e=e_H\right) f(x)\, g\left(L|e=e_H\right) dx dL \tag{41}$$

The first term in expression (40) is positive since $L^a > L^{na}$ and $v'(\cdot) > 0$. Hence $\Delta\Pi_m > 0$ as long as c is small enough. It can then be shown that c is decreasing in D and hence for high enough D we have $\Delta\Pi_m > 0$. Thus in order to prove the proposition it would suffice to show that c is decreasing in D.

Note that

$$\begin{aligned} \Pi_m^a &= \int\limits_L \int\limits_x v\left(b\left(L^a\right) - \tilde{\psi}|e=e_H\right) f(x)\, g\left(L|e=e_H\right) dx dL \qquad (42) \\ &= \int\limits_L \int\limits_x \left[(1-\phi)\, v\left(b\left(L^a\right)|e=e_H\right) + \phi v\left(b\left(L^a\right) - \psi|e=e_H\right)\right] f(x)\, g\left(L|e=e_H\right) dx dL \end{aligned}$$

where $\phi = \Pr\left(S > S^*\right)$.

Substituting (42) in (41) and taking the partial derivative of (41) with respect to D after some simplification we get

$$\begin{aligned} &\int\limits_L \int\limits_x \phi\left[v'\left(b\left(L^a\right)\right) - v'\left(b\left(L^a\right) - \psi|\cdot\right)\right]\left[\frac{\partial b}{\partial D}\right] f(x)\, g\left(L|\cdot\right) dx dL \qquad (43) \\ &- \int\limits_L \int\limits_x \phi\left[v'\left(b\left(L^a\right)\right) - v'\left(b\left(L^a\right) - \psi|\cdot\right)\right]\left[\frac{\partial \psi}{\partial D}\right] f(x)\, g\left(L|\cdot\right) dx dL \\ &+ \int\limits_L \int\limits_x \left(\frac{\partial \phi}{\partial D}\right)\left[v\left(b\left(L^a\right)|\cdot\right) - v\left(b\left(L^a\right) - \psi|e=e_H\right)\right] f(x)\, g\left(L|\cdot\right) dx dL \end{aligned}$$

In the first term note that $\frac{\partial b}{\partial D} = \frac{\partial b}{\partial L}\frac{\partial L}{\partial D}$. As proved in Proposition 2 $\frac{\partial b}{\partial L} > 0$ since bonuses are increasing in loan volume. Further, $\frac{\partial L}{\partial D} = \frac{\partial L}{\partial r_L}\frac{\partial r_L}{\partial D}$. We know $\frac{\partial L}{\partial r_L} < 0$ and $\frac{\partial r_L}{\partial D} < 0$ since as shown earlier the loan rate is decreasing in liquidity. Hence, $\frac{\partial L}{\partial D} > 0$ and thus $\frac{\partial b}{\partial D} > 0$. Furthermore, $[v'(b(L^a)) - v'(b(L^a) - \psi|\cdot)] < 0$ since $v''(\cdot) < 0$. Hence the first term in expression 43) is negative. Next note that $\frac{\partial \psi}{\partial D} < 0$ since the penalty $\psi = \min(\bar{\psi}, \gamma r_p S)$ is increasing in S. Hence the second term in (43) is negative. Finally note that $\frac{\partial \phi}{\partial D} < 0$. This is because the ex ante audit probability is given by $\phi = \Pr(S > S^*)$ where $S = \max[xD - R, 0] = \max[L - (1-x)D, 0]$ given that $R = D - L$. Since S is decreasing in D it follows that the audit probability, ϕ, is decreasing in D. Furthermore, $\{v(b|\cdot) - [v(b-\psi|\cdot)]\} > 0$ since $b > b - \psi$ and since $v'(\cdot) > 0$. Hence the third term in (43) is also negative. Q.E.D.

Proof of Proposition 5. Since the maximand (25) is decreasing in y it follows that constraint (26) is binding and thus $y^* = \bar{u}/\theta$. Inserting y^* in constraint (27) we can rewrite the incentive compatible constraint (27) as follows:

$$\theta \geq \theta^c$$

where

$$\theta^c = \frac{1}{C^e}\left[\frac{B}{1-\varphi} + \bar{u}\right].$$

It follows that if $\theta < \theta^c$ the incentive compatible constraint does not hold. Thus the incentive compatible payoff, y^*, will not be achievable given that the investor rationality constraint (26) is based on an incentive compatible contract. Q.E.D.

Proof of Proposition 6. Comparing (23) with (24) we know that $P > \bar{P}$ if and only if $r_L < r_L^{na}$. From the proof to Proposition 4 we know that $r_L < r_L^{na}$ for sufficiently high D. Let D^* denote the threshold below which $r_L < r_L^{na}$ and assume the plausible that the number of investors I is big enough so that D^* exists. Hence all we need to show is that $\frac{dD}{d\theta} < 0$ $\forall \theta \in [\underline{\theta}, 1]$. Since $D = (1 - \nu\theta) I$ $\forall \theta \in [\underline{\theta}, 1]$ it follows that $\frac{dD}{d\theta} = -\nu I < 0$ $\forall \theta \in [\underline{\theta}, 1]$. Since D is monotonically decreasing in θ for all $\theta \in [\underline{\theta}, 1]$ it follows that there exists a threshold θ^* below which $D > D^*$ and hence

$P > \bar{P}$, where θ^* is such that it solves $D^* = (1 - \nu\theta^*) I$. Q.E.D.

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