Borrowing Constraints in a Dynamic Model of Bank Asset and Liability Management

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Abstract

This paper examines factors behind the observed heterogeneity in borrowing and lending behavior across banks. A bank franchise is identified with loan opportunities and a core deposit base which, for geographical or informational reasons, are unique to the bank, and which fluctuate over time. A bank's debt capacity is limited because shareholders cannot commit to repay debt. Debt capacity and franchise value are endogenously determined in equilibrium by the evolution of lending opportunities and deposits over time. The model is consistent with existing stylized facts about the behavior of banks of different sizes. Predictions on the existence of borrowing constraints for banks with different branch size is explored.

1 Introduction

There is a fair amount of heterogeneity across U.S. banks. Banks come in different sizes, and banks of different size tend to differ strongly in the composition of both the asset and the liability side of the balance sheet. Small rural banks have been documented to hold less risky assets and more securities as a fraction of total assets than large money center

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banks. To fund their portfolios they rely to a larger extent on core deposits rather than on money-market funds.[1] There is also evidence banks operate in imperfect financial markets. A shock to deposit demand appears to force at least some banks into cutting lending, contrary to the Modigliani-Miller theorem (Kashyap and Stein (1995, 1997), Jayaratne and Morgan (1997)). The possibility that banks face borrowing constraints is also important from a policy perspective. For example, it points to an inefficiency in the allocation of funds to bank-dependent borrowers.[2] It also implies that banks play a special role in the transmission of monetary policy.[3]

The goal of this paper is to understand bank behavior in a world of imperfect markets. It postulates heterogeneity due to differences in bank-specific customer bases. Both traditional banking activities, lending to information-intensive borrowers and liquidity provision to depositors are to a large extent tied to a customer base.[4,5] An important aspect of asset and liability management is then to deal with stochastic flows of both core deposits and lending opportunities. The paper presents a dynamic model of a bank which tries to solve this problem while borrowing in an imperfect money market. A commitment problem on the part of the bank's shareholders implies that the bank's debt capacity is limited. The marginal cost of external finance is upward sloping and the bank may be rationed. At any point in time, debt capacity depends positively (and the cost of external finance depends negatively) on future rents, or the franchise value of the bank, which represents shareholders' opportunity cost of default. At the same time, future rents that can be earned from the customer base depend on debt capacity. The franchise value, debt capacity and the cost of external finance are thus simultaneously determined in a stationary equilibrium.[6]

Section 3 below studies a version of the model that abstracts from credit risk and focuses

[1] For evidence on balance sheets of banks of different sizes, see Berger, Kashyap and Scalise (1995), Boyd and Gertler (1995) and Kashyap and Stein (1997). Related evidence presented by Allen, Peristiani and Saunders (1989) shows that small banks are on average net lenders in the federal funds market, whereas large banks tend to be net borrowers.

[2] In its most extreme guise this inefficiency leads to a 'credit crunch', which has been argued to be important during the 1990/1 recession (Bernanke and Lown (1991)). For a survey of the empirical evidence, see Sharpe (1995).

[3] The 'credit channel' of monetary transmission was emphasized by Bernanke and Blinder (1988). There is a large literature debating its importance; for an overview, see Kashyap and Stein (1997). Stein (1995) uses capital market imperfections to model the transmission mechanism.

[4] For evidence about how 'informational lock-in' gives banks market power over their customers, see James (1987) and Petersen and Rajan (1992).

[5] Of course, financial innovation is gradually changing these traditional lines of business. See Edwards and Mishkin (1995), Mishkin (1998) and Allen and Santomero (1998) for a discussion of the changing nature of banks' business. However, at the present time it seems that the perspective taken here is still applicable to the majority of U.S. banks.

[6] There is a large literature on the role of the bank franchise value in mitigating the moral hazard (risk shifting) problem associated with deposit insurance (e.g., Keeley (1990)). In this literature the franchise value is typically exogenous. In addition., the role of the franchise in the present setting is different because it governs shareholders' credibility to repay creditors.

on stochastic flows of opportunities and deposits. In periods in which realized lending opportunities are larger than deposit demand, banks may be borrowing constrained. Since shareholders cannot commit to repay debt, they may not be able to finance all possible profitable lending through money market borrowing. In general, a bank with larger and less variable flows of opportunities or deposits is more valuable and can borrow more when a need for funds arises. The reason is that the promise of future profitable opportunities strengthens repayment incentives. This incentive effect is at the heart of most of the results in the paper.

The model provides a map from a bank's exogenous business environment (its stochastic lending opportunities and deposit demand) into observable characteristics such as the loan/deposit ratio and the correlation between loans and deposits. Properties of this map can help understand observed heterogeneity of US banks. Suppose that bank branches operate in markets subject to local shocks, providing some diversification. Suppose also that lending opportunities are more variable than deposits. Then combining two banks yields a new bank that has a less variable ratio of opportunities to deposits. This implies a larger franchise value per dollar of deposits for the new large banks. The large bank can borrow more and has a larger loan/deposit ratio. In addition, the incentive effect implies that a large bank is less likely to be borrowing constrained than a small one. This rationalizes the 'excess' correlation of loan and deposit growth found in empirical work for small (but not for large) banks.

Section 4 studies a richer setting where the return on loans is uncertain. Net internal funds are now a key state variable which drives franchise value and the cost of borrowing. The franchise value is increasing in internal funds. As internal funds decrease, the cost of money-market funds increases because of high default risk and eventually becomes prohibitive, so that the bank is completely shut off from the money market. Shocks to returns have persistent effects on lending through their effect on internal funds. Negative shocks to opportunities and the deposit base which are unrelated to current asset quality can also play a role in worsening financial distress, because they weaken repayment incentives and rob the bank of cheap risk insensitive funds, respectively.

Deposit insurance creates a class of creditors who are insensitive to risk. This alleviates the underinvestment problem induced by the imperfection in the money market. The existence of such creditors helps banks to keep up high levels of risky lending even after a negative shock to wealth. As long as it is likely enough that the bank bounces back to financial health, rather than incurring a period of distress that ends in default, the expected costs to the government of bailing out depositors in case of default are lower than the expected gains to the banker.

Section 5 examines empirically the incidence of borrowing constraints at banks with different average branch size. One would expect that banks with many small branches tend to do business with customers who are also their depositors. They are thus less likely to experience a high average need for money market borrowing than banks with large branches. The incentive effect from Section 3 implies that banks which have on average more opportunities relative to deposits are more valuable, have higher loan/deposit ratios and are less likely to be borrowing constrained. One would thus expect banks with small branches (which will be labelled regional banks) to be more likely borrowing constrained, then banks with large branches (labelled city banks). Following Jayaratne and Morgan (1997), Call Report data are used to test whether banks are constrained by their deposit base. There is some support for the claim that "regional banks", that is, banks with small branches are found to be more likely borrowing constrained than "city banks" with large branches.

Before the model is presented in Section 3, Section 2 discusses how it fits into the literature.

2 Relationship to the Literature

The emphasis on heterogeneity in the banks' specific opportunities and deposit flows is the key difference between the present paper and existing studies of banks facing financial market imperfections. Allen, Peristiani and Saunders (1989), Lucas and McDonald (1992) and Stein (1995) have considered adverse selection models of bank portfolio and liability choice. These models have either two or three periods, and heterogeneity across banks is in the quality of initial bank assets which is given exogenously. The model of the present paper has an infinite horizon, and bank asset are determined in a stationary equilibrium.

Stein (1995) is also interested in explaining differences in borrowing constraints across size classes. He shows that the response of lending by a class of banks to monetary policy is positively related to the severity of the adverse selection problem faced by that class of banks. The latter is parametrized by the difference in asset quality across good and bad types in the population. To interpret the empirical evidence, he argues that size is a proxy for this parameter. The present paper suggests an alternative explanation based on moral hazard, where size and the likelihood of borrowing constraints are jointly determined by the opportunities and deposit processes. An interesting aspect of the models in Lucas and McDonald (1992) and Stein (1995) is the derivation of a precautionary demand for liquid assets, an important aspect of portfolio choice that is not considered here.

The imperfection used here to characterize the relationship between the bank and lenders is similar to that considered in a large number of models on debt repudiation, both in papers on sovereign debt and in corporate finance applications.[7] Allen (1983) has shown that if repayment incentives must be provided by the continuation value of the firm, this may lead to underinvestment. The setup most closely related to the model here is that of

[7] References to the sovereign debt literature are Eaton and Gersovitz (1981), Bulow and Rogoff (1989) and Atkeson (1991). Corporate finance applications are Allen (1983), Bolton and Scharfstein (1990), Hart and Moore (1995, 1998) and Bolton and Scharfstein (1996).

Atkeson (1991), who also considers the relationship of a single borrower with a sequence of overlapping generations of lenders in a stochastic environment. His paper is concerned with the existence and structure of optimal contracts between a sovereign and foreign lenders. None of these papers deals with banks and the relationship between 'cheap funds' (deposits) and opportunities.

Most dynamic models of banking are set in a contingent claims valuation framework.[8] They are related, because they specify an exogenous stochastic processes for the value of bank assets or bank cash flow as well as the supply of insured deposits. However, shareholders in these models are not wealth constrained and agency problems between shareholders and creditors are absent.

Dynamic models of entrepreneurial firms facing financial market imperfections are building blocks in the literature which builds these imperfections into macroeconomic models.[9] The dynamics of these financial accelerator models also relies on how wealth constrained entrepreneurs' internal funds fluctuate and drive their access to external finance. Some of the propagation effects of shocks to firm wealth which have been stressed in these papers are also important here. The present paper differs in the way the imperfection is introduced, in the emphasis on core deposits as a special source of funds, and in the focus on comparative statics of the distribution of opportunities that a class of borrowers experiences.

There is a large literature on the role of the bank franchise value in determining bank behavior. Most models are static and incorporate the franchise value as an exogenous parameter (see, for example, Keeley (1990)). Hellmann, Murdoch and Stiglitz (1998), present a repeated game model of bank regulation where the value is derived endogenously, as in the model of this paper. Their setup is otherwise quite different, primarily because bankers are not wealth constrained but rather choose their level of capital as part of the stage game in every period.

The paper is also related to the large literature on underpriced deposit insurance.[10] Most papers focus on the negative consequences of excessive risk taking induced by deposit insurance. The present paper shows that a positive effect can exist since deposit insurance may alleviate the underinvestment problem caused by an agency problem in the money market.

3 The Model

There is a single bank. It is characterized by a customer base for both lending and deposit business, from which rents can be extracted. This 'technology' for generating profits

[8] See, for example, Merton (1977, 1978), Acharya (1995) and Fries, Mella-Barral and Perraudin (1997).

[9] See, for example, Bernanke and Gertler (1989), Kiyotaki and Moore (1997) and Carlstrom and Fuerst (1997). For a survey, see Bernanke, Gertler and Gilchrist (1998).

[10] For an overview, see Dewatripont and Tirole (1994b) or Freixas and Rochet (1998), ch. 9.

is described in subsection 3.1. The bank may wish to supplement funds from its core deposit base with money market funds, which are priced by a competitive market. It is owned by shareholders who receive dividends and have an option of shutting down operations. Subsections 3.2 and .3.3 present two games played by bank shareholders, depositors and money market investors in which bank debt, dividends and default are determined.

3.1 Lending Opportunities and Deposits

There is an infinite horizon and a single numeraire consumption good. The riskless interest rate r is constant and coincides with shareholders and money market investors' rate of time preference.

The bank can invest in one-period riskless assets (government securities, say) with gross return $1 + r$. In addition, in period t, it can make one-period loans $L_t \leq \overline{L}_t$, on which it realizes a stochastic gross return of R_{t+1}. On average, the bank earns rents from lending:

$$s_L := E\left[R_{t+1}\right] - (1 + r) > 0$$

The idea here is that, due to private information, the bank is a local monopolist with respect to a customer base of 'bank dependent' firms.

Similarly, the bank has a customer base of risk neutral depositors; it can take on $D_t \leq \overline{D}_t$ deposits. Depositors realize a utility gain of

$$s_D := (1 + r) - (1 + r_D) > 0$$

per unit of the good kept at the bank from t to $t + 1$. This captures liquidity services provided by the bank, e.g. because deposits are demandable.

Lending opportunities $\overline{L}_t$ and the deposit base $\overline{D}_t$ jointly follow a Markov chain on a compact subset of $\Re^2_+$. Demand shocks in the bank's local market are thus assumed to affect only quantities, not interest rate margins.[11] Apart from deposits, the bank can fund itself through retained earnings A_t or money market borrowing B_t. Assets and liabilities in period t satisfy the budget constraint

$$L_t + S_t = A_t + B_t + D_t. \tag{1}$$

How much borrowing and deposit taking is actually possible depends on the effective return that can be promised to depositors and investors. This depends in turn on the franchise value of the bank and the existence of deposit insurance.

[11] It is straightforward to extend the model to the case of downward sloping loan and deposit demand functions.

3.2 A Simple Version with No Credit Risk

The first game provides a simple laboratory to explore analytically the effect of lending opportunities and deposits on the franchise value. Assume that the return on loans R is deterministic and that the process of lending opportunities and deposits is i.i.d.

3.2.1 Debt, Default and Dividend Policy

There is a large number $\overline{B}$ of risk neutral agents. Each agent receives an endowment of one unit of the good every period. Some agents are initially bank shareholders; they also own shares in the bank. Every period, $\overline{D}_t$ agents live conveniently close to the bank's offices (or ATMs), such that they prefer to get deposit services from the bank.

During period t, shareholders pick assets and liabilities, once lending opportunities $\overline{L}_t$ and the number of depositors $\overline{D}_t$ is known. Shareholders begin this stage of the game with no retained earnings: $A_t = 0$. They announce a plan for period t assets and liabilities (L_t, S_t, D_t, B_t) as well as interest rates on bonds (ρ_t^B) and deposits $\left(\rho_t^D\right)$, such that the budget constraint (1) is satisfied. B_t money market investors and D_t of the $\overline{D}_t$ depositors are then randomly assigned to the bank and must decide whether to purchase bonds or make deposits at the offered interest rates.[12]

At the beginning of period $t+1$, shareholders renegotiate liabilities. This happens before $\left(\overline{L}_{t+1}, \overline{D}_{t+1}\right)$ is known. Shareholders make a take-it-or-leave-it repayment offer to their creditors (i.e. money market investors and depositors). If creditors reject this offer, bankruptcy is declared. Shareholders receive the current gross returns, whereas creditors become the new shareholders. [13] In contrast, if creditors accept the offer from shareholders, they receive a (pro rata) repayment, while shareholders keep the bank and the remaining gross returns as cash flow.

Finally, after renegotiation, shareholders pay out all cash flow as dividends. This assumption is motivated by the idea that 'free cash flow' entices managers to squander it on pet projects (Jensen (1986)).[14] Shareholders in period $t+1$ thus start over with zero retained earnings.

[12] The idea here is to capture price formation in a competitive money market (in which there is a large number of investors) as well as a local deposit market in which the banker is a monopolist. Of course, there are several alternative ways to decribe an 'extensive form' for this. The one given was chosen for simplicity.

[13] This polar assumption accentuates the borrowing constraints on the bank to be derived below. Similar results would obtain if sharholders can secure themselves a large enough fraction α of current gross returns, whereas creditors net a fraction $(1-\alpha)$ of current gross returns as cash flow.

[14] For concreteness, suppose that shareholders must delegate the actual operations to a manager. This manager does not respond to monetary incentives, but derives utility from (i) cash flow generated and (ii) pet projects. Assume good lending opportunities and deposit business become available sequentially. In the 'good opportunity' stage described in the text, the manager's incentives are congruent with those of shareholders. However, after renegotiation, pet projects of any scale (e.g. 'perks' or acquisition that do not generate value) become available. They yield no monetary return whatsoever, and they must be paid for in cash.

Payoffs to agents consist of the discounted expected value of their endowment plus any returns earned on securities they invest in during their lifetime. The focus in what follows is on stationary **Markov Perfect Equilibria** of this game, i.e. subgame perfect equilibria, in which every agent's strategy is time invariant and constrained to depend only on the payoff-relevant information.

3.2.2 Characterizing Equilibrium

The payoff relevant information at the time shareholders announce the new plan is given by the pair $(\bar{L}_t, \bar{D}_t)$. Let $V(\bar{L}_t, \bar{D}_t)$ denote the payoff to shareholders in that state. Then the payoff to shareholders at the time the make the bankruptcy decision is

$$V^* = E\left[V(\bar{L}_t, \bar{D}_t)\right].$$

It follows that shareholders forego bankruptcy if and only if the borrowing constraint

$$(1+\rho)\, B_t + (1+\rho^D)\, D_t \leq V^* \tag{2}$$

holds. Since returns are certain, the borrowing constraint is always satisfied at the equilibrium interest rates $\rho = r$ and $\rho^D = r^D$.[15] The model thus produces an increasing marginal cost of external finance, similar to other models with agency or asymmetric information problems, but the marginal cost here jumps at one point from the riskless rate to infinity.

Shareholders prefer accepting deposits to issuing bonds and they prefer lending to holding securities. However, the borrowing constraint might prevent them from the first best solution $\left(L_t = \overline{L}_t, D_t = \overline{D}_t\right)$. For a given 'franchise value' V^*, the optimal choice is[16]

$$
\begin{aligned}
D_t &= \min\{\bar{D}_t, (1+r^D)^{-1}V^*\} && (3)\\
L_t &= \min\{\bar{L}_t, \beta V^* + \left(1-\beta(1+r^D)\right) D_t\} && (4)\\
&= \min\{\bar{L}_t, \beta V^* + \left(1-\beta(1+r^D)\right) \min\{\bar{D}_t, (1+r^D)^{-1}V^*\}\} && (5)\\
S_t &= \max\{D_t - L_t, 0\} && (6)\\
B_t &= \max\{L_t - D_t, 0\} && (7)
\end{aligned}
$$

If the utility from pet projects is high enough relative to that from cash flow, the manager will thus always squander all cash that is left in the firm on pet projects, rather than saving the next good opportunity.

[15] No uncertainty is resolved between the announcement of plans and the bankruptcy decision. Thus creditors will not agree to a plan that involves bankruptcy. Shareholders therefore choose assets and liabilities in t by maximizing profits subject to (2), the budget constraint (1) as well as the capacity constraints. Any plan with one of the interest rates is higher than the corresponding reservation rate; reducing the rate increases profits and relaxes the borrowing constraint (thus retaining feasibility).

[16] If neither deposits nor lending are constrained by (2), $D_t = \bar{D}_t$ and $L_t = \bar{L}_t$, the banker is indifferent at the margin between holding securities and borrowing more or not. Security holdings in this case are assumed to be zero.

At any point in time, the bank either has more deposits than lending opportunities, in which case it does not borrow and holds the difference in securities, or it has more loans than deposits and makes up the difference borrowing in the money market, but in this case it does not hold any securities.[17] In either case, equilibrium profit in period t is

$$\Pi_t = s_D\, D_t + s_L\, L_t.$$

By stationarity of the equilibrium, the franchise value V^* must be equal to the banker's expected payoff at the beginning of period t, before lending opportunities and deposit demand are known:

$$\begin{aligned} r\,V^* &= s_D\, E\left[\min\{\bar{D}_t, (1+r^D)^{-1}V^*\}\right] \\ &\quad + s_L\, E[\min\{\bar{L}_t,\, \beta V^* + \beta s_D \min\{\bar{D}_t, (1+r^D)^{-1}\, V^*\}\})] \\ &=: \phi(V^*). \end{aligned} \tag{8}$$

This equation simultaneously determines V^* and bank asset and liability choices. The solution will be discussed in detail in section 4.

3.3 A Version with Credit Risk and Deposit Insurance

In the second game, players, endowments and the equilibrium concept are as above. However, returns are now allowed to be stochastic, and lending opportunities and deposits need no longer i.i.d. In addition, deposit insurance is now introduced in the following simple way: all the depositors are bailed out by the government in case of bankruptcy.[18] Finally, there are a few slight differences in the timing and the way default is modelled.

3.3.1 Debt, Default and Dividend Policy

Shareholders now begin the planning stage with a net position A_t. Retained earnings corresponds to positive A_t, but A_t might be negative if debt is rolled over from the previous period. Shareholders again announce feasible plans (L_t, S_t, D_t, B_t) as well as promised interest rates on bonds (ρ_t^B) and deposits $\left(\rho_t^D\right)$; investors and depositors then decide whether to accept or reject the offers.

At the beginning of the following period, $t+1$, the return R_{t+1} as well as the new lending capacity $\bar{L}_{t+1}$ and the new deposit demand $\bar{D}_{t+1}$ are realized. Shareholders then

[17] A demand for securities thus arises only if not enough lending opportunities are available. To explain the large security holdings of banks (including deposit rich ones) in reality, the model would need to allow for different maturities of assets and liabilities. This would generate a precautionary demand for liquid assets. See Lucas and McDonald (1992), Stein (1995) or Holmström and Tirole (1998) for examples of such models.

[18] The key assumption is that the deposit insurance premium does not respond to bank risk, so that rents are earned by shareholders because depositors are risk insensitive.

announce repayments to bondholders and depositors. If these repayments do not accord with the previously promised interest rates, shareholders get to keep the gross returns

$$E_{t+1} = R_{t+1}\, L_t + (1+r)\, S_t$$

and creditors become the new shareholders; cash flow at the disposal of shareholders is zero.

In contrast, if shareholders repay the promised amounts,, they keep the bank franchise. Per period profit in this case is

$$\Pi_{t+1} = E_{t+1} - C_{t+1} = E_{t+1} - (1+\rho_t^B)\, B_t - (1+\rho_t^D)\, D_t. \tag{9}$$

Shareholders can announce full repayment even if Π_{t+1} is negative. They can credibly commit to keep this promise within the current period, although they are not able to commit to repay one-period-ahead.[19,20]

Finally, shareholders pay out a fraction δ of cash flow Π to themselves. Assume that δ is an increasing function $\delta(\Pi)$ satisfying $0 \leq \delta(\Pi) \leq \Pi$ for $\Pi \geq 0$ and $\delta(\Pi) = 0$ for $\Pi < 0$. Shareholders thus carry a net position $A_{t+1} = \Pi_{t+!} - \delta(\Pi_{t+!})$ into the next planning stage.

3.3.2 Characterizing Equilibrium

A stationary MPE of the second game can be summarized by a triple of functions $(m,\, p,\, c)$. The contract offer function $m : \mathbb{R} \times \Omega \rightarrow \mathbb{R}^4_+$ prescribes liability and interest rate choices $m(A, \omega)$ at the beginning of the planning period for given net asset position carried into that period and exogenous variables. The portfolio choice function $p : \mathbb{R} \times \Omega \times \mathbb{R}^4_+ \rightarrow \mathbb{R}^2_+$, prescribes the portfolio $p(A, \omega, m)$ which is chosen after the offer m has been accepted (and the banker has received the funds). Finally, $c : \mathbb{R}^4_+ \times \mathbb{R}^2_+ \times \Omega \rightarrow \{0, 1\}$ indicates the default decision. Here, $c(m, p, \omega') = 1$ means that the banker continues, if exogenous variables ω' have been realized after policies m and p were chosen in the previous period. Every triple of functions implies a complete strategy for the banker, which depends only on the payoff relevant information.

Shareholders' payoff at the time plans are announced are given by a 'franchise value function' $V : \mathbb{R} \times \Omega \rightarrow \mathbb{R}$. To write down a Bellman equation for this franchise value, it is useful to think of shareholders' planning problem in two steps. First, they makes contract offers m subject to the depositors and investors breaking even. In a second step, they choose

[19] Formally, if shareholders promises a certain amount but do not deliver (within the period), they receive utility $-\infty$. Creditors in $t+1$ thus know that shareholders must earmark C_{t+1} of funds to debt repayment.

[20] The budget constraint for $t+1$ is the same regardless of whether earnings E_{t+1} are sufficient to cover debt repayment C_{t+1} or not, while the interpretation of the timing of events is slightly different in the two cases. If $E_{t+1} > C_{t+1}$, then one can assume that creditors are paid immediately after returns are realized, out of internal funds alone. Banker consumption is then a function $\delta(\Pi_{t+1})$ of the remaining internal funds. If, however, $E_{t+1} < C_{t+1}$, then old creditors are repaid in part with funds raised from new creditors. There are no dividends in this case.

a portfolio p subject to the budget constraint. In the overall maximization problem, the second stage will be subsumed in an 'incentive compatibility constraint' as in a principal agent problem.

Proceed backward from the beginning of the following period. In a given exogenous state $\omega' = (\bar{L}', \bar{D}', R')$, the banker will never repay to his creditors more than necessary, and in case of default he will repay nothing. He will thus decide to default if his payoff in this case (the current return on his portfolio) is lower than the payoff if he continues to run the bank (the cash flow plus the expected value of profits):

$$R' L + (1+r)\, S \ > \delta(\Pi') + V\left(\Pi' - \delta(\Pi'),\, \bar{L}',\, \bar{D}',\, R'\right), \tag{10}$$

where

$$\Pi' = R'L + (1+r)\, S_t - (1+\rho^B)\, B - (1+\rho^D)\, D.$$

For every policy (m,p), define the *bankruptcy set*

$$\Delta(m,p) = \{\omega : \text{Equation (10) is satisfied given } (m,\, p)\}\,.$$

Now consider portfolio choice. For given funds $A+B+D$, lending and security holdings must solve

$$\max_{(L,S)\,\in\,\mathbb{R}^2_+} E\left[\max\left\{R'\, L + (1+r)\, S,\ \delta(\Pi') + V(\Pi' - \delta(\Pi'),\, \omega')\right\} \mid \omega\right] \tag{P}$$

subject to

$$L + S = A + B + D$$
$$L \leq \bar{L}.$$

Depositors and investors must be willing to accept their respective contract offers. As before, the banker will always offer both types of agents an interest rate that makes them just break even. Since deposit insurance is assumed to be in place, depositors are offered (and accept) a gross interest rate of $1+r$. In contrast to the previous section, investors now need to be compensated for default risk. Using the assumption that creditors get nothing in case of bankruptcy, the participation constraints are

$$(1+\rho^B)\,(1 - \text{Prob}(\Delta(m,\, p))) \geq 1 + r, \tag{PC}$$
$$1 + \rho^D \geq 1 + r^D.$$

The Bellman equation may be written

$$V(A,\omega) = \max_{(m,\,p)\,\in\,F(A,\omega)} \beta\, E\left[\max\left\{R'L + (1+r)\, S,\ \delta(\Pi') + V(\Pi' - \delta(\Pi'),\, \omega')\right\} \mid \omega\right], \tag{11}$$

where

$$F(A,\omega) = \{\, (m,\, p) \in \mathbb{R}^5_+ \text{ s.t. } p \text{ solves problem (P) given } m, \text{ and } m \text{ satisfies (PC)}, \\ B \le \bar{B} \text{ and } D \le \bar{D} \}. \tag{12}$$

Note that the feasible set $F(A,\omega)$ may be empty if the initial wealth A is less than what can be borrowed. For example, if $A < -\bar{B} - \max\Delta$, the initial liability of the banker is so high that the exogenous debt constraint must be violated. As discussed earlier, the banker's payoff in this case is negative infinity:

$$V(A,\omega) = -\infty \qquad\qquad if\ F(A,\omega) = \varnothing.$$

For the computations, it is useful to note some properties of V and the set $F(A,\omega)$. First, V is nonnegative: there is limited liability of the banker. Second, $F(A,\omega)$ is nonempty for all $A \ge -\bar{D}$. The reason is that depositors do not care about credit risk: they are always willing to lend at the rate r^D. The banker can therefore always turn to them in order to raise funds to pay off his liabilities from dealing with the previous generation.

Moreover, as long as $V(\,\cdot\,,\omega)$ is increasing, for every ω, if the set $F(A,\omega)$ is empty for some $A < -\bar{D}$, then it is also empty for all lower values of A. If instead there was a feasible policy (m', p') at a lower value A', then the same portfolio could be financed at the same interest rate also at the higher value A. This because if the difference between A and A' is made up by borrowing less, this can only decrease the number of default states (from (10)) and hence raises lenders' expected return. It follows that $(B' - (A' - A),\, \bar{D},\, \rho^B, \rho^D, L', S')$ is feasible at A. The bottom line is that for increasing V, the set of states (A,ω) where V can be positive is a half interval $[A^{lo}(\omega),\, \infty)$.

3.3.3 Computation

An approximate solution for (11) is computed by value function iteration, starting with an arbitrary constant terminal value. This subsection sketches the main elements of the computational procedure.

The first issue is the dimensionality of the state space. The variation of the exogenous deposit and opportunity processes is restricted to finite grids, with only very few elements in the examples shown below. The stochastic returns R are also drawn from a finite grid, but here the number of elements is made much larger, so that the discretized distribution approximates a (scaled) beta distribution relatively well. Moreover, with independent shocks the value function actually does not depend on the just realized R. Increasing the number of states of R is thus not particularly costly. Finally, the banker's net internal funds A are allowed to vary continuously over an interval $I = [-B - \max\Delta, \bar{A}]$. $\bar{A}$ is chosen in accordance with the extraction function δ so that the process A never exits the interval.

For every value of $(\bar{L}, \bar{D})$, a piecewise linear approximation is used for the value function $V(\cdot, \omega)$ over that part of the interval I where it is positive.

Every iteration consists of two stages, the determination of the ranges of As for which the set $F(A, \omega)$ is nonempty and then a constrained maximization step to obtain the value of $V(\cdot, \omega)$ at each of the gridpoints for the approximation. The first stage uses the fact that, for fixed ω, if there is no solution to the constraints for some wealth level A, then there cannot be a solution for any lower wealth level. It determines $A^{lo}(\omega)$, the smallest A such that $F(A, \omega)$ is nonempty. Since depositors are always willing to lend, $A^{lo}(\omega) \leq -\bar{D}$.

In the first stage, for each of the finite number of ω, the algorithm thus searches downward from $-\bar{D}$ over candidate values of $A^{lo}(\omega)$, beginning with a relatively large step size. At each step it maximizes the lender's expected return (the left hand side of (PC)) over policies (m, p) such that p solves the problem (P). If this maximum is less than the riskless rate, no feasible policy exists since no level of borrowing is consistent with the constraints. In this case the algorithm backs up to the previous level of A and continues with half the previous step size. In contrast, a further downward step is undertaken if the maximal return to the lender exceeds the riskless rate. The step size is also halved on downward steps if necessary to avoid evaluating the same candidate value twice.

Once the first stage algorithm has zeroed in on $A^{lo}(\omega)$, the second stage evaluates the value function $V(\cdot, \omega)$ at all gridpoints for the piecewise linear approximation over the interval $[A^{lo}(\omega), \bar{A}]$. This stage is costly in states where borrowing is positive, because of the nature of constraints. The code exploits the fact that the participation constraint is binding at the optimum and moreover adopts the two-step view of the problem described in the previous section. The maximization in step 1 is performed over borrowing levels B and deposits D, computing for every B and D the implied interest rate and portfolio. The interest rate associated with given B and D is determined by solving for the smallest fixed point of the map $1 + \rho^B \to \frac{1+r}{1-\text{Prob}(\Delta(m,p))}$, taking into account that for every m, p must solve the problem (P).

4 Bank Heterogeneity without Credit Risk

This section describes in more detail the equilibria of the model without credit risk. This model is used to understand bank heterogeneity, the propensity to merge and the volatility of bank stock prices.

4.1 The Equilibrium Franchise Value

To examine the existence of equilibrium, consider Figure 2, which plots the left and (several versions of the) right hand side ϕ of the franchise value equation (8). The function ϕ is increasing, because a higher continuation value allows the bank to borrow more. An increase in V is reflected in expected per period profit only to the extent that $\bar{L}_t$ and $\bar{D}_t$

are large enough such that the borrowing constraint binds. The higher V, the smaller is the probability of such realizations. This implies that ϕ is concave. Since opportunities and deposits are bounded, a high enough V will ensure that the bank is never constrained. $\phi(V)$ must thus eventually become equal to

$$s_D\, E[\bar{D}] + s_L\, E[\bar{L}].$$

The profit earned on average by an unconstrained bank provides an upper bound on the equilibrium return achievable in the present environment, $r\,V^*$.

Clearly, $V^* = 0$ is always a solution to (8). This value corresponds to an equilibrium in which the bank does not operate. Since the only reason for shareholders to repay creditors is that they might want to keep the franchise, they will default for sure if the franchise value is zero. Anticipating this, investors and depositors will not lend in this case, so the bank does not operate and the value of zero is indeed consistent with equilibrium. When are the incentives for repayment given by the franchise value strong enough to allow the bank to operate ? This depends on whether the profit margins from lending and deposit taking are large enough relative to the discount rate:

Proposition 1.

(i) For $\beta\, s_L + s_D > r$, there exists an SMPE such that the bank operates at a positive scale.

(ii) For $\beta\, s_L + s_D \leq r$, the only SMPE is such that the bank does not operate.

Proof: Appendix A.

It is possible that, even with imperfect commitment, the efficient outcome will occur. In Figure 2, this corresponds to an equilibrium value in the range where ϕ is flat such as point A. A sufficient condition for this is that the spreads to be earned on either activity be high enough: the promise of future profits ensure that the banker will pay back.

4.2 Changes in Market Conditions

It is interesting to ask how bank actions and stock prices respond to permanent changes in local market conditions.

Proposition 2.

(i) Holding the distribution of $\bar{\mathrm{D}}$ fixed, changing the conditional distribution of $\bar{\mathrm{L}}$ given $\bar{\mathrm{D}}$ by a first order stochastic dominance shift increases the franchise value. The corresponding statement holds for $\bar{\mathrm{D}}$ given $\bar{\mathrm{L}}$.

(ii) Holding fixed the distribution of $\bar{\mathrm{D}}$, changing the conditional distribution of $\bar{\mathrm{L}}$ given $\bar{\mathrm{D}}$ by a mean-preserving spread decreases the franchise value. The corresponding statement holds for $\bar{\mathrm{D}}$ given $\bar{\mathrm{L}}$.

Proof. This result follows directly from (8). For given future value V^*, the period return $\phi(V^*)$ may be thought of as the 'utility' of shareholders over lotteries of $(\bar{D}_t, \bar{L}_t)$. Fixing one random variable, say $\bar{D}_t$, the min operation implies that the 'utility function' used to evaluate lotteries of L_t is concave and increasing. A decision maker with a concave, increasing utility function always likes first order shifts and dislikes mean-preserving spreads. It follows that these operations shift the function ϕ in Figure 2 up and down, respectively. ¥

It is not surprising that a (probabilistic) increase in 'rent generating opportunities' increases bank value. The key here is that it is still feasible to run the bank at the same scale as before the increase. An increase in opportunities does not generate greater 'temptation' to default, since it is known at the time debt is issued. Since decreasing the spreads s_L and s_D also shifts down ϕ in Figure 2, any announcement that suggests a reduction in future rents will result immediately not only in a lower stock price, but also in lower borrowing. It follows that a 'credit crunch' can be induced by the anticipation of low returns, rather than their realization.

Although bank shareholders are risk neutral, banks that operate in more volatile environments are worth less. The reason is that the ability to borrow is governed by mean profits, which reflect mean opportunities. If opportunities are very volatile, it will often happen that good realizations cannot be exploited. Of course, it is important that it is difficult (here: impossible) for the bank to self-insure by transferring funds through retained earnings from low-opportunity periods into high-opportunity periods.

4.3 Borrowing Constraints

This subsection develops additional comparative static predictions and uses them to discuss heterogeneity across banks with respect to the (excess) correlation of loans and deposits.

4.3.1 A simple parametrization

Consider a class of banks with identical, constant, deposit base $D := n\overline{D}$; $n \geq 1$, and identical, but independent, lending opportunity processes

$$\overline{L}_t^n = nL^e + \sqrt{n}\varepsilon_t$$

where ε_t is i.i.d. with a cdf F such that $F(0) = 0$, $F(\bar{\varepsilon}) = 1$ for some $\bar{\varepsilon}$, $E\varepsilon_t = 0$ and $\text{var}(\varepsilon_t) = 1$. The idea is that there are two types of business in local loan markets. First, there is 'liquidity demand' for loans from customers who are also depositors. This type of business is assumed to be stable, and corresponds to some fixed fraction of L^e. The second type of business consists of lending that is not so much correlated with deposits, such as real estate lending or loans to new firms; it is represented by a fraction of L^e plus ε.

The parameter n determines the size of the bank. The key assumption here is that the variance of lending opportunities grows linearly with n. This occurs naturally if a large bank is a collection of n small banks (each with $n = 1$) operating in mutually independent markets. Thus the response to changes in n creates predictions for behavior across bank size classes. In addition, the response to changes in L^e (for fixed D) creates predictions across classes of banks with a set of customers that offers more lending opportunities relative to deposits.

It is also assumed that returns are high enough so that all banks in the class access the money market at least in some states of the world. The relevant condition strengthens the existence condition above to[21]

$$\beta s_L E \left[\min \left\{ \frac{L^e}{D} + \varepsilon, 1 \right\} \right] + s_D > r \tag{13}$$

This condition is equivalent to the existence condition if there are more opportunities than deposits with probability one for all banks. More generally, it requires that the tails of the shock ε are not too 'fat' so as to allow too many periods in which the bank has significantly less loan opportunities relative to deposits.

The return condition (13) together with (8) imply that the bank can take on all deposits in equilibrium. There is thus a one-to-one relationship between the franchise value and the maximal amount of funds that can be raised

$$L^* = \beta(V^* + s_D D)$$

Manipulating (8), find that the equilibrium L^* is determined by

$$\beta s_L \int_0^{L^*} F\left(\frac{l - \sqrt{n}L^e}{\sqrt{n}}\right) dl = (\beta s_L - r)\, L^* + s_D D \tag{14}$$

This is illustrated in Figure 3. The left hand side is convex and its slope will be equal to βs_L once L^* is larger than the maximal opportunities $nL^e + \sqrt{n}\bar{\varepsilon}$, its value is $\beta\, s_L \sqrt{n}\bar{\varepsilon}$ in that region. The slope of the right hand side depends on how high the margin on loans is relative to the riskless interest rate. The downward sloping line in Figure 3 depicts an example of 'low returns', $\beta\, s_L < r$, whereas the upward sloping line represents the case of 'high returns' in which the right hand side is increasing. In either case, there is always a solution.

[21] It is equivalent to the existence condition if there are more opportunities than deposits with probability one.

4.3.2 The Correlation between Loans and Deposits

Consider the reaction of an individual bank to an small, unanticipated, temporary drop in deposit demand. There are three cases, depending on the realization of lending opportunities $\overline{L}_t$. First, a "deposit rich" bank $\left(\overline{L}_t < D\right)$ simply reduces securities one-for-one with deposits; its lending is unaffected. Second, a bank which has more opportunities than deposits $\left(\overline{L}_t < D\right)$, but 'spare debt capacity' $\left(L^* > \overline{L}_t\right)$ will substitute money market funds for deposits to keep up its lending. This will squeeze its net interest margin, but not affect the quantity of lending.

Finally, suppose that the bank is initially at the borrowing constraint $\left(L^* < \overline{L}_t\right)$. Now it cannot simply substitute money market funds for core deposits: a drop in deposits by ΔD frees up debt capacity of only $(1 + r^D)\,\Delta D$. The bank can thus borrow $\frac{1+r^D}{1+r}\,\Delta D$ more than before, but because of the difference in rates $(r > r^D)$, this is not sufficient to cover the shortfall of funds. Lending must therefore fall by $(1 - \frac{1+r^D}{1+r})\,\Delta D$. It follows that, at the level of the individual bank, deposit shocks that are orthogonal to lending opportunities can still affect lending.

The extent of 'excess' correlation between loans and deposits for the whole class of banks is then proportional to the fraction of banks in the class that are at the borrowing constraint at a point in time, or $1 - F\left(\frac{L^* - \sqrt{n}L^e}{\sqrt{n}}\right)$. Predictions about the correlation across size classes are thus derived by comparative statics on $F\left(\frac{L^* - nL^e}{\sqrt{n}}\right)$ with respect to n and L^e.

Proposition 3.

(i) The elasticity of the franchise value V^* with respect to n is greater than one.

(ii) The probability that the bank's borrowing constraint is binding is decreasing in n.

(iii) The probability that the bank's borrowing constraint is binding is decreasing in L^e.

Proof. See Appendix A.

Parts (i) provides the effect on the franchise value. This cannot be deduced from Proposition 1, because an increase in n produces both an increase in the means of L and D, which by itself would increase V^* and a mean preserving spread, which would decrease it. The key is that the ratio of opportunities and deposits becomes less risky as n increases. The homogeneity of (8) in the case of fixed D then delivers the result.

4.3.3 Bank Heterogeneity Reconsidered

A number of studies have documented that small banks rely relatively more on core deposits as opposed to money market borrowing than large banks (e.g. Berger, Kashyap and Scalise (1995)).. There is also evidence on the correlation of loans and deposits. Jayaratne and Morgan (1997) have proposed a test of borrowing constraints that exploits the analogy of the relationship of deposits and lending in models of constrained banks to that of cash flow and investment in models of constrained nonfinancial firms. The idea is to follow the lead of the sizable cash flow investment literature and regress loan growth on deposit growth while controlling for loan opportunities. They find evidence that borrowing constraints are stronger at larger banks.

Proposition 3 can help understand these facts. Compare a class of 'large banks', with $n > 1$ to a class of 'small banks' with $n = 1$. From part (i), the maximal amount of funds L_n^* that can be raised by a large bank is larger than n times that for small banks, L^*, say. It follows that large banks have a larger mean loan/deposit ratio $\frac{E\left[\min\left\{\bar{L}_t, L^*\right\}\right]}{D}$ in equilibrium. Moreover, part (ii) says that the excess correlation of loans and deposits induced by binding borrowing constraints (or, more generally, imperfect substitutability of money market funds and deposits), is stronger for the class of small banks.[22]

Another interesting dimension of bank heterogeneity is suggested by the recent merger movement. The relaxation of both intrastate and interstate branching restrictions has created a new type of large bank holding company, which relies on an extended branching network. Anecdotal evidence suggests that at least some of these new banks, such as KeyCorp, have quite different business strategies compared to traditional banks of similar size (e.g. Sinkey (1997)). In particular, they tend to focus exclusively on small business and individual lending in the communities in which the branches are located. Consistent with this, Section 6 below shows that in a sample of US banks that omits the vary largest and smallest banks, loan/deposit ratios are larger for banks with larger branches.

The different strategies of large-branch and small-branch banks can be captured by heterogeneity in opportunities. Compare two classes of banks A and B, one of which has larger mean opportunities. By proposition 2, lending is on average larger for the bank with more opportunities. Then decrease deposits of banks in B to arrive at the same mean size for both classes. Banks in B will now have a higher average loan/deposit ratio, simply because they have more opportunities. If this story is correct, then by proposition 3, part

[22]Indirect evidence on the relevance of stronger borrowing constraints at small banks is provided by the literature on the lending channel. Kashyap and Stein (1995) have shown that the reduction in lending after a tightening of monetary policy effect is stronger at small banks than at large ones. A more refined test of the existence of a lending channel is introduced by Kashyap and Stein (1997), who consider cross sectional differences in the reaction of lending to monetary policy across banks with different security/asset ratio. They find that more liquid banks react less to monetary policy, and that the difference in reaction between more and less liquid banks is stronger within the class of large banks than within the class of small banks.

(iii) one should also find stronger evidence of borrowing constraints (such as excess loan deposit correlation) at small-branch banks. Section 6 examines this question and finds some support.

5 Credit Risk and Deposit Insurance

This section presents three computational examples for the model with credit risk and deposit insurance. The first example provides a general overview of the nature of the dynamics that arise in this setting. The second example looks at changes in the distribution of opportunities. The third example investigates the implications of eliminating deposit insurance. All three examples should be viewed as numerical experiments that aid in understanding the qualitative features of the model, rather than a serious calibration which is left for future work. The nature of the results is typical of a range of parameter values that was explored, with important exceptions noted in the text.

The examples use a dividend rule according to which a constraint fraction δ is extracted every period. In each case the parameter δ is chosen high enough to guarantee the existence of a stationary distribution of the state process where wealth constraints remain an issue.

Example 5.1: Optimal Policies and the Value of the Bank

In this example, opportunities follow a two state Markov chain, and deposits are i.i.d over time conditionally on opportunities. Deposits are positively correlated with opportunities. This is taken to reflect the fact that in the region where the bank is located income of depositors is positively related to economic activity. Note that a need for external non-deposit finance is always present if opportunities are high, but is more likely not to exist if opportunities are low. The bank's gross return shock is i.i.d and distributed uniformly between .5 and 2. The mean gross return of 1.5 is thus larger than the riskless interest factor of 1.11. The complete set of parameters is listed below Table 1.

Consider the value of the bank as a function of deposits, opportunities and the net position A_t. Figure 4 plots the function $V(\cdot, \bar{L}, \bar{D})$ for each of the four deposit-opportunity pairs. The feasible set $F(\cdot, \bar{L}, \bar{D})$, varies across states. Recall from the previous subsection that the lower bound $A^{lo}(\omega)$ is at least as low as $-\bar{D}$. Here it takes exactly this value whenever deposits are high (states 1 and 2), and also when both deposits and opportunities are low (state 4). However, if deposits are low but opportunities are high (state 3), the bank survives even if A_t has dropped below the negative of available deposits.

Not surprisingly, the value is increasing in all three dimensions: A_t, deposits and opportunities. For high values of A_t, deposits become irrelevant. This is because if the bank is extremely well capitalized, it has no need for external finance at all. For very low values, opportunities become irrelevant if deposits are high. The bank will never get out of this region, all insured deposits are accepted, but bankruptcy occurs for sure. Since the excess of deposits over repayments to old creditors is too low to exhaust opportunities, opportunities do not matter any more for payoffs.

To visualize the policy functions, Figure 4 presents four graphs summarizing balance sheet positions for each of the four $(\bar{L}, \bar{D})$-pairs. The bank never borrow to invest in securities. This is because the interest rate on borrowing typically includes a risk premium. Similarly to the setting of Section ??, the bank is therefore always in one of two cases. It either has an excess of internal funds and cheap funds (deposits) over lending opportunities, in which case it does hold securities, or it has more opportunities than deposits and tries to close the gap by borrowing. In each graph, there is a cutoff level for A_t such that lending and total assets coincide at levels of A_t below this cutoff, whereas liabilities (defined as deposits plus borrowing) and deposits coincide for higher A_t. The cutoff level is higher for higher opportunities and lower for higher deposits.

For low levels of wealth, the bank is borrowing constrained. The level of A_t below which borrowing constraints bite is decreasing in deposits, although in the example here this effect is small and not readily discernible from Figure 4. It is, however, apparent that the cutoff level is higher in the high opportunity state. This is not a general result. On the one hand, the incentive effect implies that higher opportunities today increase the expected franchise value tomorrow, strengthening repayment incentives. This is reflected in lending and borrowing being higher in the high opportunity state for given A_t. On the other hand, a higher need for funds must be satisfied in the high opportunity state. In principle, the cutoff could be higher in either the low or the high opportunity state. The fact that higher current opportunities and deposits can help banks in accessing the money market is also reflected in the lowest level of A_t at which nondeposit finance is completely cut off. At this point, the level of borrowing in Figure 4 goes to zero and the money market interest rate tends to infinity. The lowest such level is reached in the state with high opportunities and deposits.

Example 5.1 (a): The Dynamics of Borrowing and Lending

This subsection presents simulation results based on Example 5.1. All simulation experiments in this paper are based on the last 5000 periods from a total of 7000 simulated periods. Summary statistics are in Table 1. Note that the averages of A_t, deposits and borrowing need not add up to total assets, because A_t does become negative in equilibrium. The last column shows that the bank can take advantage of 95% of opportunities on average.

One simple way to summarize the main features of the series is to run an unrestricted VAR on the simulated data. Impulse responses (and further details about the estimation) are presented in Figure 5. The first two graphs summarize the exogenous variables: opportunities is first order autoregressive (albeit with an unusual shock distribution), and a deposit innovation dies out immediately, since deposits are i.i.d. conditionally on opportunities.

If there were perfect markets, opportunities would equal lending. Figure 5 shows that the possibility of borrowing constraints implies that lending responds less than one for one to an innovation in opportunities. Moreover, lending responds positively to deposits. Consider next the impact of a return shock, which will first show up as a shock to A_t. A shock to A_t has a persistent effect on lending.[23]

The effects of both shocks to borrowing and deposit shocks on lending appear rather weak. One reason for this is that a linear VAR must average over regions of the state space in which the nonlinear underlying model produces different effects. For an example of this nonlinearity, consider Figure 6, which presents typical time series of opportunities, lending, borrowing and A_t for 100 periods. Note how A_t becomes negative in 'crisis' episodes. If A_t is relatively high and the bank is unconstrained, internal funds (A_t) and borrowing tend to be substitutes. For a bank with low, and especially with negative, A_t, the amount of borrowing relates positively to A_t. This is because higher A_t increases the continuation value and allows the bank to borrow more.

Example 5.1 (b): Financial Distress

It is interesting to look more closely at episodes of financial distress in which default eventually occurs. Table 2 provides some summary statistics. As is to be expected, A_t is generally low and interest rates high in the last period before default. Moreover, default often coincides with a deterioration of the environment that is unrelated to the bank's asset position, such as a drop in deposit base or opportunities. The fact that drops in deposit demand often contribute to triggering default is the most extreme incarnation of the general principle that constrained banks cannot freely substitute between core deposits and the money market. In addition, a drop in opportunities corresponds to a persistent drop in rents to the banker and thus can also help trigger default

Figure 7 provides a histogram of the realizations of the return on loans which correspond to default periods. The clustering at both the low end and the high end of the return distribution reflects the fact that there are two types of default. First, if the banker has accumulated a large amount of debt, a low realization of returns may imply that he drops below the level of A_t at which he can still refinance with the next generation of creditors. Default is then the only option left, because, even if he were to announce repayment of debt, he could not make good on this promise within the period and would obtain the penalty utility of $-\infty$. Second, default could also occur if the realization of returns is very high, especially if the environment deteriorates at the same time. In this case, the temptation to quit with the existing returns is high relative to the continuation value.

Example 5.2: Changing the Distribution of Opportunities

This subsection examines shifts in the distribution of opportunities for fixed deposits. The parameter values and results are reported in Table 3. The reference case (Bank A)

[23] This is a version of the 'financial accelerator' effect first emphasized by Bernanke and Gertler (1989). Independent shocks get propagated through the banks' balance sheet.

is one with an i.i.d opportunity process taking on two states. There is always a need for nondeposit finance in the high state, whereas this almost never occurs in the low state.

The first comparative static is an increase in the probability of the high state. This results in an increase in average lending financed by higher average borrowing. This is a manifestation of the incentive effect: higher average opportunities allow the bank to borrow more. In addition, Bank B is less likely to be borrowing constrained than Bank A. Of course, as in Section ??, this is not a general result. In principle, if the high state occurs more often this could mean that a need for funds too large to be satisfied occurs more often. Unfortunately, conditions for when the incentive effect dominates are not as easy to come by here, because the dynamics of returns and A_t interacts with that of opportunities and deposits.

A second example considers a change in the persistence of opportunities. Suppose the overall frequency of the low and the high state are left the same as for Bank A, but the bank (Bank C in Table 3) is less likely to leave the high state once it has occurred. This also results in a drop in the probability of being constrained.

Example 5.3: The Role of Deposit Insurance

The main effect of deposit insurance is the introduction of a class of lenders who are insensitive to risk. Depositors neither require a risk premium if the bank is undercapitalized, nor do they ration funds. The example compares two banks, one of which has zero deposits. This is equivalent to assuming that depositors are not subject to insurance [24].

The subsidy implicit in deposit insurance clearly raises the value of the bank. Its implications for bank behavior are shown in Figure 8. One of the implications is for banks' access to external finance for low levels of A_t. In the case considered, the insured bank can always refinance provided debt is not higher than total deposits, whereas the uninsured bank is restricted to positive A_t. Deposits also help in raising additional nondeposit funds, as the insured bank resorts to borrowing even if A_t is substantially negative.

The simulation results reported in Table 4 show that the insured Bank A is on average much larger and almost always takes advantage of all its opportunities. The high average of assets point to the fact that the insured bank is very well capitalized most of the time; it also has much less variable balance sheet positions. It rarely ventures into the region where A_t is negative and has a low probability of bankruptcy. In contrast, the uninsured Bank B has highly variable positions and a higher probability of bankruptcy. The main reason for this is that deposits provide a convenient cushion for an insured bank. If it receives a bad shock, it is not required to cut lending by much. It thus bounces back quickly from temporary drops in A_t. For the uninsured bank, a drop in A_t is more persistent since it leads to a drop in lending, which tends to make A_t lower, and so on.

[24] For computational reasons, it is actually assumed that deposits for the 'uninsured' bank are equal to .0001

What can be said about the expected costs and benefits of deposit insurance ? First, there is a cost in that the government must inject funds into the system whenever bankruptcy actually occurs. The benefit of deposit insurance accrues to the banker and consists in the difference in expected lending that deposit insurance allows. The expected discounted costs to the government may be computed as

$$C^{DI} = .025(1 + r^D)\,\bar{D}\ \text{Prob(Default of A)}\ \frac{1}{1-\beta} = .0249.$$

Similarly, the expected difference in surplus from lending is given by

$$B^{DI} = (E\,[R] - (1 + r))\,E[L^A - L^B]\,\frac{1}{1-\beta} = 2.41.$$

The cushion provided by the insensitive creditors thus makes default so rare that the benefits are larger. Of course, this result does not imply that deposit insurance is Pareto improving since surplus is not directly comparable here. However, it suggests that in a general equilibrium context the interaction of deposit insurance and the commitment problem might have interesting welfare implications. At least, the effect might be used to build a political economy story for deposit insurance.h

6 Empirical Evidence

This section explores differences in liability composition and borrowing constraints for banks that differ in the size of their branches. The basic strategy is to use a panel data set of banks of roughly the same size, classify banks into two categories, labelled 'regional banks' (banks with small branches) and city banks (banks with large branches)[25] and then test the groups individually for borrowing constraints. The type of test employed follows Jayaratne and Morgan (1997). In the regression of loan growth of core deposit growth and variables controlling for unobservable opportunities, the coefficient on core deposits is interpreted as measuring the intensity of borrowing constraints. If there were no constraints, this coefficient should be zero provided that opportunities are properly controlled for.

The empirical model used for each group may thus be summarized by

$$\Delta \log(L_t^i) = \beta_0 + \beta_1 \Delta \log(D_t^i) + \beta_2' C_t^i + u_t^i, \tag{15}$$

where C_t^i is a vector of control variables. Here the index i runs over bank holding companies and t over quarters. After a description of the data used in the next subsection, subsection 6.2 discusses various pitfalls that come with this approach and how they are addressed.

[25] Note that these labels are for the sake of the discussion only. The data does not allow to check the exact location of the branches.

6.1 Description of the Data

The data are taken from the Consolidated Reports of Conditions and Income (known as the Call Reports) which insured commercial banks are required to file every quarter with the Federal Reserve. The raw data set covers all insured commercial banks from 1993:1 to 1997:2.

The individual bank data were first consolidated to the bank holding company (BHC) level. A holding company comprising 10 unit banks is thus treated the same way as a single bank with 10 branches. This would be problematic if relations between branches were correlated with the choice of the BHC structure. While there has not been much work on this issue, several recent studies have shown that internal capital markets do exist within BHCs.[26] It thus seems appropriate to aggregate. An additional gain of choosing the BHC as the unit of analysis is that this creates a sample which contains more organizations with larger branching networks.

Even at the level of bank holding companies, however, the population of all U.S. BHCs consists mostly of institutions that are small and have only one branch office. For the purpose of isolating a group of city banks with lending opportunities not tied to local conditions, the full sample of BHCs is not suitable, as it would allow a large number of rural unit banks to drive the results. It is thus necessary to narrow the sample to exclude these small unit banks. This was accomplished by discarding all BHCs with total assets less than $ 1 bn (in 1997 dollars). To ensure a similar size distribution across the group of regionals and city banks, banks with assets higher than $ 10 bn were excluded from the sample.

A further problem is created by the considerable merger activity in banking over the sample considered. This was handled by constructing 'pro forma BHCs'. If a BHC or one of its members was involved in a merger or acquisition in during given quarter, a pro forma BHC was setup for the end of the previous quarter by adding the parties' asset and liability positions. This procedure was also used to construct observations for lagged values.

The unit of observation is a 'bank quarter': equation (15) holds for bank i in quarter t. After consolidation, sample selection and requiring that five lags are available for loans, I am left with a set of 2592 bank quarters of data. The groups of regional and city banks were formed by splitting the sample roughly in half, choosing the cutoff at $ 40 mn in assets per branch. Note that groups are formed by binning bank quarters. In other words, a BHC which is 'regional' early in the sample might jump groups if, by acquisition or otherwise, its assets grow a lot relative to its branches. This is appropriate because, according to the model, behavior is governed by current and expected opportunities and deposits. Institutional history matters only to the extent that it has a bearing on the future.

Loans are simply measured by total loans and leases. Choosing the correct balance sheet

[26] See Houston and James (1998) and Jayaratne and Morgan (1997).

measure for core deposits is more tricky. What is needed in view of the model is a class of liabilities on which banks both pay below market interest rates and whose demand can be reasonably taken to be 'local'. Core deposits are defined here as total deposits in account of less than \$ 100.000. In addition to lagged loan growth, several other standard control variables are employed. These are the capital ratio, defined as total equity capital divided by total assets, total loan loss provisions as a fraction of assets, the ratio of total loans to assets and a peer growth measure defined below.

6.2 Potential Problems with the Empirical Approach

There are three major difficulties associated with the empirical test of borrowing constraints presented in the previous section. First, it shares with all tests of financing constraints the feature that it is crucial that opportunities are well controlled for. Otherwise the coefficient β_1 in equation (15) might be positive simply because lending opportunities and deposit demand are correlated, and its size would not be linked to the existence of borrowing constraints. This issue is especially relevant given the classification of banks into groups of regionals and city banks. The vector of controls, C_t, contains two variables typically used to alleviate this concern: (1) up to four lags of individual BHC loan growth and (2) an index of peer loan growth. This index was constructed for each BHC and quarter as a weighted average of loan growth in the states in which the BHC has subsidiaries. For a given BHC, the weights on loan growth in a given state are computed by dividing the sum of loans at all subsidiaries in that state (at the beginning of the quarter) by total loans of the BHC.

Second, contrary to the theoretical model, deposit demand is probably not completely elastic up to a bound $\bar{D}_t$ and inelastic afterwards. Instead, banks can attract more core deposits by increasing deposit rates, which induces a positive slope even if deposit demands are not correlated with opportunities.[27] This does not affect a group-by-group test for borrowing constraints, if opportunities are properly controlled for due to the following reason. The borrowing constraint derived in Section ?? depends on accepted deposits D_t. If the model was extended to an imperfectly elastic deposit demand, banks would attract core deposits up to the point where the marginal costs equal that of money market funds (if funds are needed at all, that is). This amounts to a redefinition of the joint deposit-loan process and does not change the key point that, after controlling for opportunities, the coefficient β_1 on deposits is positive only if a potentially binding borrowing constraint exists. Comparisons of regression coefficients across groups, however, are more difficult.

Third, the difference across groups may be driven by a factor other than the distribution of opportunities and deposits. One factor that comes to mind is bank size, which has already

[27] Jayaratne and Morgan (1997) point out that this 'reverse causation' problem is germane to the loan-deposit test. It is also a key difference between this test and the large literature that is concerned with the relationship between investment and cash flow.

been established as important for the intensity of borrowing constraints. It is generally true that larger banks have larger branches: over the full sample, the correlation coefficient between the two variables is .27. However, this correlation appears to be driven by the vary large and very small banks. The restriction of the sample to BHCs with assets between \$1 and \$10 bn leads to size distributions for regional and city banks which look pretty similar. Indeed, a Kolmogoroff-Smirnoff test does not reject equality of the cumulative distribution functions at the 5 %- level.

6.3 Empirical Results

Table 5 presents some key balance sheet statistics for the two populations of banks. Across the two groups, most ratios look quite similar. One exception is that the average regional bank has only about two thirds the volume of commercial and industrial loans (normalized by total assets). This might reflect the fact that regional banks actually do more business in rural areas. The most important difference is in the ratio of core deposits to assets. City banks rely significantly less on core deposits than do regional banks. Of course, this might simply reflect a greater average mismatch of opportunities and deposits on the part of city banks that is not linked to imperfections. It does, however, make the a priori classification seem more reasonable. Whether borrowing constraints are present or not, the group of banks which is assumed to have more opportunities (relative to core deposits) does at least not have less.

As an aside, it is interesting to note in this context that assets per branch is important in predicting the ratio of core deposits to assets. It appears that the well known stylized fact that large banks hold less core deposits is to a large extent driven by the correlation of banks size with assets per branch. Table 6 reports the results of regressing this ratio on the logarithm of assets and assets per branch. While size retains a statistically significant role, it is apparent that assets per branch contributes most of the explanatory power. This is important in the debate on bank consolidation, since opponents of consolidation have argued large banks have 'riskier liabilities'. The result here suggests that it is one needs to differentiate between types of large bank.

Table 7 shows summary statistics of the variables used in the specification of (15) reported below. The right hand side includes, in addition to deposit growth and the control variables mentioned in Section 6.2, a number of other variables that have been employed in the literature. These include the equity ratio, the loan to asset ratio and the ratio of loan loss provisions to total assets.

Table 8 shows the results of estimating versions of equation (15). All regressions were run with quarter dummies that are not reported. When the regression is run for each group of banks separately, the estimated coefficients are drastically different. The coefficient on deposit growth is large and highly significant for the regional banks (Panel A), while it is only marginally significant for the city banks. The hypothesis that city banks do not experience borrowing constraints cannot be rejected at the 1% level. To directly test whether the coefficients in the two groups are different and to improve the estimates of the coefficients on the common regressors, equation (15) is reestimated using the whole sample. An interaction term is used to disentangle the different effects of deposit growth on lending. The p-value of this interaction term shows that the behavior of banks in the two groups is indeed different. Note, however, that this latter result must be considered with some caution, since the size of the coefficients may be biased due to the endogeneity of deposit demand alluded to before.

Interestingly, the coefficient on the loan ratio, too, is highly significant for regional banks and borderline significant for city banks. The test for borrowing constraints in Kashyap and Stein (1997) looks at the coefficients of the security ratio (which equals one minus the loan/asset ratio) which they interpret as the intensity of borrowing constraints. It appears that also according to this measure, regional banks are likely to be constrained, whereas city banks are not. Of course, this type of test is not as easily linkable to the theoretical model of earlier sections, which does not create a role for precautionary security holdings.

Overall, the results, especially the estimated coefficient β_1 in the separate regressions, do lend some support to the claim that regional banks are more likely to be borrowing constrained.

7 Appendix

Proof of Proposition 1:

Denote the right hand side of (8) by $\phi(V)$. By computing derivatives, it can be shown that the function ϕ is increasing and concave:

$$
\begin{aligned}
\phi'(V) = {} & s_D(1+r^D)^{-1}(1-G_{\bar{D}}((1+r^D)^{-1}V)) \\
& + s_L(\int_0^{(1+r^D)^{-1}V} \beta\,(1-G_{\bar{L}|\bar{D}}(\beta\,V+(1-\beta\,(1+r^D))u \mid u)\; g_{\bar{D}}(u)du \\
& + \int_{(1+r^D)^{-1}V}^{\infty} (1+r^D)^{-1}\,(1-G_{\bar{L}|\bar{D}}(\,(1+r^D)^{-1}V \mid u)\; g_{\bar{D}}(u)du) \\
& > 0
\end{aligned}
$$

$$
\begin{aligned}
\phi''(V) = {} & -s_D(1+r^D)^{-2}g_{\bar{D}}((1+r^D)^{-1}V) \\
& - s_L(\int_0^{(1+r^D)^{-1}V} \beta^2 g_{\bar{L}|\bar{D}}(\beta\,V+(1-\beta\,(1+r^D))u \mid u)\; g_{\bar{D}}(u)du \\
& + \int_{(1+r^D)^{-1}V}^{\infty} (1+r^D)^{-2}g_{\bar{L}|\bar{D}}((1+r^D)^{-1}\,V \mid u)\; g_{\bar{D}}(u)\; du) \\
& < 0
\end{aligned}
$$

Note also that ϕ is bounded above. In fact, $\phi(V) \to s_D E[\bar{D}] + s_L E[\bar{L}]$ as $V \to \infty$. A unique positive solution to (8) will thus obtain if and only if $\phi'(0) = (s_D+s_L)(1+r^D)^{-1} > r$ or equivalently $s_D + \beta s_L > r$.

Proof of Proposition 3:

The result follows by differentiation, using the implicit definition of L^* in (14). Let $G\,(l) = F\left(\frac{L^*-\sqrt{n}L^e}{\sqrt{n}}\right)$ denote the cdf of $\overline{L}_t$. The goal is to show that $\frac{dG(L^*)}{dn} > 0$. Now

$$
\begin{aligned}
\frac{dG(L^*)}{dn} &= g\,(L^*)\,\frac{dL^*}{dn} + G\,(L^*) \\
&= g\,(L^*)\,\frac{\frac{1}{2\sqrt{n}}\beta s_L \int_0^{L^*}\left(\frac{l}{\sqrt{n^3}}+\frac{L^e}{\sqrt{n}}\right)\frac{1}{\sqrt{n}}f\left(\frac{L^*-nL^e}{\sqrt{n}}\right)dl + s_D D}{r-\beta s_L\,(1-G(L^*))} - f\left(\frac{L^*-nL^e}{\sqrt{n}}\right)\left(\frac{L^*}{2\sqrt{n^3}}+\frac{L^e}{2\sqrt{n}}\right) \\
&= \frac{1}{2n}g(L^*)\left(\frac{\beta s_L \int_0^{L^*}(l+nL^e)\,g\,(l)\,dl + 2s_D nD}{r-\beta s_L\,(1-G(L^*))} - (L^*+nL^e)\right)
\end{aligned}
$$

From Figure 3, it is clear that $r > \beta s_L (1 - G(L^*))$ at the equilibrium L^*. It follows that $\frac{dG(L^*)}{dn} > 0$ if and only if

$$\beta s_L \left(\int_0^{L^*} l\, g(l)\, dl + (1 - G(L^*)\, L^*) \right) + \beta s_L (L^* + nL^e) + s_D nD > (L^* + nL^e)\, r$$

which reduces to, by (14), to

$$\beta s_L nL^e + s_D nD > nL^e r$$

But this is implied by the return condition (13).This proves part (i).

The argument for part (ii) is similar:

$$\begin{aligned} \frac{dG(L^*)}{dn} &= g(L^*) \frac{\beta s_L \int_0^{L^*} \sqrt{n} f\left(\frac{l - nL^e}{\sqrt{n}}\right) dl}{r - \beta s_L (1 - G(L^*))} - f\left(\frac{L^* - nL^e}{\sqrt{n}}\right)\sqrt{n} \\ &= n^{-1} g(L^*) \left(\frac{\beta s_L G(L^*)}{r - \beta s_L (1 - G(L^*))} - 1 \right) \end{aligned}$$

so that $\frac{dG(L^*)}{dn} > 0$ if and only if $r < \beta s_L$, which is implied by (13) □

References

[1] Acharya, Sankarshan (1995). "Charter Value, Minimum Bank Capital Requirement and Deposit Insurance Pricing in Equilibrium." Working Paper, Board of Governors of the Federal Reserve System.

[2] Allen Franklin (1983). "Credit Rationing and Payment Incentives." *Review of Economic Studies*, v50, n4, 639-46.

[3] Allen, Franklin and Anthony M. Santomero (1998). "The Theory of Financial Intermediation." *Journal of Banking and Finance* v21, n11-12, 1461-85.

[4] Allen, Linda, Stavros Peristiani and Anthony Saunders (1989). "Bank Size, Collateral, and Net Purchase Behavior in the Federal Funds Market: Empirical Evidence." *Journal of Business* v62, n4, 501-15.

[5] Angbazo, Lazarus (1997). "Commercial Bank Net Interest Margins, Default Risk, Interest-Rate Risk, and Off-Balance Sheet Banking." *Journal of Banking and Finance* v21, n1, 55-87.

[6] Atkeson, Andrew (1991). "International Lending with Moral Hazard and Risk of Repudiation." Econometrica v59, n4, 1069-89.

[7] Bernanke, Ben and Mark Gertler (1989). "Agency Costs, Net Worth and Business Fluctuations." American Economic Review v79, n1, 14-31.

[8] Bernanke, Ben S. and Alan S. Blinder (1988). "Credit, Money, and Aggregate Demand." American Economic Review v78, n2, 435-39.

[9] Bernanke, Ben S. and Alan S. Blinder (1992). "The Federal Funds Rate and the Channels of Monetary Transmission." American Economic Review v82, n4, 901-21.

[10] Bernanke, Ben S., Mark Gertler and Simon Gilchrist (1998). "The Financial Accelerator in a Quantitative Business Cycle Framework." NBER working paper 6455.

[11] Bernanke, Ben S. and Cara S. Lown (1991). "The Credit Crunch." Brookings Papers on Economic Activity v0, n2, 204-39.

[12] Berger, Allen N., Anil K. Kashyap, and Joseph M. Scalise (1995). "The Transformation of the U.S. Banking Industry: What a Long, Strange Trip It's Been." Brookings Papers on Economic Activity v0, n2, 55-201.

[13] Bolton, Patrick and David Scharfstein (1990). "A Theory of Predation Based on Agency Problems in Financial Contracting." American Economic Review v80, n1, 93-106.

[14] Bolton, Patrick and David Scharfstein (1996). "Optimal Debt Structure and the Number of Creditors", Journal of Political Economy v104, n1, 1-25.

[15] Boyd, John H. and Mark Gertler (1995). "Are Banks Dead? Or Are The Reports Greatly Exaggerated?" NBER Working Paper no. 5045.

[16] Bulow, Jeremy and Kenneth Rogoff (1989). "Sovereign Debt: Is to Forgive to Forget?" American Economic Review v79, n1, 43-50.

[17] Cantillo, Miguel (1996). "A Theory of Corporate Capital Structure and Investment." Working Paper, Haas School of Business, Berkeley.

[18] Carlstrom, Charles T. and Timothy S. Fuerst (1997). "Agency Costs, Net Worth, and Business Fluctuations: A Computable; General Equilibrium Analysis." American Economic Review, v87, n5, 893-910.

[19] Collins, M. Cary, David W. Blackwell and Joseph F. Sinkey Jr. (1994). "Financial Innovation, Investment Opportunities, and Corporate Policy Choices for Large Bank Holding Companies." Financial Review v29, n2, 223-47.

[20] Dewatripont, Mathias and Jean Tirole (1994a). "A Theory of Debt and Equity: Diversity of Securities and Manager-Shareholder Congruence." Quarterly Journal of Economics v109, n4, 1027-54.

[21] Dewatripont, Mathias and Jean Tirole (1994b). "The Prudential Regulation of Banks." MIT Press, Cambridge, Massachusetts.

[22] Diamond, Douglas W. and Philip Dybvig (1983). "Bank Runs, Deposit Insurance, and Liquidity", Journal of Political Economy v91, n2, 401-19.

[23] Diamond, Douglas W. (1984). "Financial Intermediation and Delegated Monitoring", Review of Economic Studies v51, n3, 393-414.

[24] Eaton, Jonathan and Mark Gersovitz (1981). "Debt with Potential Repudiation: Theoretical and Empirical Analysis." Review of Economic Studies, v48, n2, 289-309.

[25] Economides, Nicolas, Glenn Hubbard and Darius Palia (1996). "The Political Economy of Branching Restrictions and Deposit Insurance: A Model of Monopolistic Competition of Small and Large Banks." Journal of Law and Economics, v19, 667-704.

[26] Edwards, Franklin E. and Frederic S. Mishkin (1995). "The Decline of Traditional Banking: Implications for Financial Stability and Regulatory Policy." NBER Working Paper no 4993.

[27] Freixas, Xavier and Jean-Charles Rochet (1998). "Microeconomics of Banking." MIT Press, Cambridge, Massachusetts.

[28] Fries, Steven, Pierre Mella-Barral and William Perraudin (1997). "Optimal Bank Reorganization and the Fair Pricing of Deposit Guarantees." Journal of Banking and Finance v21, n4, 441-68.

[29] Froot, Kenneth A., David S. Scharfstein, and Jeremy C. Stein (1993). "Risk Management: Coordinating Corporate Investment and Financing Policies" Journal of Finance v48, n5, 1629-58.

[30] Gale, Douglas and Martin Hellwig (1985). "Incentive-Compatible Debt Contracts: The One-Period Problem." Review of Economic Studies v52, n4, 647-63.

[31] Gorton, Gary and Richard Rosen (1995). "Corporate Control, Portfolio Choice, and the Decline of Banking." Journal of Finance v50, n5, 1377-1420.

[32] Hart, Oliver and John Moore (1995). "A Theory of Debt Based on the Inalienability of Human Capital." NBER Working Paper No. 3906.

[33] Hart, Oliver and John Moore (1998). "Default and Renegotiation: A Dynamic Model of Debt." Quarterly Journal of Economics, v113, n1, 1-41.

[34] Hellmann, Thomas, Kevin Murdock and Joseph Stiglitz (1998). "Liberalization, Moral Hazard in Banking, and Prudential Regulation: Are Capital Requirements Enough ?" Working Paper, Stanford University.

[35] Holmström, Bengt and Jean Tirole (1997). "Financial Intermediation, Loanable Funds, and the Real Sector", Quarterly Journal of Economics v112, n3, 663-91.

[36] Holmström, Bengt and Jean Tirole (1998). "Private and Public Supply of Liquidity", Journal of Political Economy v106, n1, 1-40.

[37] Houston, Joel F. and Christopher James (1998). "Do Bank Internal Capital Markets Promote Lending?" Journal of Banking and Finance v22, n6-8, 899-918.

[38] James, Christopher (1987). "Some Evidence on the Uniqueness of Bank Loans." Journal of Financial Economics v19, n2, 217-35.

[39] Jayaratne, Jith and Don Morgan (1997). "Information Problems and Deposit Constraints at Banks." Federal Reserve Bank of New York, Research Paper no 9731.

[40] Kashyap, Anil K. and C. Jeremy Stein (1995). " The Impact of Monetary Policy on Bank Balance Sheets." Carnegie-Rochester Conference Series on Public Policy v42, n0, 151-95.

[41] Kashyap, Anil K. and C. Jeremy Stein (1997). "What do a Million Banks have to say about the Transmission of Monetary Policy ?" NBER Working Paper no. 6056.

[42] Keeley, Michael C. (1990). "Deposit Insurance, Risk, and Market Power in Banking." American Economic Review v80, n5, 1183-1200.

[43] Kiyotaki, Nobuhiro and John Moore (1997). "Credit Cycles." Journal of Political Economy v105, n2, 211-48.

[44] Lucas, Deborah J. and Robert L. McDonald (1992). "Bank Financing and Investment Decisions with Asymmetric Information about Loan Quality." Rand Journal of Economics v23, n1, 86-105.

[45] Maskin, Eric and Jean Tirole (1994). "Markov Perfect Equilibrium", Working Paper, Harvard University.

[46] Merton, Robert C. (1977). "An Analytic Derivation of the Cost of Deposit Insurance and Loan Guarantees", Journal of Banking and Finance, n1, 3-11.

[47] Merton, Robert C. (1978). "On the Cost of Deposit Insurance When There Are Surveillance Costs", *Journal of Business*, n51, 439-52.

[48] Mishkin, Frederic S. (1998). "Financial Consolidation: Dangers and Opportunities." *NBER Working Paper* no 6655.

[49] Myers, Stewart C. and Raghuram Rajan (1998). "The Paradox of Liquidity." *Quarterly Journal of Economics* v113, n3, 733-71.

[50] Petersen, Mitchell A. and Raghuram G. Rajan (1995). "The Effect of Credit Market Competition on Lending Relationships." *Quarterly Journal of Economics* v110, n2, 407-43.

[51] Ramakrishnan, Ram T. S. and Anjan V. Thakor (1984). "Information Reliability and a Theory of Financial Intermediation," *Review of Economic Studies* v51, n3, 415-32.

[52] Sharpe, Steven A. (1995). "Bank Capitalization, Regulation, and the Credit Crunch: A Critical Review of the Research Findings." Working Paper, Board of Governors of the Federal Reserve System, Finance and Economics Discussion Series: 95/20.

[53] Sinkey, Joseph (1997). "*Commercial Bank Financial Management*." New York: Macmillan.

[54] Stein, Jeremy C. (1995). "An Adverse Selection Model of Bank Asset and Liability Management With Implications for the Transmission of Monetary Policy." *NBER Working Paper* no. 5217.

[55] Stigum, Marcia (1990). "The Money Market", Chicago: Irwin.

[56] Townsend, Robert M. (1979). "Optimal Contracts and Competitive Markets with Costly State Verification." *Journal of Economic Theory* v21, n2, 265-93.

[57] Zwiebel, Jeffrey (1996). "Dynamic Capital Structure under Managerial Entrenchment." *American Economic Review* v86, n5, 1197-1215.

Table 1.
Characterization of Solution

Markov Chain with 4 States

	Deposits	Opportunities	Assets	Lending	Borrowing	Wealth
Mean	0.0423	0.9585	0.6787	0.6570	0.2356	0.0423

NOTE: Calculations are based on a simulated sample size of 7000 periods of which the first 2000 are discarted. This Table reports the mean of the characteristics of a bank using the following set of parameters: $\beta = 0.9$, $\overline{D} \in \{0.3,0.5\}$, $\overline{L} \in \{0.4,1\}$, $R \sim U[0.8, 1.4]$, $\delta = 0.6$. The opportunity processes is Markov with transition matrix

$$\begin{pmatrix} 0.9 & 0.1 \\ 0.1 & 0.9 \end{pmatrix},$$

where 0.9 is the probability of staying in the high state ($\overline{L} = 1$) and 0.1 is the probability of leaving the high state. The probability of $\overline{D} = 0.5$ conditional on being in the high opportunity state ($\overline{L} = 1$) is 0.7. The probability of $\overline{D} = 0.5$ conditional on being in the low opportunity state is 0.3.

Table 2.
Financial Distress

Panel A: Means over entire Sample

	Wealth	Interest Rate	Δ Deposits	Δ Opportunities
Mean	0.0423	0.1185	0	0

Panel B: Means at period before Default

	Wealth	Interest Rate	Δ Deposits	Δ Opportunities
Mean	-0.2746	0.5451	-0.0667	-0.1333

NOTE: Calculations are based on the same simulated sample and parameter values as in Table 1.

Table 3.
Banks with different stochastic Opportunity Processes

The mean of Bank B's opportunity process is higher than Bank A's.
The persistence of Bank C's opportunity process is higher than Bank A's.

		Assets	Lending	Borrowing	Interest Rate	Prob.of C.
Bank A	Mean	0.8606	0.8331	0.3376	0.1201	0.1536
	St.Dev.	0.2384	0.2735	0.1990	0.0693	
Bank B	Mean	0.9010	0.8862	0.3691	0.1191	0.1314
	St.Dev.	0.2151	0.2391	0.1717	0.0636	
Bank C	Mean	0.8524	0.8303	0.3294	0.1160	0.1312
	St.Dev.	0.2428	0.2721	0.1970	0.0536	

NOTE: Calculations are based on a simulated sample size of 7000 periods of which the first 2000 are discarted. This Table reports the mean and standard deviation of assets, lending, borrowing, interest rates and the probability of being borrowing constrained for three banks (A, B and C) with different lending opportunity processes. The set of parameters used for the simulations is: $\beta = 0.9$, $\overline{D} = 0.4$, $R \sim U[0.8, 1.4]$, $\delta = 0.7$, $\overline{L} \in \{0.4,1\}$. The opportunity processes of Bank A and Bank B are iid Bernoulli with the probability of the high opportunity state, $\overline{L} = 1$, being set to 0.8 and 0.9, respectively. The opportunity process of Bank C is Markov with transition matrix

$$\begin{pmatrix} 0.9 & 0.1 \\ 0.4 & 0.6 \end{pmatrix},$$

where 0.9 is the probability of staying in the high state and 0.1 is the probability of leaving the high state.

Table 4.
Deposit Insurance

Bank A is insured, Bank B is not.

		Assets	Lending	Borrowing	Interest Rate	Prob.of C.
Bank A	Mean	1.5555	0.9486	0.0363	0.1191	0.0056
	St.Dev.	0.0815	0.1718	0.0819	0.0655	
Bank B	Mean	0.4393	0.3219	0.0448	0.1517	0.0384
	St.Dev.	1.4484	0.4202	0.0864	0.0390	

NOTE: Calculations are based on a simulated sample of 7000 periods of which the first 2000 are discarted. This Table reports the mean and standard deviation of assets, lending, borrowing, interest rates and the probability of being borrowing constrained for Bank A and B. The difference between the two banks is that the deposits of Bank A are insured, while the deposits of Bank B are not insured. The set of parameters used for the simulations is: $\beta = 0.9$, $\overline{D} = 0.4$, $R \sim U[0.5, 2]$, $\delta = 0.3$, $\overline{L} = 1$.

Table 5.
Balance Sheets of Subpopulations

Panel A: Regional Banks

	Mean	St.Dev.
Assets	3,026,166	2,228,815
Branches	128.8	111.19
Loan/Asset Ratio	0.619	0.094
Core Deposits/Assets	0.618	0.083
Capital/Asset Ratio	0.083	0.012

Panel B: City Banks

	Mean	St.Dev.
Assets	3,059,992	2,172,552
Branches	47.2	46.1
Loan/Asset Ratio	0.577	0.161
Core Deposits/Assets	0.503	0.153
Capital/Asset Ratio	0.083	0.016

NOTE: The data set used this Table is quarterly from 1993:3 to 1997:2. Panel A consists of 1361 bank quarters of U.S. BHCs with assets $>$ 1 bn and assets $<$ 10 bn and assets per branch $<$ 40 mn. Panel B consists of 1231 bank quarters of U.S. BHCs with assets $>$ \$ 1 bn and assets $<$ \$ 10 bn and assets per branch $>$ 40 mn.

Table 6.
Factors explaining the Core Deposits to Assets Ratio

	Coefficient	St.Error	p-value
Constant	1.5272	0.0563	0.0000
Log(Assets)	-0.0173	0.0035	0.0000
Assets per Branch	-0.0661	0.0023	0.0000
Adjusted R^2	0.2526		

NOTE: This Table shows the results from regressing the core deposits to assets ratio on a constant, the log of assets and assets per branch for all 2592 observations of the dataset used for Table 5. Standard errors are computed using 6 Newey-West lags.

Table 7.
Summary Statistics of Subpopulations

Panel A: Regional Banks

	Mean	St.Dev.
Total Loan Growth	1.4383	3.7841
Core Deposit Growth	0.8929	4.1305
Total Loan Growth over previous year	1.3825	2.1050
Peer Loan Growth (contemporanous)	0.6671	3.2791
Capital/Asset Ratio	0.0827	0.0121
Loan Loss Provisions/Assets	0.0109	0.0047
Log(Assets)	14.6818	0.6711
Loan/Asset Ratio	0.6190	0.0942

Panel B: City Banks

	Mean	St.Dev.
Total Loan Growth	0.7980	2.6621
Core Deposit Growth	0.1995	4.1152
Total Loan Growth over previous year	0.9825	2.5750
Peer Loan Growth (contemporanous)	0.6704	3.2791
Capital/Asset Ratio	0.0833	0.0160
Loan Loss Provisions/Assets	0.0124	0.0073
Log(Assets)	14.7184	0.6398
Loan/Asset Ratio	0.5770	0.1605

NOTE: Panel A and B are defined as for Table 5.

Table 8.
Tests for Borrowing Constraints
(Quarter Dummies not reported)

Panel A: Both Groups together

	Coefficient	Std.Error	p-value
Core Deposit Growth	0.7798	0.0558	0.0000
City Dummy*Core Deposit Growth	-0.6483	0.0804	0.0000
City Dummy	-0.0215	0.0959	0.8229
Total Loan Growth over previous year	0.6596	0.1819	0.0003
Peer Loan Growth (contemporanous)	0.0278	0.0131	0.0349
Capital/Asset Ratio	-0.2293	3.6160	0.9494
Loan Loss Provisions/Assets	13.6028	10.5427	0.1971
Log(Assets)	0.0748	0.0698	0.2841
Loan/Asset Ratio	-1.5825	0.5042	0.0017
Adjusted R^2	0.5453		

Panel B: Regional Banks Only

	Coefficient	Std.Error	p-value
Core Deposit Growth	0.7798	0.0558	0.0000
Total Loan Growth over previous year	0.3980	0.1478	0.0072
Peer Loan Growth (contemporanous)	0.0202	0.0157	0.1978
Capital/Asset Ratio	-5.4758	4.5218	0.2261
Loan Loss Provisions/Assets	-11.9270	-0.9276	0.3538
Log(Assets)	0.1065	0.0873	0.2230
Loan/Asset Ratio	-2.1029	0.6295	0.0009
Adjusted R^2	0.5457		

Panel C: City Banks Only

	Coefficient	Std.Error	p-value
Core Deposit Growth	0.1296	0.057	0.0231
Total Loan Growth over previous year	0.8036	0.3108	0.0098
Peer Loan Growth (contemporanous)	0.0467	0.0243	0.0544
Capital/Asset Ratio	0.8940	5.2753	0.8655
Loan Loss Provisions/Assets	24.3439	14.4698	0.0928
Log(Assets)	0.0310	0.1129	0.7838
Loan/Asset Ratio	-1.5695	0.7169	0.0288
Adjusted R^2	0.1124		

NOTE: The data set is described in Table 5. Standard Errors are computed using 6 Newey-West lags.

period t begins

exogenous variables $\omega_t = (\bar{L}_t,\, \bar{D}_t,\, R_t)$ are realized

banker takes default decision c_t

default
banker exits, new banker enters with $A_t = 0$

continuation
banker consumes $\delta(\Pi_t)$
wealth is now $A_t = \Pi_t - \delta(\Pi_t)$

banker makes contract offers to young generation
$m_t = (B_t,\, D_t,\, \rho_t^B,\, \rho_t^D)$

investors and depositors accept or reject offers

banker chooses portfolio $p_t = (L_t,\, S_t)$

period $t+1$ begins

Figure 1: Timing.

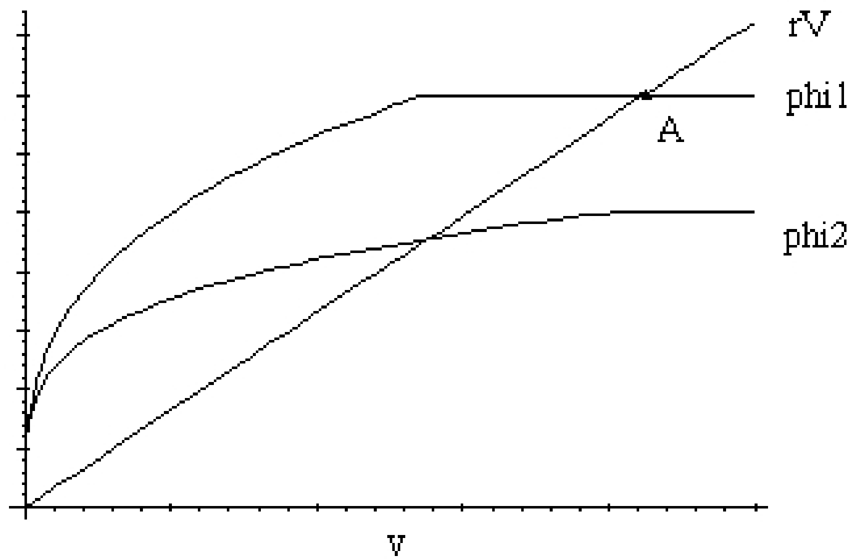

Figure 2: Determination of the Franchise Value

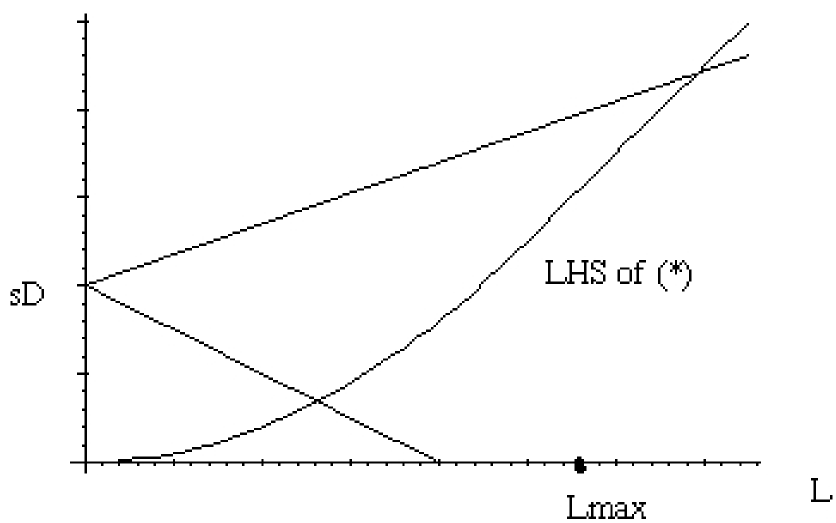

Figure 3: Determination of the Upper Bound on Lending L^*

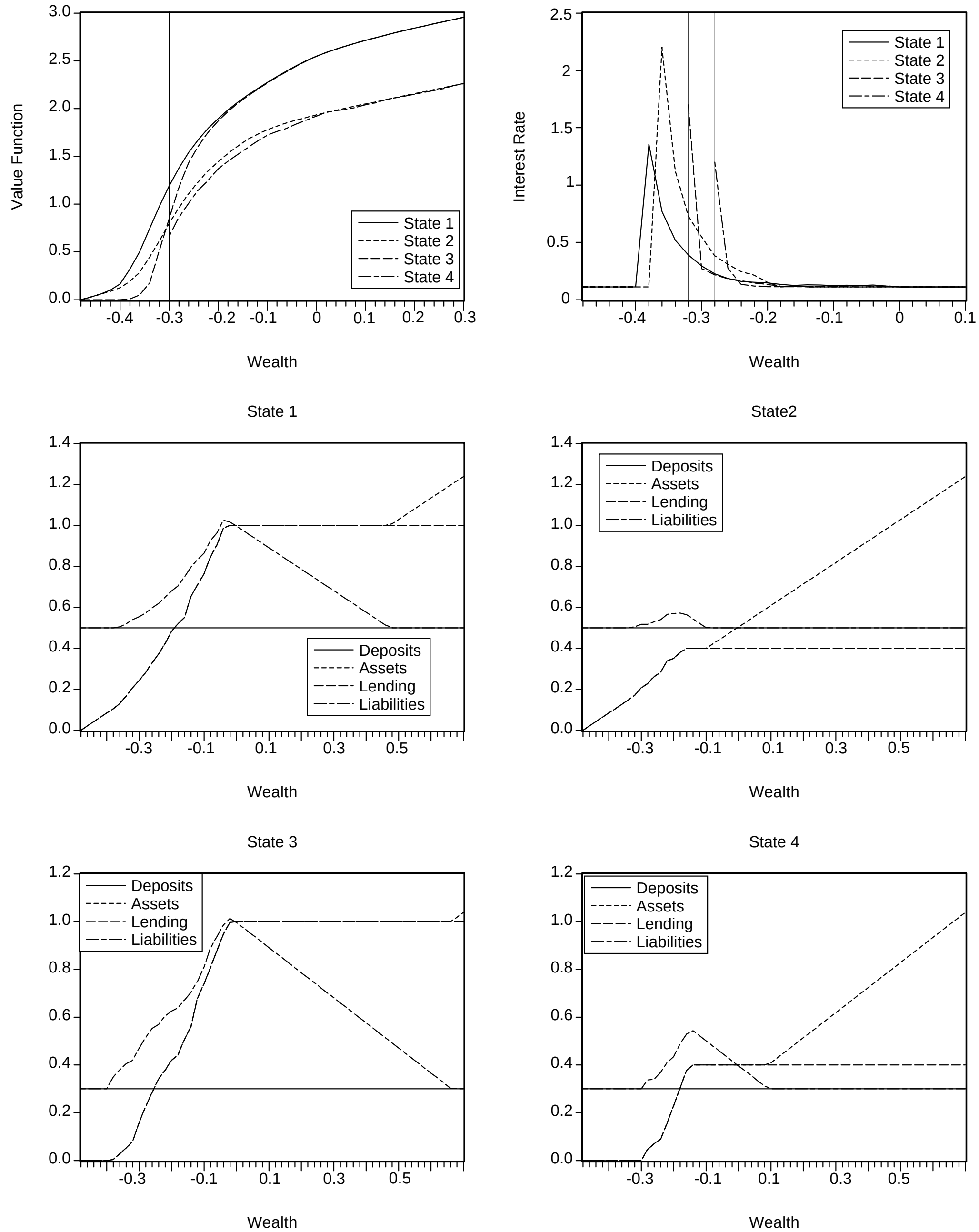

Figure 4: Characterization of Solution for Bank with 4 State Markov Chain. States 1 is $\{\overline{L} = 1, \overline{D} = 0.5\}$, state 2 is $\{\overline{L} = 0.4, \overline{D} = 0.5\}$, state 3 is $\{\overline{L} = 1, \overline{D} = 0.3\}$ and state 4 is $\{\overline{L} = 0.4, \overline{D} = 0.3\}$.

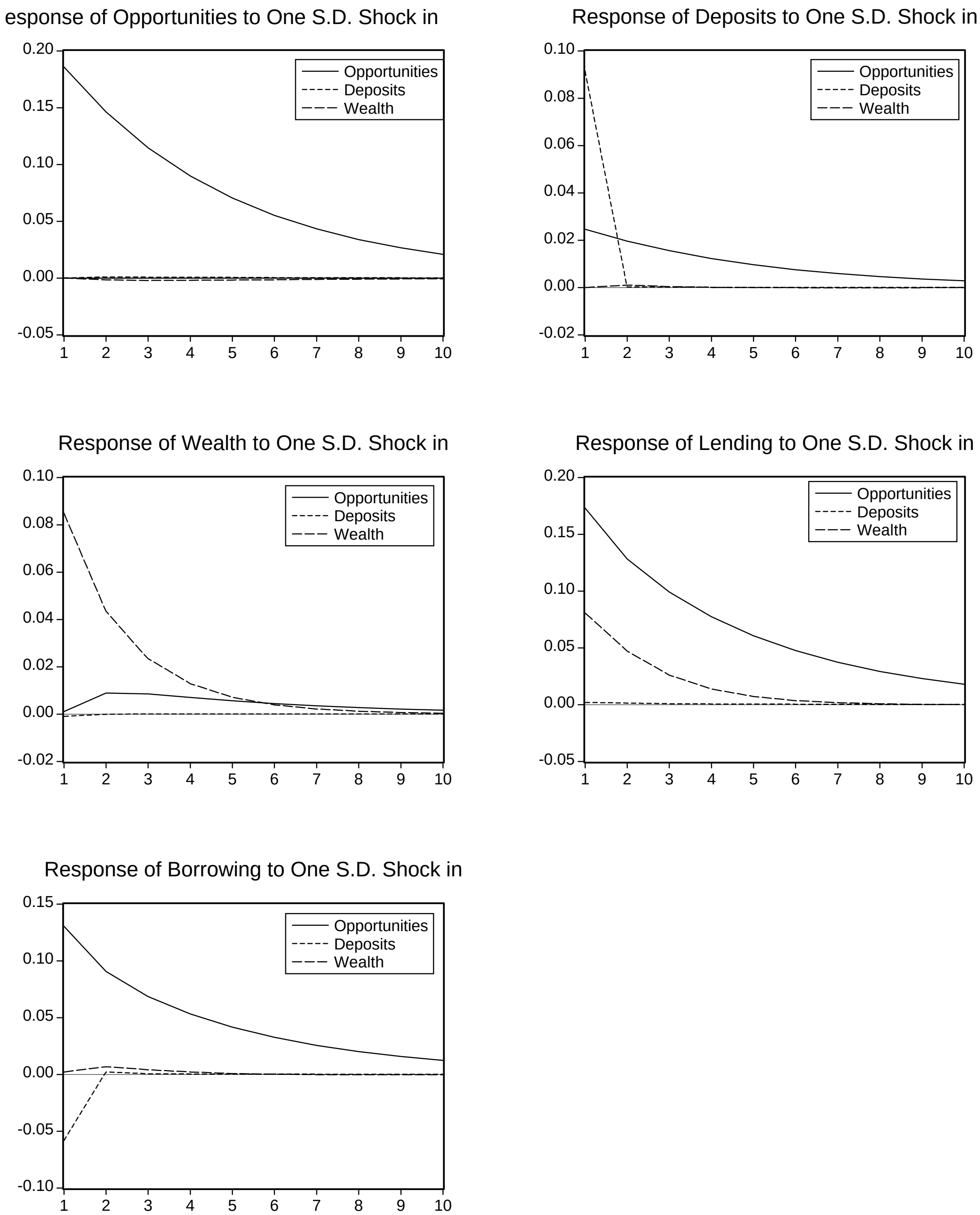

Figure 5: Impulse Responses from a VAR of order 1. The ordering of the variables (suggested by the model) is opportunities, deposits, wealth, lending and borrowing.

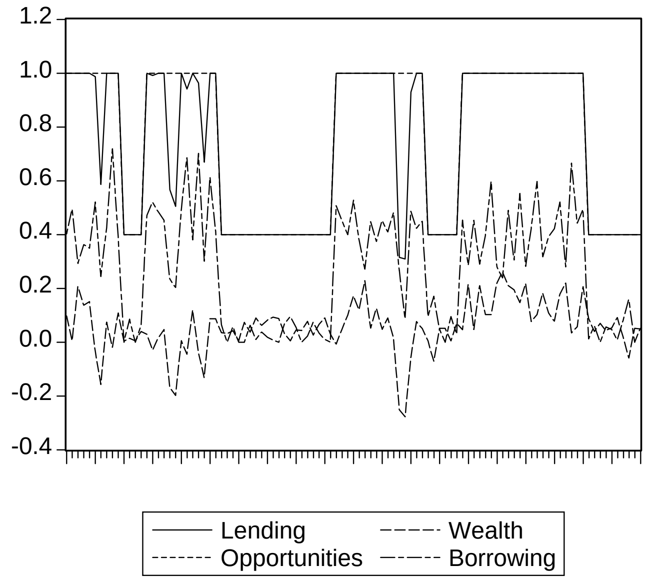

Figure 6: Time Series Plot of Variables from the Markov Chain Specification with 4 States.

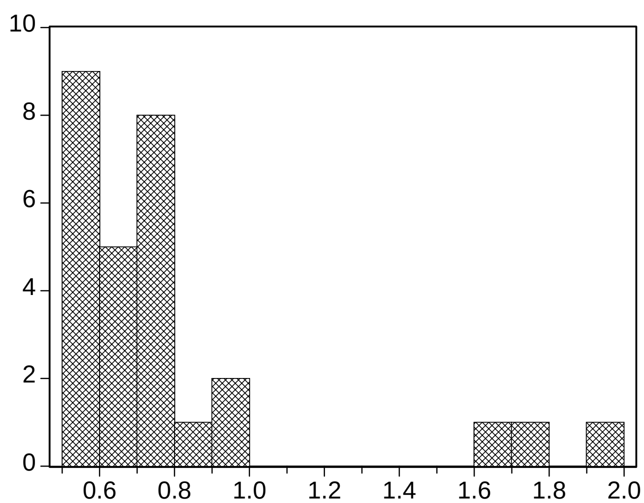

Figure 7: Histogram of Gross Return on Loans in the Default Periods.

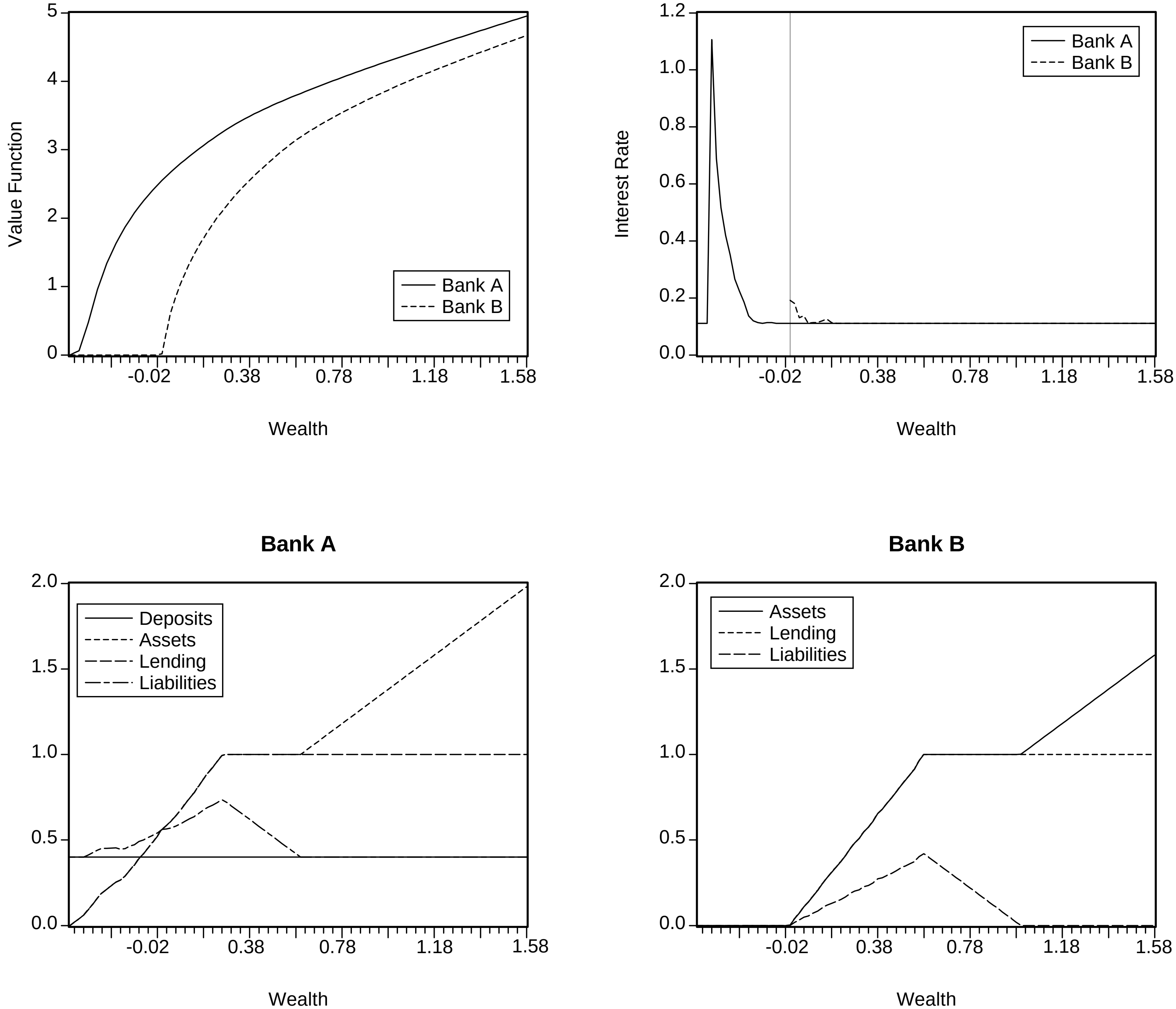

Figure 8: Comparison of Bank A (with Deposit Insurance) and Bank B (without): Value Functions, Interest Rates, and Policy Functions.