Bank Runs in Emerging Economies and the Role of Interest Rate Shocks*

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Abstract

Recent research has significantly advanced our understanding about business cycle fluctuations in emerging economies. However, while bank runs are not rare events in emerging economies, quantitative studies on bank runs with dynamic general equilibrium models have been scant. This paper contributes to the literature by developing a small open economy model with financial intermediaries and using it to evaluate the quantitative predictions of foreign interest rate shocks on the possibility of bank runs. Our main finding is that the shock may generate bank runs. This is consistent with empirical findings such as Mishkin (2006).

JEL classification: E44, F44, G21

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1 Introduction

Overview of This Project

Bank runs are one of the key characteristics of emerging economies. As Reinhart and Rogoff (2009) find, it has been recurrent. For example, Mexico 1994-1995, South Korea 1997-1998, and Argentina 2001-2002. Moreover, the wake of the financial crisis and recession of 2007-2009 shows that the meltdown of financial system can trigger the large contraction of real economy, even in advanced economies. This leads us to renew our interest for the underlying shocks of the financial crises and the mechanism for the transmission of the shocks in a macroprudential policy context. However, while recent research on emerging economies has significantly advanced our understanding about business cycle fluctuations, quantitative studies on bank runs with dynamic general equilibrium models have been scant.¹

The aim of this project is to go a step beyond the literature by quantitatively investigating the relationship between the underlying shocks of business cycles and the possibility of bank runs in emerging economies. The recent literature on the sources of business cycle fluctuations in emerging economies has resulted in two controversial views: interest rate shocks and shocks to productivity trend.² This paper highlights the role of interest rate shocks, exploring the implications on the possibility of bank runs. This is motivated by some empirical studies such as Mishkin (2006). Mishkin (2006) suggests that external factors such as foreign interest rate shocks might be one of important sources to cause financial crisis in emerging economies.

Specifically this paper investigates the following questions: Does the shock cause bank runs? How do the foreign interest rate shocks affect the balance sheet of banks? Although some studies such as Chang and Velasco (2001) have investigated qualitatively, quantitative studies have been underexplored.³ The main contribution of this project is to fill this gap and develop a model to provide a step toward evaluating the quantitative predictions of foreign interest rate shocks on the possibility of bank runs.

To this end, this paper proposes the quantitative predictions of a dynamic stochastic general equilibrium model with financial intermediaries in a small open economy. The model developed in this paper builds on Gertler and Kiyotaki (2013), which propose a model

¹The literature attends to account for four stylized facts which differ from those in developed economies: higher output volatility, higher volatility of consumption relative to output, more countercyclical net exports, and more volatile and countercyclical interest rates.

²Regarding interest rate shocks see, for example, Neumeyer and Perri (2005) and Uribe and Yue (2006). On the other hand, for instance, Aguiar and Gopinath (2008) claims the importance of shocks to productivity trend.

³Chang and Velasco (2001) provides excellent analysis on this issue, but their analysis is not quantitative and they incorporates banks with shorter horizon (3 periods) model.
with financial intermediaries and analyse the possibility of bank runs in a closed economy. Moreover, their model allows us to characterize in a quantitatively tractable way how the conditions of bank balance sheets and bank asset liquidation prices affect the possibility of bank runs. In this paper, we extend it into a small open economy. In particular, in order to consider the role of a foreign factor, my model departs from Gertler and Kiyotaki (2013) in two relevant ways. First, financial intermediaries can borrow from foreign creditors through the international financial market as well as from domestic depositors. Second, this paper introduces an exogenous foreign interest rate shock as a source of uncertainty, along with an exogenous interest rate schedule with respect to foreign debts. The latter follows García-Cicco et al. (2010).

The model demonstrates interaction between domestic financial frictions and foreign interest rate shocks, featuring both financial accelerator mechanism and bank runs. An increase in the foreign interest rate shock worsens the conditions of the balance sheet of banks, forcing depositors to fear the insolvency of banks. This affects the possibility of bank runs. Moreover, the shock increases the cost of bank credit and leads to a long lasting economic downturn through financial accelerator mechanism. Then this also leads to fear more and might increase the possibility of bank runs. In this respects the model relates the possibility of runs to macroeconomic conditions as well as the conditions of the balance sheet of banks.

After calibrating the model to emerging economies such as Argentina, we quantify these effects of foreign interest rate shocks. In particular, we compute the impulse response functions of variables consisting of the balance sheet of banks. Furthermore we calculate the possibility of bank runs to quantify the effects of foreign interest rate shocks.

Our first main finding is that the shock may generate bank runs.

**Related Literature**

This paper is closely related to a strand of literature that considers bank runs, pioneered by Diamond and Dybvig (1983). The model in this paper follows Gertler and Kiyotaki (2013). They succeed in building a simple infinite horizon model with the possibility of a bank run, while others such as Diamond and Dybvig (1983) considers only short horizons. In Gertler and Kiyotaki (2013), there exists a bank run equilibrium, depending on bank balance sheet and endogenous liquidation price for bank assets. They consider a bank run caused by productivity shocks and household liquidity risks like Diamond and Dybvig (1983). This paper differs from Gertler and Kiyotaki (2013) by extending into a small open economy. In addition, my focus is different: The effects of foreign interest rate shocks.

This work belongs to the literature that examines the effects of foreign interest rate shocks in emerging economies. For example, Change and Fernandez (2013), García-Cicco
et al. (2010), and Neumeyer and Perri (2005). García-Cicco et al. (2010) stresses the importance of country premium shocks in explaining business cycles in Argentina, using Bayesian estimation of a simple neoclassical growth model. What is new in this paper is that this paper investigates the possibility of bank runs while previous studies consider the role of foreign interest rate shocks to account for business cycle fluctuations.

There is a related theoretical literature that analyzes sovereign debt crises. Many papers present models with microfoundations for the country premium based on the risk of default. Recently, Padilla (2013) builds a model that includes the transition mechanism of sovereign defaults to the banking sector and the rest of the economy and features credit crunch in the default period of Argentina. However, the focus of Padilla (2013) is not on bank runs. In addition, my model is different. My model introduces endogenous bank’s net worth accumulation, while Padilla (2013) does not.

Numerous works on financial crisis in emerging economies are relevant. Levy-Yeyati et al. (2010) empirically finds that macroeconomic risk might lead to bank runs in Argentina. This finding may be consistent with my findings. In addition, Chang and Velasco (2001) provides qualitative analysis on bank runs on domestic deposits in emerging economies, using a simple model with shorter horizon (3 periods). The main differences with respect to Chang and Velasco (2001) is that this paper constructs infinite horizon model and evaluate the possibility of bank runs quantitatively.

Finally, the most relevant are Akinci and Queralto (2013), Oviedo (2003), and Queralto (2013). They develop models with financial intermediaries and analyze the effects of foreign interest rate shocks. In particular, Akinci and Queralto (2013) and Queralto (2013) provide similar models to this paper. However, this paper mainly differs from these papers by evaluating the possibility of bank runs. The focus of Akinci and Queralto (2013) is the boom-bust cycles in emerging economies, and Queralto (2013) mainly considers the episodes of slow recoveries from financial crises.

The rest of paper is organized as follows. Section 2 presents the model. Section 3 describes the conditions of bank runs, and section 4 calibrates the model. Section 5 provides some quantitative implications of the model, which are the main results of this paper. Section 6 concludes this paper.

2 THE ECONOMY

This section characterizes the competitive equilibrium of a small open economy model with a banking sector. The model is a small open economy version of Gertler and Kiyotaki (2013). They develop a macroeconomic model with a banking sector that features both financial

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4For example, Aguiar and Gopinath (2006), Arellano (2008), and Hatchondo et al. (2009).
accelerator and bank runs. The differences between our economy and their framework are
twofold. First, in this paper, financial intermediaries can borrow from foreign creditors
through the international financial market as well as from domestic depositors. Second,
this paper introduces a foreign interest rate shock as a source of uncertainty, along with
an exogenous interest rate schedule with respect to foreign debts.\textsuperscript{5} We use this model to
investigate the quantitative implications of foreign interest rate shocks on the balance sheet
of banks and the possibility of bank runs in a tractable way.

2.1 Basic Environment

Before introducing the model in detail, we present the basic environment.

- Infinite horizon and endowment economy.
- One goods: nondurable goods (consumption goods).
- Two type of agents: Households and Bankers with a continuum of measure unity of
each type. Bankers intermediate funds between households and productive assets.
- Two sources of liabilities for bankers: deposits from domestic households, and deposits
from foreign creditors. Only bankers can trade foreign debts.
- One asset: productive and durable asset \((capital)\). Capital could be held by both
bankers and households. Capital does not depreciate. In addition, capital is fixed
in total supply which is normalized to one. This is justified by assuming infinite
adjustment costs to capital.

\[ K^b_t + K^h_t = 1, \]

where \(K^b_t\) and \(K^h_t\) represent capital held by bankers and households respectively.

- When household invests \(K^h_t\) at \(t\), she needs to pay the management cost \(f(K^h_t)\). Then,
she obtains \(Z_{t+1}K^h_t + K^h_t\) at \(t + 1\). \(Z_{t+1}K^h_t\) means a payoff at \(t + 1\). \(Z_{t+1}\) denotes
productivity and we assume \(Z_{t+1} = Z\) for simplicity.

\[ K^h_t + f(K^h_t) \to Z_{t+1}K^h_t + K^h_t, \]

The management cost for households \(f(K^h_t)\) is defined by

\[ f(K^h_t) = \begin{cases} \frac{\alpha}{2}(K^h_t)^2, & \text{for } K^h_t \leq \bar{K}^h \\ \alpha \bar{K}^h (K^h_t - \frac{\bar{K}^h}{2}) & \text{for } K^h_t < \bar{K}^h \end{cases} \]

\textsuperscript{5}See, for example, García-Cicco et al. (2010), Neumeyer and Perri (2005), and Uribe and Yue (2006).
with $\alpha > 0$, and $\bar{K}^h \in (0, 1)$. The kinked management cost ensures that it is profitable for households to have all capital when bank runs occur and all banks are out of business.

- On the other hand, bankers have more efficient investment technology for capital, because they can collect information on capital efficiently. In other words, bankers do not have to pay the management cost at $t$. 

$$K^b_t \to Z_{t+1}K^b_t + K^b_t,$$

where $Z_{t+1}K^b_t$ represents a payoff at $t + 1$.

### 2.2 HOUSEHOLDS

Each household consumes nondurable goods and saves by investing deposits to banks or holding capital directly. Note that it is difficult for households to access to international financial markets.

Then she chooses consumption, bank deposits, and direct capital holdings ($C^h_t, D^h_t, K^h_t$) to maximize expected discounted utility, subject to the budget constraint.

As is discussed in Gertler and Kiyotaki (2013), we assume that bank runs are completely unexpected. In other words, when the representative household solves the problem at $t$, she attaches zero probability to a possibility of a run in the future. Although this might be too simplified, this allows us to quantitatively investigate the issue in a tractable way.\(^6\)

The representative household solves the following problem:

$$\max \left\{ C^h_t + D^h_t + Q_tK^h_t + f(K^h_t) = (Z_t + Q_t)K^h_{t-1} + R_{t-1}D^h_{t-1} + Z_tW^h \right\},$$

subject to

$$C^h_t + D^h_t + Q_tK^h_t + f(K^h_t) = (Z_t + Q_t)K^h_{t-1} + R_{t-1}D^h_{t-1} + Z_tW^h.$$

In the budget constraint, $Q_t$ denotes the market price of capital, and $Z_t$ means the aggregate productivity. She receives an endowment $Z_tW^h$ every period, and $R_{t-1}$ is the gross return on bank deposits from $t - 1$ to $t$.

The first order conditions are expressed as

$$\beta E_t \left[ \frac{C^h_t}{c^h_{t+1}} R^h_{t+1} \right] = 1,$$

$$\beta E_t \left[ \frac{C^h_t}{c^h_{t+1}} \right] R_t = 1,$$

\(^6\)In addition to this simplified case, Gertler and Kiyotaki (2013) also do an analysis of anticipated runs.
where \( R_{k+1}^{kh} = \frac{Z_{t+1} + Q_{t+1}}{Q_t + f'(k_t^h)} \) means the return on physical capital in case of holding it directly.

2.3 Bankers

Each banker manages a financial intermediary and bankers are homogeneous. In order to finance their capital investments, bankers have three options: issuing deposits to households, borrowing from foreign creditors (foreign debts), and using their own equity capital (net worth).

Bankers face financial constraints as follows. We assume that bankers can divert the fraction \( \theta \) of assets for personal use.\(^7\) We also assume creditors can force a banker who diverts into bankruptcy at the beginning of the next period. Then, since creditors are rational and know that banks have the incentive to divert assets, they will restrict the amount they lend. Hence bankers are constrained in their ability to obtain deposits.

In addition, we assume that bankers exit with probability \( 1 - \sigma \) for \( \sigma \in (0, 1) \). This assumption ensures that bankers cannot accumulate enough equity capital (net worth) to invest without borrowing from creditors. Every period, new bankers enter so that total population of bankers could be constant. Then new bankers have initial net worth \( \omega^b \), and exiting bankers consume all their net worth.

We assume that the bankers are risk neutral and obtain utility from their terminal consumption in the period they exit. Then they solve the following problem.

\[
\max_{\{d_t, b_t, k_t^b\}} V_t = E_t \left[ \sum_{i=0}^{\infty} \beta^i (1 - \sigma) \sigma^{i-1} c_{t+i}^b \right],
\]

subject to

\[
Q_t k_t^b = d_t + n_t + b_t, \tag{2.1}
\]

\[
n_t = \begin{cases} 
(Z_t + Q_t) k_{t-1}^b - r_{t-1} b_{t-1} - R_{t-1} d_{t-1}, & (\text{for surviving}) \\
\omega^b & (\text{for new bankers}) \end{cases} \tag{2.2}
\]

\[
V_t \geq \theta (Q_t k_t^b - c_b). \tag{2.3}
\]

\( (1 - \sigma) \sigma^{i-1} \) is the probability of exiting at date \( t + i \). \( c_{t+i}^b \) is the terminal consumption when the banker exits at \( t + i \). \( k_t^b \) means the direct capital holdings by the banker, \( d_t \) is the deposits invested by households, and \( n_t \) is the equity capital of banks (net worth). \( b_t \) represents the stock of foreign debts and \( r_{t-1} \) means the domestic interest rate on the debts held between periods \( t - 1 \) and \( t \).

\(^{7}\)For example, as in Gertler and Kiyotaki (2013), a banker can pay unwarranted bonuses to her family members.
(2.1) is the balance sheet of banks. The left hand side is the asset side (physical capital), and the right hand side is the liability side. (2.2) means the evolution of net worth.

(2.3) is the incentive constraint, which means the constraint on banker’s ability to collect deposit. As is discussed before, due to the moral hazard problem, there is a limit on the banker’s ability to collect funds. In particular, we assume that he can divert the fraction \( \theta \) of his assets. If a bank diverts assets, the creditors can re-claim the fraction \( 1 - \theta \) of funds. In order to prevent bankers from diverting, (2.3) means that the present discounted value from not diverting assets \( V_t \) must exceed the benefits from diverting. In the left hand side of (2.3), assets which can be diverted consist of total gross assets \( Q_t k^b_t \) net a fraction \( \epsilon \) for \( \epsilon \in [0, 1] \) of international borrowing \( b_t \). Here, \( \epsilon \) means the relative degree of frictions in the international market. In this way, we may permit the tightness of the constraint faced in international markets to differ from those in domestic deposits markets. If \( \epsilon = 1 \), bankers cannot divert asset financed by international borrowing. This implies the international market is frictionless. On the other hand, when \( \epsilon = 0 \), the degree of friction that constrains banker’s ability to collect funds in the international market is the same as in the domestic deposits markets.\(^8\)

To solve the problem, we guess that the franchise value \( V_t \) is a linear function of banker’s assets and liabilities. That is,

\[
V_t = \nu_{k,t} k^b_t - \nu_{b,t} b_t - \nu_{D,t} d_t. \tag{2.4}
\]

Notice that \( \nu_{k,t} \) means the marginal value of assets, \( \nu_{b,t} \) represents is the marginal cost of international borrowing, and \( \nu_{D,t} \) is the marginal cost of deposits.

Let \( x_t \) and \( \phi_t \) denote the fraction of bank assets financed by foreign debt and the maximum ratio of bank assets to net worth that satisfies the incentive constraint respectively:

\[
x_t = \frac{b_t}{Q_t k^b_t},
\]

\[
\phi_t = \frac{Q_t k^b_t}{d_t}.
\]

Then, using the balance sheet of banks (2.1), we can express (2.4) as

\[
V_t = [\mu_{1,t} + \mu_{2,t} x_t] Q_t k^b_t + \nu_{D,t} d_t
\]

where

\[
\mu_{1,t} = \frac{\nu_{k,t}}{Q_t} - \nu_{D,t},
\]

\[
\mu_{2,t} = \nu_{D,t} - \nu_{b,t}.
\]

\(^8\)We choose parameters to ensure that the constraint is always binding.
By the method of undetermined coefficients, we can show
\[
\begin{align*}
\mu_{1,t} &= \beta E_t \left[ \Omega_{t+1} \left( R_{t+1}^{kb} - R_t \right) \right], \\
\mu_{2,t} &= \beta E_t \left[ \Omega_{t+1} (R_t - r_t) \right], \\
\nu_{D,t} &= \beta E_t \left[ \Omega_{t+1} R_t \right].
\end{align*}
\]
where \(\Omega_{t+1} = (1 - \sigma) + \sigma (\mu_{1,t+1} + \mu_{2,t+1} x_{t+1}) \phi_{t+1} + \nu_{D,t+1}\) and \(R_{t+1}^{kb} = \frac{Z_{t+1} + Q_{t+1}}{Q_t}\).

Note that \(\Omega_{t+1}\) implies the stochastic shadow value of a unit of net worth to the bank at \(t+1\). For an exiting banker at \(t+1\) with probability \(1 - \sigma\), the shadow values must be unity. For a continuing banker with probability \(\sigma\), the shadow value is \(\frac{\partial V_t}{\partial n_t} = \left[ \mu_{1,t+1} + \mu_{2,t+1} x_{t+1} \right] \phi_t + \nu_{D,t+1}\). According to this expression, we learn that the shadow value for a continuing banker is the excess value of assets \(\left[ \mu_{1,t+1} + \mu_{2,t+1} x_{t+1} \right] \phi_t\) on an additional \(\phi_t\) units of assets plus an additional unit of net worth \(\nu_{D,t+1}\) she can save in deposits.

Then the bankers’ optimization problem is given by
\[
\max_{\{x_t, k_t^b\}} V_t = [\mu_{1,t} + \mu_{2,t} x_t] Q_t k_t^b + \nu_{D,t} n_t
\]
subject to
\[
\theta(1 - \epsilon x_t) Q_t k_t^b \leq V_t
\]
for \(\forall t \geq 0\). The constraint means the incentive constraint.

Let \(\lambda_t\) be the shadow value for the incentive constraint. Then we may express the first order conditions for \(k_t^b, x_t, \lambda_t\) as
\[
\begin{align*}
(\mu_{1,t} + \mu_{2,t} x_t)(1 + \lambda_t) &= \lambda_t \theta(1 - \epsilon x_t), \quad (2.5) \\
\mu_{2,t}(1 + \lambda_t) &= -\theta \epsilon \lambda_t, \quad (2.6) \\
V_t &= \theta(1 - \epsilon x_t) Q_t k_t^b. \quad (2.7)
\end{align*}
\]
When the incentive constraint is binding \((\lambda_t > 0)\), (2.5) states that bankers have the positive excess value of assets, which implies the net worth of banks is positive. In addition, according to (2.6), the marginal cost of foreign debts exceeds the marginal cost of domestic deposits. This is because assets funded by foreign debts are more difficult to divert than those financed by domestic deposits.

Finally, (2.7) is the incentive constraint. Using the guess \(V_s\), this can be expressed as
\[
\phi_t = \frac{\nu_{D,t}}{\theta(1 - \epsilon x_t) - \mu_{1,t} - \mu_{2,t} x_t}.
\]

\(^9\)Please see the appendix for details and the verification of the conjecture.
From (2.8), we learn that $\phi_t$ is increasing in the excess value of assets $\mu_{1,t} + \mu_{2,t}x_t$ and the deposits costs $\nu_{D,t}$ she can save in deposits. Intuitively, the increases in $\mu_{1,t} + \mu_{2,t}x_t$ or $\nu_{D,t}$ raise the bank’s franchise value $V_t$, which decrease the bankers’ incentive to divert. Then this leads (domestic and foreign) creditors to be happy to lend more. Hence the bank can invest more physical capital than her net worth $n_t$, which increases the ratio $\phi_t$. Conversely, the increases in $\theta$ reduce $\phi_t$.

Therefore (2.8) limits the portfolio size of the bank. In this respect, agency problem leads to an endogenous capital constraint.

When $\lambda_t > 0$, (2.5) and (2.6) give

$$\epsilon \mu_{1,t} = -\mu_{2,t}. $$

(2.9) determines the choice of the liability structure of banks.

Since $\phi_t$ is independent of individual specific factors, we can aggregate across banks to obtain the following aggregate variables of the banking system:

$$N_t = \sigma \left[ (Z_t + Q_t)K_{t-1}^{b} - R_{t-1}D_{t-1} - r_{t-1}B_{t-1} \right] + (1 - \sigma)w^b,$$

$$C_t^{b} = (1 - \sigma) \left[ (Z_t + Q_t)K_{t-1}^{b} - R_{t-1}D_{t-1} - r_{t-1}B_{t-1} \right],$$

$$Q_tK_t^{b} = D_t + N_t + B_t,$$

$$\phi_t = \frac{Q_tK_t^{b}}{N_t},$$

$$X_t = \frac{B_t}{Q_tK_t^{b}}.$$ 

### 2.4 Market Clearing

The output in the economy is

$$Y_t = K_t^{h}Z_t + K_t^{b}Z_t + Z_tW^{h} + W^{b} = Z_t + Z_tW^{h} + W^{b}.$$

Then the goods market must be cleared:

$$Y_t = f(K_t^{h}) + C_t^{h} + C_t^{b} + \Delta_t,$$

where $\Delta_t = r_{t-1}B_{t-1} - B_t$.

Deposit market is cleared,

$$D_t^{b} = D_t.$$

Capital market is also cleared,

$$K_t^{b} + K_t^{h} = 1.$$
2.5 Interest Rate on Internationally Traded Debts

Following García-Cicco, Pancrazi, and Uribe (2010) and Kollmann (2002), bankers face a debt-elastic interest-rate premium,

\[ r_t = r^* \xi_t + \psi(\exp(B_t - \bar{B}) - 1), \]  

(2.10)

where \( B_t \) is aggregate foreign debt.

2.6 Stochastic Process

In this model, we have two sources of uncertainty: Country premium shocks \( \xi_t \) and technology shocks \( Z_t \). For simplicity, we assume \( Z_t = Z \). \( \xi_t \) follows

\[ \log \xi_{t+1} = \rho \log \xi_t + \epsilon_{t+1}, \]

where \( \epsilon_t \) is iid and follows \( N(0, \sigma^2) \).

2.7 Equilibrium

An equilibrium consists of the allocations \( \{C^h_t, C^b_t, K^h_t, K^b_t, x_t, \phi_t, N_t, B_t, D_t, Y_t\}_{t=0}^\infty \) and a set of prices \( \{r_t, R_t, Q_r, R^{k,h}_t, R^{k,b}_t\}_{t=0}^\infty \) as a function of \( r_{t-1}B_{t-1}, R_{t-1}D_{t-1}, K^b_{t-1} \) and a given realization of exogenous shock such that for \( \forall t \)

1. household optimization problem,
2. banker’s optimization problem,
3. the foreign interest rates follow (2.10),
4. market clearing. \(^{10}\)

3 Bank Runs

As in Gertler and Kiyotaki (2013), we investigate the possibility of a unexpected bank run. In other words, when households invest deposits at \( t - 1 \) that mature in \( t \), they attach zero probability to a possibility of a bank run at \( t \). However, before realizing the return on bank assets at the beginning of \( t \), they must decide whether to roll over their deposits for another period or run. In this respect, the deposits from households are relatively short-term debts, while the bank assets are longer term.

\(^{10}\)See the appendix for details.
3.1 **Conditions for Bank Runs**

We impose three simplifying assumptions to simplify the analysis.

- a fraction $\gamma$ of depositors consider running at any moment and $\gamma$ is constant.
- bankers are committed to repay foreign debts under all circumstances.
- bankers attend to the requests of domestic depositors on a first come first served basis.$^{11}$

Then a bank run might occur when a household believes that bankers might not be able to satisfy their obligations on the remaining deposits if other households do not roll over their deposits. This implies that a run is possible if bankers’ liability to households exceed the liquidation value of bankers’ assets net the international borrowing at the fire-sale price $Q^*_t$ in the event of a forced liquidation such as bank runs. Hence, a run may occur if

$$
(Z_t + Q^*_t)K^b_{t-1} - r_{t-1}B_{t-1} < \gamma R_{t-1}D_{t-1}
$$

(3.1)

where $Q^*_t$ is the price of capital in the event of a forced liquidation. Since existing banks are homogeneous, the conditions for a run on the system are the same as for a run on any individual bank.

Let $\bar{Q}_t$ be the threshold value of the liquidation price below which bank runs may occur. That is, $\bar{Q}_t$ satisfies

$$(Z + \bar{Q}_t)K^b_{t-1} = \gamma R_{t-1}D_{t-1} + r_{t-1}B_{t-1}$$

Then, $\bar{Q}_t$ is expressed as

$$
\bar{Q}_t = \frac{\gamma R_{t-1}D_{t-1} + r_{t-1}B_{t-1}}{K^b_{t-1}} - Z
$$

Define $run_t$ that is the difference between $\bar{Q}_t$ and the fire sale price $Q^*_t$. Then the condition for bank runs (3.1) is equivalent to the following:

$$run_t = \bar{Q}_t - Q^*_t > 0.$$ 

Under a parametrization, $run_t$ is negative at its steady state. This means a bank run is not possible at steady state.

When we log-linearize it around its steady state $run^*$,

$$run^*\hat{run}_t > 0,$$

where hat means the percent deviation from the steady state. Since $run^* < 0$, we have

$$\hat{run}_t < 0.$$

$^{11}$This is called a sequential service constraint in the literature, as suggested in Wallace ((1996).
3.2 Determination of Liquidation Price

We assume the following. When bank runs occur at $t$,

- all banks must fully liquidate their assets that carried from $t - 1$,
- they must go out of business and they are also not able to borrow from foreigners,
- new bankers do not enter.

Let $\ast$ denote variables when bank runs occur. Then, when bank runs occur,

- Households hold all capital: $K_{t}^{h,\ast} = 1$.
- Bankers just consume their endowment: $C_{t}^{b,\ast} = W^{b} = C_{t}^{b,\ast}$.
- Household consumption: $C_{t}^{h,\ast} = ZW^{h} + Z - f(1) = C_{t}^{h,\ast}$ (from resource constraint).
- $D_{t}^{\ast} = 0$
- $B_{t}^{\ast} = 0$

From the household problem, we know

$$\beta E_{t} \left[ \frac{C_{t}^{h,\ast}}{C_{t+1}^{h,\ast}} R_{t}^{k,h,\ast} \right] = 1,$$

where

$$R_{t}^{k,h,\ast} = \frac{Z + Q_{t+1}^{\ast}}{Q_{t}^{\ast} + \alpha \bar{K}^{h}}.$$

By iterating this, we can express $Q_{t}$ as follows:

$$Q_{t}^{\ast} = Q^{\ast} = \sum_{i=0}^{\infty} \beta^{i} (Z - \alpha \bar{K}^{h}) - \alpha \bar{K}^{h}.$$

From this equation, we learn that the price of capital in the event of a forced liquidation $Q_{t}^{\ast}$ is constant in this setting.

4 Calibration

Table 1 presents the calibrated parameter values. The period of the model refers to a quarter. I follow the relevant studies on emerging economies.

- The discount factor is set to 0.98.
Following Gertler and Kiyotaki (2013), we set $\alpha$ and $\bar{K}^h$ to ensure that $K^h_t$ is strictly below $\bar{K}^h$ in the no bank run case.

- $\sigma$ is equal to 0.93. This means an expected horizon of three and half years.
- $\gamma$ is set to 0.75 as in Gertler and Kiyotaki (2013). We will change this value later.
- $\theta$ is chosen to hit the following target in steady state: a bank leverage ratio. The leverage ratio follows Fernández et al. (2013).
- The trade balance-output ratio comes from García-Cicco et al. (2010).
- $\phi$ follows Change and Fernandez (2013).
- $\epsilon = 0.5$. This means the degree of frictions for international borrowing is a half of that for domestic deposits market.
- We target the excess return $R^{k,b} - R$ equal to one hundred basis points annually. This follows Queralto (2013), which is based on evidence on BBB industrial corporate spreads in the US and Europe.
- $\rho_\xi$, $\sigma_\xi$, and $\psi$ are from García-Cicco, Pancrazi, and Uribe (2010).

### Table 1:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>0.98</td>
<td>Discount factor</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>0.93</td>
<td>Bankers survival probability</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.5</td>
<td>Fraction of depositors that can run</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.02</td>
<td>Household managerial cost</td>
</tr>
<tr>
<td>$\bar{K}^h$</td>
<td>0.48</td>
<td>Threshold capital for managerial cost</td>
</tr>
<tr>
<td>$\theta$</td>
<td>0.26</td>
<td>Fraction of assets that bankers can divert</td>
</tr>
<tr>
<td>$NX/Y$</td>
<td>0.25 percent</td>
<td>Trade balance/Output</td>
</tr>
<tr>
<td>$\phi$</td>
<td>8.30</td>
<td>Ratio of asset to net worth</td>
</tr>
<tr>
<td>$\epsilon$</td>
<td>0.5</td>
<td>the relative degree of friction in the international market</td>
</tr>
<tr>
<td>$R^{k,b} - R$</td>
<td>100 basis point</td>
<td>Steady state of $R^{k,b}_t - R$</td>
</tr>
<tr>
<td>$\psi$</td>
<td>0.001</td>
<td>Sensitivity of the country interest rate premium</td>
</tr>
<tr>
<td>$\rho_\xi$</td>
<td>0.91</td>
<td>Country premium autocorrelation</td>
</tr>
<tr>
<td>$\sigma_\xi$</td>
<td>0.056</td>
<td>Std. dev. of innovations</td>
</tr>
</tbody>
</table>
5 Numerical Results

5.1 Results: The Role of Foreign Interest Rate Shocks

After log-linearizing the model around the steady states, Figure 1 shows the impulse response functions of net worth and $run_t$ to a positive shock to foreign interest rates. It is useful to see the impacts of foreign interest rate shocks around the steady state. We learn that an increase in the foreign interest rate decreases net worth of banks. Then this figure implies that bank runs might occur.  

![Figure 1: Responses to foreign interest rate shocks](image)

6 Conclusion

Using a general equilibrium model with a banking sector, this paper evaluates the quantitative implications of foreign interest rate shocks on the possibility of bank runs. We show that the shocks may generate bank runs.

We impose many assumptions to simplify the analysis. We may relax some of them in the future: endowment economy, the assumption that a fraction $\gamma$ of depositors consider running, the unexpected bank runs, and so on.

I am trying to solve the fully nonlinear model now, using the policy function iteration. The algorithm follows the methods developed in Richter et al. (2013). I discretize the state space, using 15 points in each grid. I use time iteration to solve for the updated policy rules until the tolerance criterion ($10^{-7}$) is met. When I interpolate the policy functions, I am based on the linear interpolation. However, unfortunately, I have not yet obtained results. The results will be replaced later.
References


A GUESS AND VERIFY

Bankers solve the following

$$\max_{\{d_{t+i},b_{t+i},k_{t+i}^b\}_{i=0}^{\infty}} V_t = E_t \left[ \sum_{i=0}^{\infty} \beta^i (1 - \sigma) \sigma^{i-1} c_{t+i}^b \right],$$

subject to

$$Q_t k_t^b = d_t + n_t + b_t, \quad \text{(A.1)}$$

$$n_t = \begin{cases} (Z_t + Q_t) k_{t-1}^b - r_{t-1} b_{t-1} - R_{t-1} d_{t-1}, & \text{(for surviving)} \\ \omega^b & \text{(for new bankers)} \end{cases} \quad \text{(A.2)}$$

$$V_t \geq \theta(Q_t k_t^b - \epsilon b_t). \quad \text{(A.3)}$$

Notice that the bank’s franchise value $V_t$ can be expressed recursively

$$V_t = E_t[(1 - \sigma)n_{t+1} + \beta \sigma V_{t+1}]. \quad \text{(A.4)}$$

Then guess $V_t$ as follows:

$$V_t = (\mu_{1,t} + \mu_{2,t} x_t) Q_t k_t^b + \nu_{D,t} n_t. \quad \text{(A.5)}$$

Substituting (A.5) at $t + 1$ into (A.4) ,

$$V_t = E_t[(1 - \sigma)n_{t+1} + \sigma(\mu_{1,t+1} + \mu_{2,t+1} x_{t+1}) Q_{t+1} k_{t+1}^b + \sigma \nu_{D,t+1} n_{t+1}]. \quad \text{(A.6)}$$

Define

$$\phi_{t+1} = \frac{Q_{t+1} k_{t+1}^b}{n_{t+1}},$$

$$R_{t+1}^{kk} = \frac{Z_{t+1} + Q_{t+1}}{Q_t},$$

$$\Omega_{t+1} = (1 - \sigma) + \sigma(\mu_{1,t+1} + \mu_{2,t+1} x_{t+1}) \phi_{t+1} + \sigma \nu_{D,t+1}.$$

Using (A.2), we can express (A.6) as

$$V_t = \beta E_t[\Omega_{t+1} (R_{t+1}^{kk} - R_t + (R_t - r_t) x_t) Q_t k_t^b] + \beta E_t[\Omega_{t+1} R_t] n_t. \quad \text{(A.7)}$$

Then, comparing (A.5) with (A.7), we have

$$\mu_{1,t} = \beta E_t [\Omega_{t+1} (R_{t+1}^{kk} - R_t)],$$

$$\mu_{2,t} = \beta E_t [\Omega_{t+1} (R_t - r_t)],$$

$$\nu_{D,t} = \beta E_t [\Omega_{t+1} R_t].$$
B EQUILIBRIUM CONDITIONS

An equilibrium consists of the allocations \( \{C_t^h, C_t^b, K_t^h, K_t^b, x_t, \phi_t, N_t, B_t, D_t, Y_t, \mu_{1,t}, \nu_{D,t}, \Omega_t, \Delta_t\}_{t=0}^{\infty} \) and a set of prices \( \{r_t, R_t, Q_r, R_t^{k,h}, R_t^{k,b}\}_{t=0}^{\infty} \) as a function of \( r_{t-1}B_{t-1}, R_{t-1}D_{t-1}, K_{t-1}^b \) and a given realization of exogenous shock such that for \( \forall t \)

1. household optimization problem,
2. banker’s optimization problem,
3. the foreign interest rates follow (2.10),
4. market clearing.

The equilibrium conditions are the following:

From the household optimization

\[
\beta E_t \left[ \frac{c_t^h}{c_{t+1}^h} R_{t+1}^{kh} \right] = 1 \tag{B.1}
\]

\[
\beta E_t \left[ \frac{c_t^b}{c_{t+1}^b} \right] R_t = 1 \tag{B.2}
\]

\[
R_{t+1}^{kh} = \frac{Z_{t+1} + Q_{t+1}}{Q_t + f'(k_{t+1}^h)} \tag{B.3}
\]

From the bankers’ problem

\[
\mu_{1,t} = \beta E_t [\Omega_{t+1}(R_{t+1}^{kh} - R_t)] \tag{B.4}
\]

\[
\nu_{D,t} = \beta E_t [\Omega_{t+1}] R_t \tag{B.5}
\]

\[
R_t = r_t \tag{B.6}
\]

\[
R_{t+1}^{kh} = \frac{Z_{t+1} + Q_{t+1}}{Q_t} \tag{B.7}
\]

\[
\nu_{D,t} = \phi_t(\theta - \mu_{1,t}) \tag{B.8}
\]

\[
\Omega_{t+1} = 1 - \sigma + \sigma \theta \phi_{t+1} \tag{B.9}
\]

From the aggregation

\[
Q_t K_t^b = \phi_t N_t \tag{B.10}
\]

\[
x_t = \frac{B_t}{Q_t K_t^b} \tag{B.11}
\]

\[
N_t = \sigma(Z_t + Q_t)K_{t-1}^b - \sigma(r_{t-1}B_{t-1} + R_{t-1}D_{t-1}) + W^b \tag{B.12}
\]

\[
C_t^b = (1 - \sigma)(Z_t + Q_t)K_{t-1}^b - (1 - \sigma)(r_{t-1}B_{t-1} + R_{t-1}D_{t-1}) \tag{B.13}
\]

\[
Q_t K_t^b = D_t + B_t + N_t \tag{B.14}
\]
From the market clearing

\[ Y_t = Z_t + Z_t W^h + W^b \]  \hspace{1cm} (B.15)

\[ = \frac{\alpha}{2} (k_t^h)^2 + C_t^h + C_t^b + \Delta_t \]  \hspace{1cm} (B.16)

\[ \Delta_t = r_{t-1} B_{t-1} - B_t \]  \hspace{1cm} (B.17)

\[ K_t^h + K_t^b = 1 \]  \hspace{1cm} (B.18)

The foreign interest rate \( r_t \) follows

\[ r_t = r^\ast \xi_t + \psi \left( \exp(B_t - \bar{B}) - 1 \right) \]  \hspace{1cm} (B.19)

\[ \log \xi_{t+1} = \rho \xi \log \xi_t + \xi_{t+1} \]  \hspace{1cm} (B.20)

and finally \( Z_t = Z \).