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FINANCIAL LIBERALIZATION AND BANKING CRISES IN EMERGING ECONOMIES

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Abstract

In this paper, we provide a theoretical explanation of why financial liberalization is likely to generate financial crises in emerging market economies. We first show that under financial repression the aggregate capital stock and bank net worth are both likely to be low. This leads a newly liberalized bank to be highly levered, because the marginal product of capital—and thus loan interest rates—are high. The high returns on capital, however, also make default unlikely, and they encourage the bank to retain all of its earnings. As the bank's net worth grows, aggregate capital rises, the marginal product of capital falls and a banking crisis becomes more likely. Although the bank faces conflicting incentives toward risk-taking, as net worth continues to grow the bank will become increasingly cautious. Numerical results suggest that the bank will reduce its risk, by reducing its leverage, before issuing dividends. We also find that government bailouts, which allow defaulting banks to continue running, induce significantly more risk-taking than the liability limits associated with standard bankruptcy.

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1 Introduction

In this paper we explore the link between financial liberalization and financial crises. This link was noted as early as 1985 in a paper by Diaz-Alejandro. More recently, Kaminsky and Reinhart (1997) find that in 18 of the 26 banking crises they study, the financial sector had recently been liberalized. Caprio and Klingebiel (1996) conclude that banks are much more likely to fail in a liberalized regime than under financial repression. Financial liberalization has also been cited as a possible culprit in the Asian financial crisis by Corsetti, Pesenti and Roubini (1998) and Furman and Stiglitz (1998).

Hellman, Murdock and Stiglitz (2000) explain this relationship as a result of how banks construct their loan portfolios. When a bank's net worth and franchise value are low, the liability limits provided by bankruptcy and/or government bailouts cut off the lower portion of its return distribution. In the absence of offsetting regulation, this encourages banks to assemble loan portfolios that are riskier than would be socially optimal. Dooley (2000) and Dooley and Shin (2000) focus on the way in which deposit insurance makes depositors less willing to prevent banks from "appropriating" their deposits. Based on these ideas, policy discussions have focused on greater transparency, better bank supervision, and on the costs and benefits of bailouts.

This paper provides an alternative and complementary explanation of why financial repression leads the banking sector to be under-capitalized, and why financial liberalization creates incentives for excessive risk-taking. Our approach departs from the existing literature in two important ways. The first is that we carefully model the bank's net worth as an evolving stock variable, so that dividend decisions are important. The key decision in our model is not the choice between high-risk and low-risk loans, but the choice between raising loanable funds through retained earnings or through deposits. The second difference is that we consider the way in which a country's stock of physical capital evolves over time and how it affects bank decisions. In particular, changes in the aggregate capital stock can affect the riskiness of bank loans, while changes in bank equity and the quantity of loans can affect the capital stock. Because of these dynamic interactions, our model can explain why banks in countries that have experienced financial liberalization tend to grow rapidly at first and then enter a crisis period some time after the liberalization. Our model also explains why these banks are likely to enter financial liberalization with very little net worth.

We consider an emerging economy where all capital is funded by bank loans from a monopoly bank. Our bank's incentive structure has two essential features. The first is limited liability induced by bankruptcy or government bailouts, which cuts off the lower tail of the bank's return distribution and encourages risk-taking behavior. The second feature is the bank's monopoly franchise. This means that financial losses reduce, if not eliminate, the bank's stream of monopoly rents, and thus encourage risk-averse behavior.[1] These two incentives suggest that as a bank accumulates more equity, it will become increasingly risk-averse. The bank's incentives, however, also depend critically on the aggregate stock of

[1] Hellman, Murdock and Stiglitz (2000) discuss in some detail how increased bank competition reduces these monopoly rents, leading to riskier behavior. To the extent that liberalized markets enjoy more competition than our model permits, our results understate the likelihood of a banking crisis.

capital. With decreasing returns to capital, the interest rate charged on loans must fall as the aggregate stock of capital increases. And these lower interest rates make it more likely that the bank will not be able to pay back its depositors. This means that the effect of increasing a bank's equity is no longer clear; while a bank facing the same distribution of returns on its loans will be less risky when it has higher equity, a bank with higher equity might be operating in an environment where the returns on its loans are riskier. In other words, the bank's default risk could at times be *increasing* in the bank's equity. The goal of this paper is disentangle these interactions for a newly liberalized economy.

The starting point for the sequence of events that we study is financial repression. Under financial repression, the government pegs the interest rates on deposits and loans, and prohibits capital outflows. We show that under this regime, deposits, loans and bank net worth are all low, so that an economy emerging from repression is characterized by a highly productive capital stock but limited bank net worth. Moreover, the bank faces a (legal) leverage constraint that restricts its ratio of loans to net worth. Thus even if a newly liberalized bank is fully levered, the loans it can make are limited. Then the same high returns to capital that make lending desirable also imply that the bank, although highly levered, faces little default risk. The high returns to lending further imply that the bank will retain its earnings, so that a newly liberalized bank sees its net worth initially grow. The pivotal part of the sequence occurs once the bank has accumulated some equity. It is at this point, when the bank is still highly levered but the capital stock is larger—and less productive—that a banking crisis is most likely. If the bank can weather this period, it will transition to a regime of lower leverage and conservative behavior.

We find that the bank's attitude toward risk depends critically on how its liability is limited. In particular, government bailouts, as we define them, allow a defaulting bank to keep running, albeit with little equity. Bankruptcy, on the other hand, forces the bank to shut down forever. The permanent loss of monopoly rents makes bankruptcy much more of a deterrent; our numerical results show that government bailouts induce far more risk-taking than the liability limits associated with bankruptcy.

The paper is organized as follows. In the next section, we describe the behavior of a representative firm that faces stochastic productivity. In section 3, we derive the optimality conditions for a monopoly bank that maximizes the expected present value of its dividends, first under a liberalized regime and then under a repressed regime. In section 4, we describe the transition from financial repression to financial liberalization for the emerging market economy, both analytically and through a numerical example. In the final section, we conclude.

2 The Representative Firm

Consider an economy where in each period t, $t = 0, 1, 2, ...$, output is produced by a unit mass of ex-ante identical price-taking firms. Each firm lives two periods; across time, output is produced by overlapping generations of these firms. In the first period of their lives, firms procure capital. In the second, they produce output as a function of this capital stock and their idiosyncratic productivity levels. Any profits are then remitted to domestic households.

Productivity is stochastic, and firms must choose their capital stock before they observe their productivity levels. Since firms are identical prior to realizing their productivity shocks, every firm in a cohort chooses the same capital stock. Firms purchase their capital with funds they borrow from banks. This reflects the stylized fact that in many emerging market economies, bank loans finance almost all investment. The dominance of banks can reflect, among other things, advantages in transactions costs that have dissipated in more developed financial markets.

2.1 Technologies

The output of firm i at time t is given by

$$Y_{it} = x_{it} K_{it-1}^{\alpha}, \quad 0 < \alpha < 1,$$

where K_{it-1} is capital, purchased a period in advance, and x_{it} is firm i's realized productivity. While each firm's productivity represents an independent draw, all firms in a cohort share a common distribution for their productivity levels. This common distribution is itself stochastic, however, so that there is aggregate uncertainty. In particular, the distribution of x_{it} is fully characterized by the variable a_t, with

$$\begin{aligned} F\left(x_{it} | \, a_t = a_0\right) &> F\left(x_{it} | \, a_t = a_1\right), \; \forall x_{it} \in \mathbf{S}\left(a_0, a_1\right), \; a_0 < a_1, \\ \mathbf{S}\left(a_0, a_1\right) &\equiv \left\{x : F\left(x | \, a_0\right) > 0, F\left(x | \, a_1\right) < 1\right\}, \end{aligned} \tag{1}$$

so that conditional distributions with higher values of a_t are stochastically dominant. We assume that a_t follows a stationary Markov process over the set $\mathbf{A}$.

Recall that firms must choose their capital stock before they observe their idiosyncratic productivity levels. Since firms are identical ex-ante, each firm chooses the same capital stock. With a unit mass of firms, the aggregate production function can be expressed as:

$$Y_t = E\left(x_{it} \middle| a_t\right) K_{t-1}^{\alpha}. \tag{2}$$

2.2 The Firm's Problem

The problem facing a firm born at time t is to pick the capital stock that will maximize its expected profits at time $t+1$, given the loan interest rate i_{t+1}^{l} and the current productivity parameter a_t. The firm will demand enough bank loans to purchase this stock.

Given the timing of capital purchases, the optimization problem for an individual firm can be stated as

$$\max_{K_t} \int\limits_{x_{it+1} > x^{\min}(K_t)} \left[x_{it+1} K_t^{\alpha} - \left(i_{t+1}^{l} + \delta\right) K_t\right] dF\left(x_{it+1} \middle| a_t\right),$$

with the solvency threshold $x^{\min}\left(K_t\right)$ defined by

$$x^{\min}\left(K_t\right) = \left(i_{t+1}^{l} + \delta\right) K_t^{1-\alpha}. \tag{3}$$

The use of a truncated distribution reflects the limited liability afforded by bankruptcy; when the firm is insolvent, its returns are automatically zero.[2] Taking derivatives and imposing equation (3) produces the optimal capital stock:

$$K^{*}\left(i_{t+1}^{l}, a_t, x^{\min}\right) = \left(\frac{\alpha x^{e}\left(a_t, x^{\min}\right)}{i_{t+1}^{l} + \delta}\right)^{\frac{1}{1-\alpha}}, \tag{4}$$

[2] If there is asymmetric information about the firm's output, the presence of bankruptcy costs makes debt financing optimal.

$$x^e\left(a_t, x^{\min}\left(K_t\right)\right) \equiv E\left(x_{it+1} \middle| a_t, x_{it+1} > x^{\min}\left(K_t\right)\right).$$

Combining equations (3) and (4) yields

$$\alpha x^e\left(a_t, x^{\min}\left(K_t\right)\right) = x^{\min}\left(K_t\right).$$

When this equation has multiple solutions, the firm finds the optimal solvency threshold by solving

$$\max_{x:\alpha x^e(a_t,x)=x} \left[1 - F\left(x\middle| a_t\right)\right] \cdot \left[x^e\left(a_t, x\right) K^*\left(i^l_{t+1}, a_t, x\right)^{\alpha} - \left(i^l_{t+1} + \delta\right) K^*\left(i^l_{t+1}, a_t, x\right)\right],$$

where $F\left(\cdot\middle| a_t\right)$ is the conditional distribution for x_{it+1}. Imposing equation (4) allows us to express the solvency threshold as a function of a_t:

$$x^{\min}\left(a_t\right) \equiv \arg\max_{x:\alpha x^e(a_t,x)=x} \left[1 - F\left(x\middle| a_t\right)\right] \cdot x^e\left(a_t, x\right)^{\frac{1}{1-\alpha}} \cdot \left[1 - \alpha\right]. \tag{5}$$

The most important feature of $x^{\min}\left(a_t\right)$ is that it does not depend on i^l_{t+1} or δ. In other words, firms choose their capital stock in such a way that their default rate does not depend on the interest rate i^l_{t+1}. Continuing, we find the optimal capital stock $K^*\left(i^l_{t+1}, a_t\right)$:

$$K^*\left(i^l_{t+1}, a_t\right) = \left(\frac{x^{\min}\left(a_t\right)}{i^l_{t+1} + \delta}\right)^{\frac{1}{1-\alpha}}. \tag{6}$$

2.3 Return on Bank Loans

Once the aggregate productivity parameter a_{t+1} is realized, the bank is repaid its loans by the solvent firms, and is given the assets of the insolvent ones. Imposing the solvency threshold given by equation (3), the average return that the bank earns on its loans to firms, r_{t+1}, can be written as

$$
\begin{aligned}
r_{t+1} \;=\; & \left[1-\Pr\left(x_{it+1}<x^{\min}\left(K_t\right)\middle|\, a_{t+1}\right)\right]\cdot i^{l}_{t+1} && (7)\\
& +\Pr\left(x_{it+1}<x^{\min}\left(K_t\right)\middle|\, a_{t+1}\right)\cdot\left[E\left(x_{it+1}\middle|\, a_{t+1},x_{it+1}<x^{\min}\left(K_t\right)\right)\cdot K_t^{\alpha-1}-\delta-\zeta\right].
\end{aligned}
$$

$\zeta > 0$ reflects bankruptcy expenses and/or a limited resale value for idiosyncratic assets. ζ is an important component of a bank's risk; in its absence δ is likely to be so small—and the resale value of the asset so high—that a bank would lose very little when a firm goes bankrupt. Note that a_{t+1} is the only term in this expression not known at time t.

We assume that under financial repression, the government pegs interest rates in such a way that loan rationing is likely and firm-level default never occurs. When this happens, equation (6) ceases to hold, and the bank's return reduces to the pegged value of i^{l}_{t+1}. Under financial liberalization, however, equation (6) does hold, so that the average return can be written as a function of capital:

$$
\begin{aligned}
r_{t+1} \;=\; & \left[1-\Pr\left(x_{it+1}<x^{\min}\left(a_t\right)\middle|\, a_{t+1}\right)\right]\cdot\left[x^{\min}\left(a_t\right)\cdot K_t^{\alpha-1}-\delta\right]\\
& +\Pr\left(x_{it+1}<x^{\min}\left(a_t\right)\middle|\, a_{t+1}\right)\cdot\left[E\left(x_{it+1}\middle|\, a_{t+1},x_{it+1}<x^{\min}\left(a_t\right)\right)\cdot K_t^{\alpha-1}-\delta-\zeta\right].
\end{aligned}
$$

It is convenient to rewrite this expression as

$$1+r_{t+1}=\pi_0\left(a_{t+1},a_t\right)+\pi_1\left(a_{t+1},a_t\right)K_t^{\alpha-1}. \tag{8}$$

When firm-level default is possible, it follows from equation (1) that π_0 and π_1—and thus r_{t+1}—are strictly increasing in the productivity parameter a_{t+1}.[3] Equation (8) also shows

[3] Following standard arguments (for example, Green, Mas-Collel and Whinston, 1995, proposition 6.D.1), one can see that π_1 is strictly increasing in a_{t+1} by noting that $\pi_1 = E\left(\min\left\{x_{it+1}, x^{\min}\left(a_t\right)\right\}\middle|\, a_{t+1}\right)$, the expectation of a function that is increasing in x_{it+1}.

that the rate of return is decreasing in total capital, an immediate consequence of decreasing returns.

3 The Monopoly Bank

We model the banking sector as a single bank. This bank has monopoly power over deposits in the repressed regime, and, because of informational advantages, monopoly power over loans in both the repressed and liberalized regimes. In addition to making the model more tractable, this assumption makes our approach more conservative. Since a monopoly bank internalizes the effect its loans have on the aggregate capital stock, it recognizes how its actions affect the expected returns and riskiness of its loans. Competitive banks, which ignore these effects, are more likely to behave in a risky fashion. Hellman et al. (2000) emphasize a similar distinction.[4] To the extent that liberalization increases competition for loans, our results provide a lower bound on risk-taking behavior. Dooley and Chinn (1997) find that liberalization does increase competition in the loan market, but not as much as in the deposit market.

The monopoly bank accepts deposits and makes loans in order to maximize the expected discounted value of its dividend stream.[5] Since the bank must issue its loans before it observes the aggregate productivity level, the return on these loans is uncertain. The bank faces two finance constraints under both the repressed and the liberalized regimes. The first

[4] In contrast to our framework, Hellman et al. analyze a model where banks compete for deposits while loan rates remain fixed.

[5] We accept as a stylized fact that banks are financed primarily by debt contracts (deposits) rather than with equity. With some complication in notation, we could model the financing of banks through deposits as the optimal outcome in a world in which bank profits are not observed by depositors unless the depositors incur a bankruptcy cost.

is a non-negativity constraint on dividends that effectively prevents banks from issuing new net worth, a restriction that is both quite common in the literature and reasonably consistent with observed practice.[6] The second constraint is a capitalization requirement that limits the ratio of loans to net worth, a restriction common in both emerging and developed markets. Together, these constraints imply that banks with non-positive net worth must shut down, so that bankruptcy is possible. Bankruptcy is undesirable because the monopoly bank will lose its monopoly charter and the corresponding monopoly rents.

The bank's behavior also depends critically on the regulatory regime. When the economy is in a regime of financial repression, the government fixes both deposit and loan rates. In this case, the bank's decision is a choice over dividends and deposits, taking as given the interest rates. We show below that for reasonable parameter values, financial repression will lead to loan rationing, in that the bank will provide fewer loans than firms demand at the regulated loan interest rate. Under financial liberalization, on the other hand, the bank is free to set both deposit and loan rates. Since the bank is a price-setter, its problem can still be expressed as a choice over dividends and deposits, with constraints that capture the loan demand curve and an international arbitrage condition for deposit rates.

3.1 The Bank's Problem

The bank accepts deposits from domestic agents (B). In the liberalized regime, it also accepts deposits from foreign agents (B^*). The bank lends its deposits $(B + B^*)$, plus any

[6] The usual explanation of why firms raise so few funds by selling stock is that equity markets suffer from extreme problems of asymmetric information. Greenwald and Stiglitz (1993) provide a nice discussion.

post-dividend net worth $(Q - d)$, so that its loans are given by

$$L_t = Q_t - d_t + B_t + B_t^*, \tag{9}$$

while Q_t, the bank's pre-dividend net worth, follows

$$Q_{t+1} = \max\left\{Q^{\min}, (1 + r_{t+1}) L_t - \left(1 + i_{t+1}^b\right)(B_t + B_t^*)\right\}.$$

It is the value of $Q^{\min}$ that allows us to differentiate two important liability limits: *bankruptcy* and government *bailouts*. $Q^{\min} = 0$ characterizes the bankruptcy regime. In this regime, a bank with non-positive net worth defaults on any unpaid deposits and shuts down forever. $Q^{\min} > 0$ characterizes the government bailout regime. In this regime, a bank that crosses the bailout threshold has its net worth restored to $Q^{\min}$, so that the bank continues to operate, albeit with a miniscule amount of net worth.[7] This is an essential difference: bankruptcy ends the bank's flow of monopoly rents; government bailouts do not. As a matter of semantics, we will use the term bankruptcy or "insolvency" to refer to non-positive net worth $(Q_t \leq 0)$, and the broader term "unsound" to refer to net worth at or below the liability limit $(Q_t \leq Q^{\min})$.

Combining the two preceding equations, the law of motion for net worth becomes

$$Q_{t+1} = \max\left\{Q^{\min}, (Q_t - d_t)\left(1 + i_{t+1}^b\right) + L_t\left(r_{t+1} - i_{t+1}^b\right)\right\}.$$

It proves useful to work with the leverage ratio, ψ_t, which we define as

[7] We assume that prior to being bailed out, the bank repays depositors up to the point of insolvency. In contrast to this arrangement, which exposes depositors to some risk, government bailouts are typically accompanied by a system of deposit insurance. While we have excluded deposit insurance in order to focus on the effects of the bailouts themselves, our analytical results do not depend on this assumption. As described below, we also consider an economy with deposit insurance in our numerical analyses.

$$\psi_t\left(L_t, Q_t - d_t\right) = \begin{cases} L_t / \left(Q_t - d_t\right), & d_t < Q_t, \\ 0, & d_t = Q_t, \end{cases},$$

so that loans are given by

$$L_t = \left(Q_t - d_t\right)\psi_t. \tag{10}$$

and the evolution of the bank's net worth is given by:

$$Q_{t+1} = \max\left\{Q^{\min}, \left(Q_t - d_t\right)\left[1 + i^b_{t+1} + \psi_t\left(r_{t+1} - i^b_{t+1}\right)\right]\right\}. \tag{11}$$

Note that the lowest return on loans that allows the bank to avoid being unsound is

$$1 + r^{\min}_{t+1} = \frac{\psi_t - 1}{\psi_t}\left(1 + i^b_{t+1}\right) + \frac{Q^{\min}}{L_t}. \tag{12}$$

The bank faces two finance constraints. The first is that dividends cannot be negative, which prevents banks from issuing new net worth to avoid bankruptcy. In addition, dividends cannot exceed net worth, so that

$$0 \leq d_t \leq Q_t.$$

We assume that in equilibrium, the upper constraint binds only if a bank has declared bankruptcy.[8] Note that this no-new-net worth constraint will be circumvented unless there is some cost to entry. We capture this effect with our assumption that there is a single bank.

[8] When $Q^{\min}$ is positive, this condition must be supplemented by a no-liquidation condition to prevent the bank from paying out so many dividends at time t that Q_{t+1} would always be below $Q^{\min}$. Were this to occur, the bank could fund its dividend payments by exploiting government bailouts. In practice, $Q^{\min}$ is so low, and the benefits from levering retained earnings into loans are so high, that banks would rarely exploit this option if it were available. They would be most likely to exploit the option in the region $Q_0 < Q_t < Q^{\min}$, which is outside the absorbing set of net worth. Moreover, the timing of our model is such that a bank whose net worth enters this region will be bailed out before it can issue any dividends. This prevents managers of an unsound but solvent bank from "looting" the bank with dividend payments.

The second finance constraint is a capitalization requirement. The ratio of loans relative to retained net worth must not exceed an upper bound:

$$0 \leq L_t \leq \overline{\psi} \times (Q_t - d_t)\,, \quad 1 < \overline{\psi} < \infty.$$

In the absence of such a constraint, a liberalized bank could attract deposits from international investors to fund as many loans as it wished. In contrast, a bank with low net worth that faces a leverage constraint will have to build up its equity over time before it can fully fund the optimal capital stock. Note that in the absence of bailouts, these finance constraints will force a bank with non-positive net worth to declare bankruptcy and shut down forever: $d_{t+j} = L_{t+j} = Q_{t+j} = 0, \forall j > 0$. We assume that interest rates are such that L_t is positive for $Q_t > 0$.

The bank's goal is maximize the present discounted value of its dividends.[9] In recursive form, this problem is

$$V(Q_t, a_t) = \max_{0 \leq \psi_t \leq \overline{\psi},\ 0 \leq d_t \leq Q_t} d_t + \frac{1}{\varpi (1+\theta)} E_t \left(V(Q_{t+1}, a_{t+1}) \middle| I_t \right) \tag{13}$$

subject to the accumulation equation (11). As is standard, $V(Q_t, a_t)$ is the value of the bank, here defined over non-negative net worth. I_t denotes the bank's information set. θ is the global rate of time preference for households, and $\varpi > 1$ is the bank's "discount premium." In a riskless open economy, θ also gives the net return on bonds; setting $\varpi > 1$ ensures that the bank does not accumulate net worth indefinitely.[10]

[9] This can be justified if bank equity is a small fraction of the portfolio of well-diversified agents.

[10] Gross (1994) justifies this assumption by appealing to such works as Jenson and Meckling (1976), where shareholders fear that firms with too much cash will spend it on management perquisites. Milne and Robertson (1996) provide a similar justification.

3.2 The Bank's Cost of Funds under Financial Liberalization

Under financial liberalization, the bank is free to attract deposits from international investors, and domestic investors are free to move their funds abroad. This means that the bank's deposit rates must satisfy an international arbitrage condition, which we now derive.

We begin by considering the probability of bankruptcy. It follows from equation (7) that $r_{t+1} \leq i^l_{t+1}$—the best return on loans occurs when all firms pay back their loans. It is straightforward to see that when firm-level bankruptcy is not possible, the bank will set its loan rate, i^l_{t+1}, at least as high as its cost of funds, i^b_{t+1}. The more interesting case, of course, occurs when firms can default. Substituting equation (8) into equation (12), and setting $Q^{\min} = 0$, allows us to find a^0_{t+1}, the lowest level of aggregate productivity that keeps the bank solvent:

$$\pi_0 \left(a^0_{t+1}, a_t\right) + \pi_1 \left(a^0_{t+1}, a_t\right) K_t^{\alpha-1} = \frac{\psi_t - 1}{\psi_t} \left(1 + i^b_{t+1}\right). \tag{14}$$

Note that a^0_{t+1} can lie below the conditional support of a_{t+1}, in which case the bank is always solvent, even though firm-level bankruptcy can occur. This occurs when loans are so limited that loan interest rates are high, and the average return on capital is always high. Since π_0 and π_0 are strictly increasing in a_{t+1}, when bank-level default is possible a^0_{t+1} is increasing in K_t and ψ_t; the bank is more likely to default when it is highly leveraged and/or the aggregate capital stock is high.

The interest rate on deposits, i^b_{t+1}, is set by risk-neutral investors to ensure that the expected return on bank deposits, accounting for the prospect of default, equals the world interest rate θ. Assuming that investors have full information about the bank's riskiness, it follows that

$$1+\theta = E\left(\min\left\{1+i_{t+1}^{b}, \frac{\psi_t\left(1+r_{t+1}\right)}{\psi_t-1}\right\}\middle| I_t\right). \tag{15}$$

where the second term is the average return on deposits.[11] Imposing the definition of a_{t+1}^0, it follows that the gross interest rate on deposits must satisfy

$$\begin{aligned} 1+\theta \quad = & \int\limits_{a_{t+1}>a_{t+1}^0} \left[1+i_{t+1}^{b}\right] dF\left(a_{t+1} \mid a_t\right) \\ & + \int\limits_{a_{t+1}\leq a_{t+1}^0} \frac{\psi_t}{\psi_t-1}\left[\pi_0\left(a_{t+1},a_t\right)+\pi_1\left(a_{t+1},a_t\right)K_t^{\alpha-1}\right] dF\left(a_{t+1} \mid a_t\right). \end{aligned} \tag{16}$$

Comparative statics calculations then show that the equilibrium deposit rate is increasing in leverage and capital, as the depositors' returns from an insolvent bank are decreasing in these variables.[12]

3.3 The Bank's Optimization Problem under Financial Liberalization

As a matter of notation, define $a_{t+1}^{\min}$ as:

$$\pi_0\left(a_{t+1}^{\min},a_t\right)+\pi_1\left(a_{t+1}^{\min},a_t\right)K_t^{\alpha-1} = \frac{\psi_t-1}{\psi_t}\left(1+i_{t+1}^{b}\right)+\frac{Q^{\min}}{L_t},$$

where, in contrast to the definition of a_{t+1}^0 in equation (14), we have not restricted $Q^{\min}$ to equal zero.

Under financial liberalization, the bank is free to set both deposit and loan rates, with the deposit rates satisfying an international arbitrage condition and the loan rates set to

[11] It follows from equation (9) that the the average (gross) return on deposits is given by $L_t\left(1+r_{t+1}\right)/\left[L_t-\left(Q_t-d_t\right)\right]$. Note that this expression reflects the assumption, discussed above, that there is no deposit insurance.

[12] In performing these calculations, it is useful to note that it follows from equation (14) that small changes in a_{t+1}^0 do not affect the depositor's expected returns.

maximize profits. Recall that all capital is bank-financed, so that $K_t = L_t$. The bank's problem under financial liberalization is thus given by the value function specified in equation (13), subject to the loan demand curve as expressed in equation (8) and the deposit rate condition given by equation (16). The first order conditions are derived in Appendix A, which shows that the marginal value of net worth is

$$\begin{aligned} \frac{\partial V_t}{\partial Q_t} &= \left(\frac{\psi_t}{Q_t - d_t}\right)\frac{\partial V_t}{\partial \psi_t} + \frac{1}{\varpi}\Phi_t E\left(\left.\frac{\partial V_{t+1}}{\partial Q_{t+1}}\right| a_{t+1} > a_{t+1}^{\min}, I_t\right) \geq 1, \qquad (17) \\ \Phi_t &\equiv \frac{\Pr\left(a_{t+1} > a_{t+1}^{\min}\middle| a_t\right)}{\Pr\left(a_{t+1} > a_{t+1}^{0}\middle| a_t\right)} \leq 1, \end{aligned}$$

where, in an abuse of notation, $\frac{\partial V_t}{\partial \psi_t}$ denotes the value of relaxing the leverage constraint. In particular, $\frac{\partial V_t}{\partial \psi_t}$ will be positive only when the constraint binds. The lower bound of unity on the marginal value of equity reflects the bank's ability to pay dividends; an additional unit of net worth will at a minimum generate the bank's owners an additional unit of dividend income. Continuing, the first order condition for dividends can be expressed as

$$1 - \left(\frac{\psi_t}{Q_t - d_t}\right)\frac{\partial V_t}{\partial \psi_t} - \frac{1}{\varpi}\Phi_t E\left(\left.\frac{\partial V_{t+1}}{\partial Q_{t+1}}\right| a_{t+1} > a_{t+1}^{\min}, I_t\right) \leq 0, \qquad (18)$$

with the bank paying dividends only when the condition holds at equality. The dividend rule given by equation (18) can be interpreted as a comparison between the external value of net worth, given by 1, and its internal value to the bank as retained earnings, $\frac{\partial V_t}{\partial Q_t}$, given by the two negative terms. The value of retained earnings has two components. The first is its effect on the bank's loans. Retaining earnings allows the bank to fund more loans; the ratio $\psi_t/\left(Q_t - d_t\right)$ reflects the relative strengths of retained earnings and leverage as funding mechanisms. The second effect of retaining earnings is that the bank has more net worth in the future—this is captured by the conditional expectation.

It follows from equation (17) that the second negative term in equation (18) is bounded above by $-1/\varpi$. Recall that $\varpi > 1$. Then when ϖ is close to 1, as we normally expect it to be, equation (18) implies that the bank pays no dividends when leverage constraint is "strongly" binding. This leads to the following proposition.

Proposition 1 *When the bank's incentives to take on leverage are high, so are its incentives to retain earnings.*

Note that the bank might retain all of its earnings even if the leverage constraint is not currently binding. In particular, if the leverage constraint binds in enough feasible future states, the internal value of retained earnings will be sufficiently high to rule out current dividends. This can be seen by solving equation (17) forward to get

$$\begin{aligned} \frac{\partial V_t}{\partial Q_t} &= \sum_{j=0}^{\infty} \left(\frac{1}{\varpi}\right)^j E\left(\left(\prod_{k=0}^{j-1} \Phi_{t+k}\right) \left(\frac{\psi_{t+j}}{Q_{t+j} - d_{t+j}}\right) \frac{\partial V_{t+j}}{\partial \psi_{t+j}} \right| a_{t+j} > a_{t+j}^{\min}, I_t \Bigg), \\ \prod_{k=0}^{-1} \Phi_{t+k} &\equiv 1. \end{aligned}$$

In short, the possibility of future financial constraints affects the bank's current behavior, a result pointed out by Zeldes (1989) and many others. On the other hand, equation (18) shows that:

Proposition 2 *The bank will always be leverage-constrained either at present or in some solvent future state.*

This result follows from $\varpi > 1$. In particular, if the leverage constraint is not currently binding, equation (18) can hold only if $\frac{\partial V_{t+1}}{\partial Q_{t+1}}$ exceeds 1 in some future state.

The exact behavior of $\frac{\partial V_t}{\partial \psi_t}$, and thus the exact shape of the value function, is harder to identify. We show in Appendix B that

Proposition 3 *Assume that net worth lies in the absorbing set $\left[Q^{\min}, Q^{\max}\right]$. Assume further that under optimal behavior, firms are always sound, so that*

$$\Gamma\left(Q, a\right) \equiv F\left(a_{t+1}^{\min} \mid a_t = a; Q_t = Q\right) = 0, \ \forall Q \in \left[Q^{\min}, Q^{\max}\right], \ a \in \mathbf{A},$$

Then the value function $V\left(Q_t, a_t\right) : \left[Q^{\min}, Q^{\max}\right] \times \mathbf{A} \rightarrow \Re_{+}$ is concave in Q_t.

Extending this proposition to the case where default is possible is not straightforward. Cooley and Quadrini (2000) show in a similar framework, however, that when default is sufficiently unlikely, Proposition 3 still holds. When this is the case, banks with high net worth will in general be more risk averse. Building on the discussion in Milne and Robertson (1996), Figure 1 provides some intuition. The heavy line in Figure 1 is the bank's value function, $V\left(Q\right)$. While the function is concave over positive values of net worth, the way in which bankruptcy bounds the bank's value at zero makes the value function convex overall.[13] The bank's attitudes toward risk thus depend on the relative probability of bankruptcy.

To see this point more clearly, consider the equity value Q_0. Suppose that the bank has the choice between Q_0 and a lottery over a range of net worth centered around Q_0, which in Figure 1 is bracketed by "$\frown$". Assuming that net worth outcomes are uniformly distributed over this range, it turns out that bankruptcy is common enough to make the bank prefer the lottery. In particular, the expectation of the value function over the lottery, which can be approximated by EV_0, exceeds the value of the certain outcome $V_0 = V\left(Q_0\right)$. Now turn to the second, higher equity value Q_1, and suppose that the bank is presented with a lottery centered around Q_1. In this case, bankruptcy is sufficiently unlikely to make the bank prefer the certain outcome to the lottery. In particular, the expectation of the value

[13] Technically, we impose the bankruptcy threshold in the law of motion for net worth, so that the value function is defined only for $Q_t \geq 0$.

function over the lottery, which can be approximated by EV_1, is less the value of the certain outcome $V_1 = V(Q_1)$.

The effects of government bailouts are illustrated in Figure 1 by the "bailout limit" line. Note that even though the equity threshold associated with bailouts is very close to zero, (lying between 0 and Q_0), the lower bound on the value function is fairly large, reflecting the high returns associated with a small capital stock. Repeating the analysis of the previous paragraph shows that government bailouts make the lottery much more attractive than under bankruptcy. The possibility of default is much less appealing under bankruptcy than with bailouts, because bankruptcy terminates the bank's monopoly franchise.

One unrealistic feature of Figure 1 is that the two lotteries differ only in their conditional means. In the full model, however, the conditional mean and the conditional variance of future net worth are complicated non-linear functions of current net worth and productivity. A bank with high net worth will not face the same leverage-risk trade-off as a bank with low net worth. We will return to this issue in some detail in section 4, when we consider the transition path for a newly liberalized economy.

3.4 The Bank's Optimization Problem under Repression

The financially repressed banking system differs from the liberalized system in two ways. First, the government fixes the interest rate the bank is allowed to pay on deposits and the rate it is allowed to charge for loans. Development economists (for example, Shaw, 1973) have traditionally advocated such policies as a way of encouraging investment. We assume specifically that the loan rate is pegged at:

$$i^l = i^b + \xi,$$

where time subscripts are omitted because rates are constant. The deposit and loan rates also satisfy:

$$1 + i^b + \xi < \varpi (1 + \theta) < 1 + i^b + \overline{\psi}\xi. \tag{19}$$

Second, the government prohibits capital outflows, so that residents cannot purchase foreign assets with higher returns. These restrictions shut down the capital account of the balance of payments. With domestic interest rates below the rate of time preference, foreign agents do not purchase domestic assets, and domestic agents are prohibited from purchasing foreign assets. Since the bank cannot attract foreign deposits with the repressed interest rates, its only sources of funds are its retained earnings and the deposits domestic households hold, so that loans are given by:

$$L_t = Q_t - d_t + B_t. \tag{20}$$

The bank can choose to accept all deposits the households want to make at the restricted deposit rate, $B_t\left(i^b\right)$, but without changing interest rates, it cannot increase deposits beyond this amount.[14] This introduces an additional constraint:

$$\psi_t \leq 1 + \frac{B_t\left(i^b\right)}{Q_t - d_t}. \tag{21}$$

[14] In the interest of brevity and clarity we have omitted a formal discussion of the consumer's problem. The essential part of our argument, however, is simply that the bank cannot attract more deposits by raising interest rates. A formal treatment of the consumer's problem under financial liberalization is even more superfluous, as production requires no labor and the bank has access to international capital markets.

We turn now to describing a perfect foresight steady state, with our results also applying to stochastic fluctuations or gradual growth around this steady state, by the continuity of the value function.[15] An important maintained assumption is that the capital stock is so low that firms never go bankrupt.[16] We also assume that loan interest rates are so low that firms accept any loans that the bank is willing to make.

The bank's problem under financial repression is given by the value function specified in equation (13), subject to the constraint on deposits given above by equation (21). When the deposit constraint is not binding, the first order condition with respect to leverage is given by

$$\frac{\partial V_t}{\partial \psi_t} = \frac{Q_t - d_t}{\varpi\left(1+\theta\right)} \frac{\partial V_{t+1}}{\partial Q_{t+1}} \xi > 0,$$

so that the bank always chooses maximum leverage ($\psi_t = \bar{\psi}$) when the deposit constraint is not binding.

Let d_t^* denote the largest dividend that the bank can issue and still support the deposit level $B_t\left(i^b\right)$:

$$d_t^* = Q_t - \frac{B_t\left(i^b\right)}{\overline{\psi} - 1}. \tag{22}$$

When dividends are below this amount, $d_t < d_t^*$, the deposit constraint given by equation (21) binds and the derivative with respect to dividends is

$$\frac{\partial V_t}{d_t} = 1 - \left[\frac{1 + i^b + \xi}{\varpi\left(1+\theta\right)}\right] \frac{\partial V_{t+1}}{\partial Q_{t+1}}. \tag{23}$$

[15] We are implicitly assuming that the bank views financial liberalization as relatively unlikely; when financial liberalization is imminent, the bank is more willing to retain its earnings.

[16] When the capital stock is so low that firms never default, the bank faces no default risk, even if aggregate productivity is stochastic. Then even if deposits and capital are not constant, the results we derive below will hold as long as the bank has enough net worth to support the deposit level $B_t\left(i^b\right)$, i.e., $\left(\overline{\psi} - 1\right) Q_t > B_t\left(i^b\right)$, in every state.

But when $d_t > d_t^*$, so that the deposit constraint no longer binds, it will be the case that $\psi_t = \bar{\psi}$ and the derivative with respect to dividends is

$$\frac{\partial V_t}{d_t} = 1 - \left[\frac{1 + i^b + \overline{\psi}\xi}{\varpi (1+\theta)}\right] \frac{\partial V_{t+1}}{\partial Q_{t+1}}. \tag{24}$$

It is possible for $Q_t - d_t^*$ to take on a value such that the derivative given by equation (23) is positive, while the derivative given by equation (24) is negative.[17] When this happens, the bank retains just enough earnings to support $B_t\left(i^b\right)$. If the bank increases its dividends beyond d_t^*, it will have to shed deposits (and thus income) at the rate of leverage, but if it reduces dividends, its future income grows at an unleveraged rate, as deposits are at their maximum.

Proposition 4 *In a steady state under financial repression, the bank's dividends will satisfy equation (22).*

To prove that this characterizes equilibrium, note that in a steady state Q_{ss} must be finite, so that the bank issues dividends every period. It follows that the right hand derivative, $\partial V_{t+1}^{+}/\partial Q_{t+1}$, must equal 1 as any net worth in excess of Q_{ss} gets paid out as dividends.[18]

The left-hand derivative, $\partial V_{t+1}^{-}/\partial Q_{t+1}$, is at least this large. Then in a no-default steady state, the bank will not issue dividends in excess of d_t^* as long as

$$\frac{1 + i^b + \overline{\psi}\xi}{\varpi (1+\theta)} > 1,$$

and it will not issue fewer than d_t^* dividends as long as

$$\frac{1 + i^b + \xi}{\varpi (1+\theta)} < 1.$$

[17]Note that at this corner, the derivative $\frac{\partial V_{t+1}}{\partial Q_{t+1}}$ is not well-defined. Instead, we use the right-hand derivative of V in equation (23) and the left-hand derivative in the full-leverage case.

[18]As long as Q_{t+1} exceeds $B_{t+1}\left(i^b\right) / \left(\overline{\psi} - 1\right)$, this will be the case in an expanding and/or fluctuating economy as well.

But these two conditions are given by equation (19).

Recall that when equation (22) holds, the bank is fully levered. It immediately follows that the bank's post-dividend net worth is

$$Q_t - d_t = \frac{K_t}{\bar{\psi}}. \tag{25}$$

Since capital is usually low in emerging economies, and the leverage threshold $\bar{\psi}$ is usually high, banks in these economies will usually have very little net worth. In short, the model implies a banking system with low net worth, high profitability, and a low incidence of bankruptcy, all consistent with stylized facts in repressed economies.[19]

4 The Transition from Financial Repression to Financial Liberalization

Having analyzed the bank's behavior under both regimes, we turn to describing how it behaves as it moves from financial repression to financial liberalization. With liberalization, interest rate ceilings are removed and capital outflows are allowed. Due to informational advantages, however, firms still turn to the bank for financing their capital stock, and the bank retains its monopoly in the loan market. In the following sections we present first an analytical overview, and then some numerical exercises, that characterize bank behavior after liberalization.

[19] Our results should hold for a variety of institutional specifications. For example, financial repression in Korea took the form of pegging deposit rates and letting banks set loan rates, often at high levels. In this case, the high returns generated by a small capital stock would create incentives for full leverage. Equations (22) and (25) should still hold, and Korea's initial conditions at the advent of liberalization should have been similar to those described above.

4.1 Analytical Overview

Consider a bank in an emerging market that has just been released from financial repression. In the preceding section, we concluded that under repression both the bank's net worth and the aggregate capital stock are low. It follows that upon liberalization, the bank will probably be fully levered, because the marginal product of capital—and thus the loan interest rate—will be high. By fully levering, the bank has chosen the most risky legal outcome. The high returns to lending that lead the bank to fully lever, however, also make default unlikely. Even when bad productivity shocks occur, the marginal product of capital is sufficiently high to keep the bank sound. Moreover, it follows from Proposition 1 that the bank retains all of its earnings; the high returns to lending imply that the internal value of retained earnings exceeds their market value. With high and relatively safe returns to lending, and a policy of retaining earnings, the newly liberalized bank will see its net worth grow.

But as net worth accumulates, the capital stock increases, the marginal product of capital falls, and risk rises. It is at this point that a banking crisis is most likely. The bank now faces conflicting incentives. On the one hand, by cutting off the tail of the bank's return distribution, bankruptcy and bailouts encourage risk-taking behavior. On the other hand, financial losses depress if not end the bank's stream of monopoly rents, and thus encourage risk-averse behavior. While it is not clear *a priori* which effect dominates, the analysis of the previous section shows that as the bank accumulates more equity, it will become more risk-averse. At some level of net worth, the bank begins paying dividends—a bank that does not reach a dividend-paying state with positive probability has no value. If the value function is concave, as Proposition 3 suggests it will be, this dividend threshold characterizes the bank's behavior for higher amounts of net worth as well. (To see this, consider the bank's first-order conditions when the value function is concave.) In particular, if net worth exceeds the dividend threshold, the bank will pay out dividends until post-dividend net worth equals the threshold value, and it will then adopt the same leverage ratio as at the threshold.

4.2 Numerical Methodology

We now turn to illustrating the post-repression sequence of events with some numerical exercise. Given the stylized nature of our model, we will keep the description of our numerical methodology brief, with the details relegated to Appendix C.

To specialize the model we assume that at time t, a firm's productivity, x_{it}, can take on the high value a_H with frequency ρ_t, or the low value a_L with frequency $1-\rho_t$. Let a_t denote aggregate productivity:

$$a_t = E\left(x_{it}|\,\rho_t\right) = \rho_t a_H + \left(1-\rho_t\right) a_L.$$

We assume that the Markov process for the probability parameter ρ_t is such that aggregate productivity follows

$$a_t = \left(1-\eta\right) a_{t-1} + \eta\mu_a + u_t,$$

where μ_a is the unconditional expectation of aggregate productivity, u_t is a uniformly-dsitributed i.i.d. variable, and $\eta \in (0,1]$.

For the numerical exercises, we also modify the production function so that

$$y_{it} = x_{it}\left[K_t + \kappa\right]^{\alpha},$$

with the shift parameter $\kappa \geq 0$. It turns out that the returns to capital in a newly liberalized economy are so high that unless κ is strictly positive, the bank almost immediately jumps from a position of minimal equity to full funding; when $\kappa = 0$, the bank "leapfrogs" the region of risk.

The model is calibrated at an annual frequency. Table 1 presents the parameter values, which are described in some detail in Appendix C. A few parameters are worth noting here. First, we have set the leverage bound, $\overline{\psi}$, to 40. While this is higher than the standards set by the Basle Accord, it is consistent with the notion that newly liberalized banks are often regulated quite lightly. Second, our parameter choices imply that the productivity innovation u_t has a standard deviation equal to 45 percent of the mean productivity value of 0.67, and that the autocorrelation of the productivity process, $1 - \eta$, is 22 percent. It turns out that unless the conditional variance of productivity is high relative to its conditional mean, the bank takes on relatively little bankruptcy risk. This largely reflects the monopoly assumption: because the bank internalizes the way in which increasing the capital stock both decreases the returns and increases the risk of its loans, it is fairly unwilling to lend itself into a risky position.

Appendix C also describes how we find the decision rules implied by our model, and how we use them to generate time series. For the most part, the numerical methods we use to solve the model are very similar to those described in Jones (2000).

4.3 Numerical Results

Figure 2 shows the bank's leverage and default rates as functions of net worth for a productivity level, a_t, of 0.684, the median value in the Markov chain we use to approximate a_t. The first panel of Figure 2 shows results for the bankruptcy case. This graph shows that a bank with low net worth first levers fully, setting ψ_t to its upper bound of 40. As net worth continues to increase, however, the bank reduces its leverage sharply; by the time the bank begins to pay dividends, the leverage ratio has dropped to less than 5. The bank's dividend policy is characterized by the dividend threshold; net worth in excess of the dividend threshold is paid out as dividends, while banks with net worth below the threshold retain all their funds. The bankruptcy risk associated with these policies is measured on the right-hand vertical scale. The graph shows that bankruptcy risk initially increases in net worth, peaking at about 0.35 percent before returning to zero. While the pattern of bankruptcy risk is consistent with the analytical discussion, the levels of risk are quite small, and in fact fall within the range of approximation error.[20] The probability of default is somewhat higher at lower values of a_t, but even there it remains quite small; the bank is simply unwilling to gamble with its monopoly franchise.

The second panel of Figure 2 shows results for the government bailout case.[21] While the bank's leverage policy is qualitatively similar to the one shown in the first panel, the second panel shows that a bank operating in a regime of bailouts takes on more leverage. The

[20] In the region relevant for this analysis, the distribution of a_t has been discretized into units that each have a probability mass of 0.76%.

[21] We have also analyzed a case with government bailouts and deposit insurance, where $i^b_{t+1} = \theta$, subject only to the restriction that $E_t\left(r_{t+1}\right) \geq \theta$. This modification introduces a bit more risk-taking, but is quite similar to the bailout case described here.

additional leverage leads to considerably more risk; moving to government bailouts increases the default risk roughly twenty-fold. It is worth stressing that $Q^{\min}$ is quite small; because of the ability to lever, a toehold's worth of equity generates a lucrative stream of monopoly rents.

Figure 3 shows the averages from 5,000 dynamic simulations, again for the bankruptcy and bailout cases in turn. As in Figure 2, banks face the most default risk some time after liberalization, namely in the third year after liberalization.[22] After this point, surviving banks move on to a regime of low leverage and minimal risk. Figure 3 also shows that leverage and default are much higher under a regime of government bailouts; in fact, banks operating under bankruptcy protection never default.

Taken as a whole, Figures 2 and 3 confirm the main conclusions of the analytical section: (1) when net worth is low, the bank retains all of its earnings; (2) bankruptcy risk first increases but then decreases in net worth; (3) the bank becomes more risk averse as its net worth grows—in the exercise at hand, the bank eliminates its bankruptcy risk before paying dividends; (4) government bailouts generate much more default risk than standard liability limits.

5 Conclusion

In this paper, we provide a theoretical explanation of why financial liberalization is likely to generate financial crises in emerging market economies. We do this by studying an emerging

[22]As a matter of timing, note that the default rate for a given period depends on the leverage rate of the preceding period.

economy where all capital is funded by loans from a monopoly bank. The bank can raise loanable funds through retained earnings or through deposits, and it faces constraints on its dividends and on the ratio of its deposits to net worth—its leverage. A key part of our analysis is that we carefully model the dynamic interactions between the bank's net worth, the aggregate capital stock and the return structure of the bank's loans. This allows us to explain why banks in newly liberalized countries tend to grow rapidly at first and then enter a crisis period some time after liberalization.

We begin by showing that under financial repression the capital stock and bank equity are both likely to be low. This leads a newly liberalized bank to be highly levered, because the marginal product of capital—and thus loan interest rates—are high. The high returns on capital, however, also make bankruptcy unlikely, and they encourage the bank to retain all of its earnings. The bank thus sees its net worth grow rapidly. As net worth and capital accumulate, the marginal product of capital falls, and a banking crisis becomes more likely. While the possibility of bankruptcy generates conflicting incentives, if net worth continues to grow the bank will become increasingly cautious. Although the degree of risk-aversion is not clear, our numerical exercises suggest that the bank will eliminate most of its risk, by reducing its leverage, before issuing dividends. The numerical exercises also confirm that government bailouts generate more risk-taking than do the liability limits provided by bankruptcy, because they allow unsound banks to retain their monopoly franchise.

Although the model is highly stylized, so that the numerical results should not be taken literally, they do suggest that the monopoly bank is generally willing to take on very little risk, even in the presence of government bailouts. A monopoly in the loan market provides a very lucrative franchise. Given that liberalization also increases the competition for financing firm capital, we view our results as providing a lower bound on bank risk-taking. A useful line of future work will be to further study the effects of introducing such competition.

Appendix A

First Order Conditions

Begin by writing the bank's problem as

$$V(Q_t, a_t) = \max_{0\le\psi_t\le\overline{\psi},\ 0\le d_t\le Q_t} d_t + \frac{1}{\varpi(1+\theta)} \int_{a_{t+1}>a_{t+1}^{\min}} V(Q_{t+1}, a_{t+1})\, dF(a_{t+1} \mid a_t)$$
$$+\frac{1}{\varpi(1+\theta)} \int_{a_{t+1}\le a_{t+1}^{\min}} V\left(Q^{\min}, a_{t+1}\right) dF(a_{t+1} \mid a_t),$$

subject to the constraints described in the text.

The first order condition with respect to leverage is given by:

$$\frac{\partial V_t}{\partial \psi_t} = \frac{1}{\varpi(1+\theta)} \int_{a_{t+1}>a_{t+1}^{\min}} \left[\frac{\partial V_{t+1}}{\partial Q_{t+1}} \times \frac{\partial Q_{t+1}}{\partial \psi_t}\right] dF(a_{t+1} \mid a_t) \ge 0.$$

In a slight abuse of notation, we are using $\frac{\partial V_t}{\partial \psi_t}$ to denote the value of relaxing the leverage constraint. Using the envelope theorem, the marginal value of the value function with respect to net worth can be expressed as:[23]

$$\frac{\partial V_t}{\partial Q_t} = \frac{1}{\varpi(1+\theta)} \int_{a_{t+1}>a_{t+1}^{\min}} \left[\frac{\partial V_{t+1}}{\partial Q_{t+1}} \times \frac{\partial Q_{t+1}}{\partial Q_t}\right] dF(a_{t+1} \mid a_t) \tag{26}$$

It follows from equation (11) that

$$\frac{\partial Q_{t+1}}{\partial \psi_t} = (Q_t - d_t)\left[r_{t+1} - i_{t+1}^b + (1-\psi_t)\left(\frac{\partial i_{t+1}^b}{\partial \psi_t} + \frac{\partial i_{t+1}^b}{\partial L_t}\frac{\partial L_t}{\partial \psi_t}\right) + \psi_t \frac{\partial r_{t+1}}{\partial L_t}\frac{\partial L_t}{\partial \psi_t}\right],$$

[23]Note that $\frac{\partial V_t}{\partial d_t^*}\frac{\partial d_t^*}{\partial Q_t} = \frac{\partial V_t}{\partial \psi_t^*}\frac{\partial \psi_t^*}{\partial Q_t} = 0$, whether the inequality constraints on d_t and ψ_t bind or not. In the regions where the constraints do not bind, these derivatives equal zero from a variant of the envelope theorem. In the regions where the constraints do bind $\frac{\partial d_t^*}{\partial Q_t} = \frac{\partial \psi_t^*}{\partial Q_t} = 0$. Finally, it follows from the continuity of d_t^* and ψ_t^* in Q_t (which in turn follows from the Theorem of the Maximum) that the boundaries of these two regions are of zero measure.

$$\frac{\partial Q_{t+1}}{\partial Q_t} = (Q_t - d_t)\left[\frac{1 + i^b_{t+1} + \psi_t\left(r_{t+1} - i^b_{t+1}\right)}{Q_t - d_t} + \left((1-\psi_t)\left(\frac{\partial i^b_{t+1}}{\partial L_t}\frac{\partial L_t}{\partial Q_t}\right) + \psi_t \frac{\partial r_{t+1}}{\partial L_t}\frac{\partial L_t}{\partial Q_t}\right)\right],$$

and it follows from equation (10) that

$$\frac{\partial L_t}{\partial Q_t} = \frac{\psi_t}{Q_t - d_t}\frac{\partial L_t}{\partial \psi_t}.$$

Combining the five preceding equations allows us to rewrite equation (26) as

$$\frac{\partial V_t}{\partial Q_t} = \frac{\psi_t}{Q_t - d_t}\frac{\partial V_t}{\partial \psi_t} + \frac{1}{\varpi(1+\theta)} \int\limits_{a_{t+1} > a^{\min}_{t+1}} \frac{\partial V_{t+1}}{\partial Q_{t+1}}\left[1 + i^b_{t+1} - \psi_t(1-\psi_t)\frac{\partial i^b_{t+1}}{\partial \psi_t}\right] dF(a_{t+1} \mid a_t). \tag{27}$$

Totally differentiating and then imposing equation (16) reveals that

$$\begin{aligned}
\frac{\partial i^b_{t+1}}{\partial \psi_t} &= \frac{1}{1 - F\left(a^0_{t+1}\middle| a_t\right)} \cdot \frac{1}{(\psi_t - 1)^2} \int\limits_{a_{t+1} > a^0_{t+1}} [1 + r_{t+1}]\, dF(a_{t+1} \mid a_t) \\
&= \frac{1}{1 - F\left(a^0_{t+1}\middle| a_t\right)} \cdot \frac{1}{\psi_t(\psi_t - 1)} \cdot \left[1 + \theta - \left(1 - F\left(a^0_{t+1}\middle| a_t\right)\right)\left(1 + i^b_{t+1}\right)\right] \geq 0,
\end{aligned}$$

Inserting this result into equation (27) yields

$$\frac{\partial V_t}{\partial Q_t} = \frac{\psi_t}{Q_t - d_t}\frac{\partial V_t}{\partial \psi_t} + \frac{1}{\varpi} \cdot \frac{1}{1 - F\left(a^0_{t+1}\middle| a_t\right)}\left[\frac{1 - F\left(a^{\min}_{t+1}\middle| a_t\right)}{1 - F\left(a^{\min}_{t+1}\middle| a_t\right)}\right] \int\limits_{a_{t+1} > a^{\min}_{t+1}} \frac{\partial V_{t+1}}{\partial Q_{t+1}} dF(a_{t+1} \mid a_t),$$

which reduces to equation (17) in the main text.

Equation (18) follows immediately from

$$\frac{\partial Q_{t+1}}{\partial d_t} = -\frac{\partial Q_{t+1}}{\partial Q_t}.$$

Appendix B

Proof of Proposition 3

To prove this proposition, use equation (8) to rewrite the law of motion for net worth as

$$
\begin{aligned}
Q_{t+1} &= \phi\left(Q_t, d_t, L_t, a_{t+1}\right) \\
&= \max\left\{Q^{\min}, \left(1+r_{t+1}\right) L_t - \left(1+i_{t+1}^b\right)\left(L_t - \left(Q_t - d_t\right)\right)\right\} \\
&= \max\left\{Q^{\min}, \left(\pi_0\left(a_{t+1}\right) - i_{t+1}^b\right) L_t + \pi_1\left(a_{t+1}, a_t\right) L_t^\alpha + \left(1+i_{t+1}^b\right)\left(Q_t - d_t\right)\right\}.
\end{aligned}
$$

When banks are always sound under optimal behavior, $\phi(\cdot) > Q^{\min}$ for all possible values of a_{t+1}, and $i_{t+1}^b = \theta$. Let $d^*(Q)$ and $L^*(Q)$ denote the bank's decision rules and define

$$Q_\lambda = \lambda Q_0 + (1-\lambda) Q_1,$$

$$d_\lambda = \lambda d^*\left(Q_0\right) + (1-\lambda) d^*\left(Q_1\right),$$

$$L_\lambda = \lambda L^*\left(Q_0\right) + (1-\lambda) L^*\left(Q_1\right).$$

Then in a no-default environment

$$
\begin{aligned}
\phi\left(Q_\lambda, d_\lambda, L_\lambda, a_{t+1}\right) &\geq \lambda\phi\left(Q_0, d_0^*, L_0^*, a_{t+1}\right) + (1-\lambda)\phi\left(Q_1, d_1^*, L_1^*, a_{t+1}\right), \qquad (28) \\
&> Q^{\min},
\end{aligned}
$$

where $d_0^* = d^*\left(Q_0\right)$ and $L_0^* = L^*\left(Q_0\right)$. The second line follows from $\phi(\cdot) > Q^{\min}$ and confirms that combining optimal decisions does not violate the default threshold.

Bellman's equation can be written as

$$V\left(Q_t, a_t\right) = \max_{0 \leq L_t \leq \overline{\psi}\left(Q_t - d_t\right),\ 0 \leq d_t \leq Q_t} d_t + \frac{1}{\varpi(1+\theta)} E_t\left\{V\left(\phi\left(Q_t, d_t, L_t, a_{t+1}\right), a_{t+1}\right)\right\}$$

Let T denote the functional operator given by the right-hand-side of this equation. As outlined in Lucas and Stokey (1989), we prove concavity in Q by showing that T maps concave functions into concave functions. Let $f(Q_t, a_t)$ be concave and increasing in Q. (Even when default is possible, it is straightforward to show that V exists and is continuous and increasing.) Then

$$\begin{aligned}
(Tf)(Q_\lambda, a_t) &\geq d_\lambda + \frac{1}{\varpi(1+\theta)} \int f(\phi(Q_\lambda, d_\lambda, L_\lambda, a_{t+1}), a_{t+1})\, dF(a_{t+1} \mid a_t) \\
&\geq \lambda \left[d_0^* + \frac{1}{\varpi(1+\theta)} \int f(\phi(Q_0, d_0^*, L_0^*, a_{t+1}), a_{t+1})\, dF(a_{t+1} \mid a_t) \right] \\
&\quad + (1-\lambda) \left[d_1^* + \frac{1}{\varpi(1+\theta)} \int f(\phi(Q_1, d_1^*, L_1^*, a_{t+1}), a_{t+1})\, dF(a_{t+1} \mid a_t) \right] \\
&= \lambda (Tf)(Q_0, a_t) + (1-\lambda)(Tf)(Q_1, a_t).
\end{aligned}$$

The first inequality follows from the fact that d_λ and L_λ are feasible but not necessarily optimal at Q_λ. The second inequality holds because ϕ is concave and f is concave and increasing in Q at every value of a_{t+1}.

Appendix C

Specialization, Calibration and Numerical Methodology

To specialize the model we assume that at time t, a firm's productivity can take on the high value a_H with frequency ρ_t, or the low value a_L with frequency $1-\rho_t$, and that the probability parameter ρ_t follows a Markov process. In particular, when the previous period's frequency is ρ_{t-1}, the current frequency will come from the uniform distribution:

$$\rho_t|\, \rho_{t-1} \backsim U\left(\rho_{t-1} - \eta\left(\rho_{t-1} - \rho_L\right), \rho_{t-1} + \eta\left(\rho_H - \rho_{t-1}\right)\right).$$

with $0 < \eta < 1$ and $0 \leq \rho_L < \rho_H \leq 1$.

Let a_t denote aggregate productivity:

$$a_t = E\left(x_{it}|\, \rho_t\right) = \rho_t a_H + \left(1 - \rho_t\right) a_L, \tag{29}$$

which is also uniformly distributed within Markov bounds. Specifically, it follows from the Markov bounds for ρ_t (see Appendix D) that aggregate productivity follows

$$a_t = \left(1 - \eta\right) a_{t-1} + \eta\mu_a + u_t, \tag{30}$$

with the unconditional expectation of aggregate productivity, μ_a, given by

$$\mu_a = a_L + \frac{\rho_H + \rho_L}{2}\left(a_H - a_L\right),$$

and the innovation u_t following

$$u_t|\, a_{t-1} \backsim U\left(-\frac{\eta}{2}\left(\rho_H - \rho_L\right)\left(a_H - a_L\right), \frac{\eta}{2}\left(\rho_H - \rho_L\right)\left(a_H - a_L\right)\right).$$

As described in the main text, for the numerical exercises we modify the production function so that

$$y_{it} = x_{it}\left[K_t + \kappa\right]^{\alpha},$$

with the shift parameter $\kappa \geq 0$. Imposing this modification, the firm's optimization problem can be stated as:

$$\max_{K_t} E\left(\max\left\{a_{t+1}\left[K_t+\kappa\right]^{\alpha} - \left(i^l_{t+1}+\delta\right)K_t, \rho_{t+1}\left(a_H\left[K_t+\kappa\right]^{\alpha} - \left(i^l_{t+1}+\delta\right)K_t\right)\right\}\middle| a_t\right).$$

The first branch of the $\max\{\cdot,\cdot\}$ term will be larger when firms can always repay their loans, while the second branch will be larger when low-productivity (a_L, rather than a_H) firms default. (Note that a firm's ability to repay depends on K_t and i^l_{t+1}—both of which are known at time t—rather than a_{t+1}.) When $\kappa > 0$, the conditions that make the no-default option optimal are difficult to characterize.[24] In the numerical examples we present below, however, we set $a_L = 0$, so that low-productivity firms always default.

Note that when the firm is insolvent, the bank receives an average return of

$$\frac{a_L\left[K_t+\kappa\right]^{\alpha} - \delta K_t - \zeta K_t}{K_t}.$$

Continuing with our assumption that low-productivity firms always default, it follows that the average return that a bank earns on its loans to firms, r_{t+1}, is given by

$$r_{t+1} = \left[\rho_{t+1}\alpha a_H + \left(1-\rho_{t+1}\right)a_L\left(1+\frac{\kappa}{K_t}\right)\right]\left[K_t+\kappa\right]^{\alpha-1} - \delta - \left(1-\rho_{t+1}\right)\zeta. \tag{31}$$

[24]When $\kappa = 0$, the optimality condition is given by equation (5): $\left[E\left(a_{t+1}\middle| a_t\right)\right]^{\frac{1}{1-\alpha}} \geq E_t\left(\rho_{t+1}\middle| a_t\right)a_H^{\frac{1}{1-\alpha}}$.

Employing this result, Appendix D shows that the equilibrium deposit rate must satisfy

$$i^b_{t+1} = \theta + \frac{\eta}{2}\left(\rho_H - \rho_L\right) F\left(a^0_{t+1} \mid a_t\right)^2 \frac{\psi_t}{\psi_t - 1}\left(\left[\alpha a_H - a_L\left(1 + \frac{\kappa}{K_t}\right)\right]\left[K_t + \kappa\right]^{\alpha-1} + \zeta\right). \tag{32}$$

This turns out to be a very stable and tractable numerical relationship.

The model is calibrated at an annual frequency. Table 1 presents the parameter values. The values of α, δ, and θ are fairly standard. We set bankruptcy costs, ζ, at 25 percent (of assets), the value used by Carlstrom and Fuerst (1997). (Hellman, et al., 2000, cite a loss rate of 50 percent.) There is less guidance on how to set the equity discount premium, ϖ, and we thus set it to 1.01, to induce somewhat cautious behavior from the bank.[25] We set the leverage bound, $\overline{\psi}$, to 40 under the assumption that newly liberalized banks are often regulated quite lightly.

The productivity parameters a_L, a_H, ρ_L and ρ_H are set so that the productivity innovation u_t has a standard deviation equal to 45 percent of the mean productivity value of 0.67.[26] These values imply that $1 - \eta$, the autocorrelation of the productivity process a_t, is 22 percent. As described in the main text, unless the conditional variance of productivity is high relative to its conditional mean, the bank takes on relatively little bankruptcy risk. The resulting values of ρ_L and ρ_H imply that on average 50 percent of firms experience the productivity shock a_L and default on their loans. While this is undoubtedly too high, what matters for our analysis is the volatility of the firm-level default rates, not their average.

There is little guidance on how to set the production parameter κ and the bailout thresh-

[25] This effect is discussed in more detail in Jones (2000).

[26] In particular, the standard deviation of the innovation u_t is given by $\eta\left(\rho_H - \rho_L\right)\left(a_H - a_L\right)/\sqrt{12}$.

old $Q^{\min}$. The values used here were picked because they were fairly low but still capable of generating interesting numerical results. The post-repression equity endowment, Q_0, was picked in a similar fashion.

The numerical methods we use to solve the model are very similar to those described in Jones (2000). In solving the model we approximate the continuous distribution for a_t with a 61-state Markov chain (adapting the approach described in Tauchen, 1986) with the gridpoints clustered in the regions where bankruptcy is most likely.[27] We also assume that the value function is concave in net worth, so that the bank's policies can be described by a dividend threshold. The value functions that we generate are in fact concave.

In addition to finding the bank's decision rules, we simulate time paths of these decision variables. In each simulation, the bank is given Q_0 units of equity and a draw from the (discretized) invariant distribution of a_t. Given the bank's net worth, Q_t, and technology, a_t, the policy functions described above specify the firm's dividends, leverage and deposits.[28]

Then assuming the bank continues to operate, next period's net worth, Q_{t+1}, follows immediately from equation (11) and next period's technology, a_{t+1}. The simulation continues until Q_t drops below the threshold $Q^{\min}$, and then that bank's history is stored.

[27] On the other hand, we solve for the deposit rate i^b_{t+1} using the analytical distribution for a_{t+1}, as equation (32) generates a convergent monotone mapping.

[28] Decisions for values of net worth and productivity lying off the finite grid described above are found by linear interpolation.

Appendix D

Equilibrium Deposit Rate

We begin by finding a closed form solution for a_{t+1}^0. Using equation (31) to substitute for r_{t+1}, and imposing the definition of a_{t+1} from equation (29), we can rearrange equation (12) to show:

$$a_{t+1}^0 = a_L + \Omega_t (a_H - a_L) . \tag{33}$$

where

$$\Omega_t = \frac{\frac{\psi_t - 1}{\psi_t}\left(1 + i_{t+1}^b\right) - (1 - \delta - \zeta) - a_L\left(1 + \frac{\kappa}{K_t}\right)[K_t + \kappa]^{\alpha - 1}}{\left[\alpha a_H - a_L\left(1 + \frac{\kappa}{K_t}\right)\right][K_t + \kappa]^{\alpha - 1} + \zeta}.$$

Recall that when $\Gamma_t \equiv F\left(a_{t+1}^0 \mid a_t\right) = 0$, the bank will never go bankrupt, and the rate that it offers on deposits, i_{t+1}^b, will equal the international rate of θ. We thus focus on the case where $\Gamma_t > 0$.

It follows from the Markov bounds for ρ_t that the conditional distribution of a_t is uniform:

$$a_{t+1} | \, a_t \backsim U\left((1 - \eta) a_t + \eta A_L, (1 - \eta) a_t + \eta A_H\right),$$

$$A_L = a_L + \rho_L (a_H - a_L),$$

$$A_H = a_L + \rho_H (a_H - a_L),$$

Let $\overline{a}_{t+1}$ $\left(\underline{a}_{t+1}\right)$ denote the largest (smallest) possible value of a_{t+1} given a_t, so that the conditional distribution of a_t is uniform over $\left[\overline{a}_{t+1}, \underline{a}_{t+1}\right]$. It then follows that

$$\Gamma_t = \frac{a_{t+1}^0 - \underline{a}_{t+1}}{\eta (A_H - A_L)} .$$

Expanding equation (15) thus yields:

$$1+\theta=\int_{\underline{a}_{t+1}}^{a_{t+1}^{0}}\frac{\psi_t\left(1+r_{t+1}\right)}{\psi_t-1}dF\left(a_{t+1}\mid a_t\right)+\left(1-\Gamma_t\right)\left(1+i_{t+1}^{b}\right). \tag{34}$$

It follows from equations (8) and (29) that

$$\begin{aligned} r_{t+1} &= a_L\left[K_t+\kappa\right]^{\alpha-1}-\left(\delta+\zeta\right)+\frac{a_{t+1}-a_L}{a_H-a_L}\left[\left(\alpha a_H-a_L\left[1+\frac{\kappa}{K_t}\right]\right)\left[K_t+\kappa\right]^{\alpha-1}+\zeta\right] \\ &= \widehat{i}_{t+1}^{l}+\frac{a_{t+1}-a_L}{a_H-a_L}\left[i_{t+1}^{l}-\widehat{i}_{t+1}^{l}\right], \end{aligned}$$

$$\widehat{i}_{t+1}^{l}\equiv a_L\left(1+\frac{\kappa}{K_t}\right)\left[K_t+\kappa\right]^{\alpha-1}-\left(\delta+\zeta\right),$$

so that

$$\int_{\underline{a}_{t+1}}^{a_{t+1}^{0}} r_{t+1}dF\left(a_{t+1}\mid a_t\right)=\left[\Gamma_t\widehat{i}_{t+1}^{l}+\left(i_{t+1}^{l}-\widehat{i}_{t+1}^{l}\right)\int_{\underline{a}_{t+1}}^{a_{t+1}^{0}}\frac{a_{t+1}-a_L}{a_H-a_L}dF\left(a_{t+1}\mid a_t\right)\right]. \tag{35}$$

But

$$\begin{aligned} \int_{\underline{a}_{t+1}}^{a_{t+1}^{0}}\frac{a_{t+1}-a_L}{a_H-a_L}dF\left(a_{t+1}\mid a_t\right) &= \frac{1}{a_H-a_L}\Gamma_t\left[E\left(a_{t+1}\mid a_t, a_{t+1}\leq a_{t+1}^{0}\right)-a_L\right] \\ &= \Gamma_t\Delta_t, \end{aligned}$$

$$\Delta_t\equiv\frac{a_{t+1}^{0}+\underline{a}_{t+1}-2a_L}{2\left(a_H-a_L\right)},$$

with $0<\Delta_t<1$. Combining this result with equations (34) and (35) yields

$$1+\theta=1+i_{t+1}^{b}+\Gamma_t\left[\frac{\psi_t}{\psi_t-1}\left(1+\widehat{i}_{t+1}^{l}\right)-\left(1+i_{t+1}^{b}\right)+\frac{\psi_t}{\psi_t-1}\Delta_t\left(i_{t+1}^{l}-\widehat{i}_{t+1}^{l}\right)\right]. \tag{36}$$

Using the definition of $\widehat{i}_{t+1}^{l}$, we can rewrite equation (33) as

$$a_{t+1}^{0}=a_L+\Omega_t\left(a_H-a_L\right),$$

with

$$\Omega_t = \frac{1}{i^l_{t+1} - \widehat{i}^l_{t+1}} \left[\frac{\psi_t - 1}{\psi_t} \left(1 + i^b_{t+1}\right) - \left(1 + \widehat{i}^l_{t+1}\right) \right].$$

Substituting this expression for Ω_t into equation (36) yields

$$1 + \theta = 1 + i^b_{t+1} + \Gamma_t \frac{\psi_t}{\psi_t - 1} \left[\Delta_t - \Omega_t\right] \left(i^l_{t+1} - \widehat{i}^l_{t+1}\right).$$

But substituting the expression for a^0_{t+1} into the definition of Δ_t yields

$$\Delta_t = \frac{1}{2} \left[\Omega_t + \frac{a_{t+1} - a_L}{a_H - a_L} \right],$$

and combining a^0_{t+1}, Γ_t, and Δ_t with the definitions of A_H and A_L shows that

$$\begin{aligned} \Gamma_t &= \frac{2}{\eta\left(\rho_H - \rho_L\right)} \left[\Omega_t - \Delta_t\right] \\ &= \frac{1}{\eta\left(\rho_H - \rho_L\right)} \left[\Omega_t - \frac{a_{t+1} - a_L}{a_H - a_L} \right]. \end{aligned}$$

Inserting this expression and substituting for $i^l_{t+1} - \widehat{i}^l_{t+1}$ produces the final result:

$$1 + i^b_{t+1} = 1 + \theta + \frac{\eta}{2} \left(\rho_H - \rho_L\right) \Gamma^2_t \frac{\psi_t}{\psi_t - 1} \left(\left[\alpha a_H - a_L \left(1 + \frac{\kappa}{K_t} \right) \right] \left[K_t + \kappa\right]^{\alpha - 1} + \zeta \right). \quad (37)$$

Figure 1

A Bank's Risk-Seeking Incentives at Different Levels of Net Worth

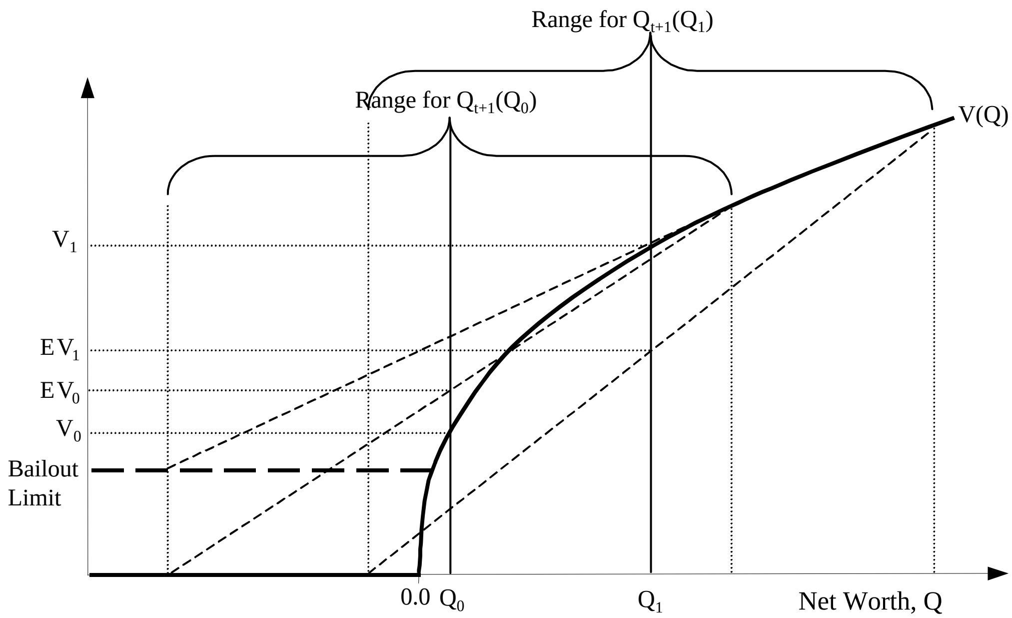
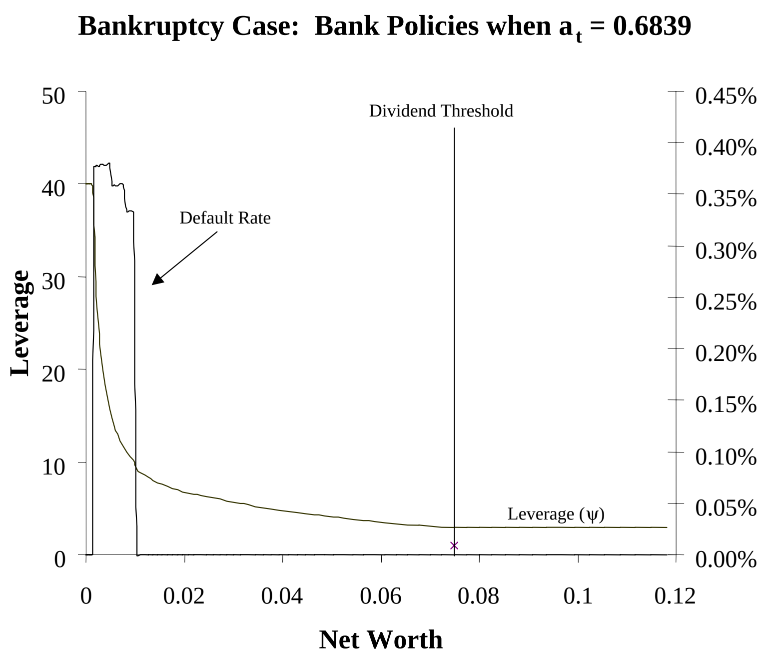


Figure 2

Leverage and Default Rates



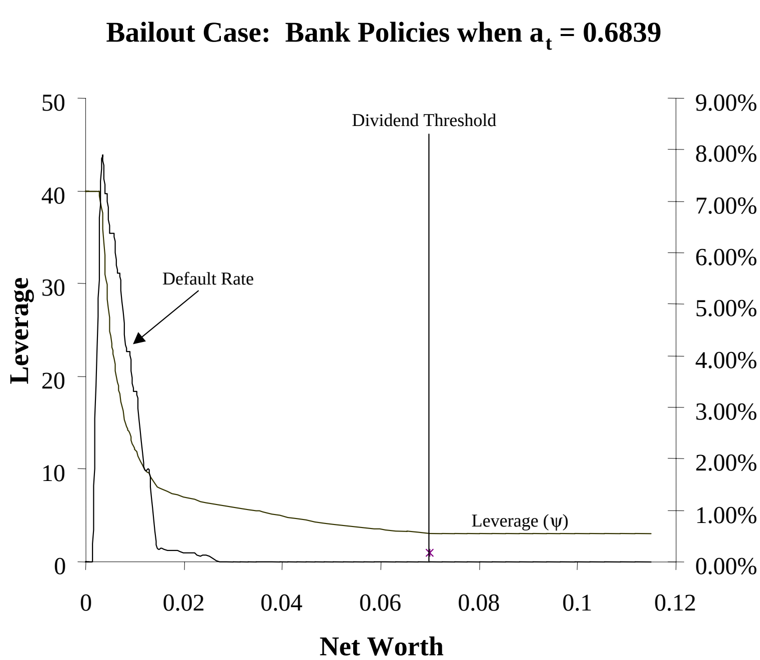
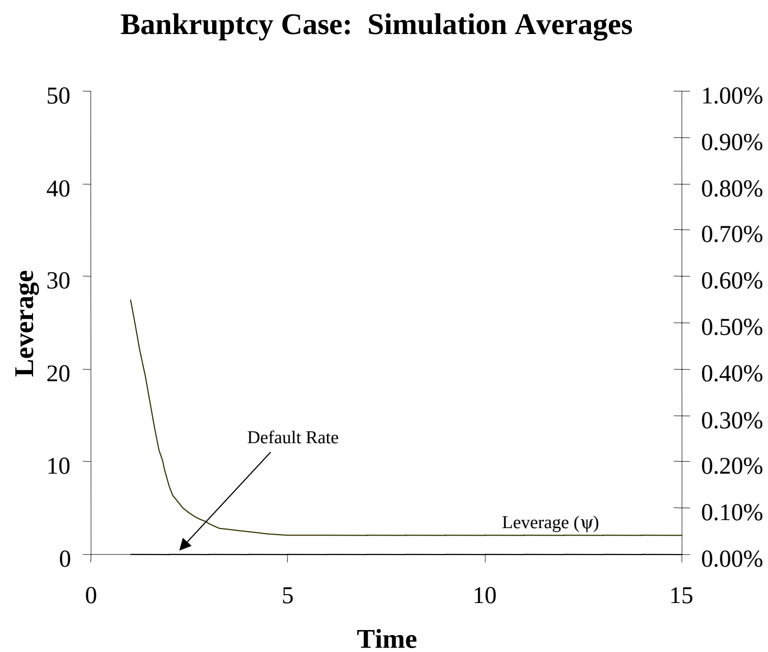


Figure 3

Simulation Averages of Leverage and Default Rates



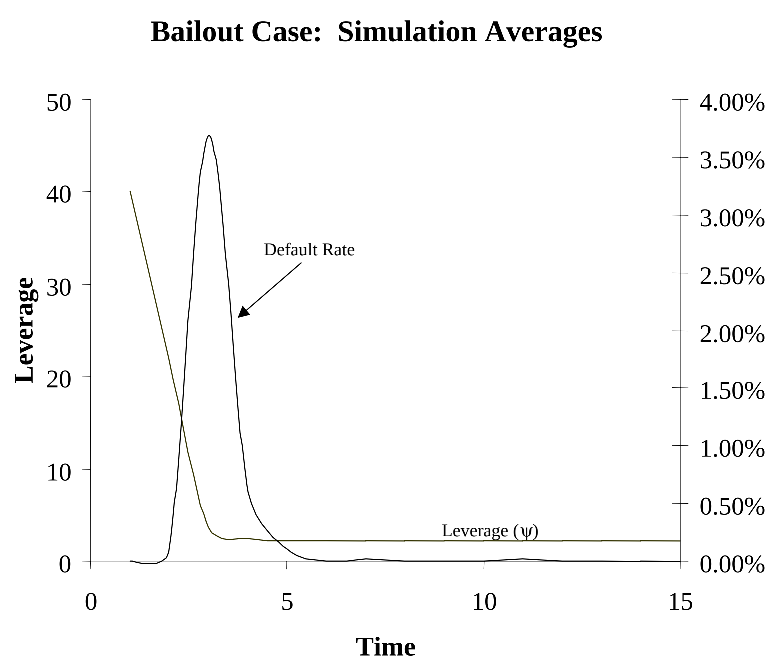


Table 1

Calibrated Parameter Values

α (Returns to Capital)	0.35
δ (Depreciation)	0.07
ς (Bankruptcy Cost Fraction)	0.25
θ (Global Interest Rate)	0.04
ϖ (Equity Discount Premium)	1.01
$\overline{\psi}$ (Leverage Bound)	40
σ_u/μ_a (Relative Volatility of Aggregate Productivity Innovation)	0.45
a_L (Low Productivity Value)	0.0
a_H (High Productivity Value)	1.343
ρ_L (Smallest $\Pr(a_H)$)	0.0
ρ_H (Largest $\Pr(a_H)$)	1.0
μ_a (Average Aggregate Productivity)	0.6715
$1-\eta$ (Autocorrelation of a_t)	0.221
κ (Shift Parameter in Production Function)	0.011
$Q^{\min}$ (Threshold for Government Bailouts)	2.76×10^{-6}
Q_0 (Initial Equity for Dynamic Simulations)	3.0×10^{-5}

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