

Financial Liberalization and Banking Crises in Emerging Economies: Extended Results*

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Abstract

Financial liberalization often leads to financial crises. This link has usually been attributed to poorly designed banking systems, an explanation that is largely static. In this paper we develop a dynamic explanation, by modelling how a newly-liberalized bank's opportunities and incentives to take on risk develop over time. The model reveals that even if a banking system is well-designed, in the sense of having good long-run properties, many countries will enjoy an initial period of rapid, low-risk growth and then enter a period with an elevated risk of banking crisis. This transition emerges because of the way in which the degree of foreign competition, the marginal product of capital, and the bank's own net worth simultaneously evolve.

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1 Introduction

Many banking crises have been preceded by financial liberalization. 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. Similar findings appear in Niimi (2000) and Gruben, Koo and Moore (2003). 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).

From a policy perspective, it is important to consider why financial liberalization is often followed by banking crises. The existing literature has focussed on the institutional structure of newly liberalized banking systems. For example, many analysts have stressed that implicit or explicit promises of government bailouts exposed many newly liberalized banking systems to severe problems of moral hazard. When banks are under-capitalized, bailouts cut off the lower portion of their return distribution, encouraging them to assemble loan portfolios that are riskier than would be socially optimal.¹ Similarly, Dooley (2000) claims that deposit insurance makes depositors less willing to monitor banks that can “appropriate” their deposits.

¹ The seminal paper on this topic is Stiglitz and Weiss (1981). Recent applications to banking crises include Dekle and Kletzer (2001) and Tornell, Westermann and Martinez (2004). Allen and Gale (2000) argue that limited liability increases the prices investors will pay for risky assets, leading to asset price bubbles and financial crises.

**Financial Liberalization and Banking Crises in Emerging Economies:
Extended Results**

Responding to these ideas, policy discussions have focused on greater transparency, better bank supervision, and on the costs and benefits of bailouts. Another important institutional concern has been the extent of competition. As Hellman, Murdock and Stiglitz (2000) point out, increased competition erodes a bank's franchise value, reducing its incentive to engage in risk-averse behavior.

It is reasonable to expect that newly liberalized banking systems will have institutional flaws. But these arguments about optimal institutional design are static in nature. They apply to all liberalized banking sectors, whether recently liberalized or not; competition and moral hazard explain the American Savings and Loan crisis just as well as they explain the banking crises in East Asia. We believe that the crises that follow liberalization involve more than poor design. Building on this belief, we develop a dynamic, small-open-economy, general-equilibrium model of the transition period following financial liberalization. The model illustrates how financial liberalization affects the evolution of a bank's franchise value, its net worth, its returns to risk-taking, and the aggregate capital stock. We show that the period shortly after liberalization can be especially risky. This occurs even if the banking system is well-designed, in the sense that banks are relatively safe in the economy's long-run equilibrium. Moreover, we show that banks can be riskier in the transition period even if competition is fiercer in the long-run. Our results in no way imply that poor design of banking systems does not contribute to banking crises, for surely it does. Our results do imply, however, that financial liberalization, in and of itself, contributes as well.²

² Our model is also complementary to the enormous literature exploring the links between banking crises and currency crises. If currency crises are a risk facing banks (e.g., Cook, 2004), our model explains why newly-liberalized banks willingly expose themselves to such risks. Conversely, if weak banking sectors trigger

Financial Liberalization and Banking Crises in Emerging Economies: Extended Results

Developing a general equilibrium growth model allows us to explain a rich set of empirical results. For example, our model can replicate the East Asian experience, where financial liberalization led first to rapid growth and then to a banking crisis. More generally, our model is consistent with the stylized fact, emphasized by Gaytan and Ranciere (2003), that “middle income” economies are most vulnerable to banking crises.

Gaytan and Ranciere also explain this stylized fact through an equilibrium growth model with risky banking. But while Gaytan and Ranciere consider a closed economy where bank risk is due to sunspot-triggered bank runs, we consider an open economy where bank risk is due to aggregate technology shocks. Our model is arguably more similar to the work of Aghion, Bacchetta and Banerjee (2004), who consider the interaction between net worth, investment and the price of a domestic factor that is in fixed supply. Aghion et al. also find that countries at an “intermediate level of financial development” are most vulnerable.³ On the other hand, risk and increasing competition, which are key elements of our model, play minor roles in theirs.

In our model we analyze an emerging small open economy where the capital stock is funded by debt from international creditors and by domestic bank loans. With better knowledge about local firms, domestic banks enjoy a cost advantage over international creditors. Initially this advantage is significant, but it shrinks over time as international creditors obtain better information. We also assume that the government provides the bank with a monopoly

currency crises (e.g., Burnside, Eichenbaum and Rebelo, 2001), our model provides an explanation of why newly-liberalized banks might become weak.

³ Caballé, Jarque and Michetti (2004) show that a modified version of Aghion et al.’s model can display chaotic dynamics during this intermediate stage.

**Financial Liberalization and Banking Crises in Emerging Economies:
Extended Results**

banking franchise in the domestic market. Together the bank's informational advantage and its protected status in the domestic market give it franchise value. Decreasing returns to capital, however, limit the quantity of loans that the bank can make at any interest rate, and thus limit the bank's rents. The bank funds its loans by retaining earnings and attracting deposits; the amount of external funding (leverage) is a key determinant of the bank's riskiness.

The returns to investment in this emerging economy are stochastic, and if they are sufficiently low, firm default on bank loans can force the bank into bankruptcy. Bankruptcy has two important features. The first is limited liability, which cuts off the lower tail of the bank's return distribution and encourages risk-taking behavior. The second feature is the bank's franchise value: bankruptcy eliminates the bank's stream of rents. The bank's desire to protect its franchise encourages risk-averse behavior. This suggests that as the bank accumulates more net worth, it will become increasingly risk-averse—a bank with high net worth has more franchise value. But even though the bank's incentives depend on the evolution of its own net worth, they also depend on the growth of the aggregate stock of capital and competition from foreign lenders.

The starting point for our analysis is the immediate aftermath of financial repression. We assume that an economy emerging from financial repression is characterized by a small capital stock—this, presumably, is why it liberalizes—and limited bank net worth. Because foreign finance is most expensive in small markets, the bank can charge high interest rates on its loans. Moreover, the bank faces a (legal) leverage constraint that restricts its ratio

Financial Liberalization and Banking Crises in Emerging Economies: Extended Results

of loans to net worth; this sort of capitalization constraint is a common regulatory practice. Even if the newly liberalized bank would like to fully fund all capital, thereby pushing interest rates below international loan rates, the leverage constraint prevents it from doing so. Additionally, the same high returns to capital that make lending desirable imply that the bank, though highly levered, faces little default risk. The high returns to lending further imply that the bank will retain its earnings, so that newly liberalized banks see their net worth grow. But the capital stock grows as well. Foreign debt becomes cheaper as foreign lenders acquire more experience in the market, and the capital stock becomes less productive as it grows, implying that loan interest rates begin to fall. It is at the point, when the bank's cost advantage is still significant but declining, that risky behavior and banking crises are most likely. If the bank can weather this period, it can enter a regime of more conservative behavior and lower leverage.

This paper is organized as follows. Section 2 contains a description of firm and household behavior, and section 3 provides a description of the financial sector. In section 4, we describe the transition from financial repression to financial liberalization for the emerging market economy. Conclusions are in section 5.

2 The Non-Financial Sector

Consider a small open economy populated by households, firms, a domestic bank, and foreign creditors.

2.1 Households

The economy is populated by a representative infinite-lived household. This household is endowed with one unit of labor, which it supplies inelastically to firms. Upon financial liberalization, the household can buy and sell risk-free international bonds, making its consumption inconsequential to banking crises. The details of the household's problem are therefore unimportant to our analysis, and in the interest of brevity we omit them.

2.2 Firms

Output is produced by a unit mass of price-taking firms. Although these firms are ex-ante identical, they receive idiosyncratic productivity shocks, and firms with particularly bad shocks will be unable to repay their bank loans. Each firm lives two periods; across time, output is produced by overlapping generations of these firms. In the first period of their lives, before they observe their productivity, firms procure capital and labor. In the second, firms realize their idiosyncratic productivity levels, produce, and repay their financiers. As is standard, we assume that capital must be installed in advance, which forces firms to finance their capital purchases through either the domestic bank or foreign creditors. Labor expenses, on the other hand, are concurrent with production, and are paid out of output.

2.2.1 Technologies

The output of firm i at time t is given by

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

**Financial Liberalization and Banking Crises in Emerging Economies:
Extended Results**

where z_{it} is firm i 's realized productivity, and K_{it} and H_{it} represent firm-specific capital and labor, respectively. Each firm's productivity is drawn independently from a common aggregate distribution. The aggregate distribution is itself stochastic over time, however, so that the bank faces aggregate as well as idiosyncratic risk.

We assume that the distribution of z_{it} is fully characterized by the variable a_t , with

$$F(z_{it}|a_t = a_0) > F(z_{it}|a_t = a_1), \forall z_{it} \in \mathbf{S}(a_0, a_1), a_0 < a_1, \quad (1)$$

$$\mathbf{S}(a_0, a_1) \equiv \{z : F(z|a_0) > 0, F(z|a_1) < 1\},$$

so that conditional distributions with higher values of a_t are stochastically dominant. We also assume that a_t follows a stationary Markov process. These conditions hold for a wide variety of stochastic environments. A familiar example occurs when z_{it} is the sum of the aggregate shock a_t and the idiosyncratic shock e_{it} , with a_t following an AR(1) process. A second example appears in the numerical exercises below, where we assume that z_{it} takes on the value z_H with probability a_t and the value $z_L < z_H$ with probability $(1 - a_t)$, with a_t a bounded transformation of an AR(1) process. In both cases, higher values of a_t increase the probability of high values of z_{it} .

2.2.2 The Firm's Problem

A firm born at time t chooses the capital stock, labor input, and a financing portfolio of bank loans (L_{it}) and foreign loans ($K_{it+1} - L_{it}$) that maximizes its expected profits at time $t + 1$. The firm's capital depreciates at the rate $\delta_{it+1} = \delta(z_{it+1})$, with $\delta'(z) \leq 0$. This reflects the notion that capital is site-specific, and that capital devoted to unproductive uses (low

**Financial Liberalization and Banking Crises in Emerging Economies:
Extended Results**

values of z_{it+1}) have a lower resale value. The firm's objective is

$$\begin{aligned} \max_{K_{t+1} \geq 0, 0 \leq L_t \leq K_{t+1}, H_{t+1} \geq 0} \int & [z_{it+1} K_{it+1}^\alpha H_{it+1}^{1-\alpha} + (1 - \delta(z_{it+1})) K_{it+1} - w_{t+1} H_{it+1}] dF(z_{it+1} | a_t) \\ & - (1 + \lambda_{t+1}^e) (K_{it+1} - L_{it}) - (1 + r_{t+1}^e) L_{it}, \end{aligned} \quad (2)$$

where r_{t+1}^e denotes the average interest rate on bank loans, and λ_{t+1}^e denotes the average interest rate on foreign loans required by the competitive loan market. The superscript “e” on these rates signifies one-period-ahead conditional expectations:

$$x_{t+1}^e \equiv E(x_{it+1} | a_t), \quad x \in (\lambda, r).$$

While the firm's lenders require average returns of r_{t+1}^e and λ_{t+1}^e , the actual interest payments will vary with the realized value of z_{it+1} . To simplify the exposition, we assume that the process for z_{it} is such that in equilibrium firms will always be able to meet their wage obligations, implying that w_{t+1} is known at time t .⁴

Imposing the equilibrium labor input of unity, the first-order conditions for an interior solution are standard and are given by

$$w_{t+1} = (1 - \alpha) z_{t+1}^e K_{it+1}^\alpha, \quad (3)$$

$$K_{it+1} = \left(\frac{\alpha z_{t+1}^e}{\lambda_{t+1}^e + \delta_{t+1}^e} \right)^{\frac{1}{1-\alpha}} \quad (4)$$

$$r_{t+1}^e = \lambda_{t+1}^e, \quad (5)$$

Since all firms in a cohort are identical when they make decisions, they all procure the same

⁴ A firm with a particularly high (out-of-equilibrium) value of employment and a low realized value of z_t could use bankruptcy protection to avoid its full wage obligation. In the numerical exercises presented below, we assume that workers facing this possibility would require the firm to provide state-contingent wages with an expected value equal to the one given in equation (3).

**Financial Liberalization and Banking Crises in Emerging Economies:
Extended Results**

inputs. Therefore, aggregate output is given by

$$Y_{t+1} = z_{t+1}K_{t+1}^\alpha, \tag{6}$$

$$z_{t+1} \equiv E(z_{it+1}|a_{t+1}),$$

with the “*i*” subscripts removed because we are taking averages across the unit mass of firms.⁵

A key feature of this aggregate production function is that α is strictly less than one, so that there are decreasing returns to capital. In contrast, much of the recent growth literature utilizes the assumption that there are constant returns in the aggregate capital stock. This need not pose a contradiction, however. Even if an economy enjoys constant returns in some broadly defined capital measure over long-term growth horizons, it can face decreasing returns over shorter horizons—as capital pours into a recently liberalized economy, it will eventually become less productive.⁶

Bank loans and foreign debt are assumed to take the form of standard debt. (In section 5.3 below, we consider a specification where foreign finance takes the form of equity.) We assume that domestic and foreign creditors share equitably in the firm’s assets when bankruptcy occurs, so that equality of expected loan rates in equation (5) implies equality of contractual loan rates. The firm agrees to pay the contractual rate of return $(1 + i_{t+1}^l)$ on loans when solvent, that is when: $z_{it+1}K_{t+1}^\alpha - w_{t+1} + (1 - \delta(z_{it+1}))K_{t+1} \geq (1 + i_{t+1}^l)K_{t+1}$.

When z_{it+1} is sufficiently low, the firm defaults, and its creditors seize its resources, in frac-

⁵ z_{t+1} is *not* the same as z_{t+1}^e : $z_{t+1} = E(z_{it+1}|a_{t+1})$, while $z_{t+1}^e = E(z_{it+1}|a_t) = E(z_{t+1}|a_t)$.

⁶ Decreasing returns to capital are a key assumption in Gaytan and Ranciere’s (2003) and Aghion, et al.’s (2004) models as well.

**Financial Liberalization and Banking Crises in Emerging Economies:
Extended Results**

tions proportional to their loans. Integrating across firms, and imposing the equilibrium wage, the contractual rate i_{t+1}^l and the expected rate r_{t+1}^e are linked by

$$\begin{aligned}
 1 + r_{t+1}^e &= 1 + \lambda_{t+1}^e & (7) \\
 &= \int_{z_{it+1} \geq z^{\text{sol}}(K_{it+1}, i_{t+1}^l, a_t)} (1 + i_{t+1}^l) dF(z_{it+1} | a_t) \\
 &\quad + \int_{z_{it+1} < z^{\text{sol}}(K_{it+1}, i_{t+1}^l, a_t)} [(z_{it+1} - (1 - \alpha) z_{t+1}^e) K_{t+1}^{\alpha-1} + 1 - \delta(z_{it+1})] dF(z_{it+1} | a_t),
 \end{aligned}$$

with the solvency threshold $z^{\text{sol}}(K_{t+1}, i_{t+1}^l, a_t)$ given by

$$z^{\text{sol}} = K_{t+1}^{1-\alpha} [i_{t+1}^l + \delta(z^{\text{sol}})] + (1 - \alpha) z_{t+1}^e. \quad (8)$$

Let $R(z_{it+1}, K_{t+1}, i_{t+1}^l, a_t)$ denote the realized gross returns on loans to firm i . Integrating across firms, the return lenders realize on their entire loan portfolio, r_{t+1} , is given by

$$1 + r_{t+1} = E(R(z_{it+1}, K_{t+1}, i_{t+1}^l, a_t) | a_{t+1}). \quad (9)$$

3 The Financial Sector

The financial sector consists of foreign creditors and a single domestic bank. Competition from foreign debt financing sets an upper bound on r_{t+1}^e , the expected return on bank loans. On the other hand, the domestic bank has lower screening and monitoring costs than its foreign competitors, due to its superior local knowledge. Together the domestic bank's monopoly status and its cost advantage give it franchise value, which it has an incentive to protect. The bank's franchise value declines, however, as foreign creditors gain experience.

3.1 Foreign Debt

To model the cost of foreign debt, we assume that the expected return demanded by foreign investors depends on X_t , their “experience” with a country’s idiosyncratic economic and institutional features, so that the expected and required rate of return is given by

$$\lambda_{t+1}^e = \lambda(X_t). \tag{10}$$

Let θ denote the international risk-free rate of return. We assume that

$$\begin{aligned} \lambda'(X) &< 0, \\ \lim_{X \rightarrow \infty} \lambda(X) &\geq \theta. \end{aligned}$$

The first of these conditions is definitional, and the second ensures that foreign loans can never be provided more cheaply than at the risk-free real international interest rate. Together, these two conditions imply that

$$\lim_{X \rightarrow 0} \lambda(X) > \theta.$$

When banks can acquire deposits at the international risk-free rate, this condition states that in markets with “inexperienced” foreign investors, the cost of foreign credit will be high relative to the risk-free rate of return.

The law of motion for experience is assumed to be

$$X_{t+1} = (1 - \gamma) X_t + \gamma K_{t+1}, \quad 0 < \gamma < 1, \tag{11}$$

so that experience is increasing in its own lag and in the capital stock of the emerging market.

This captures the notion that experience grows more quickly in larger markets. Experience

**Financial Liberalization and Banking Crises in Emerging Economies:
Extended Results**

is thus very similar to organizational capital (e.g., Hall, 2000), and in fact can be interpreted as the organizational capital of foreign banks.

Substituting equation (10) into equation (4) and using the definition of z_{t+1}^e implies that

$$K_{t+1} = \tilde{\kappa}(X_t, a_t). \quad (12)$$

Substituting equation (12) into equation (11) yields an expression for experience as a function of its own lag and the stochastic productivity shock:

$$X_{t+1} = \kappa(X_t, a_t). \quad (13)$$

with $\kappa(\cdot)$ increasing in both arguments.

Equations (12), (7) and (10) allow us to express the contractual rate on bank loans, i_{t+1}^l , as a function of current experience, X_t , and productivity, a_t . Similarly, we can use equation (12) to substitute for K_{t+1} , to express the realized return in equation (9) as:

$$1 + r_{t+1} = R(a_{t+1}, a_t, X_t). \quad (14)$$

Equation (1) can be used to show that the return on bank loans is increasing in a_{t+1} —higher values of a_{t+1} imply that fewer firms default⁷—and decreasing in experience. Note that the productivity value a_{t+1} is the only term not known at time t .

As long as firms use foreign debt as their marginal source of finance (equation (5) holds), interest rates, given by equation (14), and the capital stock, given by equation (12), evolve as a function of the state of experience and the exogenous technology parameter.⁸ Capital does

⁷ Following standard arguments (for example, Green, Mas-Colell and Whinston, 1995, proposition 6.D.1), one can see that r_{t+1} is increasing in a_{t+1} by noting that $1 + r_{t+1} = E(R(z_{it+1}, K_{t+1}, a_t, i_{t+1}^l) | a_{t+1})$, the expectation of a function that is increasing in z_{it+1} .

⁸ In the numerical exercises presented below, we allow banks to set r_{t+1}^e below λ_{t+1}^e and capture the entire lending market. In practice, banks never exploit this option.

not immediately jump to the level at which its marginal product equals the international rate of return due to the role of experience in limiting international financial flows.

3.2 The Domestic Bank

The bank accepts deposits and makes loans in order to maximize the expected discounted value of its dividend stream.⁹ Since the bank must issue its loans before it observes the aggregate productivity level, the return on these loans, given by equation (14), is stochastic. This uncertainty, combined with two finance constraints described below, implies that the bank must consider the possibility of bankruptcy. Bankruptcy is undesirable because the bank will lose its charter and the corresponding monopoly rents.

3.2.1 The Bank's Budget Constraints

The bank accepts deposits from domestic and foreign agents (B). The bank lends its deposits, along with any post-dividend net worth ($Q - d$), so that its loans are given by

$$L_t = Q_t - d_t + B_t, \tag{15}$$

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

$$\begin{aligned} Q_{t+1} &= \max \{0, (1 + r_{t+1}) L_t - (1 + i_{t+1}^b) B_t\} \\ &= \max \{0, (r_{t+1} - i_{t+1}^b) L_t + (1 + i_{t+1}^b) (Q_t - d_t)\}, \end{aligned}$$

where i_{t+1}^b is the interest rate on deposits. Defining the leverage ratio ψ_t by

$$L_t = \psi_t (Q_t - d_t), \tag{16}$$

⁹ We accept as a stylized fact that banks are financed primarily by debt contracts (deposits) rather than with equity.

**Financial Liberalization and Banking Crises in Emerging Economies:
Extended Results**

the accumulation equation for net worth becomes

$$Q_{t+1} = \max \{0, (Q_t - d_t) [(r_{t+1} - i_{t+1}^b) \psi_t + (1 + i_{t+1}^b)]\}. \quad (17)$$

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

$$1 + r_{t+1}^{\min} = \frac{\psi_t - 1}{\psi_t} (1 + i_{t+1}^b). \quad (18)$$

This implies that $r_{t+1}^{\min} < i_{t+1}^b$; even if loans do not earn enough to pay back depositors, when losses are sufficiently small, banks can bridge the difference out of their net worth. Let a_{t+1}^{\min} denote the lowest value of aggregate productivity consistent with bank solvency. Using equation (14), a_{t+1}^{\min} is implicitly given by

$$R(a_{t+1}^{\min}, a_t, X_t) = \frac{\psi_t - 1}{\psi_t} (1 + i_{t+1}^b), \quad (19)$$

with a_{t+1}^{\min} defined to be $-\infty$ when the bank is solvent under all realizations of a_{t+1} .

The bank faces two finance constraints. The first is that there is a fixed cost to issuing negative dividends, i.e., to raising new equity.¹⁰ In this paper, we assume that this cost is so high that the bank will not issue negative dividends, a restriction that is both quite common in the literature and reasonably consistent with observed practice. This requires that dividends be non-negative, prohibiting banks from issuing new net worth to avoid bankruptcy.¹¹ In addition, dividends cannot exceed net worth, so that

$$0 \leq d_t \leq Q_t. \quad (20)$$

¹⁰The 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. Gomes (2001) provides an estimate of issuance costs.

¹¹If the value of continuing the bank's franchise were to exceed the fixed cost of raising equity, banks with sufficiently bad finances would issue new stock. Cooley and Quadrini (2001) analyze this sort of behavior in their study of firm dynamics.

Financial Liberalization and Banking Crises in Emerging Economies: Extended Results

We assume that in equilibrium the upper constraint binds only if the bank has declared bankruptcy.¹²

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

$$0 \leq L_t \leq \bar{\psi} \times (Q_t - d_t), \quad 1 < \bar{\psi} < \infty. \quad (21)$$

This leverage restriction is common in the literature, in large part because it has been imposed internationally through the Basle Accord, but also because there are a number of papers suggesting that enforceability problems lead to collateral constraints.¹³ A capitalization requirement limits a bank's ability to take on risk, by forcing it to hold a buffer of net worth. In addition, by requiring the bank's owners to put some of their own funds at risk, it discourages risk-taking.

These two constraints imply that a bank with non-positive net worth can neither make loans nor raise new equity, but must instead shut down forever: $d_{t+j} = L_{t+j} = Q_{t+j} = 0, \forall j > 0$.

3.2.2 The Bank's Cost of Deposits

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 interest

¹²Note that the no-new-net worth constraint could be circumvented if the government revoked the bank's monopoly franchise, and allowed new banks to enter the market.

¹³Such papers include Kiyotaki and Moore (1997), Albuquerque and Hopenhayn (2004), Mendoza and Smith (2004) and Mendoza (2005). Note that in those models the leverage constraint depends on the market value of collateral, which in our case would be the market value of the bank's stock. Our leverage constraint depends on the book value of the bank's net worth, i.e., Q_t , which is usually much less sensitive to aggregate shocks.

**Financial Liberalization and Banking Crises in Emerging Economies:
Extended Results**

rate on deposits, i_{t+1}^b , must 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, this condition implies that for $\psi > 1$,

$$1 + \theta = \int_{a_{t+1} > a_{t+1}^{\min}} [1 + i_{t+1}^b] dF(a_{t+1} | a_t) + \int_{a_{t+1} \leq a_{t+1}^{\min}} \frac{\psi_t}{\psi_t - 1} R(a_{t+1}, a_t, X_t) dF(a_{t+1} | a_t). \quad (22)$$

where the second term in the brackets is the average return on deposits.¹⁴ Comparative statics calculations contained in Appendix A show that the equilibrium deposit rate, i_{t+1}^b , is increasing in leverage, as the depositors' returns from an insolvent bank are decreasing in this variable.

An alternative institutional arrangement would be to assume that there is deposit insurance, so that $i_{t+1}^b = \theta$. We exclude deposit insurance from our baseline model because we wish to show that financial liberalization and banking crises are linked even in the absence of policies that could be viewed as bailouts. Given that moral hazard is often thought to contribute to banking crises, however, in section 5.3 we construct and analyze a version of the model that includes deposit insurance, as well as a version with explicit bailouts.

3.2.3 The Bank's Problem

In recursive form, the bank's problem is

$$V(Q_t, a_t, X_t) = \max_{0 \leq \psi_t \leq \bar{\psi}, 0 \leq d_t \leq Q_t} d_t + \frac{1}{\varpi(1 + \theta)} E(V(Q_{t+1}, a_{t+1}, X_{t+1}) | I_t), \quad (23)$$

¹⁴It follows from equation (15) that the the average (gross) return on deposits is given by $L_t(1 + r_{t+1}) / [L_t - (Q_t - d_t)]$.

**Financial Liberalization and Banking Crises in Emerging Economies:
Extended Results**

subject to the law of motion for net worth given by equation (17) and the arbitrage condition on the deposit rate given by equation (22). As is standard, $V(Q_t, a_t, X_t)$ is the market value of the bank, here defined over non-negative net worth, with $V(0, a_t, X_t) = 0$. $\varpi > 1$ is the bank's "discount premium;" because θ is the international rate of return on risk-free bonds, setting $\varpi > 1$ ensures that the bank does not accumulate net worth indefinitely.¹⁵

The first order conditions are derived in Appendix A, which shows that the marginal value of net worth is

$$\frac{\partial V_t}{\partial Q_t} = \left(\frac{\psi_t}{Q_t - d_t} \right) \frac{\partial V_t}{\partial \psi_t} + \frac{1}{\varpi} E \left(\frac{\partial V_{t+1}}{\partial Q_{t+1}} \Big| a_{t+1} > a_{t+1}^{\min}, I_t \right) \geq 1, \quad (24)$$

where, in an abuse of notation, $\frac{\partial V_t}{\partial \psi_t}$ denotes denotes the marginal return from increased leverage. The lower bound of unity on the marginal value of net worth reflects the bank's ability to pay dividends; an additional unit of net worth will at a minimum generate an additional unit of dividend income.

The first order condition for dividends can be expressed as

$$1 - \left(\frac{\psi_t}{Q_t - d_t} \right) \frac{\partial V_t}{\partial \psi_t} - \frac{1}{\varpi} E \left(\frac{\partial V_{t+1}}{\partial Q_{t+1}} \Big| a_{t+1} > a_{t+1}^{\min}, I_t \right) = 1 - \frac{\partial V_t}{\partial Q_t} \leq 0, \quad (25)$$

with the bank paying dividends only when the condition holds at equality. The dividend rule given by equation (25) 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 equation (24). In making this interpretation, it proves useful to solve equation (24) forward,

¹⁵This sort of discount premium appears frequently in the literature on constrained corporate finance. Gross (1994) justifies this assumption by appealing to such works as Jensen 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.

**Financial Liberalization and Banking Crises in Emerging Economies:
Extended Results**

yielding:

$$\frac{\partial V_t}{\partial Q_t} = \sum_{j=0}^{\infty} \left(\frac{1}{\varpi}\right)^j E \left(\left(\frac{\psi_{t+j}}{Q_{t+j} - d_{t+j}} \right) \frac{\partial V_{t+j}}{\partial \psi_{t+j}} \Big| a_{t+j} > a_{t+j}^{\min}, I_t \right).$$

Even when the bank is not leverage-constrained today, if the leverage constraint binds in enough feasible future states, then the internal value of retained earnings will be high enough to rule out current dividends. The possibility of future financial constraints affects the bank's current behavior, a result pointed out by Zeldes (1989) and many others.

Equation (25) also shows that the bank pays dividends to keep the marginal value of equity bounded below by unity. In particular, with $\varpi > 1$ and $\frac{\partial V_{t+1}}{\partial Q_{t+1}} \geq 1$, it must be the case that:

Proposition 1 *The bank will always be leverage-constrained either at present or in some solvent future state.*

One implication of this trade-off between current and future leverage is that:

Corollary 1 *When the expected value of internal funds in the future is relatively low (high), the bank will (not) be fully levered today.*

To see this result, note that it follows trivially from equation (25) that

$$\frac{\partial V_t}{\partial \psi_t} \geq 0 \geq \frac{Q_t - d_t}{\psi_t} \left[1 - \frac{1}{\varpi} E \left(\frac{\partial V_{t+1}}{\partial Q_{t+1}} \Big| a_{t+1} > a_{t+1}^{\min}, I_t \right) \right]. \quad (26)$$

Suppose that the bank's future prospects are relatively bleak, so that the expected marginal value of equity in the future is unity. Then the term in the square brackets in equation (26) will be positive, implying that the current marginal value of leverage is positive, which in turn implies that the bank is fully levered. This reflects a situation where the bank's franchise value has deteriorated so much that it is willing to gamble, paying dividends and

**Financial Liberalization and Banking Crises in Emerging Economies:
Extended Results**

levering fully. Alternatively, when the expected value of internal funds in the future is relatively high, the term in the square brackets will be negative, and $\frac{\partial V_t}{\partial \psi_t}$ might equal zero. It is in this situation that paying dividends is most likely to trigger future leverage constraints, particularly those in bad states, before triggering the current one. In these circumstances, the bank's franchise value is large enough that it will not lever fully today, but it will pay just enough dividends to allow the leverage constraint to bind in some bad future states.

The exact behavior of $\frac{\partial V_t}{\partial \psi_t}$, and thus the exact shape of the value function, is harder to establish. Using standard arguments (see Lucas and Stokey, 1989), it is straightforward to show that when default does not occur, the value function is concave over non-negative net worth. Limited liability, on the other hand, makes the value function convex around the default point, $Q_t = 0$. Nonetheless, Cooley and Quadrini (2001) show, using a framework similar to ours, that as long as default is sufficiently unlikely, the value function is concave over non-negative net worth. Figure 1 illustrates these conflicting incentives, using value functions from the numerical exercises described below. Figure 1 shows that, holding experience fixed, increasing a bank's net worth along the horizontal axis makes it more risk averse; as net worth increases, the outcomes of any lending "gamble" move rightward into the concave region of the domain.¹⁶ Figure 1 also shows that increasing foreign experience (X_t) flattens the value function for solvent banks and rotates it downward, as stronger competition reduces the bank's lending spreads and profits. This strengthens the convexity produced by bankruptcy, causing the bank to become less risk-averse.

¹⁶Because bank deposits must offer an expected return of θ , the bank cannot use bankruptcy to reduce its expected deposit expenses. This means the bank views choices over risk as choices over mean-preserving spreads in its expenses.

4 Equilibrium

Given the initial values (Q_0, X_0) and the exogenous process $\{a_t\}_{t=0}^\infty$, an equilibrium is a collection of stochastic processes for quantities, $\{K_{t+1}, H_{t+1}, L_t, Q_{t+1}, \psi_t, d_t, X_t\}_{t=0}^\infty$, and prices, $\{w_{t+1}, \lambda_{t+1}^e, r_{t+1}^e, i_{t+1}^l, r_{t+1}, i_{t+1}^b\}$ such that: (i) given $\{w_{t+1}, \lambda_{t+1}^e\}$, $\{K_{t+1}, H_{t+1}\}$ satisfy the optimality conditions for the firm given by equations (3) and (4); (ii) given $\{K_{t+1}, H_{t+1}, w_{t+1}, \lambda_{t+1}^e\}$, $\{r_{t+1}^e, i_{t+1}^l, r_{t+1}\}$ satisfy the arbitrage conditions given by equations (5), (7) and (9), and $0 \leq L_t \leq K_{t+1}, \forall t$; (iii) given $\{r_{t+1}\}$, $\{Q_{t+1}, \psi_t, d_t, L_t, i_{t+1}^b\}$ satisfy the optimality conditions for the bank given by equations (23), (25), (17), (21), (20) and (22), and $\{L_t\}$ obeys equation (16); (iv) $\{\lambda_t^e\}$ obeys equation (10) and $\{X_{t+1}\}$ obeys equation (11); (v) the markets for labor ($H_{t+1} = 1$), bank loans (L_t), foreign loans ($K_{t+1} - L_t$), and international deposits ($L_t - Q_t + d_t$) all clear.¹⁷

5 The Transition from Financial Repression to Financial Liberalization

We turn to describing how the bank evolves as it moves from financial repression to a long-run stochastic equilibrium under financial liberalization. Because the model lacks a closed form solution, we rely instead on numerical analysis, and use the theoretical results derived above to interpret our findings.

¹⁷Equilibrium also requires that the household behave optimally, and that the market for goods clears. In the small open economy considered here, however, this imposes no restrictions on the variables of interest.

5.1 Calibration and Numerical Methodology

To specialize the model we assume that at time t , a firm's productivity, z_{it} , takes on the high value z_H with frequency a_t and the low value z_L with frequency $1 - a_t$, with $z_L < z_H$. Similarly, we assume that $\delta(z_H) = \delta_H$ and $\delta(z_L) = \delta_L$, with $\delta_L > \delta_H$. Let z_t denote aggregate productivity:

$$z_t = E(z_{it} | a_t) = a_t z_H + (1 - a_t) z_L.$$

We assume that a_t is a logistic transformation of the underlying variable v_t , i.e.,

$$a_t = \frac{\exp(v_t)}{1 + \exp(v_t)},$$

where v_t follows an AR(1) process with uniformly-distributed innovations:

$$v_{t+1} - \mu_v = \phi(v_t - \mu_v) + \varepsilon_{t+1},$$

$$\varepsilon_{t+1} \sim U(-\varepsilon_D, \varepsilon_D),$$

with $\phi \in [0, 1)$. An important feature of this specification is that when the support of v_t is positive (the support of a_t lies above 50 percent), the distribution of a_t will have a fatter lower tail than the distribution of v_t . This captures the significant downside risks faced by banks in developing countries. Moreover, the conditional variance of a_t will be higher when a_t takes on a low value, capturing the notion that banks in a weak economy face more risk than banks in a healthy economy.

We specialize the cost of foreign debt, λ_{t+1}^e , as

$$\lambda_{t+1}^e = \theta + \kappa_0 + [X_t + \kappa_1]^{-\kappa_2}, \quad \kappa_0, \kappa_1, \kappa_2 > 0. \tag{27}$$

Financial Liberalization and Banking Crises in Emerging Economies: Extended Results

The parameter κ_1 bounds λ_{t+1}^e from above, so that even in small markets, foreign debt can be the marginal source of funds. The constant κ_0 , on the other hand, provides a lower bound on the equity premium, ensuring that the bank always has some franchise value.

The model is calibrated at an annual frequency. Where possible, we base our parameter values on data for countries involved in the Southeast Asian crises of 1997, or on general studies of emerging markets. Table 1 presents the parameter values.

We normalize z_H to 1, and z_L to 0, which ensures that low-productivity firms fail. This simplification also implies that $z_t = a_t$. To calibrate the process for v_t (and thus a_t and z_t), we estimated (linear) trend-stationary AR(1) processes for industrial output in Malaysia and Korea. For the period 1985-2004, the two countries have an average autocorrelation coefficient of 0.5 and an average innovation standard deviation of 5 percent. As described in Appendix B, we set ϕ and ε_D so that the AR(1) process fit to $\ln(z_t)$ has the same properties. These estimates are consistent with those drawn from the larger sample of developing countries used by Agénor, McDermott and Prasad (2000).¹⁸

We set α to 0.4, a fairly standard value for developing countries (e.g., Barro and Sala-i-Martin, 1995). Following Mendoza (1991), we set δ_H to 0.1. We set δ_L to 35 percent. The gap $\delta_L - \delta_H$ represents the reduction in asset value that occurs when a firm fails. The gap of 25 percent used here is the same one used by Carlstrom and Fuerst (1997), who survey a

¹⁸Agénor, McDermott and Prasad (2000) argue that industrial output provides a good measure of business cycle volatility in emerging markets. Because the mapping between the volatility of industrial output and the volatility of z_t is unclear, we assume the two quantities are equal. Although the volatility of output generally exceeds the volatility of productivity, the total industrial sector is probably less volatile than the sectors financed by bank loans. In addition, if one expands the definition of z_t to include sources of volatility—for example, exchange rate shocks—not formally included in the model, the standard measure of TFP will understate loan risk.

Financial Liberalization and Banking Crises in Emerging Economies: Extended Results

number of studies, but it is much smaller than the loss rate of 50 percent cited by Hellman, et al. (2000) and slightly larger than estimates of the "costs of financial distress" of between 10 and 20 percent by Andrade and Kaplan (1998). We set the leverage bound, $\bar{\psi}$, to 20. While this exceeds the standards set by the Basle Accord, it is consistent with the post-liberalization experience in countries such as Thailand Indonesia and Malaysia, where asset/capital ratios reached 18, 19, and 21, respectively, shortly after liberalization.

We set initial bank net worth, Q_1 , low to reflect weak bank balance sheets under financial repression (Kaminsky and Schmukler, 2003, and Hanson, 2003). The value we choose is low enough to expose banks to significant default risk, yet high enough to let banks capture a significant portion of the lending market. The end result is a value of Q_1 equal to about 10% of average output, a ratio similar but somewhat higher than those observed in the Southeast Asian economies in the year prior to liberalization;¹⁹ given that we are assuming complete bank financing, a higher value is not unreasonable and is arguably conservative. To calibrate the parameters determining the evolution of experience (the depreciation rate γ and the initial value X_1) and the resulting interest rates (the parameters $\kappa_0, \kappa_1, \kappa_2$ in equation (27)), we would need lending interest rate data for at least one country (and preferably many) that had engaged in simultaneous and unexpected current and capital account liberalization and maintained it over time without crisis. Since no country followed the experiment we model, we set parameters to yield paths consistent with evidence that market lending rates tend

¹⁹In the year of liberalization, the bank capital/output ratio (Q_1/Y_1 where Q_1 is measured in the data as the stock at the end of the previous period) varies from a low of 2.4% in Indonesia to a high of 6.3% in the Phillipines. Korea, Malaysia, and Thailand have intermediate values of 3.1%, 5.1%, and 5.1%, respectively. The liberalization dates are given below in footnote 24.

Financial Liberalization and Banking Crises in Emerging Economies: Extended Results

to increase with financial liberalization, and that real interest rates in recently liberalized emerging markets are higher than those in industrialized countries (Honohan, 2001). Two features of the interest rate path we use are particularly important: (1) interest rates immediately after liberalization are high enough to support rapid, low-risk growth in lending and bank capital; and (2) interest rates fall quickly enough to expose “mid-transition” economies to significant default risk.

Appendix B also describes how we find the decision rules implied by our model, and how we use them to generate time series. Further details appear in Appendix C, which shows how we calculate the equilibrium lending and deposit rates, i_{t+1}^l and i_{t+1}^b .

5.2 The Transition

Consider a bank in an emerging market that has just experienced financial liberalization. As discussed immediately above, under repression both the aggregate capital stock and the experience of foreign investors are low. It follows that upon liberalization, the marginal product of capital and the cost of foreign debt will both be high. This implies that the loan interest rate will be high as well, and the bank will choose high leverage. The high returns to lending that lead the bank to high leverage, 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 equation (25) 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 fully retaining earnings, the newly-liberalized bank will see its net worth grow.

Financial Liberalization and Banking Crises in Emerging Economies: Extended Results

These effects are shown in the four panels of Figure 2. To construct Figure 2, we simulate the transition paths of 40,000 artificial economies, drop the economies whose banks have defaulted, and take averages over the remaining, solvent, banking sectors. Panel A shows that upon liberalization, the market rate of return, $r_{t+1}^e = \lambda_{t+1}^e$, exceeds 8 percent, well above the international rate of 4 percent. Average leverage is high, with a value for ψ in excess of 19, close to the model's regulatory limit of 20. As shown in Panel B, lending rates are high relative to deposit rates, and banks issue very few dividends. Panel A reveals that in the first 3 years, average net worth—expressed as a fraction of K^* , the average capital stock that firms would hold at the risk-free international interest rate θ —more than doubles.

But as net worth accumulates, the capital stock increases as well, and its marginal product falls. Moreover, as the market grows, so does foreign experience, and this increased competition lowers the cost of foreign debt. Loan interest rates fall, reducing intermediation spreads. Banks now face a higher probability of low returns on their loan portfolios. Holding leverage fixed, these changes mechanically imply that bank-level default is more likely.

The bank responds to these changes by adjusting its leverage. The possibility of default generates conflicting incentives. On the one hand, bankruptcy cuts off the tail of the bank's return distribution. It is a standard result that truncating the return distribution in this way encourages risk-taking behavior. On the other hand, bankruptcy ends the bank's stream of monopoly rents, and thus encourages risk-averse behavior. The key to determining how bank risk evolves is whether the lending gambles available to the bank lie in the convex or in the concave region of the value function, as illustrated in Figure 1. As the bank's

**Financial Liberalization and Banking Crises in Emerging Economies:
Extended Results**

net worth increases, indicated by a rightward movement of Q_t along the horizontal axis, the gambles drift into the concave region. But as experience and the aggregate capital stock increase, the return to bank loans, r_{t+1}^e , falls. The fall in return reduces the bank's franchise value, flattening and shifting the value function down, making convexity more important. In the simulations shown in Figure 2, it is the increased role of convexity that initially dominates. Even though leverage declines, it remains high enough for the exit rate, signifying the probability of a crisis, to increase rapidly. Panel A shows that although only 1 percent of the banks alive in year 1 default at the beginning of year 2, the exit rates after years 2 and 3 are 2.6 and 2.9 percent, respectively. The probability of a crisis is highest several years after liberalization.

Panel C allows us to compare the book value (net worth, Q) of solvent banks to their market value (franchise value, $V(Q)$). Although net worth grows rapidly, the bank's market value does not increase nearly as much, as falling intermediation spreads and increasing default risk depress market value. Note that exit rates, signifying the probability of a crisis, peak when market value and net worth are high. High returns and high leverage have increased market value and net worth, but combined with the dynamic evolution of foreign experience and the marginal product of capital, risk has also increased. At this point, it is useful to consider the subset of banks that actually default. To get a better sense of how failing banks behave, Panel D shows market and book value for banks that experience a crisis within 9 years of liberalization—as panel A shows, this is the period of highest risk.²⁰ Because these failing banks have unusually bad productivity draws, their market value steady declines,

²⁰As before, banks are removed from the simulations once they fail.

Financial Liberalization and Banking Crises in Emerging Economies: Extended Results

and, after an initial increase, their net worth declines as well. The behavior is consistent with Burnside, Eichenbaum and Rebelo (2001), who found that bank stocks in Thailand and Korea had been falling for over a year prior to the crisis, those in Malaysia and the Phillipines had been falling for about half a year, and bank stocks in Indonesia were recovering from a recent dip.

Panel B shows that banks passing through the high-risk period pay high dividends, as interest rate spreads remain above their long-run limit, and banks enjoy high profits. At first, these interest rate spreads are high enough to justify net worth growth, but as the spreads continue to decline, banks increase dividends, letting their net worth decline. The long-run status of these banks depends on their long-run franchise value, which in turn depends on the long-run level of foreign lending rates. If λ_{t+1}^e declines sufficiently as capital and experience approach their stationary distributions, banks will lose all franchise value and be indifferent about staying in business. Banks then choose maximum leverage and thus maximum risk, a point emphasized by Hellman, et al. (2000). This is stated in the Corollary, which shows that banks will fully lever when the expected value of retained earnings, $E\left(\frac{\partial V_{t+1}}{\partial Q_{t+1}} \middle| a_{t+1} > a_{t+1}^{\min}, I_t\right)$, is low. In contrast, if banks retain an informational advantage in the long-run, they will adopt more conservative policies to protect their franchise value.

In the simulations shown in Figure 2, the economy settles down into a regime of lower leverage and lower default rates. Even though the banks' franchise values are lowest in the long-run, where the average return to bank loans is only six basis points above the international risk-free rate, the bank chooses risk averse behavior and leverage rates stay

**Financial Liberalization and Banking Crises in Emerging Economies:
Extended Results**

low. The main reason for the apparent anomaly is that even though the interest rate spread is higher in, say, period 5 than in period 20, franchise value, measured as the ratio of market to book value, is similar in both periods. This is because franchise value is a forward-looking measure and long-term interest rate spreads are low at both dates. Therefore, at time 5 the gains to gambling, given by the current interest rate spreads, are higher than at time 20, but the costs, given by lost franchise value, are relatively similar. This leads the bank to gamble more in period 5 than in period 20.²¹ The bank's long-run conservative behavior is due to an interest rate spread that is high enough to yield positive franchise value, but low enough to limit the returns to gambling. Although banks are more conservative, the Corollary shows that there will be always some conditions where banks choose full leverage. Banks continue to exit the market, albeit at very slow rates.

It is useful to compare the predictions of the model to experiences of liberalizing countries. The model implies that bank capital should grow and leverage should fall following liberalization. Additionally, crises should develop a few years after liberalization instead of immediately. However, comparing the simulations to the transition paths actually observed is not simple. No country has engaged in the exact experiment considered in this paper, namely an unexpected complete and simultaneous liberalization of the capital account and the banking sector. Instead, liberalization has tended to proceed slowly, and has sometimes been reversed. The liberalizations most similar to those in the model occurred in Asia during

²¹A third reason is that because λ_{t+1}^e is higher at time 5, the aggregate capital stock is lower and the marginal product of capital is higher. This means that variations in output—variations in a_{t+1} —have a bigger effect on the rate of return earned by firms, increasing the degree of risk.

Financial Liberalization and Banking Crises in Emerging Economies: Extended Results

the late 1980's and early 1990's.²²

To compare the predictions of the model with data for these countries, we compute time paths for bank capital and leverage for Indonesia, Thailand, Philippines, Malaysia, and Korea, following financial liberalization using IFS data. We define liberalization as the latest date for either interest rate or capital account liberalization, using Kaminsky and Schmukler (2003).²³ For example, the liberalization date for the Philippines is the date on which capital markets were opened, 1994, with interest ceilings having been lifted much earlier, in 1982.

The model predicts that bank capital will grow following liberalization, due to its high internal value, and that leverage will fall over time as profit opportunities shrink and the bank chooses to take on less risk. Figure 3 contains paths for bank capital and leverage which begin with the year of liberalization for each country and end prior to the 1997 crisis. Data for the crisis year of 1997 are not comparable to our simulation results, which are averages over the simulated transitions for countries (banks) that have *not* suffered a crisis. In all of these countries, the 1997 crisis developed several years after liberalization. Panel A of Figure 3 shows bank capital deflated by the CPI and normalized by its initial value in the year of liberalization.²⁴ Note the strong growth in bank capital following liberalization.

In all cases except the Philippines, for which we have only three years of post-liberalization

²²The Latin interest rate liberalizations in the 1970's were typically accompanied by capital controls. Even so, bank capital grew following the interest rate liberalizations, although the response of leverage was inconsistent. The Latin liberalizations in the late 1980's were confounded with the policy changes, including bank recapitalization, that followed the 1982 debt crisis, and by the Argentine crisis in the early 1990's.

²³Liberalization dates we used are Indonesia - 1988, Korea - 1988, Malaysia - 1991, Philippines - 1994, Thailand - 1992.

²⁴The first observation is bank capital at the beginning of the year of liberalization (in the data this is the end-of-the-year stock the year prior to liberalization) deflated by the price index during the year of liberalization. Therefore, if liberalization occurs in 1988, the first observation is bank capital at the end of 1987 deflated by the CPI for 1988. All values for real bank capital are normalized by this initial value.

Financial Liberalization and Banking Crises in Emerging Economies: Extended Results

data, pre-crisis data, bank capital doubles within two to five years. Panel B plots leverage for the same countries beginning in the year of liberalization.²⁵ In four of the five countries, leverage falls, as predicted by the model. Leverage does not fall in the Philippines, perhaps reflecting the fact that interest liberalization occurred twelve years earlier and that leverage is already low in the year in which the capital account is finally liberalized.

5.3 Sensitivity Analyses

To further illuminate the mechanics of the model, we consider some alternative specifications.

The first alternative is to introduce deposit insurance, so that the deposit rate i_{t+1}^b always equals the international rate θ . Deposit insurance has several conflicting effects. First, because the possibility of default no longer leads to higher deposit rates, deposit insurance leads banks to place a lower value on future solvency and become less risk averse. On the other hand, we assume—in the interest of simplicity—that deposit insurance is provided to banks for free, and ignore the cost of financing it.²⁶ As a result, deposit insurance is a subsidy that increases a bank’s franchise value, and leads it to act more cautiously. A third effect is that by reducing the deposit rate, deposit insurance lowers r_{t+1}^{\min} , the rate of return on loans needed for bank solvency. This mechanically reduces default rates, but it also encourages banks to take on more risk.

²⁵Bank leverage is computed as the sum of all bank assets in a particular year divided by bank capital at the end of the previous year. This corresponds to the dating in the model where stocks (bank capital) are measured at beginning of the period values, and flows (in the model bank assets have a single period duration and hence behave like flows) are measured as values over the period.

²⁶The other extreme is a system where deposit insurance is funded by risk-based premiums. Such a system would in many ways resemble the baseline specification, where banks “insure” their depositors by offering higher deposit rates. An intermediate arrangement, where the system is funded by bank fees that are not (fully) risk-adjusted, is beyond the scope of this paper.

Financial Liberalization and Banking Crises in Emerging Economies: Extended Results

The net effect of all these incentives can be seen by comparing panel A of Figure 4 to the baseline specification in Figure 2. (A similar but less-detailed comparison can be found in Table 2.) This comparison shows that deposit insurance has little effect on exit rates during the high-risk crisis period, but significantly raises long-run exit rates.²⁷ Although deposit insurance lowers one cost of higher risk—higher deposit rates—it still allows the bank to lose its franchise. Since the bank’s franchise value is highest immediately after liberalization, it is not surprising that deposit insurance has little effect at that point. It is only in the longer term, when the rewards to staying solvent are more tenuous, that deposit insurance increases default.

Not surprisingly, “true” bailouts—bailouts that protect the bank’s owners as well as its depositors—encourage much more risk-taking. This can be seen in Panel B of Figure 4, where we assume that failing banks are re-capitalized with 0.005 units of net worth (equalling 0.12% of K^*). (Banks that require recapitalization are dropped from the graphs.) Although this is a very small recapitalization, it allows banks to retain and rebuild their franchise. Rebuilding takes time, however, and banks that were bailed out soon after liberalization would find themselves undercapitalized during the short period that profits are highest. Once again, it is in the longer-term, when lending spreads have settled down, that bailouts have their biggest effects. Even though these results do *not* imply that bailouts do not contribute to banking crises—if bailouts are sufficiently large, banks will take on excessive risk even when

²⁷Although long-run exit rates are higher in panel A of Figure 3, average leverage rates are lower. This apparent contradiction reflects composition effects. The leverage rates shown in the figures are unweighted averages of the leverage ratios at each bank. These simple averages do not adjust for other risk-affecting factors, such as the distribution of net worth, that differ greatly in the two cases.

Financial Liberalization and Banking Crises in Emerging Economies: Extended Results

lending spreads are high—they reinforce the point that the dynamics of newly-liberalized banking sectors reflect more than poor institutional design.

The third alternative is to increase the bank's impatience by raising ϖ from 1.002 to 1.005. This relatively small decrease in patience acts like a long-term decrease in interest rate spreads. As panel C of Figure 4 shows, this reduces franchise value enough to change the long-term behavior of the banking sector. Compared to Figure 2, banks take on higher leverage and exit the market more rapidly. These long-run results are very similar to the results stressed by Hellman et al. (2000). It is worth stressing, however, that the initial effects of liberalization closely resemble the ones shown in Figure 2. After a period of rapid low-risk growth, banks enter a period of high risk.

The fourth alternative is to lower $\bar{\psi}$, the upper bound on leverage, from 20 to 12.5, the inverse of the Basle capitalization ratio of 8 percent. As Hellman, et al. (2000) point out, increasing a bank's capitalization requirements in this fashion affects the bank's attitudes toward risk in two ways. The first effect is the standard one: holding everything else constant, reducing the bank's ability to lever reduces its ability to take on risk. The second effect is that leverage restrictions reduce the bank's current and future profitability and hence its franchise value.²⁸ This reduces the penalty to failed gambles, and encourages banks to take on more risk. Panel D shows that for the specification considered here, the first effect dominates. At a leverage ratio of 12.5 it is mechanically difficult for banks to take on risk.

The fifth alternative is to assume that foreign finance takes the form of equity, rather

²⁸The underlying results show that franchise value (the market to book ratio) does in fact fall when $\bar{\psi}$ is lowered to 12.5, and it rises when deposit insurance is introduced.

**Financial Liberalization and Banking Crises in Emerging Economies:
Extended Results**

than debt. Since the domestic bank can use the foreign equity as collateral for its loans, this modification significantly changes the equilibrium lending and deposit rates, i_{t+1}^l and i_{t+1}^b . (See Appendix C.) Panel E of Figure 4 shows the revised transition path. Not surprisingly, foreign equity finance leads to much lower bank default rates.

The sixth alternative is to double the banks' initial net worth, from 0.1407 to 0.2813. Panel F shows that even though this endowment is still well below the bank's intermediate target for net worth, it is sufficiently high to eliminate much of its default risk. An increase in internal funds can be quite important.

The seventh alternative is to reduce $\delta_L - \delta_H$, the additional depreciation suffered by failing firms, from 25 to 15 percent. Recall that this difference can be interpreted as the cost of bankruptcy. Although the baseline difference of 25 percent is lower than some estimates, Andrade and Kaplan (1998) find that the "costs of financial distress" are in fact smaller, lying between 10 and 20 percent. Panel G shows that reducing bankruptcy costs, not surprisingly, reduces the risk of financial crises. The dynamics of the transition path, however, are very similar to the baseline case.

The final alternative is to increase ϕ , the persistence parameter for the aggregate productivity shock, from 0.515 to 0.85, while keeping the average innovation standard deviation at 5 percent. Panel H suggests that shock persistence is less important than conditional uncertainty: moving to a high value of ϕ does not change the overall dynamic pattern.

6 Conclusion

Financial liberalization often leads to financial crises. This link has usually been attributed to moral hazard from promised bailouts, or to pressure from increased competition. Neither mechanism, however, is unique to financial liberalization. In this paper we develop a dynamic model that shows that financial liberalization, in and of itself, contributes to banking crises. The model shows that between an initial period of rapid, low-risk growth and a long-run outcome of a safe banking system, many banking systems will experience a transitional period with an increased risk of banking crisis. This transition emerges because of the way in which the degree of foreign competition, the marginal product of capital, and the bank's own net worth simultaneously evolve.

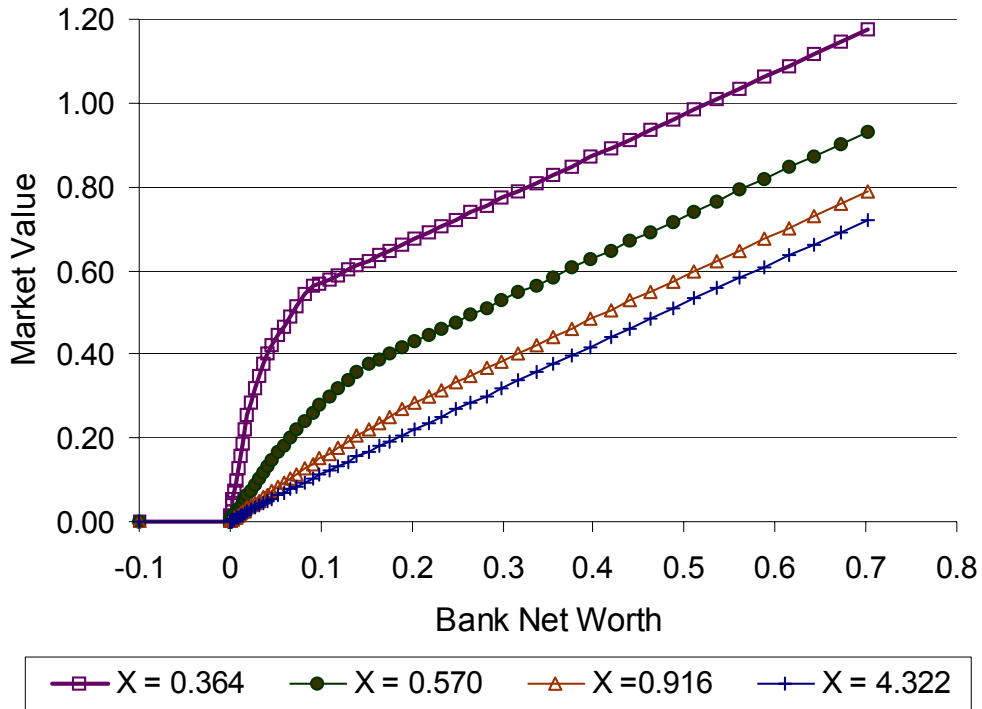
Immediately following liberalization, the capital stock is low, so that the marginal product of capital is high even when productivity is bad. The bank's foreign competitors lack experience with the emerging market, and lend only at high interest rates. As a result, returns on bank loans are high, and even though banks choose high leverage, they face very little risk. Newly-liberalized banks enjoy high profits and see their net worth grow rapidly. But the capital stock grows as well, and becomes less productive. Foreign debt becomes cheaper as foreign lenders acquire more experience in the market. Loan interest rates begin to fall. It is at the point, when the bank's competitive advantage is still significant but declining, that risky behavior and banking crises are most likely. If the bank can weather this period, and retain a sufficiently large cost advantage over international lenders, it can enter a regime of more conservative behavior and lower risk.

Financial Liberalization and Banking Crises in Emerging Economies: Extended Results

What are the policy implications of our analysis? The model implies that a period of increased bankruptcy risk is inherent in an emerging economy's transition from repression to liberalization. This occurs in the absence of any implicit or explicit bailouts—in our model defaulting banks lose their franchise—implying that reducing such bailouts need not eliminate the risk of crises following financial repression. The sensitivity analyses suggest that by reducing the upper bound on leverage, that is, by increasing the bank capitalization requirement as in the Basle Accord, the risk of bankruptcy can be reduced. The sensitivity analyses also suggest the probability of a crisis can be reduced by capitalizing the bank prior to liberalization. Neither of these policies necessarily increase welfare. A higher capitalization requirement comes at the cost of lower returns for the bank, and capitalizing emerging banks diverts resources from other uses. Alternatively, postponing liberalization until banks have capitalized could reduce the pace of economic growth. Finding the welfare impact of these policy actions requires us to model the aggregate costs of banking crises, a topic we leave for future research.

Figure 1

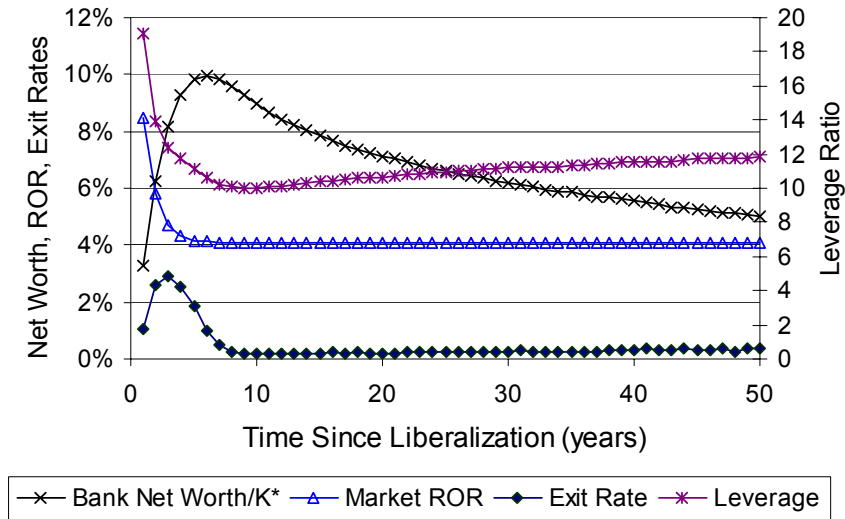
Value Functions at Different Levels of Experience (X)



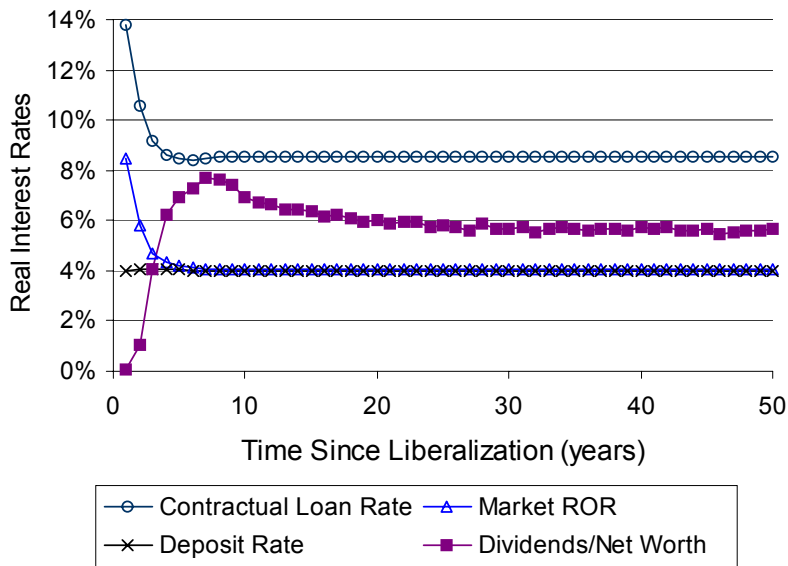
Note: Value functions calculated as part of the numerical exercises for the baseline specification. All the value functions shown here are based on a success rate (a_t) of 0.95.

Figure 2

Simulation Results: Baseline Specification



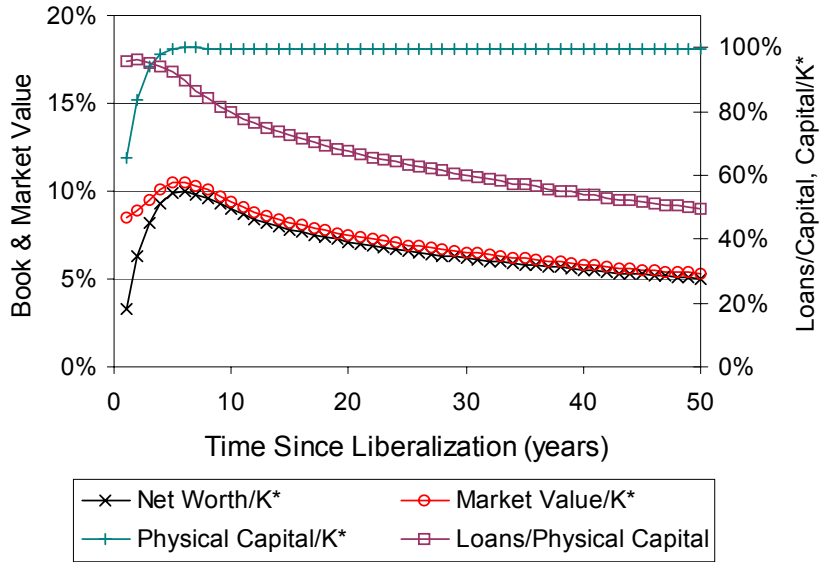
Panel A



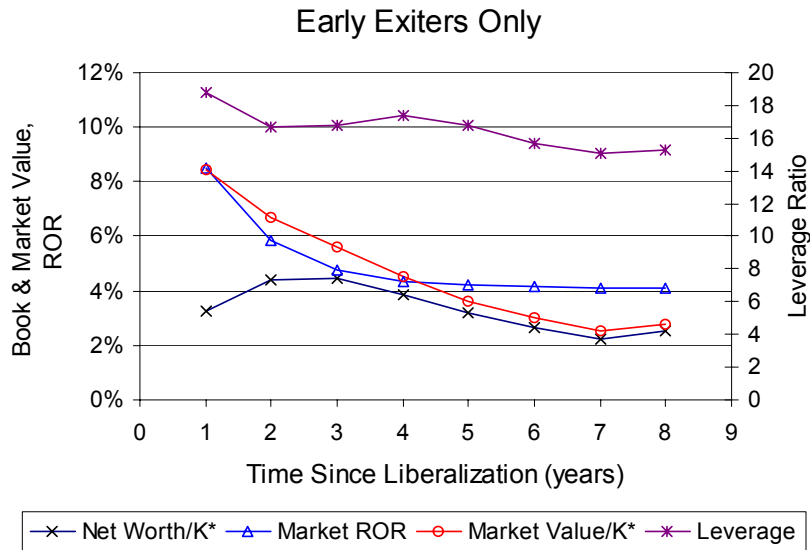
Panel B

Figure 2 (continued)

Simulation Results: Baseline Specification



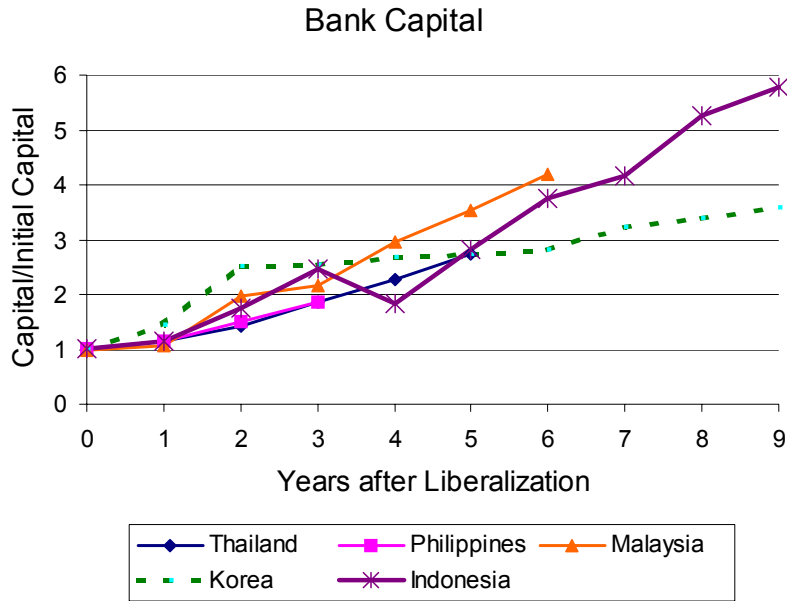
Panel C



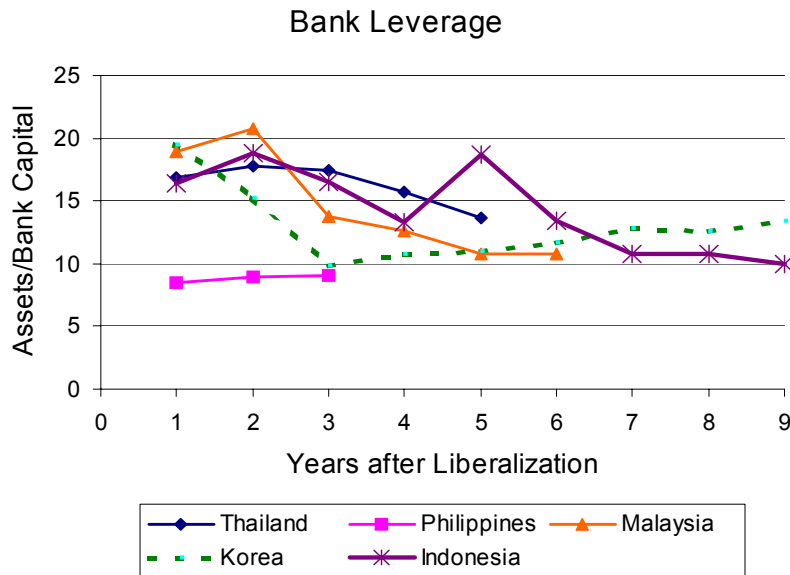
Panel D: Early Exiters Only

Figure 3

Post-Liberalization Bank Capital and Leverage in Southeast Asia

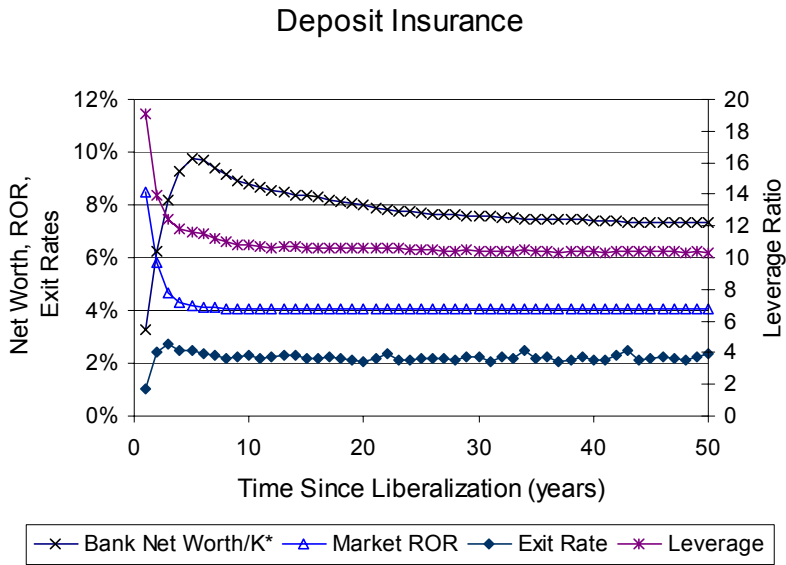


Panel A: Bank Capital



Panel B: Leverage

Figure 4
 Simulation Results: Sensitivity Analyses



Panel A: Deposit Insurance

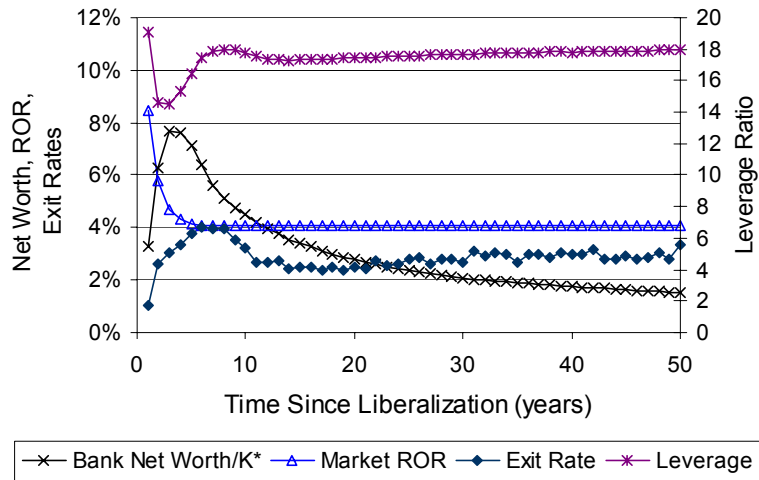


Panel B: Bailouts with Recapitalization

Figure 4 (continued)

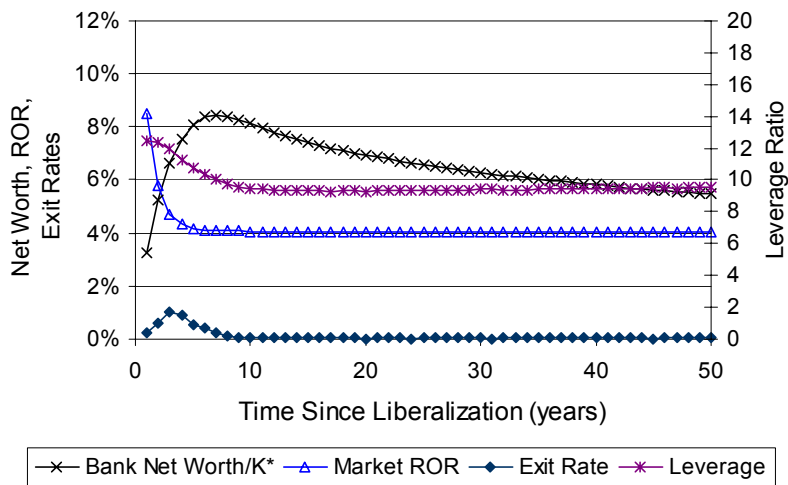
Simulation Results: Sensitivity Analyses

Higher Bank Impatience



Panel C: Higher Bank Impatience

Lower Leverage Limit

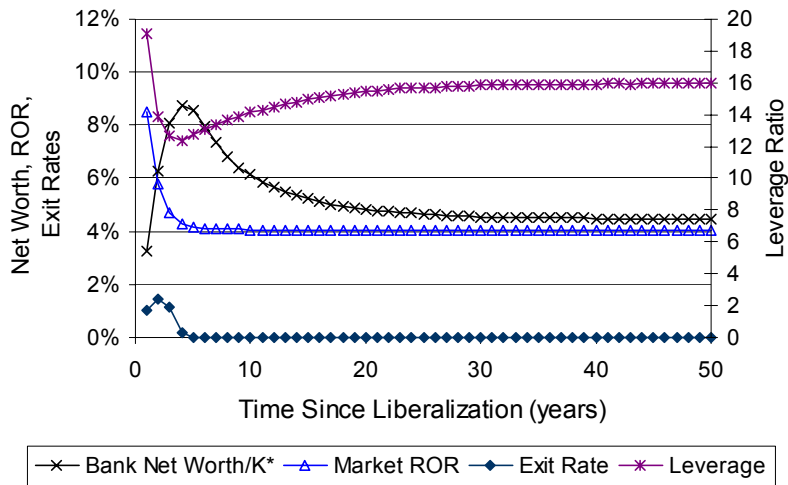


Panel D: Lower Leverage Limit

Figure 4 (continued)

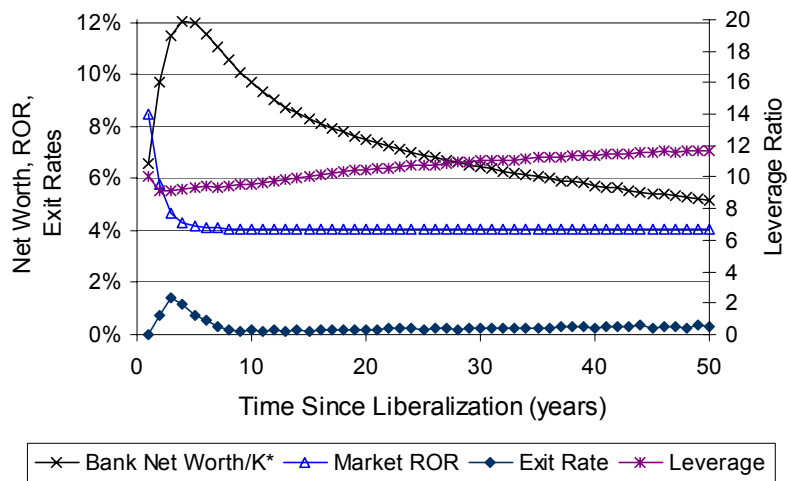
Simulation Results: Sensitivity Analyses

Foreign Equity Finance



Panel E: Foreign Equity Finance

Higher Initial Bank Net Worth

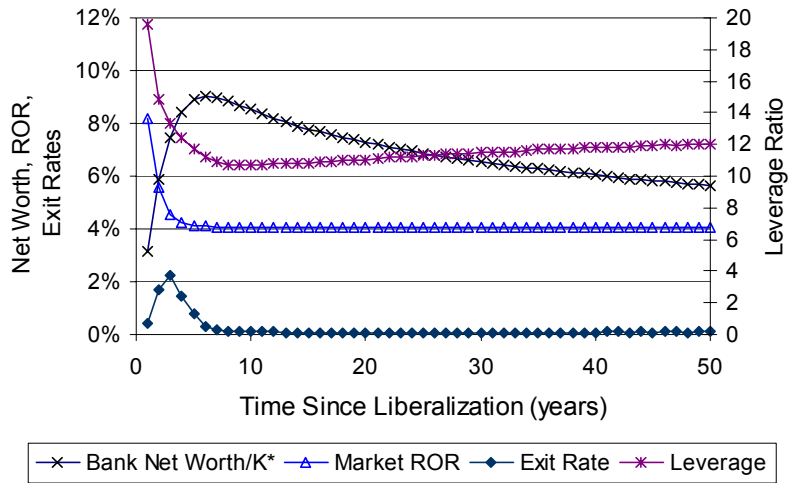


Panel F: Higher Initial Bank Net Worth

Figure 4 (continued)

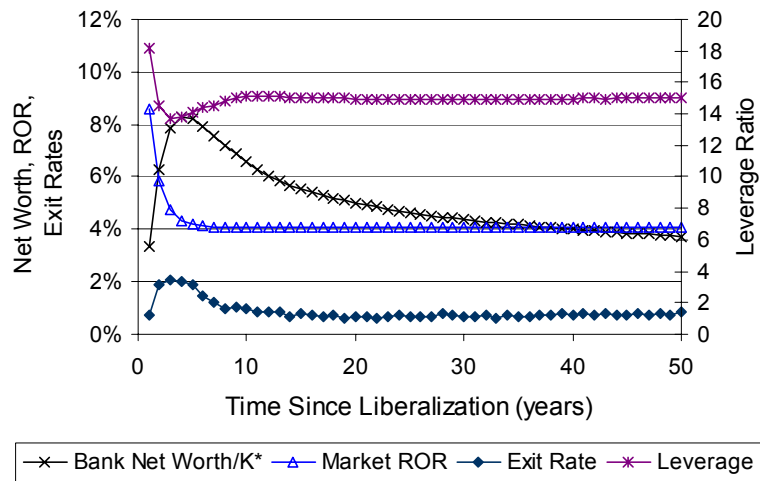
Simulation Results: Sensitivity Analyses

Lower Bankruptcy Costs



Panel G: Lower Bankruptcy Costs

More Persistent Technology Shocks



Panel H: More Persistent Technology Shocks

Table 1
Calibrated Parameter Values

α (Returns to Capital)	0.4
δ_H (Capital Depreciation Rate for High-Productivity Firms)	0.1
δ_H (Capital Depreciation Rate for Low-Productivity Firms)	0.35
γ (Depreciation Rate for Experience)	0.1
θ (Global Interest Rate)	0.04
ϖ (Equity Discount Premium)	1.002
$\bar{\psi}$ (Leverage Bound)	20
z_L (Low Productivity Value)	0.0
z_H (High Productivity Value)	1.0
z_t ($= a_t$) Aggregate Productivity (Success Rate)	
Median Value	0.95
Mean Value	0.934
φ (First autocorrelation of $\ln(z_t)$)	0.5
$\widehat{V}(\ln(z_t) \ln(z_{t-1}))$ (“Innovation Variance”)	0.05^2
κ_0 (Shift Parameter in $\lambda(X)$, per Equation (27))	0.0006
κ_1 (Curvature Parameter in $\lambda(X)$, per Equation (27))	1
κ_2 (Exponent in $\lambda(X)$, per Equation (27))	7.0
Q_1 (Initial Bank Equity for Simulations)	0.1407
X_1 (Initial Foreign Experience)	0.5626

**Financial Liberalization and Banking Crises in Emerging Economies:
Extended Results**

Table 2
Sensitivity Analyses

Year (t)	Q_t (% of K^*)			ψ_t (Leverage)			Exit Rate (%)			
	1	3	10	1	3	10	1	3	10	30
Benchmark	3.3	8.2	9.0	19.1	12.4	10.0	1.1	2.9	0.2	0.3
Deposit Insurance	3.3	8.2	8.8	19.1	12.4	10.8	1.0	2.7	2.3	2.3
Bailouts	3.3	8.1	6.4	19.1	13.2	16.5	1.2	3.2	5.4	7.1
$\varpi = 1.005$	3.3	7.7	4.5	19.1	14.6	17.8	1.1	3.1	3.2	2.7
$\bar{\psi} = 12.5$	3.3	6.7	8.1	12.5	11.9	9.5	0.2	1.0	0.1	0.0
$Q'_1 = 2Q_1$	6.6	11.5	9.7	10.0	9.2	9.6	0.0	1.4	0.2	0.2
Foreign Equity	3.3	8.1	6.1	19.1	12.6	14.1	1.1	1.1	0.0	0.0
$\delta_L - \delta_H = 0.15$	3.2	7.5	8.5	19.6	13.3	10.7	0.5	2.2	0.1	0.1
$\phi = 0.85$	3.3	7.9	6.6	18.1	13.7	15.2	0.8	2.1	1.0	0.7

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Appendix A

First Order Conditions

Begin by writing the bank's problem as

$$V(Q_t, a_t, K_t) = \max_{0 \leq \psi_t \leq \bar{\psi}, 0 \leq d_t \leq Q_t} d_t + \frac{1}{\varpi(1+\theta)} \int_{a_{t+1} > a_{t+1}^{\min}} V(Q_{t+1}, a_{t+1}, K_{t+1}) dF(a_{t+1} | a_t),$$

subject to the constraints described in the text.

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

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

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 firm with respect to net worth can be expressed as:²⁹

$$\frac{\partial V_t}{\partial Q_t} = \frac{1}{\varpi(1+\theta)} \int_{a_{t+1} > a_{t+1}^{\min}} \left[\frac{\partial V_{t+1}}{\partial Q_{t+1}} \times \frac{\partial Q_{t+1}}{\partial Q_t} \right] dF(a_{t+1} | a_t) \quad (28)$$

It follows from equation (17) that

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

²⁹Note 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.

**Financial Liberalization and Banking Crises in Emerging Economies:
Extended Results**

and it follows from equation (16) that

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

so that

$$\frac{\partial Q_{t+1}}{\partial Q_t} = \left(\frac{\psi_t}{Q_t - d_t} \right) \frac{\partial Q_{t+1}}{\partial \psi_t} + 1 + i_{t+1}^b - \psi_t (1 - \psi_t) \frac{\partial i_{t+1}^b}{\partial \psi_t}.$$

Combining the six preceding equations allows us to rewrite equation (28) as

$$\frac{\partial V_t}{\partial Q_t} = \frac{\psi_t}{Q_t - d_t} \frac{\partial V_t}{\partial \psi_t} + \frac{1}{\varpi (1 + \theta)} \int_{a_{t+1} > a_{t+1}^{\min}} \frac{\partial V_{t+1}}{\partial Q_{t+1}} \left[1 + i_{t+1}^b - \psi_t (1 - \psi_t) \frac{\partial i_{t+1}^b}{\partial \psi_t} \right] dF(a_{t+1} | a_t). \quad (29)$$

Totally differentiating and then imposing equation (22) reveals that

$$\begin{aligned} \frac{\partial i_{t+1}^b}{\partial \psi_t} &= \frac{1}{1 - F(a_{t+1}^{\min} | a_t)} \cdot \frac{1}{(\psi_t - 1)^2} \int_{a_{t+1} \leq a_{t+1}^{\min}} [1 + r_{t+1}] dF(a_{t+1} | a_t) \\ &= \frac{1}{1 - F(a_{t+1}^{\min} | a_t)} \cdot \frac{1}{\psi_t (\psi_t - 1)} \cdot [1 + \theta - (1 - F(a_{t+1}^{\min} | a_t)) (1 + i_{t+1}^b)] \geq 0, \end{aligned}$$

so that the deposit rate is increasing in leverage. Inserting this result into equation (29)

yields

$$\frac{\partial V_t}{\partial Q_t} = \frac{\psi_t}{Q_t - d_t} \frac{\partial V_t}{\partial \psi_t} + \frac{1}{\varpi} \cdot \frac{1}{1 - F(a_{t+1}^{\min} | a_t)} \int_{a_{t+1} > a_{t+1}^{\min}} \frac{\partial V_{t+1}}{\partial Q_{t+1}} dF(a_{t+1} | a_t),$$

which reduces to equation (24) in the main text.

Equation (25) follows immediately from

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

Appendix B

Technology Specification and Numerical Methodology

To specialize the model we assume that at time t , a firm's productivity can take on the high value z_H with frequency a_t , or the low value z_L with frequency $1 - a_t$, and that the probability parameter a_t follows a Markov process. In particular, we assume that a_t is a logistic transformation of the underlying variable v_t , i.e.,

$$a_t = L(v_t) \equiv \frac{\exp(v_t)}{1 + \exp(v_t)},$$

with the reverse transformation

$$v_t = L^{-1}(a_t) = \ln\left(\frac{a_t}{1 - a_t}\right). \quad (30)$$

We assume further that v_t follows an AR(1) process with uniformly-distributed innovations:

$$\begin{aligned} v_{t+1} &= \phi v_t + (1 - \phi) \mu_v + \varepsilon_{t+1}, \\ \varepsilon_{t+1} &\sim U(-\varepsilon_D, \varepsilon_D), \end{aligned}$$

with $\phi \in [0, 1)$.

To calibrate μ_v , we exploit the fact that v_t is symmetric, so that its mean and median are the same. Assuming that firms that realize z_L default, we can interpret $1 - a_t$ as a non-performing loan ratio. Let a_M denote the unconditional median of a_t : since the non-performing loan ratio at a healthy (developing country) bank is less than 10 percent,³⁰ we set $a_M = 0.95$. Because $L(\cdot)$ is a monotonic function, the median of a_t equals $L(\cdot)$ evaluated at

³⁰Demirguc-Kunt and Detragiache 1998 use 10% as the threshold which constitutes a banking crisis.

**Financial Liberalization and Banking Crises in Emerging Economies:
Extended Results**

the median of v_t : $a_M = L(\mu_v)$. It then follows from equation (30) that

$$\mu_v = L^{-1}(a_M) = \ln\left(\frac{0.95}{1-0.95}\right) = 2.944.$$

Even though the innovation ε_t follows a uniform distribution, the distribution of v_t , being concentrated around μ_v , will not be uniform. In contrast to the mean of v_t , the unconditional mean of a_t lacks a closed form solution, as does the unconditional variance. We therefore estimate these objects through simulation.

Fortunately, it is the conditional distribution of a_t that we are most interested in. In particular, the conditional distribution of v_t is

$$\begin{aligned} v_{t+1}|v_t &\sim U(\underline{v}_{t+1}, \bar{v}_{t+1}), \\ \bar{v}_{t+1} &= \phi v_t + (1-\phi)\mu_v + \varepsilon_D, \\ \underline{v}_{t+1} &= \phi v_t + (1-\phi)\mu_v - \varepsilon_D. \end{aligned}$$

Note that the anti-derivative of the logistic function $L(\cdot)$ is

$$\int L(v) dv = \ln(1 + e^v). \quad (31)$$

It follows that the conditional expectation of a_t is given by

$$\begin{aligned} E(a_{t+1}|v_t) &= \int_{\underline{v}_{t+1}}^{\bar{v}_{t+1}} \left(\frac{e^v}{1+e^v}\right) \frac{1}{2\varepsilon_D} dv \\ &= \frac{1}{2\varepsilon_D} [\ln(1+e^v)]_{\underline{v}_{t+1}}^{\bar{v}_{t+1}} \\ &= \frac{1}{2\varepsilon_D} \left[\ln\left(\frac{1 + \exp(\phi v_t + (1-\phi)\mu_v + \varepsilon_D)}{1 + \exp(\phi v_t + (1-\phi)\mu_v - \varepsilon_D)}\right) \right]. \end{aligned} \quad (32)$$

Although the conditional variance of v_{t+1} is easy to find,

$$V(v_{t+1}|v_t) = \frac{(2\varepsilon_D)^2}{12} = \frac{\varepsilon_D^2}{3},$$

**Financial Liberalization and Banking Crises in Emerging Economies:
Extended Results**

the conditional variance of a_{t+1} is quite messy. Moreover, the conditional variance of a_{t+1} will depend on a_t , leaving us with no simple analytical object for calibration. Matters get even messier when we consider aggregate productivity

$$z_t = E(z_{it} | a_t) = a_t z_H + (1 - a_t) z_L,$$

and its log, $\ln(z_t)$. However, we can approximate the average “innovation variance” of $\ln(z_t)$ as

$$\widehat{V}(\ln(z_t) | \ln(z_{t-1})) \equiv (1 - \varphi^2) V(\ln(z_t)), \quad (33)$$

where φ is the correlation coefficient for $\ln(z_t)$; note that both $V(\ln(z_t))$ and φ will have to be estimated via simulation.

The numerical methods we use to solve the model are very similar to those described in Jones (2003). In solving for the bank’s decision rules, we approximate the continuous distribution for a_t with a 14-state Markov chain, adapting the approach described in Tauchen (1986). Using discretization rather than numerical integration yields a significant savings in computational time. We also assume that the results of Cooley and Quadrini (2001) hold, so that the value function is concave in net worth. An extremely useful consequence of concavity (and the fact that returns are linear in dividends) is that the bank’s policies can be described by a dividend threshold—any net worth above this threshold is paid out as dividends. Exploiting this property allows us to find the model’s decision rules much more quickly. 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 and the experience variable X_t . In each simulation, the bank is given Q_0 units of

Financial Liberalization and Banking Crises in Emerging Economies: Extended Results

net worth and a draw from the invariant distribution of a_t . Similarly, X_t is initialized to X_0 . Given the bank's net worth, Q_t , technology, a_t , and experience, X_t , the policy functions described above specify the firm's dividends, leverage and deposits. Decisions for values of net worth, experience and productivity lying off the finite grid described above are found by linear interpolation. Next period's net worth, Q_{t+1} , follows immediately from equation (17) and next period's technology, a_{t+1} . Similarly, next period's experience, X_{t+1} , follows from equations (11) and (4). The simulation continues until Q_t crosses the bankruptcy threshold ($Q = 0$), and then that bank's history is stored. It is worth noting that although the distribution of a_t is discretized when we find the decision rules, in the simulations we use draws from a continuous distribution. This reduces the sensitivity of the simulations to decision rules at particular values of a_t .

A key part of the numerical exercises is computing the equilibrium lending and deposit rates, i_{t+1}^l and i_{t+1}^b . Appendix C provides a detailed description.

Appendix C

Equilibrium Lending and Deposit Rates

The derivations presented here generalize the analysis presented in the main text to include the possibility of equity finance. In particular, let ℓ_t denote the firm's financing ratio:

$$\begin{aligned}\ell_{t+1} &= 1, & \text{if foreign finance is debt,} \\ &= \frac{K_{t+1}}{L_t}, & \text{if foreign finance is equity.}\end{aligned}$$

We begin by finding the bank's lending rate, i_{t+1}^l . Define \widehat{i}_{t+1}^l to be the net return the bank receives from a firm that receives the bad productivity shock z_L . If $[z_L - (1 - \alpha) z_{t+1}^e] K_{t+1}^\alpha + (1 - \delta_L) K_{t+1} \geq (1 + i_{t+1}^l) \ell_{t+1}^{-1} K_{t+1}$, firms never default and $i_{t+1}^l = \widehat{i}_{t+1}^l = r_{t+1} = \lambda_{t+1}^e$. When firm-level default is possible (as will be the case here)

$$\widehat{i}_{t+1}^l = \max \{0, \ell_{t+1} [(z_L - (1 - \alpha) z_{t+1}^e) K_{t+1}^{\alpha-1} + (1 - \delta_L)]\} - 1.$$

The $\max \{ \}$ operator accounts for the possibility that defaulting firms may not be able to cover their wage obligations, in which case the bank receives nothing. Recall from equation (12) that K_{t+1} is a function of experience, X_t , and lagged productivity, $a_t(v_t)$, and recall from equation (10) that the international lending rate λ_{t+1}^e is a function of experience. Continuing, it must always be the case—whether default is possible or not—that

$$\widehat{i}_{t+1}^l = \widehat{i}^l(X_t, v_t, L_t),$$

with loans, L_t , playing a role only when foreign finance takes the form of equity. Using this

**Financial Liberalization and Banking Crises in Emerging Economies:
Extended Results**

result, it follows from equations (5) and (7) that i_{t+1}^l is given by

$$i_{t+1}^l = i^l(X_t, v_t, L_t) = \widehat{i}_{t+1}^l(X_t, v_t, L_t) + \frac{\lambda_{t+1}^e(X_t) - \widehat{i}_{t+1}^l(X_t, v_t, L_t)}{a_{t+1}^e}, \quad (.34)$$

$$a_{t+1}^e \equiv E(a_{t+1} | v_t).$$

Given that a_{t+1}^e is given by equation (32), equation (34) provides a closed-form expression for the lending rate.

Let's turn to the deposit rate i_{t+1}^b . It follows from equation (14) that the realized return on a loan portfolio, r_{t+1} , depends on the realized value of a_{t+1} :

$$r_{t+1} = \widehat{i}_{t+1}^l + a_{t+1} \left(i_{t+1}^l - \widehat{i}_{t+1}^l \right). \quad (35)$$

With this result, we can find a closed form solution for a_{t+1}^{\min} . Inserting equation (35) into equation (18), we get

$$a_{t+1}^{\min} = \frac{1}{i_{t+1}^l - \widehat{i}_{t+1}^l} \left[\frac{\psi_t - 1}{\psi_t} (1 + i_{t+1}^b) - (1 + \widehat{i}_{t+1}^l) \right]. \quad (36)$$

It can also be useful to work with the transformed threshold

$$v_{t+1}^{\min} = \ln(a_{t+1}^{\min} / (1 - a_{t+1}^{\min})). \quad (37)$$

Recall that when $\Gamma_t \equiv F(a_{t+1}^{\min} | a_t) = 0$, the bank will not go bankrupt in period $t + 1$, 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 $\Gamma_t > 0$. Recalling the process for v_t , when bankruptcy is possible,

**Financial Liberalization and Banking Crises in Emerging Economies:
Extended Results**

the bank's default rate follows

$$\begin{aligned}\Gamma_t &= \Gamma\left(i_{t+1}^l, \widehat{i}_{t+1}^l, \psi_t, i_{t+1}^b, v_t\right) \\ &= \frac{v_{t+1}^{\min} - \underline{v}_{t+1}}{2\varepsilon_D} \\ \underline{v}_{t+1} &= \phi v_t + (1 - \phi)\mu_v - \varepsilon_D.\end{aligned}\tag{38}$$

Rewriting equation (22) yields:

$$1 + \theta = \int_{\underline{a}_{t+1}}^{a_{t+1}^{\min}} \frac{\psi_t (1 + r_{t+1})}{\psi_t - 1} dF(a_{t+1} | a_t) + (1 - \Gamma_t) (1 + i_{t+1}^b).\tag{39}$$

Now equation (35) implies that

$$\int_{\underline{a}_{t+1}}^{a_{t+1}^{\min}} (1 + r_{t+1}) dF(a_{t+1} | a_t) = \Gamma_t \left(1 + \widehat{i}_{t+1}^l\right) + \left(i_{t+1}^l - \widehat{i}_{t+1}^l\right) \int_{\underline{a}_{t+1}}^{a_{t+1}^{\min}} a_{t+1} dF(a_{t+1} | a_t).\tag{40}$$

Inserting this result into equation (39) and using equation (31), we get

$$\begin{aligned}1 + \theta &= 1 + i_{t+1}^b + \Gamma_t \left[\frac{\psi_t}{\psi_t - 1} \left(1 + \widehat{i}_{t+1}^l + \Delta_t \left(i_{t+1}^l - \widehat{i}_{t+1}^l\right)\right) - (1 + i_{t+1}^b) \right], \\ \Delta_t &\equiv E(a_{t+1} | a_{t+1} < a_{t+1}^{\min}, a_t) \\ &= \frac{1}{\Gamma_t} \int_{\underline{v}_{t+1}}^{v_{t+1}^{\min}} \left(\frac{e^v}{1 + e^v}\right) \frac{1}{2\varepsilon_D} dv = \frac{1}{\Gamma_t} \left(\frac{1}{2\varepsilon_D}\right) [\ln(1 + e^v)]_{\underline{v}_{t+1}}^{v_{t+1}^{\min}},\end{aligned}\tag{41}$$

with $0 < \Delta_t < a_{t+1}^{\min}$. Now it follows from equation (36) that

$$\frac{\psi_t}{\psi_t - 1} \left(1 + \widehat{i}_{t+1}^l\right) - (1 + i_{t+1}^b) = -\frac{\psi_t}{\psi_t - 1} a_{t+1}^{\min} \left(i_{t+1}^l - \widehat{i}_{t+1}^l\right),$$

and equation (41) simplifies to

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

**Financial Liberalization and Banking Crises in Emerging Economies:
Extended Results**

or

$$i_{t+1}^b = \theta + \Gamma_t \frac{\psi_t}{\psi_t - 1} (a_{t+1}^{\min} - \Delta_t) (i_{t+1}^l - \widehat{i}_{t+1}^l). \quad (42)$$

Because Γ_t , a_{t+1}^{\min} and Δ_t are all increasing in i_{t+1}^b , equation (42) is a fixed point relationship. In particular, we can rewrite equation (42) as $i_{t+1}^b = B(i_{t+1}^b)$. Note that $a_{t+1}^{\min} - \Delta_t$ is increasing in a_{t+1}^{\min} , as Δ_t , being an average over the range $[\underline{a}_{t+1}, a_{t+1}^{\min}]$, cannot increase one-for-one with a_{t+1}^{\min} . It follows that $B(i_{t+1}^b)$ is increasing in i_{t+1}^b . Moreover, it is easy to see that $B(\theta) \geq \theta$, as $a_{t+1}^{\min} \geq \Delta_t$ and $i_{t+1}^l \geq \widehat{i}_{t+1}^l$. It follows that the function $B(i_{t+1}^b)$ is an increasing function that crosses the 45-degree line from above. This means that iterating on equation (42) from the initial value of θ provides a stable method for finding i_{t+1}^b .