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Bank Runs and Business Cycles in a Small Open Economy

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This paper incorporates financial intermediaries within a small open DSGE model and studies the effects of bank runs on economic activities. Shocks to the world interest rate induce capital outflows and asset price reduction, and the decline in asset prices weakens intermediaries' balance sheets, making them vulnerable to bank runs and leading, in turn, to a more severe and persistent recession. Our model is successful in generating some key properties observed in emerging market business cycles. We also asses the stabilization effect of capital control policy, numerical experiment suggests that countercyclical tax on capital flows is effective in absorbing the disturbance from external financial shocks and reducing the probability of bank runs.

Key Words: Bank runs; Financial frictions; Business cycles; Capital control.
JEL Classification Numbers: E32, E44, F41.

1. INTRODUCTION

Financial distresses have been playing an increasingly important role in economic fluctuations, not only in developed countries but also in emerging economies. Emerging economies often suffer from the large changes in world financial conditions. These kinds of crises feature tremendous capital outflow, current account surplus and output contraction. Economists describe this phenomenon as Sudden Stops. In this paper, we build a general equilibrium model to capture these main regularities in emerging economic business cycles and propose an implementable policy to stabilize the economy by insulating the impact of foreign financial disturbances.

There is a large body of literature on emerging economy business cycles, and the studies mainly focus on explaining the higher volatility of output, consumption, and investment than that observed in developed countries. To capture the great volatility in emerging economies, economists have in-

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corporated many types of financial frictions into the standard small open RBC model developed by Mendoza (1991); these frictions include risk premium and working capital (Neumeyer and Perri 2005), financial accelerator (Fernández 2015) and so on. The modifications cited above can successfully generate enough volatility, however, they are not capable of capturing two key properties observed during business cycles: nonlinearities and asymmetries. In addition, the previous research has ignored the connection between the collapse of financial systems and business cycles. Motivated by these empirical facts, we build a model to provide a possible explanation for financial panics and recessions in emerging economies.

The aim of this paper is to present a general equilibrium framework that can reproduce some key features of emerging economy fluctuations and assess the effectiveness of capital control policy on reducing financial risks. To do so, we develop a small open economy model with financial intermediations that allows bank runs to happen. Financial intermediaries can manage capital more efficiently than households, but they are subject to financial constraints that limit the amount of assets that they can acquire. During business cycles, pro-cyclical movement in intermediaries' balance sheets weakens their ability to repay liabilities; if creditors think bankers are not credible and withdraw their deposits before maturity, intermediaries are forced to liquidate their assets and go to bankruptcy, causing bank runs to occur. Bank runs in our model are self-fulfilling because a liquidation problem will never occur if depositors keep rolling over their deposits, as financial constraints are always satisfied without liquidation of assets.

The financial accelerator mechanism still works in our model, but with larger amplification effects. This is because both the net worth of financial intermediaries and asset prices drop larger in this framework, thus the demand for capital also goes to a lower level, far below that without bank runs. Besides dampening the demand for investment by the balance sheet effect, financial frictions in our model also damage the supply side of the economy. In the presence of financial constraints, intermediaries' ability to improve efficiency by facilitating the allocation of capital to more productive sectors has been limited, so a portion of capital is managed by less productive households, as a result, the average productivity of capital is below the optimal level. In a bank run equilibrium, intermediaries sell their assets to households and exit from the market at the time when a bank run occurs, thus the productivity of capital declines further. By impacting both the demand side and the supply side, the financial frictions that we have considered display a much bigger amplification effect than shown in literature.

Our model is successful in generating some key regularities of business cycles in emerging economies, such as capital outflows, financial turmoil, as well as nonlinearities and asymmetries. Once a bank run occurs, there would be a dramatic decline in, for example, output, investment and asset prices. However the recession caused by a small shock is much milder, as it is amplified only by the financial accelerator. So, the responses of economic variables to a large shock and small one are nonlinear. For a similar reason, positive shocks are less amplified than are negative shocks, and this is the origin of asymmetries. Moreover, when a bank run happens, the reallocation of capital leads to the decline in measured productivity, which is also a key feature in financial crises. Many researches address this phenomenon by introducing capital utilization, but our work provides a more intuitive explanation.

We also shed light on the effect of capital control policy on stabilizing the economy. Quantitative simulation suggests that countercyclical tax on capital flows can reduce the probability of bank runs. Bank runs happen when balance sheets deteriorate and depositors believe that the value of capital held by intermediaries is not enough to cover their liabilities, in this situation, households have incentive to stop rolling over their deposits and banks go to bankruptcy. With capital control tax being in place, capital outflow during recession is mitigated, and the degree of the decrease in asset prices is lower than that without the intervention. Thus, intermediaries would have healthier balance sheets and be less likely to meet solvency problems under the protection of capital control.

Our model builds on the work of Gertler and Kiyotaki (2015) and Gertler, Kiyotaki and Prestipino (2016), which outline a new framework to analyze bank runs in an infinite horizon endowment economy. Their work was then extended by Gertler, Kiyotaki and Prestipino (2017) to an economy with production and sticky prices to study financial panics. There are two main differences between our work and Gertler, Kiyotaki and Prestipino (2017): the first is that we focus on an open economy, and the shock we consider is from foreign sector. The second is that, instead of assuming that holding capital leads to disutility, we postulate that households are less efficient in managing productive capital, as proposed by Brunnermeier and Sannikov (2014). This assumption is more intuitive than that utilized by Gertler, Kiyotaki and Prestipino (2017) as the main function of financial sector is to acchive resource allocation efficiency in real world.

Our research shares some similarity with Mendoza (2010), who studied sudden stops in an economy with collateral constraint. In Mendoza's paper, the capacity to borrow from a foreign country is limited by the value of the borrower's assets; when financial constraint change from slackness to bindingness, capital inflows stop and there are current account reversals. Similar research dealing with nonlinearities can also be found in Brunnermeier and Sannikov (2014). In our model, the great recession also comes from the deterioration of the financial market and the limitation of borrowing capacity, though in a different manner.

This paper is also related to a strand of literature concerning macroprudential policies in emerging economies, such as Gertler, Gilchrist and Natalucci (2007) and Davis and Presno (2017). Gertler, Gilchrist and Natalucci (2007) successfully generates the Korean business cycle properties during the Asian financial crises and studied different exchange rate regimes in a model with financial accelerators. Davis and Presno (2017) advocates the use of capital control thus monetary policy can concentrate on price stabilization. Bianchi (2011) and Korinek and Sandri (2016) also suggest the use of capital control to improve social welfare, but their proposals are based on the assumption that externalities exist, and, thus, agents tend to overborrowing, with the result that government intervention is needed to offset the market imperfectness.

This article is organized as follows. Section 2 describes the model framework. Section 3 reports the results of our numerical experiment and section 4 concludes.

2. MODEL

We start with a description of the model setup. There are five types of agents in the economy: households, financial intermediaries, the intermediate goods producer, the capital producer and monopolistic retailers. In addition, there is a government that conducts monetary and macroprudential policies and a foreign sector.

2.1. Households

We assume there is a continuum of identical households in the economy, within a household, $1-f$ fraction of household members are bankers and the remaining f fraction are workers. The workers supply labour and earn wages in a perfect competitive labour market, and each banker manages a financial intermediary and transfers it's profits to the household. Within the family, each member consumes the same amount of consumption goods. Households have access to three different assets: bank deposits, foreign bonds and physical capital. However, we assume that the capital held by households is less productive than is that held by financial intermediaries.

The representative household has the utility form:

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t U(C_t, N_t) \right\} \tag{1}$$

where C_t and N_t are consumption and labour supply respectively, and β is the subjective discount factor. The household chooses consumption, hours to work and portfolio choice to maximize its lifetime utility. The sequence of budget constraints is as follows:

$$C_t + Q_t K_{t+1}^h + D_t + S_t B_t^f = w_t N_t + \chi\left(\frac{K_t^h}{K_t}\right) r_t^k K_t^h + (1-\delta) Q_t K_t^h + R_{t-1} D_{t-1} + S_t R_{t-1}^f B_{t-1}^f + \Pi_t \quad (2)$$

where K_t^h is the capital owned by the household at the beginning of period t; K_t is the total amount of capital in the economy, and $\chi\left(\frac{K_t^h}{K_t}\right)$ is the productivity of households, which is smaller than one and decreases as the share of household capital increases. δ is the depreciate rate and Q_t is the real price of capital in terms of consumption goods, w_t denotes the real wage, r_t^k represents the real return on capital; D_t is the real bank deposits owned by the household, with the rate of return R_t; S_t is the real exchange rate, B_t^f represents bonds issued by the foreign sector. The rate of return on foreign bonds R_t^f depends on the world interest rate and an endogenous risk premium:

$$R_t^f = R_f^* \exp\left[-\varsigma(B_t - \bar{B})\right] \quad (3)$$

this assumption is required to induce a stable model, and we set ς very small in numerical exercises.

The first order conditions of the household are:

$$E_t\left(\Lambda_{t,t+1} R_t\right) = 1 \quad (4)$$

$$E_t\left[\Lambda_{t,t+1}\frac{S_{t+1}}{S_t}\left(R_t^f - R_t\right)\right] = 0 \quad (5)$$

$$-\frac{U_{N,t}}{\Xi_t} = w_t \quad (6)$$

$$Q_t = E_t\left\{\Lambda_{t,t+1}\left[\chi\left(\frac{K_{t+1}^h}{K_{t+1}}\right) r_{t+1}^k + Q_{t+1}(1-\delta) + \chi'\left(\frac{K_{t+1}^h}{K_{t+1}}\right)\frac{K_{t+1}^h}{K_{t+1}} r_{t+1}^k\right]\right\} \quad (7)$$

where $\Xi_t = U_c(C_t, N_t)$ is the marginal utility and $\Lambda_{t,t+1} = \beta\frac{\Xi_{t+1}}{\Xi_t}$ is the stochastic discount factor. (4) is the Euler's equation, and (5) specifies the optimal demand of foreign assets; from these two conditions we can see that the return on domestic and foreign bonds are the same after being adjusted by the expected change in the exchange rate, i.e., the uncovered interest parity condition holds. Equation (6) gives the optimal condition of the labour supply. And equation (7) determines the capital demand of the household.

The consumption goods is composed of foreign and domestic goods using the following technology:

$$C_t = \left[\gamma^{\frac{1}{\eta}} C_{H,t}^{1-\frac{1}{\eta}} + (1-\gamma)^{\frac{1}{\eta}} C_{F,t}^{1-\frac{1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{8}$$

where $C_{H,t}$ and $C_{F,t}$ are goods that are produced by firms in the home country and the foreign country, respectively, γ is the parameter determining the relative importance of the two goods in home market, and η is the elasticity of substitution. Let $P_{H,t}$ and $P_{F,t}$ be the prices of the two kinds of goods in the home currency, then the price level of final goods C_t is given by $P_t = \left[\gamma P_{H,t}^{1-\eta} + (1-\gamma) P_{F_t}^{1-\eta}\right]^{\frac{1}{1-\eta}}$; thus, the demand functions of domestic and foreign goods are:

$$C_{H,t} = \gamma \left[\frac{P_{H,t}}{P_t}\right]^{-\eta} C_t \tag{9}$$

$$C_{F,t} = (1-\gamma) \left[\frac{P_{F,t}}{P_t}\right]^{-\eta} C_t \tag{10}$$

For simplicity, we take the price of foreign goods $P_{F,t}$ as given and set it to unity, hence the real price of imported goods equals the real exchange rate.

2.2. Financial Intermediaries

There is a continuum of financial intermediaries who purchase capital from the the capital producer for the next period's production. Intermediaries finance their investment by issuing one period deposits to households and offer risk free interest rates. Note that different from the traditional setting, whereby banks buy state contingent securities issued by the intermediate goods producer, we postulate that banks hold capital directly and rent to the firm in a competitive rental market. These two setups lead to the same outcome since there are no frictions between intermediaries and the production sector. The return on capital equals the rental rate plus the value of capital after depreciation:

$$R_t^k = \frac{r_t^k + Q_t(1-\delta)}{Q_{t-1}} \tag{11}$$

Let $NW_{j,t}$ be the net worth of a specific bank at the beginning of period t, and $D_{j,t}$ denotes the deposits it acquires from the household, we can express the bank's balance sheet as:

$$Q_{j,t} K_{j,t}^b = NW_{j,t} + D_{j,t} \tag{12}$$

where $K^b_{j,t}$is the amount of assets the bank purchases, and the net worth at the end of period $t+1$ equals the gain from investment activity minus the payment to depositors:

$$\begin{aligned} NW_{j,t+1} &= R^k_{t+1}Q_{j,t}K^b_{j,t} - R_t D_{j,t} \\ &= R^k_{t+1}Q_{j,t}K^b_{j,t} - R_t(Q_{j,t}K^b_{j,t} - NW_{j,t}) \\ &= (R^k_{t+1} - R_t)Q_{j,t}K^b_{j,t} + R_t NW_{j,t} \end{aligned} \tag{13}$$

To avoid self-financing, we assume that, in each period, every bank has an i.i.d. probability σ of surviving until the next period and a probability $1-\sigma$ of exiting. The assets of exited banks is transferred to the household. We use $V_{j,t}$ to denote the market value of a bank that still operates at period t, thus $V_{j,t}$ is given by:

$$V_{j,t} = \max_{S_{j,t},D_{j,t}} E_t \left\{\Lambda_{t,t+1}\left[(1-\sigma)NW_{j,t+1} + \sigma V_{j,t+1}\right]\right\} \tag{14}$$

And we also assume that a moral hazard problem exists here. Like Gertler and Karadi (2011), we suppose that, at the beginning of each period before returns on investment are realized, a bank can divert a fraction θ of assets for personal use and then exit from the economy. Thus, for the bank not to withdraw it's business, the following incentive constraint must be satisfied:

$$V_{j,t} \geq \lambda Q_{j,t}K_{j,t+1} \tag{15}$$

Which means that the bank's value of staying in the market is not less than the value of the amount of assets that can be diverted. The motivation of diverting assets introduces a limit on banks' ability to issue deposits, if the constraint is binding, the total assets of a bank is a constant proportion of it's market value. In equilibrium, inequality (15) is always holding, otherwise the household would not save assets as bank deposits, as they could soon be stolen by bankers. The bank chooses the volume of deposits and the quantity of capital to maximize it's present value (14) under the constraints of (12) and (15). Guessing that $V_{j,t}$ is proportional to the net worth:$V_{j,t} = \psi_{j,t}NW_{j,t}$, substituting it into (14) and solving the maximization problem, we can find the evolution function of $\psi_{j,t}$:

$$\psi_t = E_t\left\{\Lambda_{t,t+1}\left[(1-\sigma+\sigma\psi_{t+1})\left(\frac{\psi_t}{\lambda}(R^k_{t+1}-R_t)+R_t\right)\right]\right\} \tag{16}$$

We have omitted j from the subscripts because every banker face the same first order condition, so ψ_t depends only on aggregate shocks and each bank has the same marginal value ψ_t. To derive (16), we have used the condition that the incentive constraint is always binding, and it is easy to show that (15) is binding if $E_t\left(R_t^k - R_t\right) \geq 0$. That is very intuitive, if the rate of return on investment is greater than the interest rate of deposits, banks will absorb deposits and buy assets at full capacity.

At each period, $(1-f)\sigma$ bankers exit and the same amount of new bankers enter the economy. Every new banker receives a transfer from the household as startup capital, and we assume that the total new capital transferred to bankers is a constant proportion of the aggregate capital in the economy. The aggregate net worth of the banking sector evolves according to:

$$NW_t = \sigma\left[r_t^k K_t^b + Q_t(1-\delta)K_t^b - R_{t-1}D_{t-1}\right] + \omega Q_t K_t \tag{17}$$

The fist term on the righthand side of equation (17) is the net worth of banks that survived from the previous period, and the second term is the newly injected capital.

2.3. Capital Producer

The representative capital producer repurchases depreciated capital and combines it with investment goods I_t to produce capital stock that will be used in production in the next period, the technology used for capital production is as follows:

$$K_{t+1} = (1-\delta)K_t + \left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right] I_t \tag{18}$$

where $S(\cdot)$ is the adjustment cost, which is concave and satisfies $S(1) = 0$, $S'(1) = 0$. Since the capital producer is owned by households, it chooses investment level I_t to maximized the sum of profits discounted by the discount factor of households:

$$E_0\left\{\sum_{t=0} \beta^t \frac{\Xi_t}{\Xi_0}\left[Q_t K_{t+1} - I_t - Q_t(1-\delta)K_t\right]\right\}$$

the optimal investment rate is given by the following condition:

$$\begin{aligned} 1 = Q_t &\left[1 - S\left(\frac{I_t}{I_{t-1}}\right) - S'\left(\frac{I_t}{I_{t-1}}\right)\frac{I_t}{I_{t-1}}\right] \\ &+ E_t\left\{\Lambda_{t,t+1} Q_{t+1} S'\left(\frac{I_{t+1}}{I_t}\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right\} \end{aligned} \tag{19}$$

if the adjustment cost is absent, the price of capital equals one.

The investment goods are the same as the consumption goods, thus the capital producer's demands for domestic and foreign goods are given by:

$$I_{H,t} = \gamma \left[\frac{P_{H,t}}{P_t}\right]^{-\eta} I_t \tag{20}$$

$$I_{F,t} = (1-\gamma) \left[\frac{P_{F,t}}{P_t}\right]^{-\eta} I_t \tag{21}$$

2.4. Intermediate Firm

The intermediate goods firm is perfectly competitive, it uses labor and capital to produce intermediate goods. It's production function is:

$$Y_t = A_t \hat{K}_t^{\alpha} N_t^{1-\alpha} \tag{22}$$

where $\hat{K}_t = K_t^b + \chi\left(\frac{K_t^h}{K_t}\right) K_t^h$ is the total effective capital in the economy. The cost minimization incentive leads to the following demands for capital and labour:

$$\frac{r_t^k}{w_t} = \frac{\alpha}{1-\alpha}\frac{N_t}{\hat{K}_t} \tag{23}$$

and the real price of intermediate goods equals to the marginal cost, as the zero profit condition must be satisfied,

$$P_t^w = P_t(1-\alpha)^{\alpha-1}\alpha^{-\alpha}\frac{1}{A_t}{r_t^k}^{\alpha}{w_t}^{1-\alpha} \tag{24}$$

The rent of capital is paid to households and financial intermediaries.

2.5. Retailers

There are infinite monopolistic competitive retailers with measure 1, and each firm buys intermediate goods and differentiates the goods without cost into $Y_{i,t}$. The domestic goods is a CES combination of a continuum of differentiated goods:

$$Y_{H,t} = \left(\int {y_{i,t}}^{1-\frac{1}{\rho}} \mathrm{d}i\right)^{\frac{\rho}{\rho-1}} \tag{25}$$

Thus, the price of $Y_{H,t}$ is $P_{H,t} = \left(\int {p_{i,t}}^{1-\rho}\mathrm{d}i\right)^{\frac{1}{1-\rho}}$, where $p_{i,t}$ is the price of goods i. Cost minimization behaviors of households and the capital producer imply that the demand of the firm's product is:

$$Y_{i,t} = \left[\frac{p_{i,t}}{P_{H,t}}\right]^{-\rho} Y_{H,t} \tag{26}$$

In order to introduce price stickiness into our model, we assume, at each period, that every retailer can reset the price of it's own goods but faces an adjustment cost as proposed by Rotemberg (1982). So firm i chooses the price to maximize the sum of its discounted profits:

$$E_t \left\{ \sum_{s=0}^{\infty} \beta^s \frac{\Xi_{t+s}}{\Xi_t} \left[\left(\frac{p_{i,t+s}}{P_{t+s}} - P_{t+s}^w \right\} \right) Y_{i,t+s} - \frac{\theta}{2} Y_{H,t+s} \left(\frac{p_{i,t+s}}{p_{i,t+s-1}} - 1 \right)^2 \right] \tag{27}$$

deriving the fist order condition and imposing symmetry of each firm, we can obtain the following Phillip's curve:

$$\left(\frac{P_{H,t}}{P_{H,t-1}} - 1 \right) \frac{P_{H,t}}{P_{H,t-1}} = \frac{\rho}{\theta} \left(P_t^w - \frac{\rho - 1}{\rho} \frac{P_{H,t}}{P_t} \right) + E_t \left[\beta \frac{\Xi_{t+s}}{\Xi_t} \frac{Y_{H,t+1}}{Y_{H,t}} \left(\frac{P_{H,t+1}}{P_{H,t}} - 1 \right) \frac{P_{H,t+1}}{P_{H,t}} \right] \tag{28}$$

in the steady state, the real price of domestic goods equals the marginal cost of intermediate goods adjusted by a constant markup.

2.6. Monetary Policy

We assume that the central bank adjusts the nominal interest rate according to a standard Taylor rule:

$$\frac{i_t}{i} = {\pi_t}^{\phi_\pi} \left(\frac{Y_{H,t}}{Y_{H,t}} \right)^{\phi_y} \tag{29}$$

where $i_t = E_t \left(R_t \pi_{t+1} \right)$ is the nominal interest rate.

2.7. Equilibrium

In equilibrium, the aggregate demand for H country goods is the sum of domestic consumption, investment, export and price adjustment cost:

$$Y_{H,t} = C_{H,t} + I_{H,t} + EX_t + \frac{\theta}{2} Y_{H,t} \left(\frac{P_{H,t}}{P_{H,t-1}} - 1 \right)^2 \tag{30}$$

and the aggregate demand equals aggregate supply:

$$Y_{H,t} = Y_t \tag{31}$$

for simplicity, we assume the foreign demand for domestic goods EX_t is constant. In addition, the current account is defined by:

$$CA_t = P_{H,t} EX_t - S_t Y_{F,t} \tag{32}$$

2.8. Bank Runs

There are two equilibria in our model: a traditional equilibrium and a equilibrium with bank runs. Bank runs occur when households stop rolling over deposits and banks have to sell assets to repay their liabilities. Selling assets causes capital price to fall, and households withdraw their deposits before maturity only if banks cannot repay their deposits at the liquidation price. Let Q_t^* be the liquidation price of capital if banks sell all their capital holdings to households, and a bank run is possible if the value of the assets owned by banks is smaller than the total claim of the creditor:

$$\left[r_t^k + Q_t^*(1-\delta)\right] K_{t-1}^b \leq R_{t-1} D_{t-1} \tag{33}$$

if we define $\bar{Q}_t$ as the threshold level of asset price that makes banks breakeven:

$$\left[r_t^k + \bar{Q}_t(1-\delta)\right] K_{t-1}^b = R_{t-1} D_{t-1} \tag{34}$$

then a run can occur if and only if the liquidation price is below the threshold level:

$$Run = Q_t^* - \bar{Q}_t \leq 0 \tag{35}$$

Where *Run* is an indicator for the existence of a bank run equilibrium. We consider only unanticipated bank runs, thus a household does not take into account the possibility of a bank run when making decisions. And a bank run comes as a sunspot shock when inequality (34) is satisfied.

3. NUMERICAL EXPERIMENT

3.1. Functional Forms and Calibration

In this section, before conducting a numerical experiment, we choose functional forms and parameter values. The functional forms of preference, household productivity, and capital adjustment cost are the following:

$$U(C_t, N_t) = \frac{1}{1-\sigma_c}\left[C_t - \nu \frac{{N_t}^{1+\varphi}}{1+\varphi}\right]^{1-\sigma_c} \tag{36}$$

$$\xi\left(\frac{K_t^h}{K_t}\right) = \bar{\xi}\left[1 - \frac{\vartheta}{2}\left(\frac{K_t^h}{K_t} - 0.5\right)^2\right] \tag{37}$$

$$S\left(\frac{I_t}{I_{t-1}}\right) = \frac{\Psi}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 \tag{38}$$

We assume that the utility function takes the Greenwood, Hercowitz and Huffman (1988) form, thus the income effects on labor supply is eliminated.

And the household productivity specified in function (37) representing the efficiency of the household in managing capital is decreasing if the capital share of the household exceeds the steady state level, which will be determined later.

The values assigned to parameters are listed in TABLE 1. Some parameters are standard in DSGE models and and we use conventional values for those parameters. To be specific, we set $\beta = 0.99$, $\alpha = 0.5$, and $\delta = 0.025$, these values are used widely and are consistent with the real interest rate, the capital income share in emerging economies, and the ratio of investment to capital. The risk aversion parameter σ_c and the inverse of labour supply elasticity φ are set to 2 and 0.6, respectively, which are used in Fernández and Gulan (2015). We choose ν to ensure that the steady state labour supply is 0.35. The values of ρ and Ψ are 10 and 2.48, respectively, taken from the estimations of Smets and Wouters (2003). The elasticity of substitution between domestic and foreign goods is 3 and the share of domestic goods in consumption and investment is 0.5, which is consistent with Davis and Presno (2017). We set θ to be 105, which makes the elasticity of inflation rate to marginal cost is consistent with that in Calvo settings with a average duration of newly setting price being 4 quarters.

The parameters values related to the banking sector and household productivity are of vital importance to our model. We choose parameter values to meet the following targets: (1)the steady state share of bank capital is 50%, (2) the steady state leverage of the banking sector equals 5; and (3) the average excess rate of return on capital over deposits is 2%. ϑ doesn't influence steady states, but it captures the sensitivity of the response of capital price to economic fluctuations. Under our value choice of ϑ, the economy is not threatened by bank runs in steady states, but runs become possible when some negative shocks occur.

Following the standard Taylor rule, we set $\phi_\pi = 1.5$ and $\phi_y = 1$.

3.2. Model Dynamics

In this section, we study the dynamic behavior of of our economy after it is hit by an external shock. The shock we consider is an unexpected 25 basis points' rise in the world interest rate, with a quarterly autoregressive factor of 0.9. Figure 1 displays the impulse responses of some key variables.

The economy experiences a recession after a hike in foreign interest rate, as investment, consumption and output all decrease, and a similar response is observed in the financial intermediaries' net worth. The effect of external shock is amplified by a financial accelerator mechanism, as documented by previous research (Gertler and Karadi 2011). By inducing households to consume less and invest more in foreign bonds, an unexpected surge in the world interest rate pushes up the domestic risk free rate. Meanwhile, the demand for investment decreases due to the increase in funding cost and

TABLE 1.

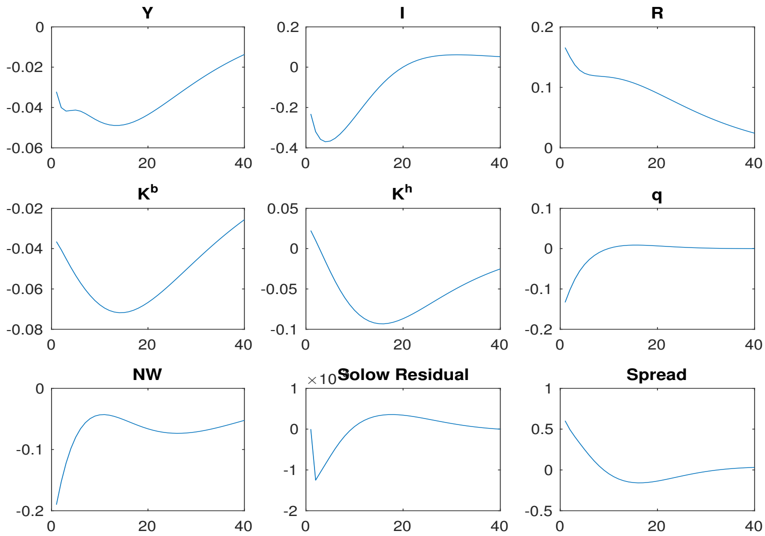
Calibration

Parameter	Description	Value
β	Subjective discount factor	0.99
σ_c	Relative risk aversion	2
φ	Inverse of Frisch elasticity	0.6
ν	Labor supply parameter	9.48
δ	Depreciation rate	0.025
Ψ	Investment adjustment cost	2.48
α	Capital share	0.5
θ	Price adjustment cost	105
ρ	Elasticity of substitution across varieties	10
η	Elasticity of substitution across home and foreign goods	3
γ	Share of domestic goods	0.5
ϑ	Household productivity parameter	10
$\bar{\chi}$	Steady state productivity of the household	0.88
σ	Survival rate of banks	0.95
λ	Fraction of capital that can be diverted	0.37
ω	Proportional transfer to newly entering banks	0.002
ς	Risk premium	0.0001
ϕ_r	Inflation coefficient of Taylor rule	1.5
ϕ_y	Output gap coefficient of Taylor rule	1

causes the asset price to drop. The decline in asset price harms the balance sheets of banks and thus their net worth decreases. The reduction in intermediaries' net worth tightens their financial constraints, thus curbing their ability to acquire new deposits. Consequently, investment declines by a larger magnitude, and the asset price then also falls more deeply; this feedback rule contributes to a more severe recession. The deterioration of financial conditions can be shown by the increase in the spread between capital return and the risk free rate, as indicated by panel 8 of FIGURE 1. In an economy without financial frictions, this gap always stays at zero, so the value of the spread is an indicator of financial market efficiency, the larger this gap, the less efficient the economy. Moreover, in line with the capital owned by banks decreasing, the capital holdings of households increases, as a result of which, the average productivity of capital declines.

Despite the financial accelerating effect, frictions in the financial market harms the economy in another dimension. In the model in which banks have unlimited access to obtain deposits, households would not own capital at all, but, instead, would invest all their assets in bank deposits and foreign bonds to pursue higher returns. Thus only intermediaries manage capital.

FIG. 1. A Foreign Interest Rate Shock

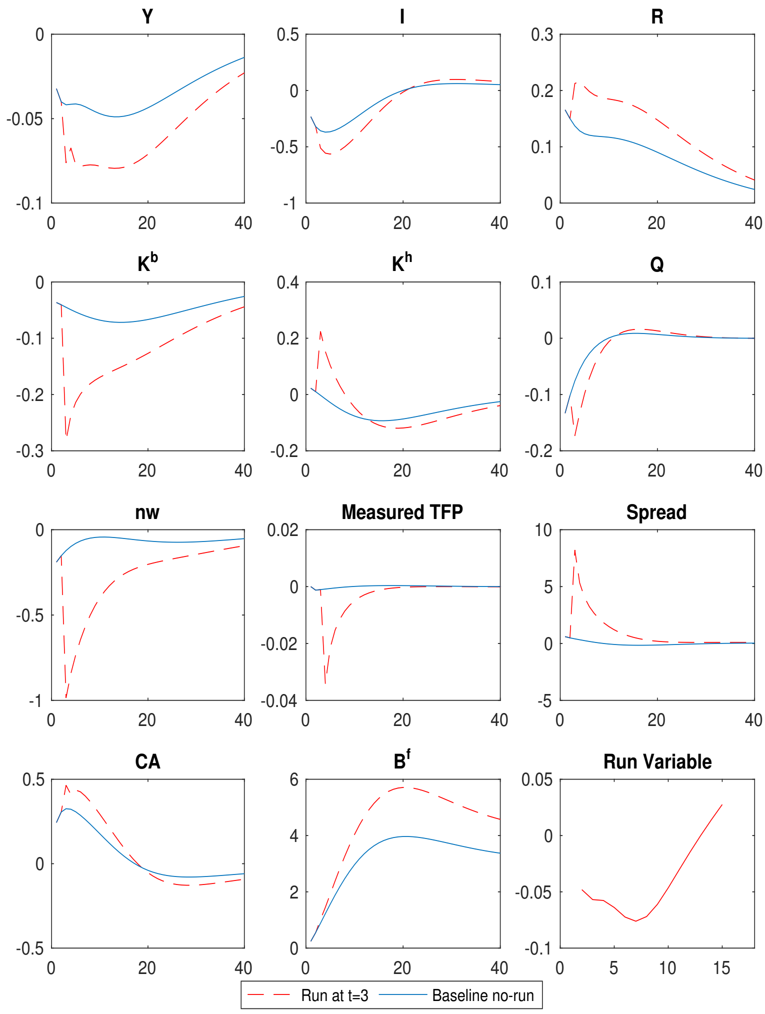


In this case, the average productivity is higher than that in our baseline model. Thus, the absence of financial frictions leads to higher utilization rate of capital and improves social welfare. Based on the above analysis, we conclude that financial frictions both distort the resource allocation efficiency and amplify economic fluctuations.

3.3. Bank Runs and Economic Fluctuations

In the previous discussion, the economy stays in the traditional equilibrium and the household chooses not to withdrawn its deposit, so the balance sheets of intermediaries do not worsen to the point that they cannot repay deposits, and no bank run occurs. In this section, we consider the case with a bank run. Although a run can happen whenever the liquidation price is below the threshold level, we only consider the situation where the economy is hit by a shock at period 1 and a bank run occurs at period 3. To capture the nonlinearities arising in this situation, we perform the simulation under perfect foresight, the percentage deviations from the steady state of main variables are displayed in FIGURE 2, and the responses of current account and foreign bond are in levels since their steady states are zero in our calibration. The last panel of the figure reports the value of the run variable in different periods; if this variable is less than zero, a run on banks is feasible at that period. We can see that a run is actually possible in period 3 under our parameter choice, and a bank run can only happen in the initial several periods since later the net worth of banks recovers gradually, so banks can pay repay their liabilities even at the liquidate price.

FIG. 2. A Bank Run After a Foreign Interest Rate Shock



The locus of all variables in the initial two periods are the same as those depicted in the last figure since the shock is the same size as in the former experiment. In period 3, depositors stop rolling over their deposits and banks are forced to sell their capital to households at a lower price in order to repay their liabilities. As a consequence, there is a surge in households' capital holding, and, at the same time, banks' capital changes in the opposite direction and the net worth drops to near zero. Due to the low productivity of households, asset prices need to drop in order for them to be willing to absorb such a higher amount of capital. So there is an almost 10 percent declines in asset prices at the third period compared to the case without bank runs. Low net worth and low asset prices contribute jointly to the tightness of bankers' financial constraints. So, the financial accelerating effect is much more severe and the recession lasts much longer, because it will take a long time for intermediaries to accumulate capital and recover their net worth. The collapse of the financial markets harms the financial market efficiency, as spread between capital return and risk free rate increases dramatically. The response of total output and investment also display larger declines in the bank run equilibrium.

Aside from characterizing bank runs and their implications, our model also has the potential to address some key phenomena observed in business cycles. When a bank run happens, we observe capital flows, a sudden increases in current account, declines in output and dramatic drops in asset prices, these phenomena constitutes key features of Sudden Stops. From this point of view, our model presents an explanation for economic failure in many emerging countries. Moreover, as big shocks can trigger bank runs and small shocks are amplified only by the financial accelerator, the contraction behavior of our model is nonlinear. Due to the similar reason, a positive shock and a negative one of the same size have asymmetric impacts on the economy.

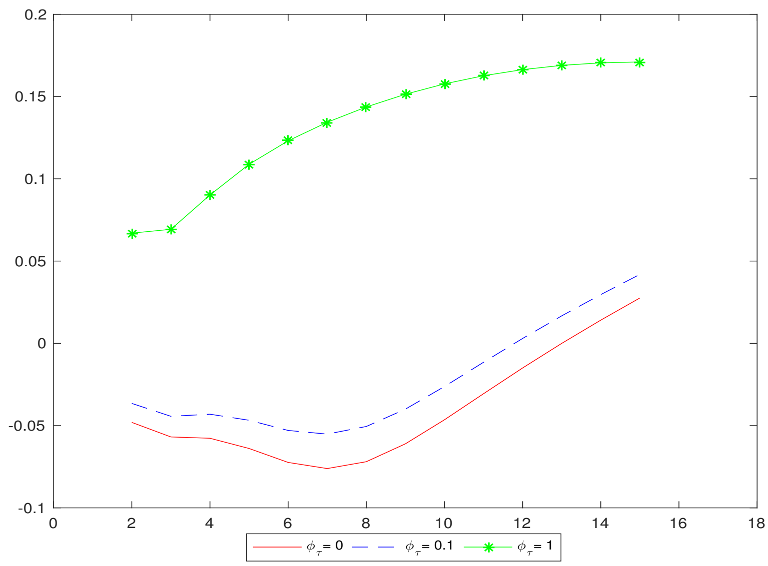
Another issue we are going to analyze is the decrease in measured total factor productivity that is observed in business cycles in both developed and emerging countries; for this reason, many economists consider total factor productivity shock to be the driven force of business cycles. In the paper studying Korean financial crises, Gertler, Gilchrist and Natalucci (2007) show that the drop in Solow Residual may be the result of the decline in capital utilization rate. In our model, however, bank runs can successfully lead measured productivity to decline, this is reported in panel 8 of FIGURE 2, where the measured TFP is defined as $Y_t/\left(K_t^{\alpha}N_t^{1-\alpha}\right)$. As a consequence of the bank run, capital is reallocated from banks to households. and, given that the household is less efficient in using capital than intermediaries, the average productivity is far below unity, and the effective capital that can be used for production is less than the physical capital stock. The reallocation of capital leads to a decrease in measured total factor productivity of near 4 percent. This channel is similar to that presented by Ferrante (2018), who also studied the collapse of the shadow banking system, but using a much more complicated model. So the decline in output caused by the shrink in demand is enhanced by the downturn in the supply side.

3.4. Capital Control and Bank Runs

Imperfectness in the financial market provides scope for government interventions. We now consider controls in capital flows enforced by government, assume that a tax with the form of equation (39) is levied on foreign bond returns.

$$\tau_t = \phi_\tau \left[E_t(R^k_{t+1} - R_t) - (R^k - R) \right] \tag{39}$$

FIG. 3. Run Variable with Capital Control



When the capital control tax is in place, the ex post revenue from investing in foreign assets is reduced when the financial condition of intermediaries, as measured by the interest rate spread, worsens, and foreign bond will become less attractive to households. We are going to asses the effects of this policy on the probability of a bank run. In this exercise, several different intervention intensities are considered, and the three curves in Figure 3 correspond to cases where $\phi_\tau = 0, 0.1$ and 1, respectively. Obviously, the conduct of capital control policy can reduce the probability of a bank run. And, the more intense the policy, the less likely that a bank run is going to happen. Capital control contributes to the stabilization of the economy through reducing capital outflow when the economy goes to recession. By preventing domestic investors from over-allocating assets on foreign bonds, capital control tax directly increases the demand for home assets and, thus, weakens the downturn of asset prices. As a consequence, banking net worth would not decrease by as much as it would without government intervention.

A bank run occurs because the leverage of financial intermediary is very high and households believe that the liquidation of assets would make them insolvent, so household will withdraw their deposits before maturity. With capital control tax being in place, the decease in asset prices is mitigated, so this kind of policy can help prevent bank runs.

4. CONCLUSION

We have built a macroeconomic model with financial intermediaries and analyzed the impact of bank runs on emerging economies. The increase in foreign interest rate leads to the contraction in domestic economic activity. As the asset prices decrease and the banks' balance sheets are weakened, bank runs can occur if depositors lose confidence in the repayment capacity of bankers. Bank runs cause much severe recessions. And these kinds of recessions show some key features of emerging economies' business cycles, such as capital outflow, current account reversals, nonlinearities and asymmetries. Bank runs lead to a reallocation of capital from efficient agents to their less efficient counterparts, so the average productivity declines and we observe a salient decrease in measured total factor productivity. Our model have provided a tractable framework to analyze financial crises in developing countries.

We have also investigated the effectiveness of countercyclical capital control taxes, numerical experiment suggests that intervention in capital flows can mitigate the effects of foreign interest rate shock and reduce the probability of bank runs. Since bank runs generate resource allocation inefficiency, management on capital account may also be an effective way to improve efficiency and social welfare.

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