TARGETED RESERVE REQUIREMENTS FOR MACROECONOMIC STABILIZATION

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Abstract. We study the effectiveness of targeted reserve requirements (RR) as a policy tool for macroeconomic stabilization. Targeted RR adjustments were implemented in China during both the 2008-09 global financial crisis and the recent COVID-19 pandemic. We develop a model in which risky firms with idiosyncratic productivity borrow from two types of banks—local or national—to finance working capital. National banks provide liquidity services, while local banks have superior monitoring technologies, such that both types coexist. Firms pay a fixed cost if they switch lenders, and they choose to switch only under large shocks. Reducing RR on local banks boosts leverage and aggregate output, whereas reducing RR on national banks has an ambiguous output effect. Target RR policy that reduces RR for local banks relative to national banks can ease bank switching costs following large recessionary shocks, stabilizing macroeconomic fluctuations. However, targeted RR also boosts local bank leverage, increasing risks of default and raising financial stability concerns.

Date: January 14, 2023.

Key words and phrases. Targeted reserve requirements, macroeconomic stabilization, bank sizes, costly state verification, business cycles.

JEL classification: E32, E52, E21.

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I. Introduction

Recent macro-prudential policy initiatives have attempted to mitigate financial instability through differential capital requirements on large and small banks. For example, the Basel III framework imposes higher capital requirements on large and systemically important banks than small banks. In practice, some central banks have implemented macro-prudential initiatives through targeted reserve requirements (RR). For example, Brazil has reduced RR to induce large banks to extend liquidity to small banks through asset purchases (e.g. Tovar, Garcia-Escribano and Martin (2012)). Brazil's RR system also partly exempts small banks on a variety of deposits (Glocker and Towbin (2015)).

The People's Bank of China (PBOC) has also implemented targeted RR adjustments. It cut RR more aggressively for small and medium-sized banks than large national banks during the 2008 global financial crisis. The PBOC then again widened the RR wedge between small and large banks in response to the COVID-19 pandemic (see Figure 1). However, unlike the macro-prudential considerations that have driven the debate on bank-specific, time-varying capital requirements and Brazil's targeted RR policies, the PBOC's RR adjustments appear to have been motivated by the desire to stabilize macroeconomic fluctuations.

In this paper, we study the potential effectiveness of targeted RR adjustments as a policy tool for macroeconomic stabilization. We present a model that features two types of banks: national and local. National banks face lower funding costs, but local banks have better monitoring technologies (e.g., because of superior information about local borrowers), allowing both types to exist in equilibrium. Firms face idiosyncratic productivity shocks and they borrow from banks to finance working capital. Low productivity firms choose to default and costly state verification gives rise to credit spreads, as in Bernanke, Gertler and Gilchrist (1999). A firm in a relationship with a bank (local or national) can switch lenders, but this switch incurs a fixed cost. As a result, firms only switch banks given sufficiently large aggregate shocks—such as the 2008 financial crisis or the COVID-19 pandemic.

The government provides deposit insurance for all savers, financed by lump-sum taxes. The government also sets RR policy which can differ across the two types of banks.

We then calibrate the model to Chinese data and study the implications of targeted RR adjustments over business cycles.

To better understand the transmission mechanism of targeted RR adjustments, we posit two extreme cases of bank switching cost: one case assumes that firms can costlessly switch banks while the other case assumes that firms cannot switch banks and therefore features segmented credit markets.

Under our calibration, cutting the RR for local banks (denoted by τ_l) unambiguously increases aggregate output in both cases. In particular, as τ_l is reduced, local bank funding

FIGURE 1. China's required reserve (RR) ratios for banks of different sizes.

costs fall, as do their required return on lending. Since local banks are more efficient in monitoring, shifting funding from national to local banks expands firm leverage and increases output. This stimulation effect is larger when firms can costlessly switch banks.

RR adjustments for national banks (τ_n) have different implications for the two cases. In the case where firms can costlessly switch banks, cutting τ_n has two opposing effects on aggregate output. At the intensive margin, the reduction in τ_n lowers national bank lending rates, raising leverage by firms that are already borrowing from national banks. However, at the extensive margin, the switching of some firms from local banks to national banks reduces average leverage, since national banks require more compensations for borrower risk due to their inferior monitoring technology. Under our calibration, the extensive-margin effect dominates, such that cutting τ_n reduces total output. However, in the case where firms cannot switch banks, cutting τ_n only has intensive margin effects, leading to higher firm leverage and boosting aggregate output.

We also study the implications of targeted RR adjustments for macroeconomic stabilization over the business cycle. We consider a central bank that makes targeted adjustments in RR by bank type to respond to deviations of real GDP from its trend. We evaluate the implications of symmetric and asymmetric feedback rules for national and local bank RR adjustments. Our results indicate that asymmetric RR rules outperform symmetric rules for stabilizing macroeconomic fluctuations in environments with large shocks because such targeted RR adjustments mitigate the costly bank-switching that disrupts existing bank relationships.

Our work is related to the literature on the positive and normative implications of capital or reserve requirement policies. The literature highlights a tradeoff between prudential and macroeconomic goals. den Heuvel (2008) demonstrates that restricting bank lending through capital requirements raises borrowing costs, which reduces welfare. Nicolò, Gamba and Lucchetta (2014) demonstrate that this tradeoff results in an interior solution for optimal bank capital requirements in a dynamic model aimed at discouraging excessive bank risk taking under deposit insurance. Several studies extend this analysis to consider this tradeoff under both capital and reserve requirements (e.g. Gorton, Lewellen and Metrick (2012) and Christiano and Ikeda (2016)).[1]

A recent paper by Corbae and D'Erasmo (2019) considers heterogeneity across banks by size in the form of a single representative "big bank" and a large number of atomistic small banks that take interest rates as given. While their paper focuses primarily on capital requirement policies, it obtains heterogeneous responses by large and small banks to changes in capital requirements and possible welfare enhancement through targeted heterogeneous changes in capital controls.[2] They also consider differential capital requirements between large and small banks.

Changes in reserve requirements have similarly been found to discourage lending activity [e.g. Loungani and Rush (1995)], but as a result will also have implications for macroeconomic stability. They can then be used as a tool to complement monetary policy in macroeconomic stabilization. Alper, Binici, Demiralp, Kara and Özlü (2018) demonstrate that RR increases, by reducing the liquidity of the banking system, can serve as a vehicle for reducing domestic credit and economic activity. Similarly, Brei and Moreno (2019) demonstrate in Latin American bank-level data increases in reserve requirements can reduce lending activity without increasing deposit rates, and thereby serve as a useful vehicle for stemming disruptive capital inflows. The literature documents the extensive use of reserve requirement policy as a tool for macroeconomic stabilization in emerging market economies [e.g. Montoro and Moreno (2011), Federico, Vegh and Vuletin (2014), and Mora (2014)], with China making particularly frequent reserve requirement adjustments (Chang, Liu, Spiegel and Zhang

[1]The robustness of this result has been called into question, as some models suggest that when deposit rates can adjust, raising capital requirements can actually increase bank lending (e.g. Begenau (2020)).

[2]Corbae and D'Erasmo (2019) do consider the implications of liquidity requirements, which can be interpreted as similar to minimum reserve requirements.

(2019)). Agénor, Alper and da Silva (2018) demonstrate in a DSGE framework for a small open economy that a counter-cyclical reserve requirement rule can mitigate financial and macroeconomic instability.

Finally, our paper is specifically related to the literature on the potential allocative effects of adjustments to the supply of or demand for reserves. On the supply side, Kashyap and Stein (2000) demonstrate that, for example, removal of reserves by the monetary authority can drag on bank lending behavior. Moreover, they demonstrate that these changes disproportionately impact on lending by less liquid smaller banks in the financial system. On the demand side, usually driven by changes in reserve requirements, Górnicka (2016) demonstrate that increases in RR can influence the share of bank intermediation relative to "shadow banks".

II. The model

The economy is populated by a continuum of infinitely lived households. The representative household consumes homogeneous goods produced by firms using capital and labor.

Firms face working capital constraints. Each firm finances wages and rental payments using both internal net worth and external debt. Following Bernanke et al. (1999), we assume that external financing is subject to a costly state verification problem. In particular, while each firm can costlessly observe its own idiosyncratic productivity shocks, creditor liquidation subsequent to default is costly. As a result, defaults chosen by firms with sufficiently low productivity relative to their nominal debt obligations yield deadweight losses.

Financial intermediation is conducted by two types of banks – national and local. There is a unit continnum of banks, indexed by $i \in [0, 1]$, of each type. Both types of banks intermediate between households (savers) and firms (borrowers) and compete in lending and deposit markets. The two types of banks differ in four dimensions: (1) national banks enjoy advantages in funding costs by providing nationwide liquidity services on deposit products; (2) local banks have advantages in monitoring firms compared to national banks; (3) both types of banks carry government provided deposit insurance but with different treatment in case of bankruptcies: local banks are liquidated while national banks are recapitalized; (4) two types of banks can face different government-imposed reserve requirements (RR).

II.1. **Households.**

There is a continuum of infinitely lived and identical households with unit mass. The representative household has preferences represented by the expected utility function

$$U = \mathrm{E}\sum_{t=0}^{\infty} \beta_t \left[\ln(C_t) - \Psi_h \frac{H_t^{1+\eta}}{1+\eta} + \Psi_n \ln(D_{n,t}) \right], \tag{1}$$

where E is an expectations operator, C_t denotes consumption, H_t denotes labor hours and $D_{n,t}$ denotes deposits in national banks. The parameter $\beta \in (0,1)$ is a subjective discount factor, $\eta > 0$ is the inverse Frisch elasticity of labor supply, and $\Psi_h > 0$ reflects labor disutility. $\Psi_n > 0$ reflects the utility of consuming nationwide liquidity services that national banks provide through deposit products.

The household faces the sequence of budget constraints

$$C_t + I_t + D_{nt} + D_{lt} = w_t H_t + r_t^k K_{t-1} + R_{n,t-1}^d D_{n,t-1} + R_{l,t-1}^d D_{l.t-1} + T_t, \tag{2}$$

where I_t denotes the capital investment, $D_{l,t}$ the deposits in local banks, w_t the real wage rate, r_t^k the real rental rate on capital and K_{t-1} the level of the capital stock at the beginning of period t. $R_{n,t-1}^d$ and $R_{l,t-1}^d$, respectively, denote the gross interest rate on deposits in national banks and local banks from period $t-1$ to period t. T_t denotes the lump-sum transfers from the government and earnings received from firms based on the household's ownership share.

The capital stock evolves according to the law of motion

$$K_t = (1-\delta)K_{t-1} + [1 - \frac{\Omega_k}{2}\left(\frac{I_t}{I_{t-1}} - g_I\right)^2]I_t, \tag{3}$$

where we have assumed that changes in investment incur an adjustment cost reflected by parameter Ω_k. The constant g_I denotes the steady-state growth rate of investment.

The household chooses C_t, H_t, D_{nt}, D_{lt}, I_t, and K_t to maximize (1), subject to the constraints (2) and (3). The optimization conditions are summarized by the following equations:

$$w_t = \frac{\Psi H_t^\eta}{\Lambda_t}, \tag{4}$$

$$1 = \mathrm{E}_t \beta R_{nt}^d \frac{\Lambda_{t+1}}{\Lambda_t} + \Psi_n \frac{1}{\Lambda_t D_{n,t}}, \tag{5}$$

$$1 = \mathrm{E}_t \beta R_{lt}^d \frac{\Lambda_{t+1}}{\Lambda_t}, \tag{6}$$

$$1 = q_t^k \left[1 - \frac{\Omega_k}{2}\left(\frac{I_t}{I_{t-1}} - g_I\right)^2 - \Omega_k \left(\frac{I_t}{I_{t-1}} - g_I\right)\frac{I_t}{I_{t-1}}\right] + \beta \mathrm{E}_t q_{t+1}^k \frac{\Lambda_{t+1}}{\Lambda_t}\Omega_k \left(\frac{I_{t+1}}{I_t} - g_I\right)\left(\frac{I_{t+1}}{I_t}\right)^2 \tag{7}$$

$$q_t^k = \beta \mathrm{E}_t \frac{\Lambda_{t+1}}{\Lambda_t}[q_{t+1}^k(1-\delta) + r_{t+1}^k]. \tag{8}$$

where Λ_t denotes the Lagrangian multiplier for the budget constraint (2), and $q_t^k \equiv \frac{\Lambda_t^k}{\Lambda_t}$ is Tobin's q, with Λ_t^k being the Lagrangian multiplier for the capital accumulation equation (3).

II.2. **Firms.**

II.2.1. *Production.* Firms produce homogeneous goods using capital and labor inputs under working capital constraints. In particular, firms pay wage bills and capital rents prior to production. They finance their working capital payments through their beginning-of-period net worth and by borrowing from banks. Banks are of two types: national (type n) and local (type l). In each period, each firm chooses and borrows from one bank.[3] Both firms and banks are perfectly competitive.

Consider a representative firm that borrows from a type-b bank $b \in \{n, l\}$. Each firm produces a homogeneous wholesale good $Y_{b,t}$ using capital $K_{b,t}$ and two types of labor inputs—household labor $H_{b,ht}$ and entrepreneurial labor $H_{b,et}$, with the production function

$$Y_{b,t} = A_t \omega_{b,t} (K_{b,t})^{1-\alpha} \left[(H_{b,et})^{1-\theta} H_{b,ht}^{\theta} \right]^{\alpha}, \tag{9}$$

where A_t denotes aggregate productivity, and the parameters $\alpha \in (0,1)$ and $\theta \in (0,1)$ are input elasticities in the production technology. The term $\omega_{b,t}$ is an idiosyncratic productivity shock that is i.i.d. across firms and time, and is drawn from the distribution $F(\cdot)$ with a nonnegative support.

Productivity A_t contains a common deterministic trend g^t and a stationary component A_t^m so that $A_t = g^t A_t^m$. The stationary component A_t^m follows the stochastic process

$$\ln A_t^m = \rho_a \ln A_{t-1}^m + \epsilon_{at}, \tag{10}$$

where $\rho_a \in (-1, 1)$ is a persistence parameter, and the term ϵ_{at} is an i.i.d. innovation drawn from a log-normal distribution $N(0, \sigma_a)$.

The firm's working capital constraint is then given by,

$$N_{b,t} + B_{b,t} = w_t H_{b,ht} + w_t^e H_{b,et} + r_t^k K_{b,t}. \tag{11}$$

where $N_{b,t}$ and $B_{b,t}$ denotes the representative firm's beginning-of-period net worth and bank loans, respectively. w_t^e denotes the real wage rate of managerial labor in sector j.

Given the working capital constraints in Eq. (11), cost-minimization implies that factor demand satisfies

$$w_t H_{b,ht} = \alpha\theta(N_{b,t} + B_{b,t}), \tag{12}$$

$$w_{jt}^e H_{b,et} = \alpha(1-\theta)(N_{b,t} + B_{b,t}), \tag{13}$$

$$r_t^k K_{b,t} = (1-\alpha)(N_{b,t} + B_{b,t}). \tag{14}$$

Substituting these optimal choices of input factors in the production function (9), we obtain the firm's the rate of return on the firm's investment financed by external debt and

[3] A bank can lend to multiple firms.

internal funds

$$\tilde{A}_t = A_t \left(\frac{1-\alpha}{r_t^k}\right)^{1-\alpha} \left[\left(\frac{\alpha(1-\theta)}{w_{jt}^e}\right)^{1-\theta} \left(\frac{\alpha\theta}{w_t}\right)^{\theta}\right]^{\alpha}. \tag{15}$$

II.2.2. *Financial contract.* Following BGG, we assume that lenders can only observe borrowers' realized returns at a cost. In particular, under a firm default the bank pays the liquidation cost, which is equal to a fraction m_b of output, and obtains the firm's generated revenue. We assume that this lost liquidation cost satisfies $m_n > m_l > 0$, implying that local banks can monitor and liquidate firms at a lower cost than national banks.

The bank charges a state-contingent gross interest rate $Z_{b,t}$ on the firm to cover monitoring and liquidation costs. Under this financial arrangement, firms with sufficiently low levels of realized productivity will not be able to make repayments. There is therefore a cut-off level of productivity $\bar{\omega}_{b,t}$ such that firms with $\omega_{b,t} < \bar{\omega}_{b,t}$ default, where $\bar{\omega}_{b,t}$ satisfies

$$\bar{\omega}_{b,t} \equiv \frac{Z_{b,t} B_{b,t}}{\tilde{A}_t (N_{b,t} + B_{b,t})}, \tag{16}$$

We now describe the optimal contract. Under the loan contract characterized by $\bar{\omega}_{b,t}$ and $B_{b,t}$, the expected nominal income for a firm that borrows from a type-b bank is given by

$$\begin{aligned} &\int_{\overline{\omega}_{b,t}}^{\infty} \tilde{A}_t \omega_{b,t} (N_{b,t} + B_{b,t}) dF(\omega) - (1 - F(\overline{\omega}_{b,t})) Z_{b,t} B_{b,t} \\ = \;& \tilde{A}_t (N_{b,t} + B_{b,t}) [\int_{\overline{\omega}_{b,t}}^{\infty} \omega dF(\omega) - (1 - F(\overline{\omega}_{b,t})) \overline{\omega}_{b,t}] \\ \equiv \;& \tilde{A}_t (N_{b,t} + B_{b,t}) h(\overline{\omega}_{b,t}), \end{aligned} \tag{17}$$

where $h(\overline{\omega}_{b,t})$ is the share of production revenue going to the firm under the loan contract.

The expected nominal income for the lender is given by

$$\begin{aligned} &(1 - F(\overline{\omega}_{b,t})) Z_{b,t} B_{b,t} + \int_0^{\overline{\omega}_{b,t}} \{(1 - m_b) \tilde{A}_t \omega (N_{b,t} + B_{b,t})\} dF(\omega) \\ = \;& \tilde{A}_t (N_{b,t} + B_{b,t}) \{[(1 - F(\overline{\omega}_{b,t})) \overline{\omega}_{b,t} + (1 - m_b) \int_0^{\overline{\omega}_{b,t}} \omega dF(\omega)\} \\ \equiv \;& \tilde{A}_t (N_{b,t} + B_{b,t}) g_b(\overline{\omega}_{b,t}), \end{aligned} \tag{18}$$

where $g_b(\overline{\omega}_{b,t})$ is the share of production revenue going to the lender. Note that

$$h(\overline{\omega}_{b,t}) + g_b(\overline{\omega}_{b,t}) = 1 - m_b \int_0^{\overline{\omega}_{b,t}} \omega dF(\omega). \tag{19}$$

Under the assumption that local banks are able to liquidate firms at a lower cost than national banks ($m_n > m_l > 0$), we have,

$$For \quad each \quad \overline{\omega}_t > 0, \quad g_n(\overline{\omega}_t) < g_l(\overline{\omega}_t) \tag{20}$$

The optimal contract is a pair $(\bar{\omega}_{b,t}, B_{b,t})$ chosen at the beginning of period t to maximize the borrower's expected period t income,

$$\max \tilde{A}_t(N_{b,t} + B_{b,t})h(\overline{\omega}_{b,t}) \tag{21}$$

subject to the lender's participation constraint

$$\tilde{A}_t(N_{b,t} + B_{b,t})g_b(\overline{\omega}_{b,t}) \geq R_{b,t}B_{b,t}. \tag{22}$$

where $R_{b,t}$ denotes the average loan return required by type-b bank.

The optimizing conditions for the contract characterize the relation between the leverage ratio and the productivity cut-off

$$\frac{N_{b,t}}{B_{b,t} + N_{b,t}} = -\frac{g_b'(\overline{\omega}_{b,t})}{h'(\overline{\omega}_{b,t})}\frac{\tilde{A}_t h(\overline{\omega}_{b,t})}{R_{b,t}}. \tag{23}$$

Denote $ROE_{b,t} \equiv h(\overline{\omega}_{b,t})\frac{\tilde{A}_t(N_{b,t}+B_{b,t})}{N_{b,t}}$ as a firm's ex-ante return to equity if the firm borrows from a type-b bank, where $(\bar{\omega}_{b,t}, B_{b,t})$ are chosen to solve the firm's optimization problem given by (21) subject to (22).

II.2.3. *Bank choice.* We assume that borrowers face switching costs when switching from one bank to another.[4] In particular, consider an individual firm i in period t. Denote $\mathcal{B}_t(i)$ as the choice of the bank type of the firm in period t. We assume that the firm incurs a cost equaling a fraction $\gamma > 0$ of the firm's net worth in the process of setting up relationship with a new bank. Given this cost, in equilibrium firms would only switch banks if they are also switching bank types, i.e if the firm's bank type in the current period $\mathcal{B}_t(i)$ differs from its choice in the previous period $\mathcal{B}_{t-1}(i)$.

We now discuss the firm's optimal choice of bank type. We assume that each firm manager survives at the end of each period with probability ξ_e, and distributes their terminal net worth to the shareholders of their firms, the household, if not surviving. The firm manager chooses bank type to maximize its expected terminal wealth, given by,

$$\mathbb{V}_t(\nu_{t-1}(i), \mathcal{B}_{t-1}(i)) \equiv \max_{\mathcal{B}_t(i)} \mathrm{E}_t \sum_{j=0} (1-\xi_e)\xi_e^j \beta^j \Lambda_{t+j}\nu_{t+j}(i) \tag{24}$$

where $\nu_t(i)$ denotes the firm's net worth by the end of the period t.

[4]Asymmetric information between borrowers and banks create barriers for borrowers to switch banks and, therefore, borrowers may incur switching costs when setting up a close tie with a bank (e.g. Boot, 2000). Switching costs have also appear to be prevalent in the Chinese bank loan market. For example, Yin and Matthews (2018) demonstrate that in a sample of Chinese firms and banks over the period 1999-2012 and found that around half of firms with bank credit history have switched to a new bank in the sample, and small, opeque firms are less likely to switch than large, transparent firms.

If the firm does not switch ($\mathcal{B}_t(i) = \mathcal{B}_{t-1}(i)$), its expected terminal wealth equals,

$$\mathrm{E}_t \sum_{j=0} (1-\xi_e)\xi_e^j \beta^j \Lambda_{t+j}\nu_{t+j}(i) = (1-\xi_e) ROE_{\mathcal{B}_t(i),t}\nu_{t-1}(i) + \xi_e \beta \mathrm{E}_t \mathbb{V}_{t+1}(ROE_{\mathcal{B}_t(i),t}\nu_{t-1}(i), \mathcal{B}_t(i)), \tag{25}$$

If the firm switches its bank type ($\mathcal{B}_t(i) \neq \mathcal{B}_{t-1}(i)$), its expected terminal wealth equals,

$$\mathrm{E}_t \sum_{j=0} (1-\xi_e)\xi_e^j \beta^j \Lambda_{t+j}\nu_{t+j}(i) = (1-\xi_e)(ROE_{\mathcal{B}_t(i),t} - \gamma)\nu_{t-1}(i) + \xi_e \beta \mathrm{E}_t \mathbb{V}_{t+1}((ROE_{\mathcal{B}_t(i),t} - \gamma)\nu_{t-1}(i), \mathcal{B}_t(i)), \tag{26}$$

To solve the problem, we guess that the value function $\mathbb{V}_t(\nu_{t-1}(i), b)$ is linear in $\nu_{t-1}(i)$:

$$\mathbb{V}_t(\nu_{t-1}(i), b) \equiv V_{b,t}\nu_{t-1}(i), \tag{27}$$

where $V_{b,t}$ is then given by,

$$V_{b,t} = \max\{[(1-\xi_e) + \xi_e \beta \mathrm{E}_t V_{b,t+1}] ROE_{b,t}, [(1-\xi_e) + \xi_e \beta \mathrm{E}_t V_{b',t+1}](ROE_{b',t} - \gamma)\}. \tag{28}$$

where $b' \neq b$ denotes the other bank type that differs from the bank type b.

The firm's optimal choice of bank type is then summarized as follows,

$$\begin{cases} \mathcal{B}_t(i) = l, \quad \text{if } \bar{V}_{l,t}(ROE_{l,t} - \gamma) \geq \bar{V}_{n,t} ROE_{n,t} \quad \text{and} \quad \mathcal{B}_{t-1}(i) = n, \\ \mathcal{B}_t(i) = n, \quad \text{if } \bar{V}_{n,t}(ROE_{n,t} - \gamma) \geq \bar{V}_{l,t} ROE_{l,t} \quad \text{and} \quad \mathcal{B}_{t-1}(i) = l, \\ \mathcal{B}_t(i) = \mathcal{B}_{t-1}(i), \quad \text{if} \quad \text{otherwise}. \end{cases} \tag{29}$$

where $\bar{V}_{b,t}$ denotes the firm's expected terminal wealth per unit of its end-of-period net worth and is given by

$$\bar{V}_{b,t} = (1-\xi_e) + \xi_e \beta \mathrm{E}_t V_{b,t+1} \tag{30}$$

II.2.4. *Aggregate wealth accumulation.* As mentioned above, we assume that each firm manager survives at the end of each period with probability ξ_e, so that the average lifespan for the firm is $\frac{1}{1-\xi_e}$. The $1 - \xi_e$ fraction of exiting managers is assumed to be replaced by an equal mass of new managers, so that the population size of managers stays constant.

Both surviving and new managers earn managerial labor income. Consequently, both surviving managers whose firm goes bankrupt in the current period and new managers have start-up funds equal to their managerial labor income. We assume that each manager supplies managerial labor that is proportional to the firm's net worth so that changes in the bank switching cost (γ) only affects the dynamic equilibrium but does not change the steady state equilibrium in our model. We also follow the literature and fix the total supply of managerial labor to unity (so that $H_{et} = 1$).

For simplicity, we assume that new managers that serve an existing firm has set up a relationship with the bank that the firm borrows from in the current period. This implies that they do not need to pay an additional cost if they choose to borrow from the same bank in the next period.

Denote $\bar{N}_{b,t}$ as the end-of-period aggregate net worth of all firms financed with bank type b in period t, which consists of profits earned by surviving firms plus managerial income,

$$\bar{N}_{b,t} = \xi_e[\tilde{A}_t h(\overline{\omega}_{b,t})(N_{b,t} + B_{b,t}) - \gamma \max\{N_{b,t} - \bar{N}_{b,t-1}, 0\}] + \frac{N_{b,t}}{N_{n,t} + N_{l,t}} w_t^e H_{et}. \tag{31}$$

where $N_{b,t} - \bar{N}_{b,t-1}$, if positive, measures the aggregate net worth of all firms that switch to bank type b from another bank and incur a switching cost.

Denote $\bar{N}_t$ as the net worth of all firms by the end of period t,

$$\bar{N}_t = \bar{N}_{n,t} + \bar{N}_{l,t}. \tag{32}$$

Figure 2 presents the timeline of individual firms' financing decisions and the evolution of the aggregate net worth of firms. Recall that $N_{b,t}$ denotes the aggregate net worth of firms that choose bank type b at the beginning of period t, and therefore,

$$N_{l,t} + N_{n,t} = \bar{N}_{t-1}, \tag{33}$$

Given the borrowers' optimal choice of bank type (29), these aggregate beginning-of-period net worths are given by,

$$\begin{cases} N_{l,t} \in (0, \bar{N}_{l,t-1}), N_{n,t} \in (\bar{N}_{n,t-1}, \bar{N}_{t-1}), & \text{if} \quad \bar{V}_{l,t} ROE_{l,t} - \bar{V}_{n,t} ROE_{n,t} = -\gamma \bar{V}_{n,t}, \\ N_{l,t} = \bar{N}_{l,t-1}, N_{n,t} = \bar{N}_{n,t-1}, & \text{if} \quad -\gamma \bar{V}_{n,t} < \bar{V}_{l,t} ROE_{l,t} - \bar{V}_{n,t} ROE_{n,t} < \gamma \bar{V}_{l,t}, \\ N_{l,t} \in (\bar{N}_{l,t-1}, \bar{N}_{t-1}), N_{n,t} \in (0, \bar{N}_{n,t-1}), & \text{if} \quad \bar{V}_{l,t} ROE_{l,t} - \bar{V}_{n,t} ROE_{n,t} = \gamma \bar{V}_{l,t}. \end{cases} \tag{34}$$

The first line of the above equation represents the case where ...

(34) gives the optimal choice of bank type in the interior solution where firms borrow from both types of banks, which will be the case under our calibration. It is also notable that, with extreme calibrated values, the gap in the overall return to equity between the two types of banks could be large enough so that all firms choose the same bank type in a corner solution:

$$\begin{cases} N_{l,t} = 0, N_{n,t} = \bar{N}_{t-1}, & \text{if} \quad \bar{V}_{l,t} ROE_{l,t} - \bar{V}_{n,t} ROE_{n,t} < -\gamma \bar{V}_{n,t}, \\ N_{l,t} = \bar{N}_{t-1}, N_{n,t} = 0, & \text{if} \quad \bar{V}_{l,t} ROE_{l,t} - \bar{V}_{n,t} ROE_{n,t} > \gamma \bar{V}_{l,t}. \end{cases} \tag{35}$$

II.3. **Banks.** There are two types of competitive commercial banks, national banks (type n) and local banks (type l). There is a unit continuum of banks for each type. Consider a type-b bank i, with $b \in \{n, l\}$, $i \in [0, 1]$. At the beginning of each period t, the bank obtains household deposits $d_{b,t}(i)$ at interest rate $r^d_{b,t}(i)$ subject to the demand schedule,

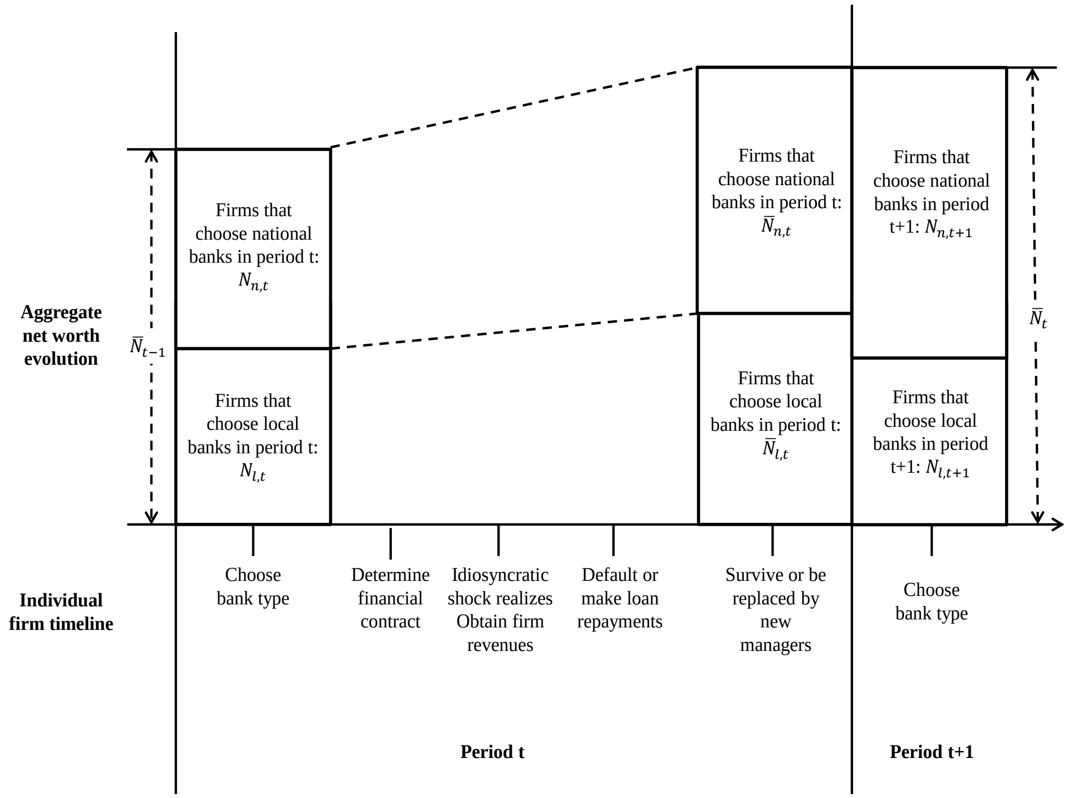

FIGURE 2. The timeline of individual firms' financing decisions and the evolution of the aggregate net worth of firms.

$$d_{b,t}(i) = \left(\frac{r^d_{b,t}(i)}{R^d_{b,t}} \right)^{-\theta_d} D_{b,t}, \tag{36}$$

The above demand schedule is derived under the assumption that the unit of type-b ($b \in \{n, l\}$) deposits held by the households is a composite CES basket of differentiated deposits supplied by individual banks, with elasticity of subsitution equal to $\theta_d < 0$.[5] Under this assumption, the aggregate-individual relations of deposits and deposit rates are given by,

$$D_{b,t} = \left[\int_0^1 d_{bt}(i)^{\frac{\theta_d - 1}{\theta_d}} di \right]^{\frac{\theta_d}{\theta_d - 1}}, \tag{37}$$

$$R^d_{b,t} = \left[\int_0^1 r^d_{b,t}(i)^{1-\theta_d} di \right]^{\frac{1}{1-\theta_d}}, \tag{38}$$

[5]This assumption is a useful modeling device to capture the existence of market power in the banking industry. For a similar approach, see, for example, Ulate (2021), Angelini, Neri and Panetta (2014), and Gerali, Neri, Sessa and Signoretti (2010).

The bank lends $b_{b,t}(i)$ to firms and is regulated by the RR $\tau_{b,t}$, which is set by the government. The bank's flow of funds constraint is then given by,

$$d_{b,t}(i) = \tau_{b,t}d_{b,t}(i) + b_{b,t}(i). \tag{39}$$

The bank faces default risk on firm loans. These firm loans generate a random return $\epsilon_{bt}R_{b,t}$ by the end of period t, where $R_{b,t}$ denotes the average return on firm loans of the representative type-b bank, and ϵ_{bt} is an idiosyncratic shock to the loan quality of each individual bank and becomes observable to the bank only after the loans have been granted. The idiosyncratic shock ϵ_{bt} is i.i.d across banks and time, and is drawn from the distribution $\Phi(\cdot)$ with a unity mean $E(\epsilon_{bt}) = 1$ and a nonnegative support.

The bank's payoff from its asset holdings by the end of period t is then given by,

$$\tau_{b,t}d_{b,t}(i) + \epsilon_{bt}R_{b,t}b_{b,t}(i)$$

Given sufficiently low realized ϵ_{bt}, the bank's payoff from its asset holdings will be inadequate for it to service its deposit obligations. We define $\bar{\epsilon}_{b,t}(i)$ as the value below which the bank chooses default, where $\bar{\epsilon}_{b,t}(i)$ satisfies

$$\bar{\epsilon}_{b,t}(i) = \max\{0, \frac{r^d_{b,t}(i)d_{b,t}(i) - \tau_{b,t}d_{b,t}(i)}{R_{b,t}b_{b,t}(i)}\}. \tag{40}$$

In case of bank default, the government compensates depositors for any losses. The government does not charge an insurance premium ex-ante but, when needed, levies lump-sum taxes on households in order to break even in each period. In addition, we assume that, in the case of bankruptcies, national banks are recapitalized while local banks are liquidated. In particular, liquidating a local bank incurs a deadweight loss equaling to a fraction μ_l of the local banks' generated payoff from its loan holdings.

The presence of deposit insurance distorts banks' lending decisions. When making lending decisions, the bank's expected value of its profit by the end of period t is then given by,

$$\pi_t(i) = \mathrm{E}_t \int_{\bar{\epsilon}_{b,t}}^{+\infty} \left[\tau_{b,t}d_{b,t}(i) + \epsilon_{bt}R_{b,t}b_{b,t}(i) - r^d_{b,t}(i)d_{b,t}(i)\right] d\Phi(\epsilon_{bt}). \tag{41}$$

The bank maximizes its expected profits subject to the flow of funds constraint (39) and the deposit demand schedule (36). The bank's optimal decisions imply that the average lending return it requires are related to the it's deposit rates and the RR as follows,

$$\left[\frac{\int_{\bar{\epsilon}_{b,t}(i)}^{+\infty} \epsilon_{bt}R_{b,t}d\Phi(\epsilon_{bt})}{1 - \Phi(\bar{\epsilon}_{b,t}(i))} - \frac{r^d_{b,t}(i) - \frac{1}{\theta_d}r^d_{b,t}(i) - \tau_{b,t}}{1 - \tau_{b,t}}\right] = 0. \tag{42}$$

where $r^d_{b,t}(i) = R^d_{b,t}$ in a symmetric equilibrium.

Equation (42) implies that a bank's valuation of its loans only reflects the states in which its realized return on its loans is sufficiently high that it is solvent. This leads to overlending. This over-lending problem can be mitigated by raising RR τ_b, which reduces the probability of bank default. In the extreme case where τ_b is so high that probability of a bank default reaches zero ($\bar{\epsilon}_{b,t} = 0$), the bank's valuation of firm loans reflects their true expected values and the distortion is eliminated.

II.4. **Market clearing and equilibrium.** In equilibrium, the markets for final goods, intermediate goods, capital and labor inputs, and loans all clear.

Final goods market clearing implies that

$$\begin{aligned} Y_t^f = \quad & C_t + I_t + \sum_{b=n,l} \tilde{A}_t(N_{b,t} + B_{b,t}) m_b \int_0^{\overline{\omega}_{bt}} \omega dF(\omega) \\ & + \mu_l \int_0^{\bar{\epsilon}_{l,t}} \epsilon_{l,t} R_{l,t} b_{l,t} d\Phi(\epsilon_{l,t}) + \sum_{b=n,l} \gamma \max\{N_{b,t} - \bar{N}_{b,t-1}, 0\}. \end{aligned} \tag{43}$$

Factor market clearing implies that

$$K_{t-1} = K_{n,t} + K_{l,t}, \quad H_t = H_{n,ht} + H_{l,ht}. \tag{44}$$

The loans market clearing implies that,

$$\forall b \in \{n, l\}, B_{b,t} = \int_0^1 b_{b,t}(i) di. \tag{45}$$

We define real GDP as final output net of the deadweight costs of firm bankruptcies. In particular, real GDP is defined as

$$GDP_t = C_t + I_t. \tag{46}$$

III. Calibration

We solve the model numerically based on calibrated parameters. Where possible, we use parameter values available from Chinese data. Five sets of parameters need to be calibrated. The first set are those in the household decision problem. These include β, the subjective discount factor; η, the inverse Frisch elasticity of labor supply; Ψ_h, the utility weight on leisure; Ψ_n, the utility weight on liquidity services; θ_d, the elasticity of substitution across individual bank deposits; δ, the capital depreciation rate; and Ω_k, the investment adjustment cost parameter. The second set includes parameters in the decisions for firms and financial intermediaries. These include g, the average trend growth rate; $F(\cdot)$, the distribution of the firm idiosyncratic productivity shock, respectively; α, the capital share in the production function; θ, the share of labor supplied by the household; m_b, the monitoring cost by type b banks; ξ_e, the survival rates of firm managers;$\Phi(\cdot)$, the distribution of the idiosyncratic loan quality shock. The third set of parameters are those in government policy and the shock processes, which includes $\bar{\tau}_b$, the steady-state RR on national banks and local banks, respectively; μ_l, the liquidation cost in case of bankruptcies by local banks; ρ_a, σ_a, the persistence and standard deviation of the productivity shock. Table 1 summarizes the calibrated parameter values.

A period in the model corresponds to one quarter. We set the subjective discount factor to $\beta = 0.9975$. We set $\eta = 1$, implying a Frisch labor elasticity of 1, which lies in the range of empirical studies. We calibrate $\Psi_h = 7.5$ such that the steady state value of labor hour is about one-third of total time endowment (which itself is normalized to 1). We calibrate the utility weight on liquidity services $\Psi_n = 0.005$ and the deposit elasticity of substitution $\theta_d = -163$ such that national banks' lending rate $4(R_n - 1)$ and deposit rate $4(R_n^d - 1)$, respectively, equals 6% per annum and 3% per annum, which is consistent with the historical average of the policy lending rate and policy deposit rate in China. For the parameters in the capital accumulation process, we calibrate $\delta = 0.035$, implying an annual depreciation rate of 14%, which also matches Chinese data. We set the investment adjustment cost parameter $\Omega_k = 5$, which lies in the range of empirical estimates of DSGE models (Christiano, Eichenbaum and Evans, 2005; Smets and Wouters, 2007).

For the technology parameters, we set the steady-state balanced growth rate to $g = 1.0125$, implying an average annual growth rate of 5%. We assume that firms' idiosyncratic productivity shocks are drawn from a unit-mean log normal distribution such that the logarithm of ω follows a normal distribution $N(-\sigma^2/2, \sigma)$. We calibrate the distribution parameter σ to match empirical estimates of cross-firm dispersions of TFP in China's data. In particular, Hsieh and Klenow (2009) estimated that the annualized standard deviation of the logarithm of TFP across firms is about 0.63 in 2005. This implies that $\sigma = 0.63/2$. We calibrate the labor income share to $\alpha = 0.5$, consistent with empirical evidence in Chinese data (Brandt, Hsieh and Zhu, 2008; Zhu, 2012).

For the parameters associated with financial frictions, we follow Bernanke et al. (1999) and set the local banks' liquidation cost parameters to $m_l = 0.1$. We set the managerial labor share $1 - \theta = 0.04$ such that entrepreneurs' labor income account for 2% of the total output. The other two parameters (the national bank monitoring cost m_n and the firm survival rate ξ_e) are calibrated to target a number of steady-state values: (1) the firm loan default ratio is 0.10 (2) the fraction of firm loans granted by local banks is 0.5. The first number matches the loan delinquency ratio on business loan, reported by the People's Bank of China. The second number matches the fraction of business loans granted by local banks (including city commercial banks and rural commercial banks) reported by China Banking Regulatory Commission.

Table 1. Calibrated values.

Variable	Description	Value
	A. Households	
β	Subjective discount factor	0.9975
η	Inverse Frisch elasticity of labor supply	1
Ψ_h	Weight of disutility of working	7.5
Ψ_n	Weight of utility of liquidity services	0.005
θ_d	Deposit elasticity of substitution	-163
δ	Capital depreciation rate	0.035
Ω_k	Capital adjustment cost	5
	B. Firms and financial intermediaries	
g	Steady state growth rate	1.0125
σ	Volatility parameter in log normal distribution of firm idiosyncratic shocks	0.315
α	Capital income share	0.5
m_n	National bank monitoring cost	0.2
m_l	Local bank monitoring cost	0.1
ξ_e	Firm manager's survival rate	0.86
θ	Share of household labor	0.96
σ_l	Volatility parameter in log normal distribution of local bank idiosyncratic shocks	0.005
γ	Bank switching cost	0.009
	C. Government policy and shock processes	
$\bar{\tau}_n$	RR on National bank	0.15
$\bar{\tau}_l$	RR on Local bank	0.15
μ_l	Liquidation cost of local banks	0.03
ρ_z	Persistence of TFP shock	0.95

For the parameters associated with the banking sector, we assume that the idiosyncratic shock on firm loans ϵ_b are drawn from a unit-mean log normal distribution such that the logarithm of ϵ_b follows a normal distribution $N(-\sigma_b^2/2, \sigma_b)$. We set $\sigma_b = 0.01/2$ to match the annualized standard deviation of loan delinquency ratio across individual banks of 0.01 in the data. Firms' bank switching cost is set to $\gamma = 0.009$ to match the volatility of the share of firm loans granted by local banks of 0.01 in the data.

For the government parameters, we calibrate the steady-state RR to 0.15 for both national banks and local banks. We have less guidance for calibrating the parameter μ_l that reflects the size of the liquidation cost in case of bankruptcies by local banks. We set $\mu_l = 0.03$ as a benchmark, implying that the total liquidation cost in case of bankruptcies by local banks account for 0.001 of total output in the steady state. For the parameters related to the shock process, we follow the standard business cycle literature and set the persistence parameter to $\rho_a = 0.95$ for the technology shocks. In Section V We consider a variety of shock sizes for each shock to examine how the size of the shocks affect the performance of the RR policy.

IV. RR Transmission Mechanism

We first use the calibrated model to explore the dynamics of the economy following unexpected changes in RR policies. In particular, we consider an unexpected cut in the RR for each type of the banking sector:

$$\tau_{b,t} = \tau_b + \epsilon^b_{\tau,t}. \tag{47}$$

To illustrate the role of switching costs when borrowers switch banks in the transmission mechanism of RR policies, we compare the impulse response to two types of RR changes in two cases: one case with no switching costs ($\gamma = 0$), the other case with infinite switching costs ($\gamma = +\infty$).

IV.1. **RR on local banks.** Figures 3 and 4 display the impulse responses to a 1% negative RR shock on local banks ($\epsilon^l_{\tau,t} = -0.01$). Reducing τ_l lowers the local banks' funding cost and thus their required return on lending. However, reducing τ_l also leads local banks to hold less riskless bank reserves and deteriorates financial stability by raising local banks' probability of bankruptcy. The increase in local banks' bankruptcy probability exacerbates the overvaluation distortion on local bank lending and eases their lending terms. As local banks expand their credit supply, the national banking sector shrinks and the liquidity services provided by national banks becomes more valuable, therefore lowering the deposit rate faced by national banks and leading to a decline in national banks' bankruptcy probability.

In the case with no switching costs ($\gamma = 0$), the fall in interest charged by local banks' leads some firms to switch their borrowing from national banks to local banks. Since local banks have superior monitoring technology and are willing to take riskier borrowers with higher leverage and higher default ratios, the firms' shift to local banks raises average firm leverage and default ratios. As a result, reducing τ_l raises firms' leverage, leading to increased output. However, reducing τ^l also raises the firms' default costs, as well as the local banks' bankruptcy costs.

In the case with infinite switching costs ($\gamma = +\infty$), reducing τ_l lowers the local banks' required return on lending, and firms respond by taking higher leverage with higher default ratio, thus stimulating the total output. However, compared with the case with no switching costs ($\gamma = 0$), this stimulative impact is much weaker because infinite switching costs prevent firms from switching to local banks and the extensive-margin expansionary effect disappears.

IV.2. **RR on national banks.** Figures 5 and 6 display the impulse responses to a 1% negative RR shock on national banks ($\epsilon^n_{\tau,t} = -0.01$). In the case with no switching costs ($\gamma = 0$), cutting τ_n have two opposite effects on total output: At the intensive margin, cutting τ_n lowers national banks' required return on lending and encourages increased leverage among firms borrowing from national banks. At the extensive margin, firms shift from local banks to

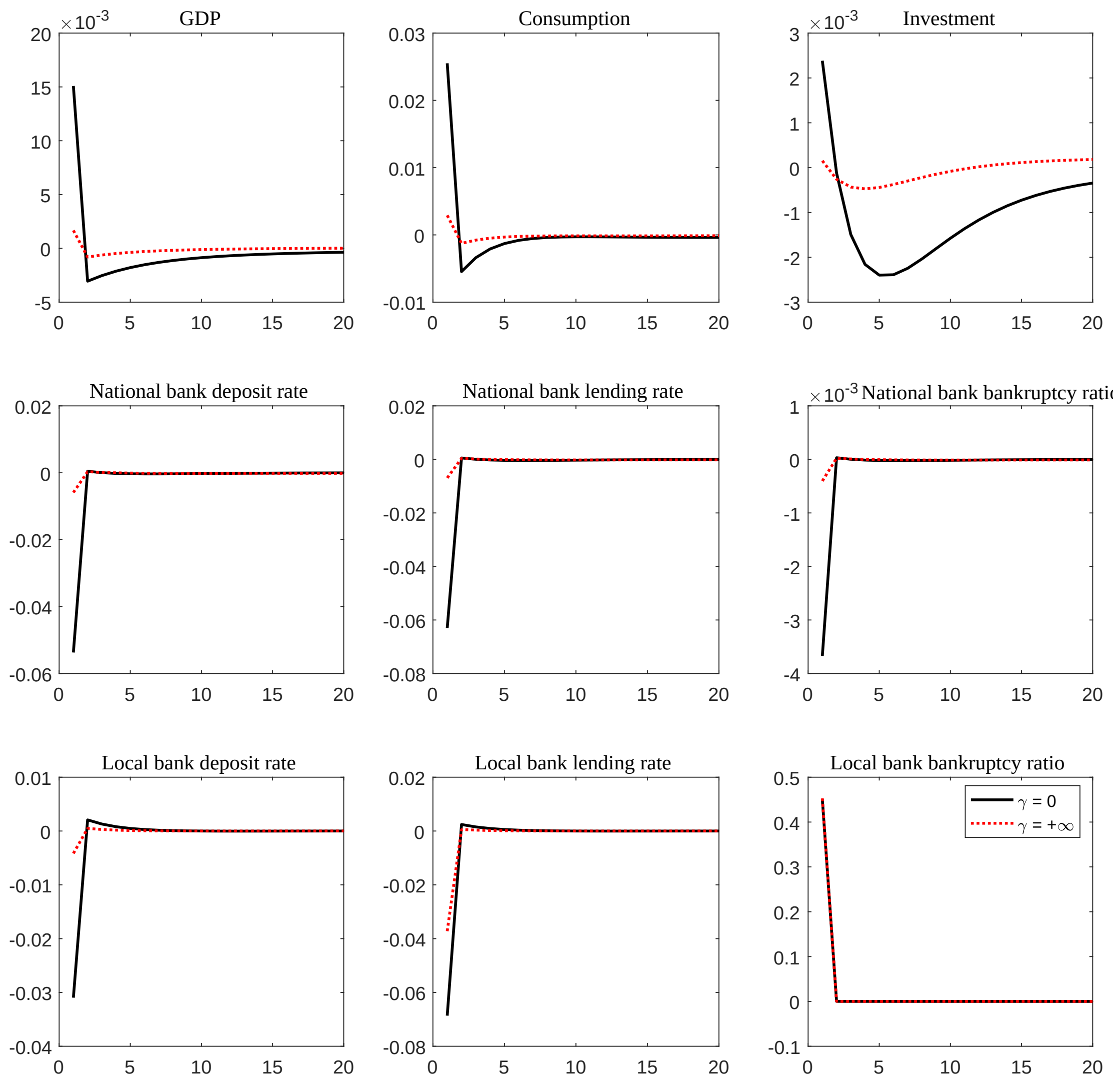

FIGURE 3. Impulse responses of a 1% negative RR shock on local banks ($\epsilon^l_{\tau,t} = -0.01$) for macroeconomic variables. Black solid lines: no switching costs ($\gamma = 0$); red dotted lines: infinite switching costs ($\gamma = +\infty$). The horizontal axes show the quarters after the impact period of the shock. The units on the vertical axes are percentage-point deviations from the steady state levels for banks' bankruptcy ratios. The units on the vertical axes are percent deviations from the steady state levels for other variables.

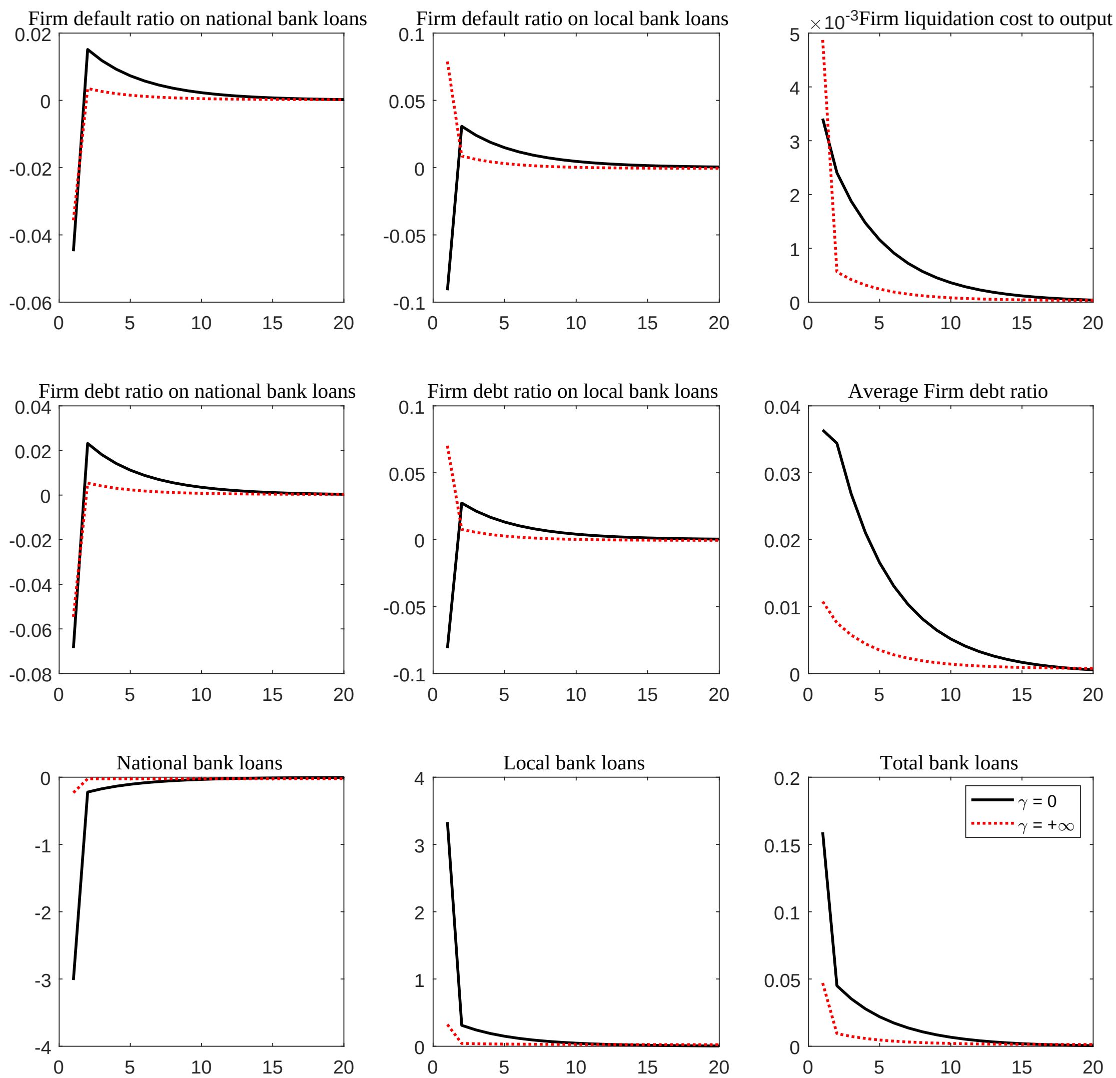

FIGURE 4. Impulse responses of a 1% negative RR shock on local banks ($\epsilon^l_{\tau,t} = -0.01$) for financial variables. Black solid lines: no switching costs ($\gamma = 0$); red dotted lines: infinite switching costs ($\gamma = +\infty$). The horizontal axes show the quarters after the impact period of the shock. The units on the vertical axes are percentage-point deviations from the steady state levels for firms' default ratios, firms' debt ratios and firm liquidation cost to output ratio. The units on the vertical axes are percent deviations from the steady state levels for other variables.

national banks, which reduces the average firm leverage ratio since local banks have superior monitoring technology and are willing to accept riskier borrowers with higher leverage and default ratios. Under our calibration, the extensive-margin effect dominates the intensive-margin effect. In this case, cutting τ_n leads to a fall in total output.

In the case with infinite switching costs ($\gamma = +\infty$), firms do not switch between banks and the extensive-margin effect no longer operates. Cutting τ_n then raises the national bank credit supply and reduces firm funding costs, encouraging production. In this case, cutting τ_n leads to a rise in total output.

V. Business cycle analysis

In this section, we consider the dynamic implications of pursued RR policy in China in the wake of adverse technology shocks. We characterize China RR policy in terms of two alternative feedback rules which the central bank follows in response to deviations of the real GDP from its trend. One rule is assumed to prevail under normal conditions, and the other is adopted in response to deep downturns. We compare these dynamics to a benchmark regime where RR of both types of banks are kept constant at their steady state levels over the course of the cycle.

Under our calibration, firms borrow from both types of banks and are indifferent between the two types of banks in the initial steady state. As is implied by (29), they switch across banks only when the economy is hit by a sufficiently large shock that the improvement in the their return to equity of switching from one bank to another exceeds the switching cost. This implies that our model contains occasionally binding constraints.[6]

V.1. **RR rules.** The central bank adjusts the required reserve ratio ($\tau_{n,t}$ or $\tau_{l,t}$) to respond to deviations of real GDP from trend.

$$\tau_{l,t} = \bar{\tau}_l + \psi_{ly} \ln \left(\tilde{GDP}_t \right) \tag{48}$$

$$\tau_{n,t} = \bar{\tau}_n + \psi_{ny} \ln \left(\tilde{GDP}_t \right) \tag{49}$$

where the parameters ψ_{ly} and ψ_{ny} measure the responsiveness of the require reserve ratios to the output gap.

We first consider a symmetric RR rule, under which the reaction coefficients $\psi_{ly} = \psi_{ny} = 1$, which characterizes PBOC policy under normal conditions. We estimate the value of the

[6]We solve the model using a popular model solution toolbox called OccBin developed by Guerrieri and Iacoviello (2015). The toolbox adapts a first-order perturbation approach and applies it in a piecewise fashion to solve dynamic models with occasionally binding constraints.

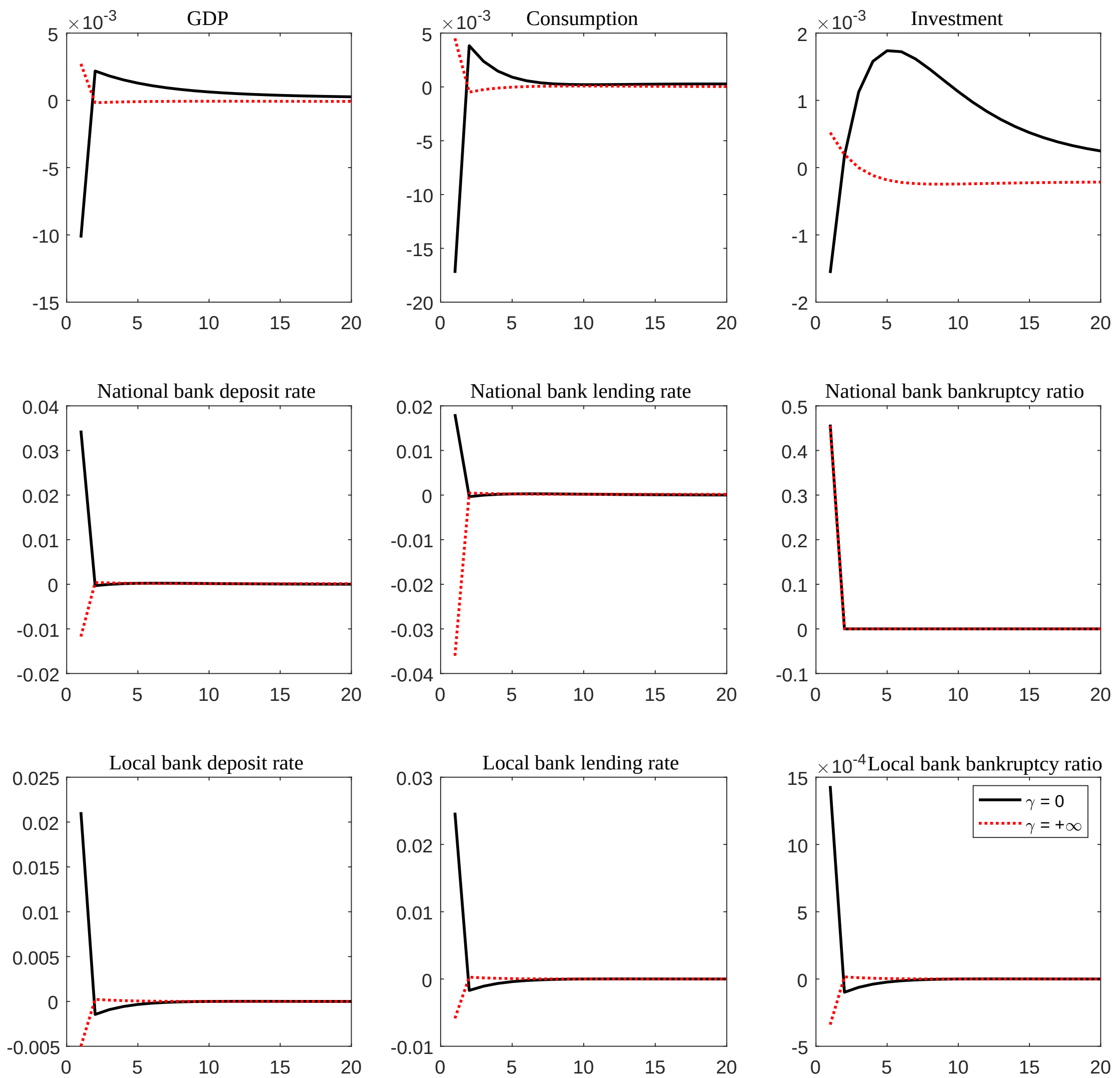

FIGURE 5. Impulse responses of a 1% negative RR shock on national banks ($\epsilon^n_{\tau,t} = -0.01$) for macroeconomic variables. Black solid lines: no switching costs ($\gamma = 0$); red dotted lines: infinite switching costs ($\gamma = +\infty$). The horizontal axes show the quarters after the impact period of the shock. The horizontal axes show the quarters after the impact period of the shock. The units on the vertical axes are percentage-point deviations from the steady state levels for banks' bankruptcy ratios. The units on the vertical axes are percent deviations from the steady state levels for other variables.

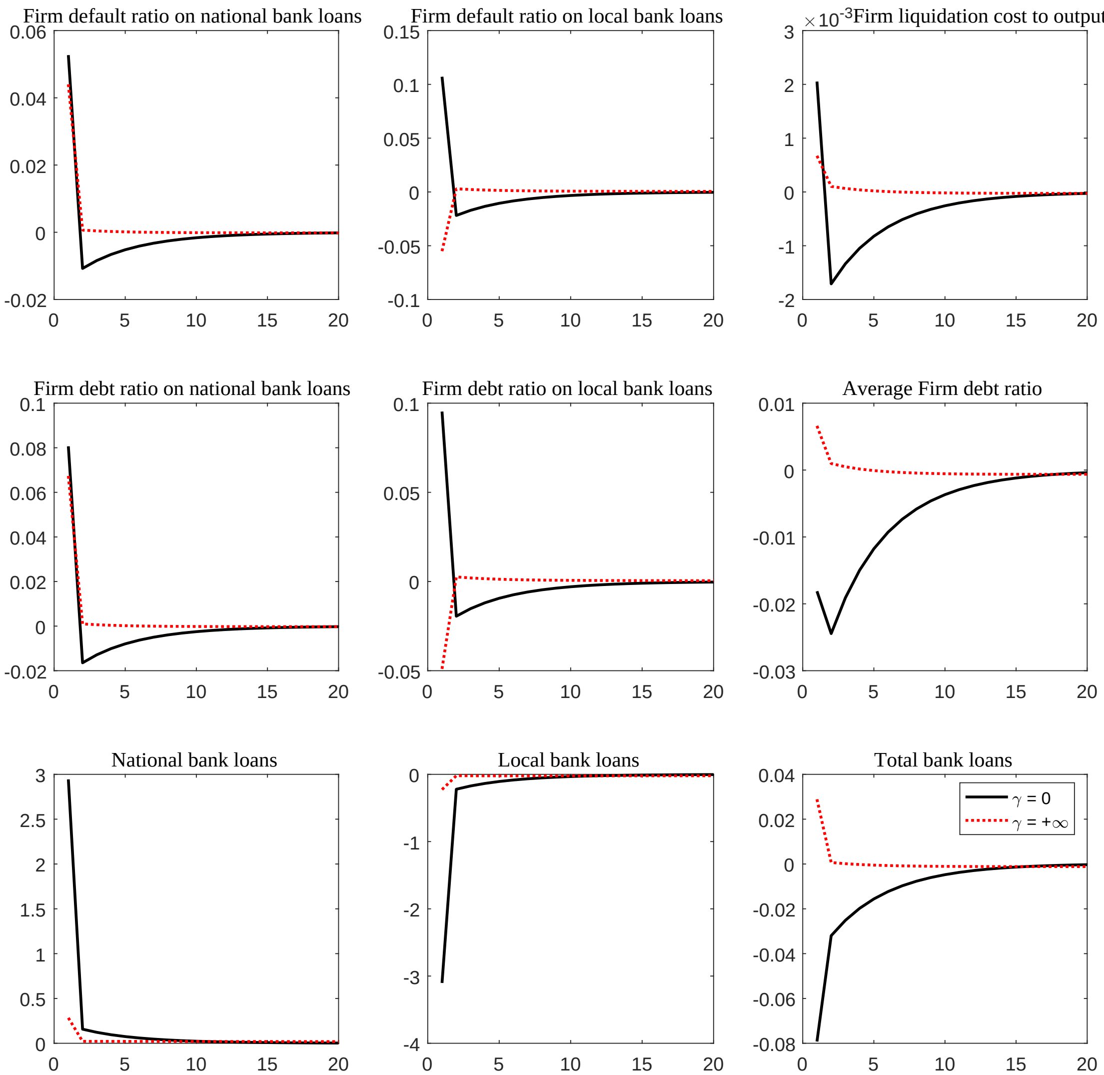

FIGURE 6. Impulse responses of a 1% negative RR shock on national banks ($\epsilon^n_{\tau,t} = -0.01$) for financial variables. Black solid lines: no switching costs ($\gamma = 0$); red dotted lines: infinite switching costs ($\gamma = +\infty$). The horizontal axes show the quarters after the impact period of the shock. The units on the vertical axes are percentage-point deviations from the steady state levels for firms' default ratios, firms' debt ratios and firm liquidation cost to output ratio. The units on the vertical axes are percent deviations from the steady state levels for other variables.

reaction coefficient by regressing the RRs on the real GDP gap and the CPI inflation rate using Chinese quarterly data from 2000 to 2020.

Our second policy rule is asymmetric, under which the RR reaction coefficients $\psi_{ly} = 2$ and $\psi_{ny} = 0$, and reflects pursued PBOC policy in the wake of deep adverse shocks. Under this rule, the central bank aggressively cuts RRs on local banks in response to downturns but barely adjusts RRs on national banks. This fits the pattern of pursued policy during the recent coronavirus pandemic.[7]

V.2. **Impulse responses.** We first consider a relatively small negative technology shock $\epsilon_{at} = -0.01$. Figure 7 and 8 display the impulse responses to that shock under the three policy rules.

Under the benchmark regime, a negative technology shock reduces firms' return to investment, imposing upward pressure on firm default possibilities and credit spreads at existing lending levels. In response to higher spreads and reduced profitability, firms respond by reducing their leverage ratio. This leads to reduced returns on equity.

Firms that borrow from local banks are more negatively affected than those that borrow from national banks. As local banks, due to their monitoring advantages, have higher steady state leverage and default probabilities. This leaves local bank terms more sensitive to the adverse shock than national banks. However, under the small technology shock the switching cost is too high, precluding firms borrowing from local banks from switching to national banks. As the local-bank-borrowing firms do not switch, lending by both types of banks falls, reducing output.

With no switching taking place, the decline in aggregate TFP leads to a fall in real GDP. In this case, the symmetric RR policy and the assymmetric RR policy are almost equally effective in stabilizing the output. In particular, the RR cut on both types of banks under the symmetric rule reduces the funding costs of both types of banks and mitigates the fall in real GDP by raising credit supply in both banking sectors. By comparison, the asymmetric cut that only reduces RR on local banks stimulates the credit supply by local banks more aggressively but raises bankruptcy probabilities in local banks.

Alternatively, consider a relatively large negative technology shock $\epsilon_{at} = -0.05$. Figure 9 and 10 displays the impulse responses to the shock in an economy.

Under the benchmark regime, the negative technology shock reduces all firms' return to equity, although more acutely for firms borrowing from local banks. In this case, the improvement in returns to equity from switching to national banks are large enough to cover

[7]As shown in Figure 1, the PBOC dropped RR for both large banks as well as medium and small banks during the 2008 global financial crisis. However, it dropped those for medium and small banks far more aggressively than it did for large banks, in line with the asymmetry pursued during the pandemic.

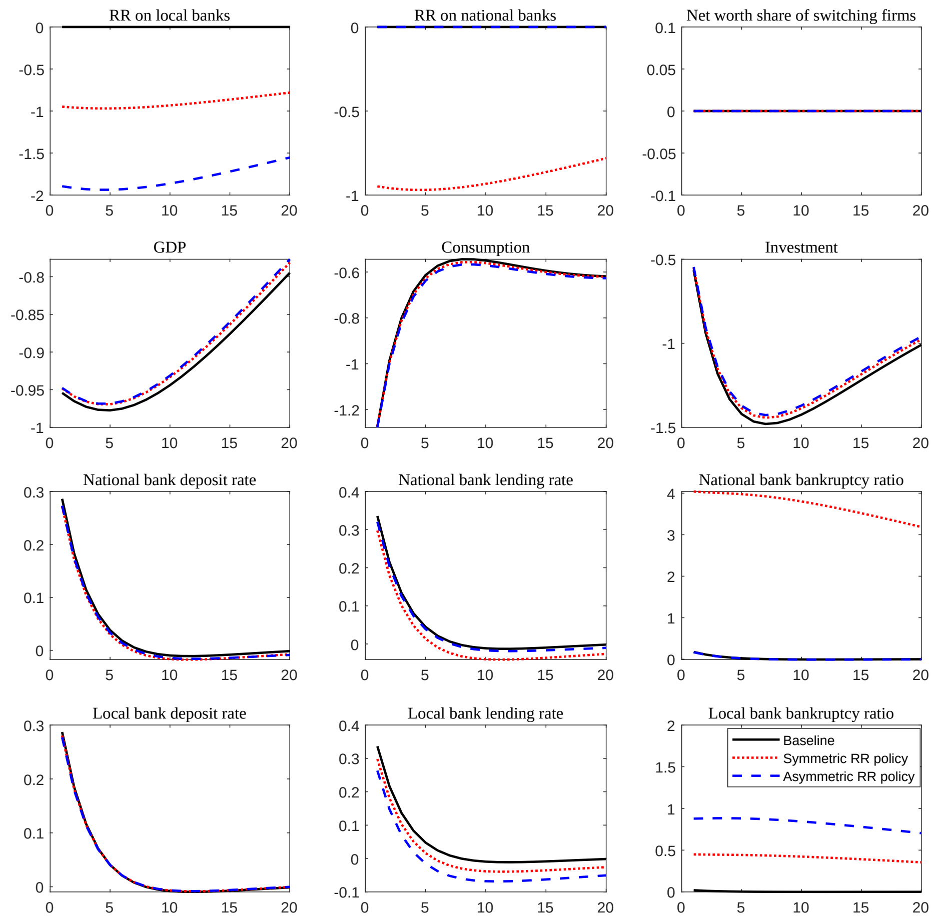

FIGURE 7. Impulse responses of aggregate variables to a small negative technology ($\epsilon_{at} = -0.01$) under alternative policy rules. Benchmark rule: black solid lines; symmetric RR rule: blue dashed lines; assymmetric rule: red dashed lines. The horizontal axes show the quarters after the impact period of the shock. The units on the vertical axes are percentage-point deviations from the steady state levels for RRs, net worth share of switching firms and banks' bankruptcy ratios. The units on the vertical axes are percent deviations from the steady state levels for other variables. The variable "Net worth share of switching firms" refers to the ratio of the net worth of firms that switch from local banks to national banks to the net worth of all firms.

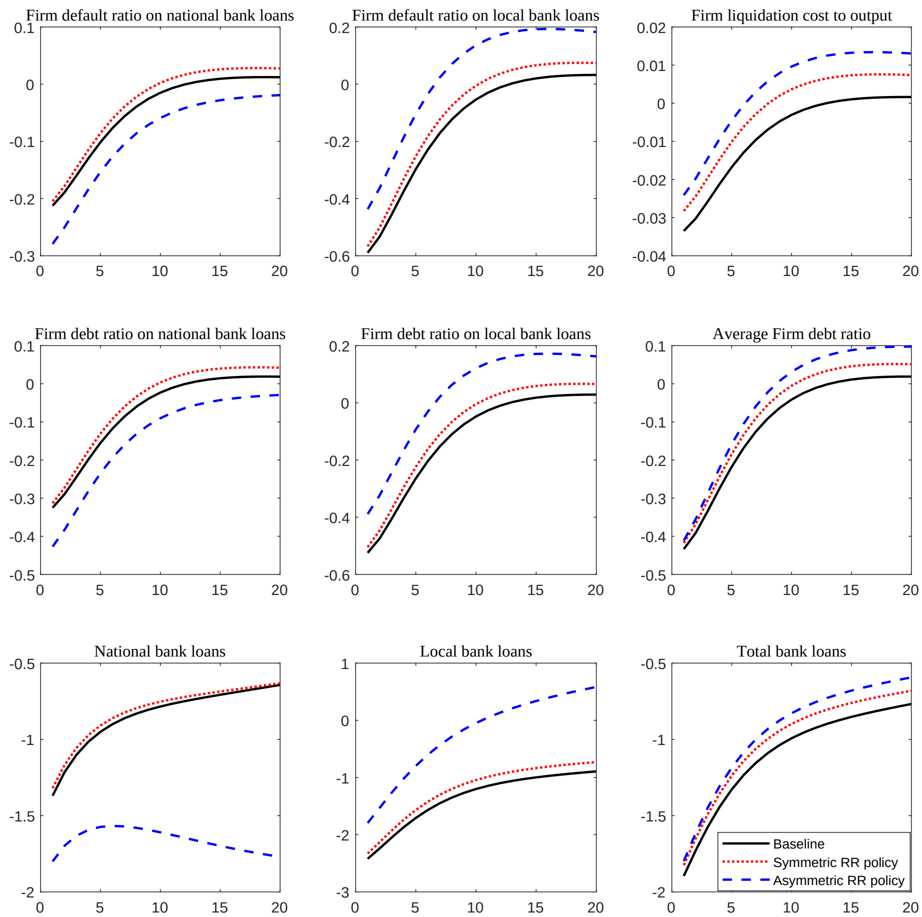

FIGURE 8. Impulse responses of financial variables to a small negative technology ($\epsilon_{at} = -0.01$) under alternative policy rules. Benchmark rule: black solid lines; symmetric RR rule: blue dashed lines; assymmetric rule: red dashed lines. The horizontal axes show the quarters after the impact period of the shock. The units on the vertical axes are percentage-point deviations from the steady state levels for firm default ratios, firm debt ratios and firm liquidation cost to output ratio. The units on the vertical axes are percent deviations from the steady state levels for other variables.

the switching cost for some local bank borrowers. As a result, while total lending falls, national bank lending rises. The shift to national banks also lowers the average leverage ratio, further reducing total output.

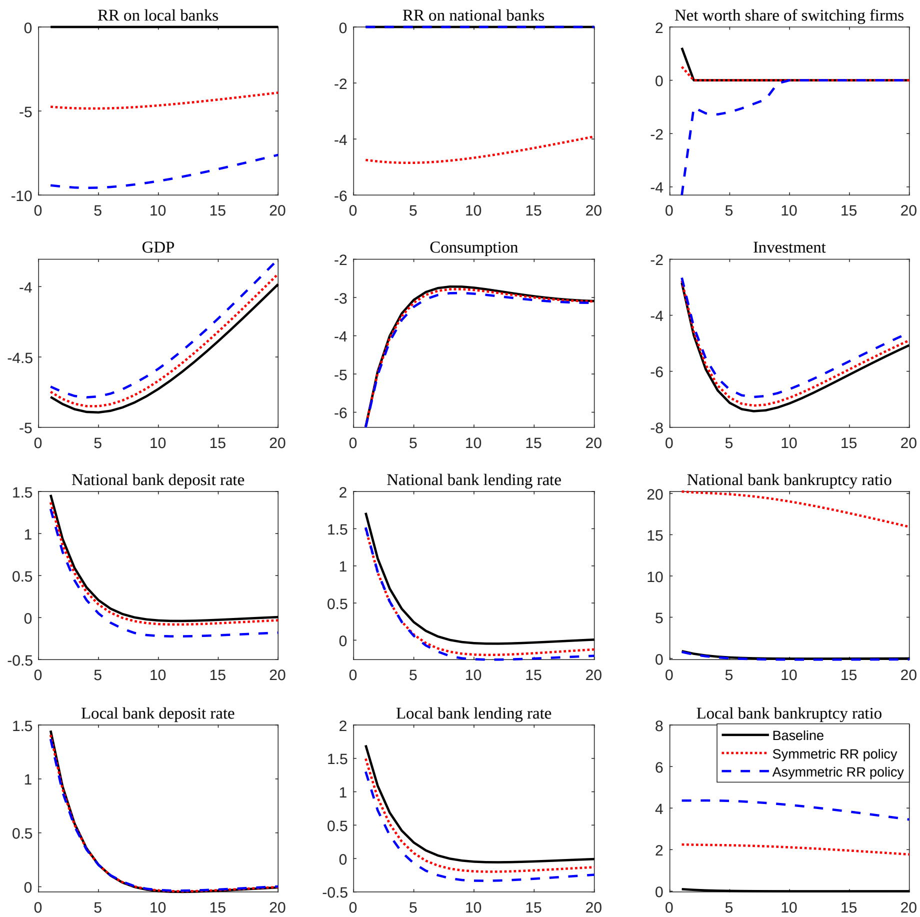

FIGURE 9. Impulse responses of aggregate variables to a large negative technology ($\epsilon_{at} = -0.05$) under alternative policy rules. Benchmark rule: black solid lines; symmetric RR rule: blue dashed lines; assymmetric rule: red dashed lines. The horizontal axes show the quarters after the impact period of the shock. The units on the vertical axes are percentage-point deviations from the steady state levels for RRs, net worth share of switching firms and banks' bankruptcy ratios. The units on the vertical axes are percent deviations from the steady state levels for other variables. The variable "Net worth share of switching firms" refers to the ratio of the net worth of firms that switch from local banks to national banks to the net worth of all firms.

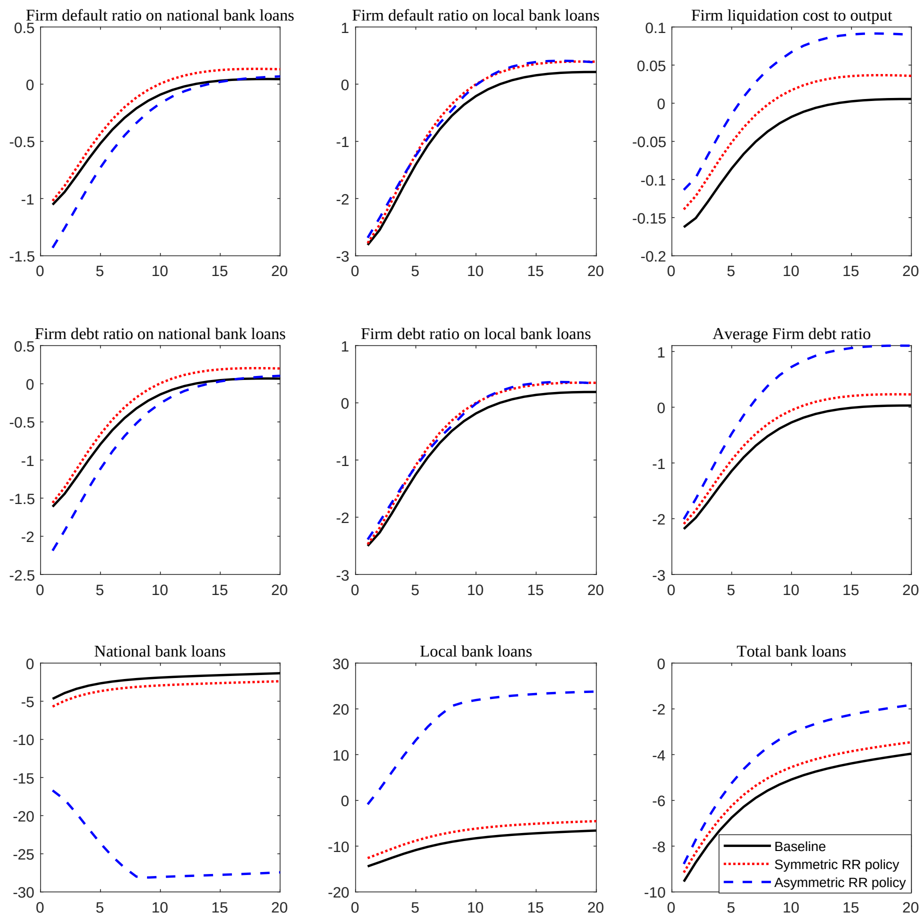

FIGURE 10. Impulse responses of financial variables to a small negative technology ($\epsilon_{at} = -0.01$) under alternative policy rules. Benchmark rule: black solid lines; symmetric RR rule: blue dashed lines; assymmetric rule: red dashed lines. The horizontal axes show the quarters after the impact period of the shock. The units on the vertical axes are percentage-point deviations from the steady state levels for firm default ratios, firm debt ratios and firm liquidation cost to output ratio. The units on the vertical axes are percent deviations from the steady state levels for other variables.

Given the large shock, the RR cut on both types of banks helps to reduce all banks' funding costs and mitigates the fall in the real GDP. However, the asymmetric cut stabilizes the real GDP better than symmetric cuts on both types of RRs. This is because the asymmetric RR cut on local banks helps reduce the lending rate required by local banks compared with those by national banks, and prevents firms from switching to national banks. By comparison, while the symmetric cut stimulates both types of bank lending, it does not raise the total credit as much because it fails to prevent firm switching to national banks.

V.3. **Optimal asymmetric RR adjustments.** In this section, we consider a variety of technology shock sizes and study the optimal rule and the relative performance of the asymmetric RR policy under various shock sizes. In particular, we restrict that the average of the two RR reaction coefficient ψ_{ny} in (49) and ψ_{ly} in (48) equals 1, an estimate based on Chinese quarterly data on RR adjustments and real GDP. Given this restriction ($\frac{\psi_{ny}+\psi_{ly}}{2} = 1$), the government chooses the two reaction coefficients ψ_{ny} and ψ_{ly} to minimize the loss function as follows,

$$L = \mathrm{E}\left[(\tilde{C}_t)^2 + \Psi_h \eta \bar{H}^{1+\eta}(\tilde{H}_t)^2\right] \tag{50}$$

where $\tilde{C}_t$ denotes the deviation of consumption from trend; $\bar{H}$ and $\tilde{H}_t$, respectively, denotes the steady-state value of labor hours and its deviation from the steady state. The above loss function is derived from the second-order approximation of the household's welfare except that the planner does not value bank deposit balances.[8]

To solve for the optimal values of ψ_{ly} and ψ_{ny}, we perform a grid search within a reasonable range $\psi_{ly} - \psi_{ny} \in [-2, 2]$. Note that the government implements symmetric RR policies when $\psi_{ly} = \psi_{ny} = 1$.

Figure 11 considers a variety of technology shock sizes and shows the performance of various asymmetric RR policies under various shock sizes. The figure implies a trade-off between macro stability and financial stability when the government adopts asymmetric RR policies: an increase in the difference in RR reaction coefficient between local banks and national banks $\psi_{ly} - \psi_{ny}$ helps stabilizes the GDP but makes bankruptcies in local banks more volatile. This is because, in times of economic depression, firms experience lower return to investment, local banks receive lower return on their loan portfolio and their bankruptcy ratio increases. Under these circumstances, if the government cuts the RR on local banks to stimulate the output for macro stabilization, the fraction of local banks going bankruptcy rises further, dampening the financial stability.

It is also notable that, the larger the shock, the more efficient is raising $\psi_{ly} - \psi_{ny}$ in stabilizing the economy. This reason is demonstrated in our impulse responses, where the more aggressive cut of RR on local banks relative to national banks helps reduce the amount of costly switching between banks or even reverse the switching during severe economic downturns.

Figure 12 considers a variety of technology shock sizes and shows the optimal policy rule and its performance under various shock sizes. We found that, when the shock size is sufficiently small ($\sigma_a \leq 0.02$), the RR on local banks responds to the output gap less

[8]Including national banks' deposits in the loss function would imply that the social planner treats the two banking sectors differently and tends to stabilize the national banking sector, which seemed to be an unappealing feature in the welfare analysis.

aggressively than the RR on national banks. This is because, in times of economic depression, the RR cut on local banks will raise the costly bankruptcies in local banks and deteriorate the financial stability. However, the RR cut on national banks could stabilize the output without such negative side effects.

However, when the shock size is large enough ($\sigma_a \geq 0.03$), the RR on local banks responds to the output gap more aggressively than the RR on national banks. This is because, under large shocks, firms begin to switch between banks and the extensive-margin effect from bank switching will exaggerate the output fluctuations. In this case, RR adjustments on local banks could help reduce the bank switching behavior and therefore stabilize the output more efficiently relative to the case with small shocks and no bank switching by firms.

VI. Conclusion

This paper examines the effectiveness of targeted changes in reserve requirement policy as macroeconomic stabilization tools. These policies have also been implemented by China in their discrimination between local and national bank reserve requirement policies in China during the 2008 global financial crisis, the 2018 slowdown, and the 2020 COVID-19 pandemic. We develop a model in which risky firms with idiosyncratic productivity borrow from either local banks, who enjoy superior monitoring technologies, or national banks, who have superior funding technologies, to finance working capital. Our model includes banking relationships, modeled as a real cost of switching between bank types.

Our framework demonstrates that established banking relationships, which can leave it costly for a bank to switch from, for example, a local bank to a national one, can influence the desirability of targeted reserve requirement policies. In particular, we obtain superior stabilization and welfare enhancement in the wake of large shocks through targeted reserve requirement policies. In particular, given large enough shocks that would induce costly disruption of banking relationships, targeted reserve requirement adjustments that mitigate the cost of interrupting bank relationships and switching to more cost effective banks can be welfare enhancing. Our results therefore indicate that differential reserve requirements of this type can be useful as macroeconomic stabilization tools, complementing their value as macro-prudential policy instruments stressed in the existing literature.

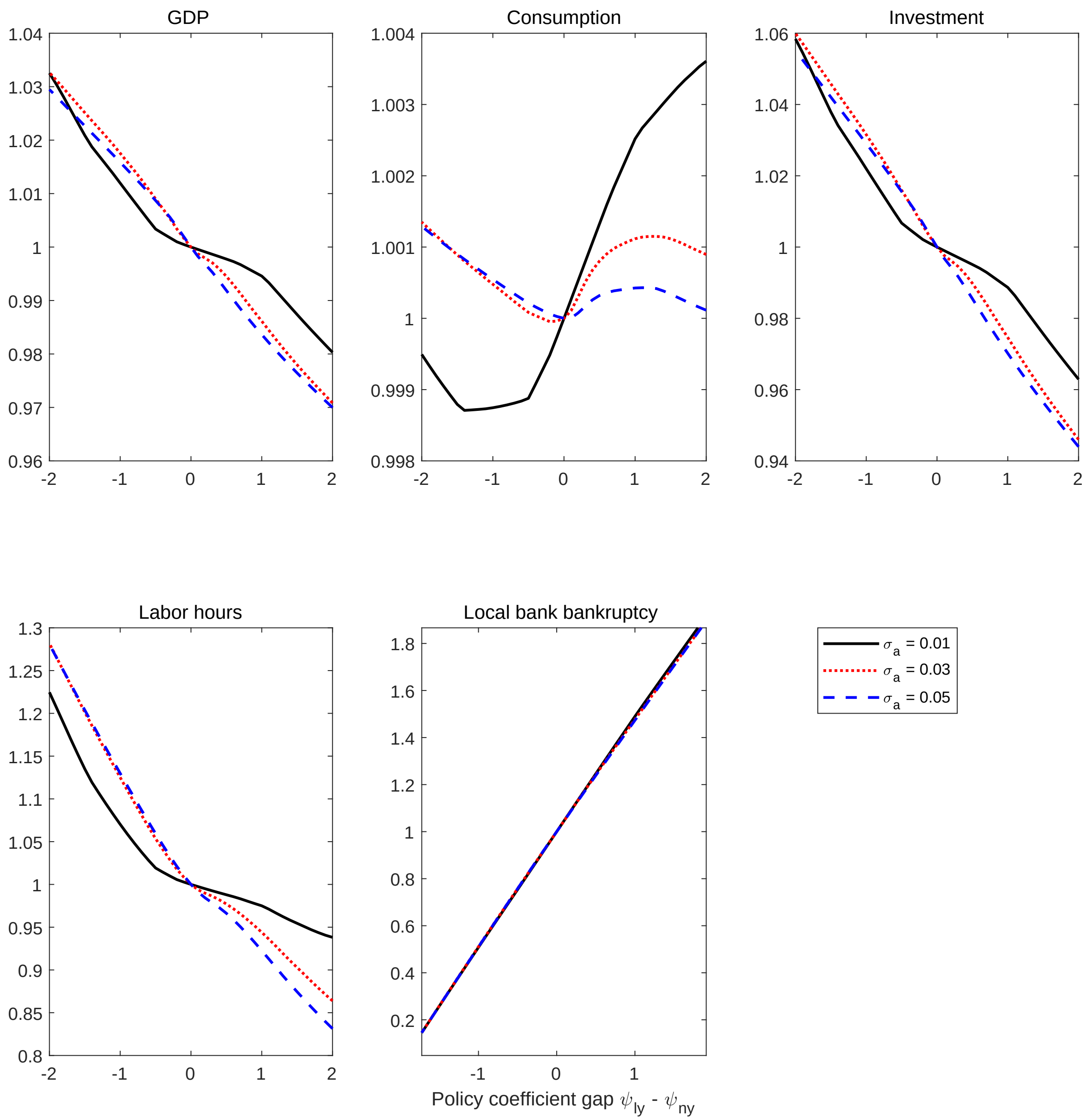

Figure 11. Performance of various asymmetric RR policies under technology shocks. The horizontal axes show the difference in RR reaction coefficient between local banks and national banks $\psi_{ly} - \psi_{ny}$. The vertical axes show the volatility of the corresponding variable under the alternative policy regime scaled by the volatility of the variable under the symmetric RR policy where $\psi_{ly} = \psi_{ny} = 1$.

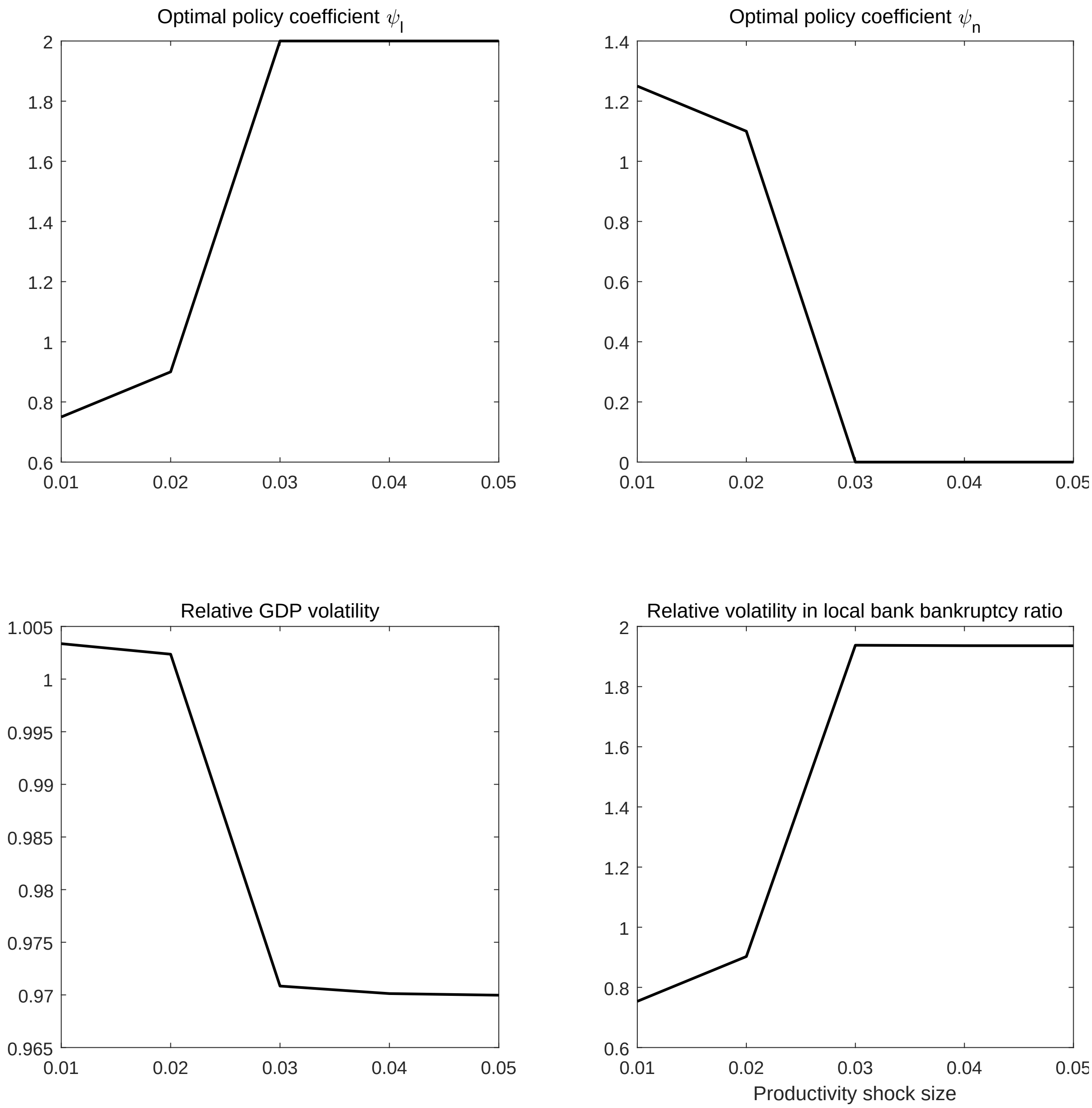

FIGURE 12. Optimal asymmetric RR policy under technology shocks. The horizontal axes show the size of the technology shock σ_a. The upper left panel and the upper right panel, respectively, show the optimal values of the two reaction coefficients ψ_{ly} for local banks and ψ_{ny} for national banks. The lower left panel and the lower right panel, respectively, shows the ratio of the volatility in output gap $\sqrt{\mathrm{E}[(G\tilde{D}P_t)^2]}$ and the volatility in local bank bankruptcy ratio $\sqrt{\mathrm{E}\left[(F(\bar{\epsilon}_{l,t}))^2\right]}$ under the optimal asymmetric RR policy to its counterpart under the symmetric RR policy where $\psi_{ly} = \psi_{ny} = 1$.

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