RESERVE REQUIREMENTS AND OPTIMAL CHINESE STABILIZATION POLICY

CHUN CHANG, ZHENG LIU, MARK M. SPIEGEL, JINGYI ZHANG

Abstract. China's central bank frequently uses reserve requirements as an additional policy instrument. We argue that the use of reserve requirements can be effective and desirable as a second-best policy for macroeconomic stabilization given the distortions in China's existing financial system. In China, state-owned enterprises (SOEs) enjoy superior access to bank loans relative to private firms, who rely more heavily on the shadow banking sector for financing. Regulatory restrictions such as reserve requirements have different impacts on these alternative forms of finances. Commercial banks are subject to reserve requirements, and their depositors enjoy implicit government guarantees. Neither of these features hold for the shadow banks. We build a two-sector DSGE model that incorporates these characteristics. Given that the SOE sector is less productive on average than the POE sector, adjusting reserve requirements in this environment involves a tradeoff between efficiency and risk: Higher required reserve ratios raise the relative funding costs for SOE firms and reallocates resources from the SOE sector to the private sector, raising aggregate productivity. However, a higher level of required reserves also raises the incidence of costly firm failures. We examine the implications of changes in reserve requirements for the steady-state equilibrium, for stabilization of business cycle fluctuations, and also for transition dynamics in the case of a permanent increase in SOE productivity.

I. Introduction

The Peoples Bank of China (PBOC) frequently uses reserve requirements as a policy instrument for macroeconomic stabilization. For example, in the past decade, the PBOC has adjusted its reserve requirement ratio (RRR) 38 times. During tightening cycles from 2006 to 2011, the RRR has been raised from 8.5 percent to 21.5 percent. These frequent and

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Date: December 30, 2015.

Key words and phrases. Reserve requirements, monetary policy, China, shadow banking, financial accelerator, reallocation, aggregate productivity, welfare.

JEL classification: E21, P31, D81.

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substantial changes in reserve requirements have served as an important policy tool over this period for the PBOC (Ma et al., 2013).

China is not alone in its use of reserve requirement adjustments as a stabilization tool. Federico et al. (2014) find that about two-thirds of the emerging market countries in their study use reserve requirements as counter-cyclical stabilization tools. In many cases, they find that the counter-cyclical reserve requirement adjustments are used to partially offset pro-cyclical monetary policy. Under open capital accounts, monetary policy tightening through increases in reserve requirements rather than raising interest rates can help avoid attracting further expansionary capital inflows (Montoro and Moreno, 2011).

It has been argued that the reliance by the PBOC on reserve requirements reflects the unique responsibilities of China's central bank for mopping up foreign exchange revenues (Ma et al., 2013). In the aftermath of the global financial crisis, Chinas limited capital mobility combined with low foreign interest rates raised the fiscal cost of sterilizing capital inflows. Chang et al. (2015) demonstrate that Chinas prevailing capital account and exchange rate regimes present a tradeoff between sterilization costs and domestic price stability. The use of reserve requirements may therefore be understood as a useful alternative tool for the central bank to alleviate inflation pressures while reducing the pace of sterilization.

However, other financial intermediaries, such as the shadow banking sector, are exempt from reserve requirements. Changes in reserve requirements therefore affects the relative lending costs of different forms of financial intermediaries and their clients. The full impact of reserve requirement adjustments can therefore be understood only in a model that tracks the implications of these distortions on credit allocations between banking and non-banking sectors. In this paper, we develop such a model with characteristics unique to China. We use the model to evaluate the implications of using reserve requirements, both as a policy tool for stabilization and in transition, on capital allocation, aggregate productivity, and welfare.

China's financial system is quite distorted, with firms in different sectors enjoying differential access to credit. In particular, state-owned enterprises (SOE) enjoy better access to bank loans than private firms. This may stem from direct channels, such as directed lending to favored sectors or firms; or indirect channels, such as credit allocations that favor sectors or firms privy to implicit government guarantees. In China, SOEs appear to fall into the latter category and can obtain funding from banks, which are mostly state-owned as well. Financing of private firms, especially small and medium-sized firms, relies on informal markets such as shadow banks (Lu et al., 2015).

China's informal, or "shadow," banking sector has grown substantially since 2009. Lending by the shadow banking sector has increased by more than 30% per year between 2009 and 2013, resulting in a rapid increase in China's debt-to-GDP ratio (Hachem and Song, 2015).

At the same time, lending from small and medium-sized Chinese banks were constrained by a cap on the loan-to-deposit ratio of 75%. This limitation on bank lending, combined with the deposit rate ceilings that prevailed during that period and the large increases in the reserve requirement ratio, encouraged off-balance-sheet financial activity and various forms of shadowing banking activity. In particular, constrained banks often issue financial products such as "wealth management products" to attract additional deposits. These financial products are typically unregulated and are kept off the banks' balance sheets. Although the four largest Chinese banks are not constrained by the loan-to-deposit cap, they also issue wealth management products to maintain their market shares (Hachem and Song, 2015). While such shadow banking activity can help reduce intermediation costs, their unregulated activity also raises risks for financial stability (Gorton and Metrick, 2010; Elliott et al., 2015).[1]

In this paper, we evaluate the implications of adjustments in the required reserve ratio for capital allocation and aggregate productivity in a two-sector DSGE model with financial frictions. A homogeneous intermediate good is produced by firms in two sectors: an SOE sector and a private (POE) sector. These sectors have the same production technology, with total factor productivity higher in the private sector. To model financial frictions, we build on the fundamental framework of Bernanke et al. (1999) (thereafter, BGG) with a costly state verification problem, generalized to our two-sector environment. In particular, we assume that firms in each sector needs to finance working capital with both internal net worth and external debt. Production and financing decisions are made after receiving an aggregate productivity shock, but before receiving an idiosyncratic shock. As in Bernanke et al. (1999), loan contracts are signed before the realization of idiosyncratic shocks, and thus the loan rate is identical for all firms. In equilibrium, there is a threshold level of idiosyncratic productivity, above which firms have sufficient funds to repay their loans at their contractual rates and earn non-negative profits. Firms with productivity below the threshold level, however, default. In the event of default, firms undergo costly liquidation.

Our model deviates from the BGG framework in several dimensions. First, we assume that credit markets are segmented, with banks lending to only SOE firms. POE firms borrow from informal financial intermediaries, which we term "shadow banks." For simplicity, we take this complete separation of lending activity as an assumption, but we note in passing that it matches the empirical fact that the bulk of commercial bank lending is directed towards state-owned enterprises, while firms in the private sector, especially those small and

[1]The role of unregulated shadow banking sectors in exacerbating macroeconomic volatility has been documented in the literature, e.g. (Verona et al., 2013).

medium-sized firms, are much more dependent on non-bank funding, such as shadow banking (Lu et al., 2015).

Second, bank depositors are implicitly guaranteed by the government against losses, while investors in shadow banks are not. We model this disparity by assuming that in the event of default and liquidation by an SOE firm, the government covers the bank's loan losses. This guarantee leaves bank loans effectively risk free. This guarantee is an implicit subsidy to SOE firms since it reduces SOE funding costs. In contrast, as there is no such government guarantee for shadow bank loans, the POE sector mimics the standard BGG environment, in which firms face higher average funding costs because their lender charges a premium to compensate for losses under bankruptcy.

Third, banks are subject to reserve requirement. They are required to hold a fraction of their deposits as reserves at the central bank. Since banks do not earn any interest on reserves, this requirement acts as a tax on banks and drives a wedge between deposit and lending rates. Shadow banks are exempt from any such regulation.

To introduce nominal rigidities, we assume that there is a final goods sector, with monopolistically competitive retailers, each using the homogenous intermediate good as input to produce a differentiated retail product. Price adjustments in the final goods sector are costly, following Rotemberg (1982). The representative household purchases a composite of final goods for consumption or capital investment. The household also supplies labor to intermediate good firms.

As only commercial banks are subject to reserve requirements in our model, raising reserve requirements also adversely impacts on the sector dependent on that form of intermediation, namely the SOEs. As we show below, such a policy diverts resources from the SOE sector to the POE sector. Moreover, since SOE firms have lower average productivity, increases in reserve requirements can raise aggregate output and aggregate total factor productivity (TFP), as resources are diverted to the more productive POE sector. However, an increase in reserve requirements also raises the funding costs for SOE firms and leads to additional bankruptcies. Since liquidation of bankrupt firms is costly, the welfare implications of raising reserve requirements, even when SOEs are less productive, are a priori ambiguous, even though adjusting reserve requirements can be an effective policy instrument for achieving macroeconomic stability.

To evaluate the usefulness of reserve requirements as a policy tool, we therefore conduct a few calibration experiments. In the first experiment, we focus on the steady-state effects of changes in the reserve requirement ratio on macroeconomic variables and welfare. Consistent with the tradeoff described above between allocative efficiency and firm bankruptcy costs, we find that raising the reserve requirement ratio leads to an increase in the relative output of the POE sector, and accordingly, an increase in aggregate TFP. At the same time, however, the increased funding costs for SOE firms also lead to a higher bankruptcy ratio for SOE firms and thus an increase in the costs of liquidating those failed firms. We therefore find that there is an interior optimal steady-state level of the required reserve ratio that balances these costs and benefits and maximizes social welfare.

In the second experiment, we compare the stabilizing performance of two simple policy rules, a nominal interest rate rule and a reserve requirement rule in an economy hit by an aggregate technology shock. Under each policy rule, the policy instrument reacts to changes in output gap and inflation, with the coefficients in the reaction function chosen to maximize the representative household's welfare. We find that an optimal interest rate rule is more effective for stabilizing inflation, whereas an optimal reserve requirement rule is more effective for stabilizing real GDP. Under the optimal interest rate rule, the deposit rate increases with inflation and decreases with real GDP, and thus the policy rule is accommodative to aggregate TFP shocks. Under the optimal reserve requirement rule, the reserve requirement ratio increases with real GDP and decreases with inflation and thus, this policy rule is a "lean-against-the-wind" policy. When the planner is allowed to optimally choose the coefficients in both policy rules, the planner raises reserve requirement aggressively, leading to a decline in SOE output and an increase in POE output. The policy responses also raise the bankruptcy ratios and therefore the social cost of liquidation. But overall, social welfare is substantially higher when the planner can optimize over both rules, suggesting that these policy rules are complementary stabilization tools.

A key source of distortion in our model stems from the implicit government guarantees of SOE loans. Such guarantees eliminate the default premium for SOE firms and thus result in over-production by the SOE sector despite its lower average productivity. These guarantees of SOE loans also imply that the BGG type of financial accelerator mechanism is muted for the SOE sector. Thus, in designing optimal policy rules, the planner faces the tradeoff between reallocating resources from SOE firms to more productive POE firms and the social costs of defaults that arise from the financial accelerator in the POE sector. Our results indicate that all policy rules are chosen to mitigate this distortion to some extent, by shifting resources to the more productive POE sector.

In the third experiment, we consider how reserve requirements affect the transition dynamics when the SOE firm's productivity is improved permanently, holding all else constant. In particular, we calculate the required reserve ratio that maximizes social welfare along the transition path, starting in the period when SOE productivity rises. We find that the optimal required reserve ratio in the final steady state is lower than that in the initial steady state, because SOE productivity becomes permanently higher in the final steady state. Along the transition path, however, the optimal require requirement ratio is even lower. This temporarily low level of required reserve ratio helps accelerate the reallocation from the POE sector to the SOE sector.

II. Model

The economy is populated by a continuum of infinitely-lived households. The representative household consumes a basket of differentiated goods purchased from retailers. Retailers produce differentiated goods using homogeneous intermediate goods as inputs. These intermediate goods are produced by two types of firms: state-owned firms, and private firms. The two types of firms have identical production technologies ex-ante except that private firms' total factor productivity is higher.

In particular, each firm produces homogeneous intermediate goods using capital and labor and is subject to an idiosyncratic productivity shock that is realized only after production takes place. They pay the wage bills and the capital rents before production, and finance the working capital externally. Each firm is also subject to a costly verification problem following Bernanke et al. (1999): only borrowers can observe the realized shock without cost; lenders need to pay a liquidation cost to be able to observe the realized shock and liquidate production.

There are two types of financial intermediaries: commercial banks and private intermediaries. Both financial intermediaries take deposits from the representative household with a promise to pay a predetermined nominal interest rate in the next period. There are three main differences between the two financial intermediaries: State guarantees, market segmentation and reserve requirements. First, the Chinese government implicitly guarantees the repayment of SOE loans. Second, credit markets are segmented: state-owned firms firms raise funds from commercial banks, while private firms raise funds from private intermediaries, which we term shadow banks. Formally, we assume that the government covers losses on SOE loans but does not cover losses on POE loans. Finally, the model assumes that commercial banks are subject to reserve requirements, while private intermediaries are not. Reserve requirements induce a spread over funding costs in commercial bank lending rates.

II.1. **The household.** The representative household life-time expected utility function is given by:

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

where C_t is consumption and H_t represents labor hours. H_t is a composite of labor hours working on both SOEs $H_{s,t}$ and POEs $H_{p,t}$:

$$H_t = (\mu H_{s,t}^{1+\sigma_L} + (1-\mu)H_{p,t}^{1+\sigma_L})^{\frac{1}{1+\sigma_L}}. \tag{2}$$

where σ_L measures the elasticity of substitution between labor hours in SOEs $H_{s,t}$ and labor hours in POEs $H_{p,t}$. The two types of labor hours are perfectly substitutable if $\sigma_L = 0$ and has a unit elasticity of substitution if $\sigma_L = -1$.

At the beginning of each period, the household allocates her savings between private deposits D_t^p and bank deposits D_t^s. Both types of deposits pay a risk-free rate R_t at the beginning of the next period.

At the end of each period, the household invests I_t in physical capital. The household's sources of income include wage income, interest income on deposits, firm dividends and government transfers. The budget constraint of the household at the end of each period is given by:

$$C_t + I_t + \frac{D_{p,t} + D_{s,t}}{P_t} = w_{s,t}H_{s,t} + w_{p,t}H_{p,t} + r_k K_{t-1} + R_{t-1}\frac{D_{s,t-1} + D_{p,t-1}}{P_t} + T_t. \tag{3}$$

where $w_{s,t}$ and $w_{p,t}$ are the real wage rates prevailing in SOEs and POEs respectively. r_t^k is the real rental rate. R_t is the nominal gross interest rate on savings. T_t denotes the lump-sum transfers from firm dividends and the government to the household.

Capital accumulation follows

$$K_t = (1-\delta)K_{t-1} + [1 - \frac{\Omega_k}{2}(\frac{I_t}{I_{t-1}} - g_I)^2]I_t. \tag{4}$$

The household maximizes (1) subject to (3) and (4). Household optimizing conditions are summarized by

$$\begin{aligned}
\Lambda_t &= \frac{1}{C_t}, && (5)\\
\Lambda_t w_{s,t} &= \Psi H_t^{\eta-\sigma_L}\mu H_{s,t}^{\sigma_L}, && (6)\\
\Lambda_t w_{p,t} &= \Psi H_t^{\eta-\sigma_L}(1-\mu)H_{p,t}^{\sigma_L}, && (7)\\
\Lambda_t &= \beta R_t \frac{\Lambda_{t+1}}{\pi_{t+1}}, && (8)\\
\Lambda_t &= \Lambda_t^k[1 - \frac{\Omega_k}{2}(\frac{I_t}{I_{t-1}} - g_I)^2 - \Omega_k(\frac{I_t}{I_{t-1}} - g_I)\frac{I_t}{I_{t-1}}] + \beta\Lambda_{t+1}^k\Omega_k(\frac{I_{t+1}}{I_t} - g_I)(\frac{I_{t+1}}{I_t})^2. && (9)\\
\Lambda_t^k &= \beta[\Lambda_{t+1}^k(1-\delta) + \Lambda_{t+1}r_{t+1}^k], . && (10)
\end{aligned}$$

where Λ_t denotes the Lagrangian multiplier for the budget constraint (3), Λ_t^k denotes the Lagrangian multiplier for the capital accumulation constraint (4), and $\pi_t = \frac{P_t}{P_{t-1}}$ denotes the inflation rate from period $t-1$ to period t.

We define Tobin's q as follows:

$$q_t = \Lambda_t^k / \Lambda_t. \tag{11}$$

II.2. **Retail sector and price setting.** To motivate sticky prices, we assume monopolistic competition occurs at the "retail" level. Let $Y_t(z)$ be the quantity of output sold by retailer z, measured in units of intermediate goods, and let $P_t(z)$ be the nominal price. Total final usable goods Y_t^f are the following composite of individual retail goods:

$$Y_t^f = [\int_0^1 Y_t(z)^{(\epsilon-1)/\epsilon} dz]^{\epsilon/(\epsilon-1)}, \tag{12}$$

where ϵ denotes the elasticity of substitution among retail goods with $\epsilon > 1$. The corresponding price index is given by,

$$P_t = [\int_0^1 P_t(z)^{(1-\epsilon)} dz]^{1/(1-\epsilon)}, \tag{13}$$

Given the index that aggregate individual retail goods into final goods, the demand curve facing each retailer is given by,

$$Y_t(z) = (\frac{P_t(z)}{P_t})^{-\epsilon} Y_t^f, \tag{14}$$

We assume that price adjustment is costly. Following Rotemberg(1982), retailers face a quadratic cost of price adjustment

$$\frac{\Omega_p}{2}(\frac{P_t(z)}{\pi P_{t-1}(z)} - 1)^2 C_t,$$

where Ω_p is the average size of adjustment costs and π is the steady-state inflation rate. In particular, retailer z chooses his price to maximize expected discounted profits, given by

$$\sum_{i=0}^{\infty} \beta^i E_t \Lambda_{t+i} [\frac{P_{t+i}(z) - P_{t+i}^w}{P_{t+i}} Y_{t+i}(z) - \frac{\Omega_p}{2}(\frac{P_{t+i}(z)}{\pi P_{t+i-1}(z)} - 1)^2 C_{t+i}], \tag{15}$$

where P_t^w is the nominal price of intermediate goods and Y_{t+i} is given by Eq. (14).

The optimal price-setting decision implies that, in a symmetric equilibrium with $P_t(z) = P_t$ for all z, we have

$$\frac{1}{x_t} = \frac{\epsilon - 1}{\epsilon} + \frac{\Omega_p}{\epsilon} \frac{1}{Y_t} [(\frac{\pi_t}{\pi} - 1) \frac{\pi_t}{\pi} C_t - \beta E_t \frac{\Lambda_{t+1}}{\Lambda_t} (\frac{\pi_{t+1}}{\pi} - 1) \frac{\pi_{t+1}}{\pi} C_{t+1}]. \tag{16}$$

where $x_t = P_t / P_t^w$ is the markup of the retail price over the wholesale price.

II.3. **Firms.** We consider a representative firm of type c: $c = p$ for a private firm; $c = s$ for a state-owned firm. Each firm produces intermediate goods using capital and labor and externally finances its working capital in each period. In particular, in period t, a type-c firm combines managerial labor $H_{c,e,t}$, household labor $H_{c,t}$ and capital $K_{c,t}$ to produce intermediate goods $Y_{c,t}$. The production function is given by,

$$Y_{c,t} = A_t \bar{A}_c \omega_{c,t} (K_{c,t})^{1-\alpha} [H_{c,e,t}^{1-\theta} H_{c,t}^{\theta}]^{\alpha}. \tag{17}$$

where α and θ are the production shares. The term $\omega_{c,t}$ is an idiosyncratic productivity shock that differs across individual firms. It is realized after production and is freely observable only to the individual firm. The lender needs to pay a liquidation cost to be able to observe the shock and liquidate production. $\omega_{c,t}$ has mean unity and has accumulative distribution function $F(\cdot)$ over a non-negative range. The term A_t is the common productivity shock to all firms and is publicly observed before firms take production decisions. A_c is a constant reflecting TFP differences across types.

The evolution of A_t follows,

$$\ln(A_t) = g_A t + \rho_s \ln(A_{t-1}) + \epsilon_{a,t}. \tag{18}$$

where The parameter g_A is the steady-state growth rate of the technology. $\epsilon_{a,t}$ is a productivity shock that follows a log-normal distribution $N(0, \sigma_a)$.

The payment of wage bills and captial rents must be made in advance of the production. At the beginning of period t, the type-c firm has net worth $N_{c,t-1}$ and borrows $B_{c,t}$ to satisfy the working captial constraint:

$$\frac{N_{c,t-1} + B_{c,t}}{P_t} = w_{c,t} H_{c,t} + w_{c,t}^e H_{c,e,t} + r_t^k K_{c,t}. \tag{19}$$

where $w_{c,t}^e$ is the real wage rate of managerial labor.

We first focus on the production decision. At the beginning of period t, the firm chooses $H_{c,e,t}$, $H_{c,h,t}$ and $K_{c,t}$ to maximize expected production revenue

$$P_t Y_{c,t} / x_t, \tag{20}$$

subject to Eq.(19).

The optimal production decision is then given by,

$$w_{c,t} H_{c,t} = \alpha\theta \tfrac{N_{c,t-1} + B_{c,t}}{P_t}, \tag{21}$$

$$w_{c,t}^e H_{c,e,t} = \alpha(1-\theta) \tfrac{N_{c,t-1} + B_{c,t}}{P_t}. \tag{22}$$

$$r_t^k K_{c,t} = (1-\alpha) \tfrac{N_{c,t-1} + B_{c,t}}{P_t}. \tag{23}$$

Given the optimal production decision, the actual production revenue of the firm is given by,

$$
\begin{aligned}
& P_t A_{c,t}\omega_{c,t}(K_{c,t})^{1-\alpha}[H_{c,e,t}^{1-\theta}H_{c,t}^{\theta}]^{\alpha}/x_t,\\
=& P_t A_{c,t}\omega_{c,t}(\frac{(1-\alpha)(N_{c,t-1}+B_{c,t})}{r_t^k P_t})^{1-\alpha}[(\frac{(1-\theta)\alpha(N_{c,t-1}+B_{c,t})}{w_t^e P_t})^{1-\theta}(\frac{\theta\alpha(N_{c,t-1}+B_{c,t})}{w_{c,t}P_t})^{\theta}]^{\alpha}/x_t,\\
=& A_{c,t}\omega_{c,t}(\frac{1-\alpha}{r_t^k})^{1-\alpha}[(\frac{\alpha(1-\theta)}{w_{c,t}^e})^{1-\theta}(\frac{\alpha\theta}{w_{c,t}})^{\theta}]^{\alpha}(N_{c,t-1}+B_{c,t})/x_t,\\
\equiv& \tilde{A}_{c,t}\omega_{c,t}(N_{c,t-1}+B_{c,t}).
\end{aligned}
$$

where $\tilde{A}_{c,t}$ is defined as $\tilde{A}^{c,t} \equiv A_{c,t}(\frac{1-\alpha}{r_t^k})^{1-\alpha}[(\frac{\alpha(1-\theta)}{w_{c,t}^e})^{1-\theta}(\frac{\alpha\theta}{w_{c,t}})^{\theta}]^{\alpha}/x_t$.

Financial intermediaries invest in type-c firms in forms of a bond contract to ensure a risk-free interest rate $R_{c,t}$. Since the lender can observe an individual borrower's realized return only at a cost, in equilibrium they charge a state-contingent gross interest rate $Z_{c,t}$ over the cost of funds to cover their liquidation costs. Under this financial arrangement, type-c firms with sufficiently low levels of realized productivity are not able to make repayments. There is a cut-off level of productivity $\bar{\omega}_{c,t}$ such that firms with $\omega_{c,t} < \bar{\omega}_{c,t}$ choose to default. The default decision is described by

$$
\omega_{c,t} < \bar{\omega}_{c,t} \equiv \frac{Z_{c,t}B_{c,t}}{\tilde{A}_{c,t}(N_{c,t-1}+B_{c,t})}. \tag{24}
$$

If the firm fails to make its repayments, it is liquidated by the lender. In the process of liquidation, a fraction $m_{c,t}$ of output is lost and the remainder is obtained by the lender. The government takes over failing SOE firms and covers a fraction l_c of the loan loss using lump sum taxes collected from the households. We assume that $m_{s,t} < m_{p,t}$ such that SOEs have lower liquidation costs than POEs. We also assume that $l_s = 1$ and $l_p = 0$ such that the government cover all the loss for SOE borrowing, but does not cover losses on POE borrowing.

We now describe the optimal contract. Under the bond contract featured by $\bar{\omega}_{c,t}$ and $B_{c,t}$, the expected nominal income for the type-c firm is given by,

$$
\begin{aligned}
&\int_{\overline{\omega}_{c,t}}^{\infty} \tilde{A}_{c,t}\omega_{c,t}(N_{c,t-1}+B_{c,t})dF(\omega) - (1-F(\overline{\omega}_{c,t}))Z_{c,t}B_{c,t}\\
&= \tilde{A}_{c,t}(N_{c,t-1}+B_{c,t})[\int_{\overline{\omega}_{c,t}}^{\infty}\omega dF(\omega) - (1-F(\overline{\omega}_{c,t}))\overline{\omega}_{c,t}]\\
&\equiv \tilde{A}_{c,t}(N_{c,t-1}+B_{c,t})f(\overline{\omega}_{c,t}).
\end{aligned}
$$

where $f(\overline{\omega}_{c,t})$ is the share of production revenue going to the SOE under the bond contract.

The expected nominal income for the lender is given by,

$$
\begin{aligned}
&(1-F(\overline{\omega}_{c,t}))Z_{c,t}B_{c,t}+\int_0^{\overline{\omega}_{c,t}}\{(1-m_{c,t})\tilde{A}_{c,t}\omega(N_{c,t-1}+B_{c,t})\\
&\qquad +l_c[Z_{c,t}B_{c,t}-(1-m_{c,t})\tilde{A}_{c,t}\omega(N_{c,t-1}+B_{c,t})]\}dF(\omega)\\
&= \tilde{A}_{c,t}(N_{c,t-1}+B_{c,t})\{[1-(1-l_c)F(\overline{\omega}_{c,t})]\bar{\omega}_{c,t}+(1-m_{c,t})(1-l_c)\int_0^{\overline{\omega}_t}\omega dF(\omega)\}\\
&\equiv \tilde{A}_{c,t}(N_{c,t-1}+B_{c,t})g_{c,t}(\overline{\omega}_{c,t}). \qquad (25)
\end{aligned}
$$

where $g_c(\overline{\omega}_{c,t})$ is the share of production revenue going to the lender under the bond contract with type-c firm. Note that

$$f(\overline{\omega}_{c,t})+g_{c,t}(\overline{\omega}_{c,t})=1-m_{c,t}\int_0^{\overline{\omega}_{c,t}}\omega dF(\omega)+l_c\int_0^{\overline{\omega}_{c,t}}[\overline{\omega}_{c,t}-(1-m_{c,t})\omega]dF(\omega).$$

The optimal contract is the pair $(\bar{\omega}_{c,t}, B_{c,t})$. The firm chooses $(\bar{\omega}_{c,t}, B_{c,t})$ at the beginning of period t to maximize expected income

$$\max \tilde{A}_{c,t}(N_{c,t-1}+B_{c,t})f(\overline{\omega}_{c,t}) \qquad (26)$$

subject to the lender's participation constraint

$$\tilde{A}_{c,t}(N_{c,t-1}+B_{c,t})g_c(\overline{\omega}_{c,t})\geq R_{c,t}B_{c,t}. \qquad (27)$$

Optimization implies that the leverage ratio satisfies

$$\frac{N_{c,t-1}}{B_{c,t}+N_{c,t-1}}=-\frac{g_c'(\overline{\omega}_{c,t})}{f'(\overline{\omega}_{c,t})}\frac{\tilde{A}_{c,t}f(\overline{\omega}_{c,t})}{R_{c,t}}, \qquad (28)$$

We assume that there is a one unit continuum of firms of each type. Each firm is managed by a manager with a finite expected life horizon. In particular, we assume that each manager has a constant probability ξ_c of surviving to the next period (implying an expected lifetime of $1/(1-\xi_c)$). The assumption of finite horizons for managers is intended to capture the practice of management turnover, as well as to preclude the possibility that SOEs will ultimately accumulate enough wealth to be fully self-financing[2].

At the end of each period t, a fraction $1-\xi_c$ of managers exit. Managers who exit are replaced by entering (or "new") managers. We assume a manager birthrate that keeps the total number of managers constant. To ensure new managers have start-up funds, we assume that, in addition to operating their firms, managers supplement their income by supplying managerial labor $H_{c,e,t}$ at the wage rate $w_{c,t}^e$. Each manager supplies one unit of labor inelastically and can only move within his or her sector (i.e. $H_{c,e,t}=1$). The end-of-period aggregate net worth of all type-c firms is then given by,

[2]With an infinite horizon, a manager optimally retains all the earnings until it is fully self-financing.

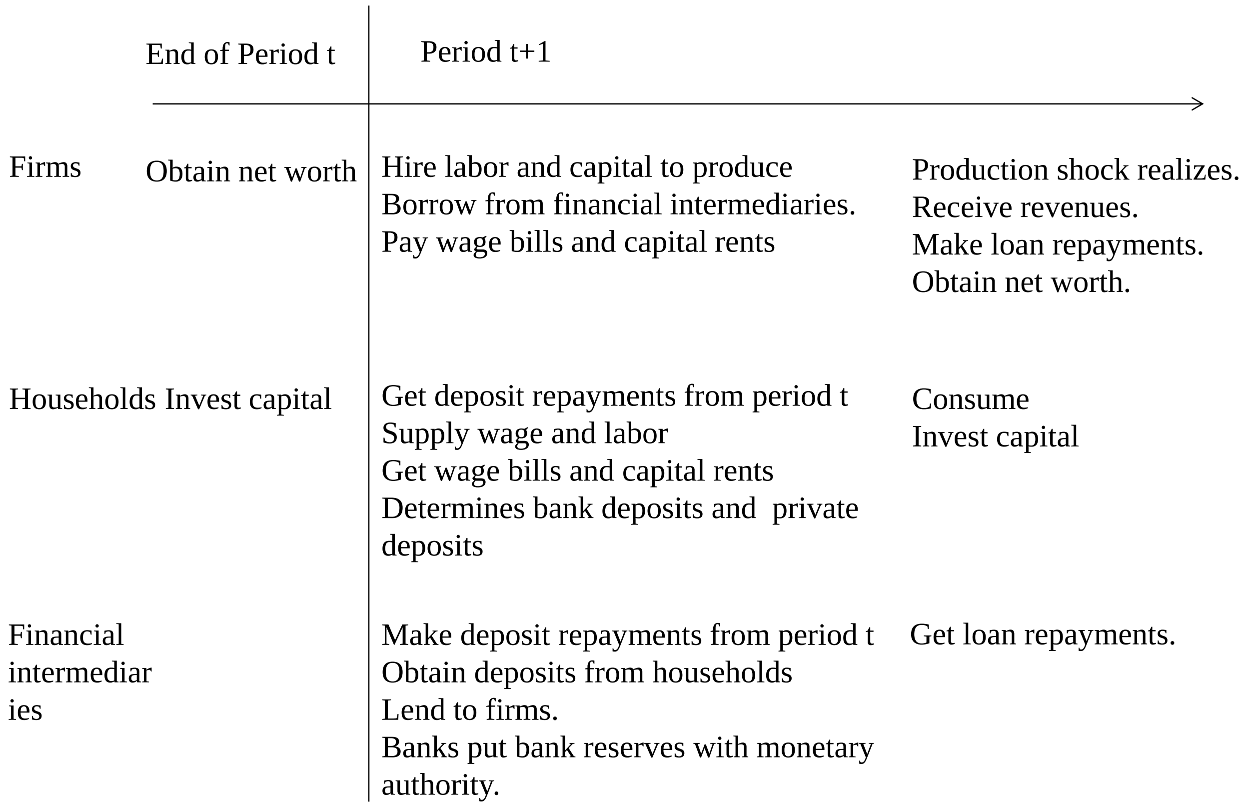

FIGURE 1. Timeline of the Model.

$$N_{c,t} = \xi_c \tilde{A}_{c,t}(N_{c,t-1} + B_{c,t}) f(\overline{\omega}_{c,t}) + w^e_{c,t} H_{c,e,t}. \tag{29}$$

where $\tilde{A}_{c,t}(N_{c,t-1} + B_{c,t}) f(\overline{\omega}_{c,t})$ is the aggregate net profit of all type-c firms obtained from operating in period t.

II.4. **Financial intermediaries.** At the beginning of each period t, both commercial banks and private intermediaries obtain deposits from households at the interest rate R_t and grant loans to firms. The timeline of the model is as follows:

Commercial banks obtain household deposits $D_{s,t}$ at interest rate R_t. They are required to hold a fraction τ_t of the deposits at the monetary authority. They grant the remainder as loans $B_{s,t}$ to state-owned firms at the risk-free interest rate $R_{s,t}$. Banks therefore maximize profits

$$R_{s,t} B_{s,t} + \tau_t (D_{s,t}) - R_t D_{s,t}, \tag{30}$$

subject to their balance sheet constraint,

$$D_{s,t} = \tau_t D_{s,t} + B_{s,t}. \tag{31}$$

Their optimization condition satisfies

$$(R_{s,t} - 1)(1 - \tau_t) = (R_t - 1). \tag{32}$$

Private intermediaries obtain household deposits $D_{p,t}$ at the interest rate R_t and grant loans $B_{p,t}$ to private firms at the risk-neutral interest rate $R_{p,t}$. Therefore, private intermediaries maximize their profit function:

$$R_{p,t}B_{p,t} - R_t D_{p,t}, \tag{33}$$

subject to the balance sheet constraint

$$D_{p,t} = B_{p,t}. \tag{34}$$

Their optimization condition satisfies,

$$R_{p,t} = R_t. \tag{35}$$

II.5. **Monetary policy and market clearing.** Monetary policy is conducted by the central bnka through two policy tools: Reserve requirements, τ_t, and the deposit rate R_t. We assume that the central bank adjusts these policy tools in response to the output and the inflation gaps as follows:

$$\ln(R_t/R) = \rho_r \ln(R_{t-1}/R) + \psi_{rp}\ln(\pi_t/\Pi) + \psi_{ry}\ln(GDP_t/GDP). \tag{36}$$

where R, Π and GDP are the steady state values of R_t, π_t and GDP_t, and

$$\tilde{\tau}_t - \tilde{\tau} = \rho_\tau(\tilde{\tau}_{t-1} - \tilde{\tau}) + \psi_{\tau p}\ln(\pi_t/\pi) + \psi_{\tau y}\ln(GDP_t/GDP). \tag{37}$$

where $\tilde{\tau}_t$ increases with τ_t such that $\tau_t \in [0, 1]$

$$\tau_t = f(\tilde{\tau}_t) = (atan(\tilde{\tau}_t) + \frac{\pi}{2})/\pi. \tag{38}$$

Final output may be either transformed into a single type of consumption good, invested, consumed by the government or used in liquidation efforts. Goods market clearing then implies

$$\begin{aligned} Y_t^f &= C_t + \frac{\Omega_p}{2}(\frac{\pi_t}{\pi} - 1)^2 C_t + I_t + G_t + \tilde{A}_{s,t}(N_{s,t-1} + B_{s,t})m_t \int_0^{\bar{\epsilon}_{s,t}} \omega dF(\omega) \\ &\quad + \tilde{A}_{p,t}(N_{p,t-1} + B_{p,t})m_t \int_0^{\bar{\epsilon}_{p,t}} \omega dF(\omega). \end{aligned} \tag{39}$$

We define GDP as final output excluding liquidation and price adjustment costs

$$GDP_t = C_t + I_t + G_t, \tag{40}$$

The government consumption (G_t) to GDP ratio fluctuates around the steady-state the govenrment consumption to GDP ratio, g

$$G_t = GDP_t g_t, \tag{41}$$

where g_t follows,

$$\ln(g_t/g) = \rho_g \ln(g_{t-1}/g) + \epsilon_{g,t}. \tag{42}$$

where ϵ_t^g is a government consumption shock that follows a log-normal distribution $N(0, \sigma_g)$.

Final output is a combination of differentiated retail goods, produced with the intermediate goods supplied by private and state-owned firms,

$$Y_t^f = (Y_{s,t} + Y_{p,t})/x_t. \tag{43}$$

We define two types of the aggregate TFP, based on output and GDP respectively

$$\tilde{A}_{Y,t} = \frac{Y_{s,t} + Y_{p,t}}{(K_{s,t} + K_{p,t})^{1-\alpha} H_t^{\alpha\theta}}. \tag{44}$$

$$\tilde{A}_{GDP,t} = \frac{GDP_t}{(K_{s,t} + K_{p,t})^{1-\alpha} H_t^{\alpha\theta}}. \tag{45}$$

Note that GDP_t differs from $Y_{s,t} + Y_{p,t}$ in that it not only excludes the liquidation and price adjustment costs but also includes the markup of retail goods x_t.

Using firms' production decisions, we express output-based aggregate TFP as an average of SOE and POE TFP, weighted by their spending $N_{c,t} + B_{c,t}$:

$$\tilde{A}_{Y,t} = \mu^{1-\alpha} (\frac{H_{s,t}}{H_t})^{(1+\sigma_L)(1-\alpha)+\alpha\theta} A_t A_s + (1-\mu)^{1-\alpha} (\frac{H_{p,t}}{H_t})^{(1+\sigma_L)(1-\alpha)+\alpha\theta} A_t A_p.$$

The market also clears for physical capital

$$K_{t-1} = K_{s,t} + K_{p,t}. \tag{46}$$

II.6. **Shocks.** We consider three exogenous shocks to the economy. The first shock is the government consumption shock $\epsilon_{g,t}$. The second shock is the aggregate productivity shock $\epsilon_{a,t}$. The third shock is the financial shock $\epsilon_{m,t}$, captured by the variation in monoitoring costs.

III. Calibration

Parameters are selected to best capture the specific ratios in Chinese economy. Table 1 summarizes the calibrated parameter values. Our time unit is one quarter.

We set the discount rate $\beta = 0.99$ and set the steady-state balanced growth rate g and the target inflation rate π such that the annual growth rate of output is 5% and the annual inflation rate is 2%. We calibrate the elasticity of substitution among retail goods ϵ at 5 to match the average of the gross profit margin of industrial enteprises (20%). We set $g = 13\%$ to match the government consumption ratio $\frac{G}{C+I+G}$ in Chinese economy. We set $\Omega_p = 22$, implying an average duration of price contracts of about four quarters.[3]

For utility function parameters, we set $\eta = 2$, implying a Frisch elasticity of 0.5, consistent with microevidence by Pencavel (1987). We set Ψ such that the steady state value of total labor hours is around 1/3. We set the labor elasticity of substitution between two sectors $\sigma_L = 1$ following the estimate of Horvath (2000), and calibrate SOE labor share $\mu = 0.67$ such that the wage rate of SOEs and POEs equals $w_s = w_p$ in the steady state.

Regarding technology, we set the capital depreciation rate δ at 0.035. We set the investment adjustment cost parameter $\Omega_k = 3$. We set the labor share $\alpha = 0.5$. We take the idiosyncratic productivity shock $\omega_{i,t}$ to be Pareto distributed following the estimate in Song and Hsieh (2015).[4] We set SOEs' TFP parameter $\bar{A}_s = 1$. We set the household labor share to $\theta = 0.94$. We calibrate the POEs' TFP parameter at $\bar{A}_p = 1.23$ to target the steady-state outcome that the ratio of SOEs' value added and POEs' value added in the industrial sector is around 0.4 on average from 2011 to 2014. Note that our calibrated $A_p/A_s = 1.23$ is lower than Hsieh and Klenow (2009)'s estimate of a "revenue-TFP gap" of 1.42.

Regarding the financial parameters, we set the loan coverage ratio $l_p = 0$ for POEs and $l_s = 1$ for SOEs. We set the liquidation cost to $m_s = 0.15$ for SOEs and $m_p = 0.15$ for POEs following BGG. We set the SOE manager's survival rate at $\xi_s = 0.98$ (implying an average term of around 16 years) and the POE manager's survival rate at $\xi_p = 0.62$ (implying

[3]Log-linearizing the optimal pricing decision equation (16) around the steady state leads to a linear form of Phillips curve relation with the slope of the Phillips curve given by $\kappa = \frac{\epsilon-1}{\Omega_p}\frac{C}{Y}$. Our calibration implies a steady state ratio of consumption to gross output of about 48%. The values of $\epsilon = 5$ and $\Omega_p = 22$ imply that $\kappa = 0.086$. In an economy with Calvo-type price contracts, the slope of the Phillips curve is given by $(1 - \beta\alpha_p)(1 - \alpha_p)/\alpha_p$ where α_p is the probability that a firm cannot re-optimize prices. To obtain a slope of 0.086 for the Phillips curve in the Calvo model, α_p must be set equal to 0.75, which corresponds to an average duration of price contracts of about four quarters.

[4]Song and Hsieh (2015) estimated that the standard deviation of log TFP across firms is around 1.2. The underlying standard deviation of TFP level across firms is around 3.22 if TFP level log-normally distributed with mean unity. In our model, we assume the cumulative distribution function $F(\omega) = 1 - (\frac{\omega_m}{\omega})^k$ over the range $[\omega_m, +\infty)$. We set $k = 2.14$ and $\omega_m = 0.53$ such that $var(\omega_{i,t}) = 3.22$.

an average term of around 8 months) to target the steady state outcome that the annual bankruptcy ratio is around 0.25 for both SOEs and POEs.[5]

For the monetary policy parameters, we set the steady-state required reserve ratio to $\tau = 0.15$. We set the interest rate rule at $\rho_r = 0$, $\psi_{rp} = 2$, and $\psi_{ry} = 0.5$ with no required reserve ratio response ($\psi_{\tau p} = 0$ and $\psi_{\tau y} = 0$).

IV. Quantitative results

We next illustrate the implications of adjusting reserve requirements for aggregate productivity and welfare in the calibrated model. First, we consider the steady state equilibrium, and examine how equilibrium values depend on the required reserve ratio τ. Second, we study optimal simple policy rules, with the policy instrument given by the nominal interest rate (i.e., the deposit rate R_t) or the required reserve ratio τ_t. We assume that the policy instrument responds to deviations of real GDP from potential GDP and of inflation from target, with the response coefficients optimally chosen to maximize the representative household's welfare. Third, we evaluate the implications of changes in reserve requirements for a counterfactual economy going through transition, during which the average productivity of SOE firms gradually rises to a permanently higher level.

IV.1. **Optimal steady-state reserve requirements.** We begin by exploring the effects of changes in the required reserve ratio τ on resource allocations and welfare. To do this, we focus on the deterministic steady-state equilibrium, in which all exogenous shocks are turned off.

Figure 2 displays the relations between a few steady-state variables (on the vertical axes) and the steady-state values of the required reserve ratio τ (on the horizontal axes). The figure shows that, as τ rises, SOE output falls relative to POE output, since a higher value of τ implies a higher bank loan rate for SOE firms, less capital and labor would be used by SOE firms and more would be employed by private firms. Since SOE firms have lower average productivity than private firms, the reallocation of production factors raises aggregate TFP. However, as they face higher funding costs, the default rate of SOE firms increases, leading to higher bankruptcy costs. These increases in bankruptcy costs reduce the resources available for consumption and investment, leading to a decline in real GDP.

These steady-state results illustrate the tradeoff involving adjustments of the required reserves. On one hand, raising required reserves can improve allocation efficiency. On the

[5] The NBS industrial survey reports that the annual fraction of industrial firms that earns negative profits is around 24% for SOEs and 10% for POEs. However, this number is likely to be underestimated, especially for POEs, because the NBS industrial survey disproportionately collects information from large industrial firms.

other hand, it also increases the bankruptcy ratio for SOE firms, and thus raises liquidation costs. In general, there will be an interior optimum for the social welfare maximizing required reserve ratio (τ^*).

IV.2. **Optimal simple policy rules.** In addition to its implications for steady-state allocation and welfare, the required reserve ratio can be used as a policy instrument to stabilize macroeconomic fluctuations. To illustrate this point, we compare two simple policy rules: A standard Taylor rule, under which the central bank adjusts the nominal deposit rate to respond to fluctuations of output gap and inflation, and a reserve requirement rule, which is similar to the Taylor rule but with the policy instrument being the required reserve ratio instead of the nominal interest rate.

In particular, the Taylor rule is given by

$$\ln\left(\frac{R_t}{R}\right) = \psi_{rp}\frac{\pi_t}{\bar{\pi}} + \psi_{ry}\frac{Y_t}{\bar{Y}}, \tag{47}$$

where R_t is the nominal (risk-free) deposit rate, π_t is the inflation rate, and Y_t is the real GDP. The variables without a time subscript denote the steady-state values. The parameters ψ_{rp} and ψ_{ry} measure the responsiveness of the nominal interest rate to fluctuations in inflation and output gap.

The reserve requirement rule is given by

$$\ln\left(\frac{\tau_t}{\tau}\right) = \psi_{\tau p}\frac{\pi_t}{\bar{\pi}} + \psi_{\tau y}\frac{Y_t}{\bar{Y}}, \tag{48}$$

where τ_t denotes the required reserve ratio, and τ is the steady-state value. Similar to those in the Taylor rule, the parameters $\psi_{\tau p}$ and $\psi_{\tau y}$ measure the responsiveness of the required reserve ratio to changes in inflation and output gap.

We consider a benchmark policy, under which the central bank follows the Taylor rule in Equation (47), with $\psi_{rp} = 2.0$ and $\psi_{ry} = 0.5$ and keeps the required reserve ratio constant ($\tau_t = \tau$ for all $t \geq 0$). We compare the stabilizing properties and welfare implications of this benchmark to 3 optimal simple rules: The first is an optimal interest-rate rule, under which the policy coefficients ψ_{rp} and ψ_{ry} in Equation (47) are set to maximize the representative household's welfare, while keeping τ_t at its steady-state value τ. The second is an optimal reserve requirement rule, under which the policy coefficients $\psi_{\tau p}$ and $\psi_{\tau y}$ in Equation (48) are optimally set, while the Taylor rule coefficients are kept at their benchmark values (i.e., $\psi_{rp} = 2.0$ and $\psi_{ry} = 0.5$). The third is a jointly optimal rule, with the policy coefficients in Equations (47) and (48) are all optimally set to maximize social welfare. Under each optimal simple rule, we use the benchmark rule as initial guesses for a Nelder-Mead simplex direct search algorithm that searches for optimal coefficients to maximize social welfare.

We consider a single aggregate TFP shock that follows an AR(1) stochastic process with a persistence parameter of 0.8 and a standard deviation of the innovation of 0.01.

Figures 3 and 4 display the impulse responses of a few macroeconomic variables to a positive aggregate TFP shock under the three different optimal policy rules. The impulse responses reveal a few interesting results. First, the optimal interest-rate rule is accommodative in the sense that a positive TFP shock leads to monetary policy easing by lowering the interest rate. The interest rate declines because the shock lowers inflation. This result is consistent with the standard New Keynesian literature. Second, in contrast to the optimal interest rate rule, the optimal reserve requirement rule is a "leaning against the wind" policy: A positive TFP shock leads to monetary policy tightening by raising the required reserve ratio. Third, the jointly optimal policy features a sharp increase in the required reserve ratio, accompanied by a moderate decline in the deposit rate. These differences in the policy responses under different optimal rules result in different aggregate and sectoral dynamics.

In our model, the POE sector features the standard financial accelerator mechanism as in the model of Bernanke et al. (1999). The effects of a positive TFP shock on POE output is amplified by this channel. The expansion in POE output raises POE firms' net worth and lowers the credit spread. These effects enable the POE firms to increase leverage to finance more working capital, leading to additional POE output expansion.

In contrast, because of the government guarantees to SOE firms, the financial accelerator mechanism is muted for that sector. In particular, the loan rate for SOE firms does not depend on default risk. The positive aggregate TFP shock therefore has a relatively smaller expansionary effects on SOE output than on POE output, as shown in Figure 4.

Since POE firms are on average more productive than SOE firms, optimal policy would further reallocate resources away from the SOE sector toward the POE sector. Such policy would further dampen fluctuations in SOE output and amplify fluctuations in POE output following the positive TFP shock. However, different optimal policy rules embed different mechanisms to achieve such reallocation.

Under the optimal interest-rate rule, the deposit rate declines, lowering the funding costs for both banks and shadow banks. Since the financial accelerator is muted in the SOE sector, the decline in deposit rate under the optimal interest-rate rule benefits the POE sector more than it does the SOE sector. Accordingly, as shown in Figure 4, leverage and output in the POE sector increase much more than in the SOE sector. Furthermore, the reallocation of resources from SOE to POE firms raises aggregate TFP, reinforcing the initial increase in aggregate productivity and leading to further expansions in real GDP, as shown in Figure 3. The decline in the deposit rate also stimulates aggregate demand, so that the decline in inflation following the positive TFP shock is relatively muted.

Under the optimal reserve requirement rule, the required reserve ratio rises following the positive aggregate TFP shock. The higher required reserve ratio directly raises the loan rate for SOE firms, with only indirect effects on the funding costs for POE firms. The positive TFP shock raises leverage and output in both sectors, but the increase in required reserves dampens the increase in leverage for SOEs. However, Figure 4 shows that raising reserve requirements is less effective for dampening SOE activity than for lowering the deposit rate. Although the positive TFP shock lowers the SOE bankruptcy rate, the increase in reserve requirements again dampens the decline in SOE bankruptcy. This smaller decline in SOE bankruptcy costs implies a smaller expansion of real GDP (Figure 3). Of course, as resources shift to the POE sector, leverage and the bankruptcy ratio in that sector both increase, although the increases here are less pronounced than in the case with the optimal interest-rate rule.

Under the jointly optimal rules, the required reserve ratio is raised aggressively, leading to a decline in SOE leverage and output and an greater expansion in POE leverage and output, as shown in Figure 4. The reallocation from SOEs toward POEs raises aggregate productivity and real GDP further. Since the interest rate rule is also optimized at the same time, the deposit rate declines, leading to higher aggregate demand and resulting in a greater expansion in real GDP and a net moderate increase in inflation, as shown in Figure 3.

Table 2 shows the macroeconomic volatilities and social welfare under the benchmark policy and the three different types of optimal policy rules. Consistent with the impulse responses, the optimal interest-rate rule is accommodative to TFP shocks in that the deposit rate declines if inflation declines or real GDP increases. Indeed, the optimal interest rate rule is more aggressive in stabilizing inflation, since it assigns a much larger weight on inflation than the benchmark rule (6.7 vs. 2.0). As a result, the volatility of real GDP is higher and the volatility of inflation is lower under the optimal interest rate rule than under the benchmark rule.

The optimal reserve requirement rule, on the other hand, is a "lean-against-the-wind" policy. In particular, the required reserve ratio decreases with inflation and increases with real GDP. This optimal rule implies moderately less volatile fluctuations in both real GDP and inflation than does the benchmark policy rule.

The jointly optimal rule prescribes that the deposit rate increase with inflation and decrease with real GDP, as does the optimal interest-rate rule. It also prescribes that the required reserve ratio increases with inflation and decreases with real GDP, in contrast to the simple reserve requirement rule. Since the jointly optimal rule is much more aggressive in stabilizing inflation, inflation volatility is smaller than under the benchmark rule.

Table 2 also reports the welfare outcomes under each policy rule. We measure welfare as the change in permanent consumption relative to steady-state consumption, such that the representative household is indifferent between living in an economy under a given policy rule and in the steady state. Specifically, welfare is measured by Δ, which is implicitly solved from

$$(1-\beta)\sum_{t=0}^{\infty}\beta_t\left[\ln(C_t)-\Psi\frac{H_t^{1+\eta}}{1+\eta}\right]=\ln((1+\Delta)C)-\Psi\frac{H^{1+\eta}}{1+\eta}. \tag{49}$$

Table 2 also shows that optimal reserve requirement rule improves welfare relative to the benchmark policy, although optimal interest-rate rule performs achieves even higher welfare and the jointly optimal rule achieves the highest welfare level. In particular, the benchmark policy leads to welfare losses of about 0.112% of consumption relative to the steady state without any shocks. The optimal reserve requirement rule implies a smaller welfare loss of about 0.108% of consumption relative to the steady state. The optimal interest-rate rule leads to a small welfare gain of about 0.002% relative to the steady state. Finally, the jointly optimal rule yields a welfare gain of about 0.138% of consumption relative to the steady state.

IV.3. **Reserve requirements and transitional dynamics.** During the past three decades, China has implemented various economic reforms and liberalization policies, which have raised aggregate productivity and propelled China's rapid economic growth. In particular, the large-scale SOE reforms implemented in the late 1990s have transformed China's SOE sector and led to substantial improvement in relative SOE productivity (Song and Hsieh, 2015). Nonetheless, under the current policy regime, SOE firms remain less productive than private firms and continue to rely on preferential government policy.

In the past 2 years, the Chinese government laid out a reform blueprint that includes further structural reforms of the SOE sectors. We therefore consider a counterfactual experiment in which the average productivity of SOE firms improves gradually starting from period $t = 1$ and eventually reaches a permanently higher level. We examine the role of reserve requirement policy for accelerating the economy's transition to the more efficient new steady state.

In particular, we consider the following structural changes. The economy starts in period $t = 0$ with an average productivity of SOE firms $A_s = 1$ and the required reserve ratio is at the calibrated value of $\tau = 0.15$. Starting from period $t = 1$, the SOE TFP increases gradually and converges to a permanently higher new steady state level of $A_s = 1.1$. In the transition process, the central bank adjusts the required reserve ratio to a new value $\tau = \tau'$. Under this policy with τ', the economy starts transition to the new steady state.

For any given value of τ', we compute welfare (the value function for the representative household) along the transition path, including the periods when the economy settles down in the new steady state. In particular, we define $V_1 = \sum_{t=1}^{\infty} \beta^t U(C_t, H_t)$ as the discounted sum of utility flows at $t = 1$. We express the welfare V_1 as a function of τ' and examine how the new required reserve require τ' affects welfare during the transition.

Figure 5 displays the relationship between the required reserve ratio τ' and social welfare associated with the transition dynamics. Welfare initially increases with the required reserve ratio up to a point when τ' reaches $\tau^* = 59\%$. In particular, as τ' increases from 15% to 59%, the increase in welfare is equivalent to an increase in the consumption by 0.05% in each period. However, when τ' rises above 59%, welfare starts to fall if τ' rises further.

The optimal value of the required reserve ratio $\tau^* = 59\%$ along the transition path is lower than those for both the initial and final steady states (with $\tau_1^* = 82\%$). In the initial steady state, SOE productivity is low and the government guarantees on SOE loans lead to a greater resource allocation distortion. The tradeoff between allocative efficiency and costly SOE bankruptcy implies a relatively large optimal required reserve ratio (denoted by τ_0^*, which is 83% in the initial steady state). In the final steady state, SOE productivity is permanently higher, so the optimal required reserve ratio declines modestly to $\tau_1^* = 82\%$. During the transition process, SOE firms become gradually more productive. This change calls for reallocations from the POE sector to the SOE sector relative to the initial steady state. A lower value of the required reserve ratio helps speed up this reallocation process along the transition path. When the economy eventually settles down at the new steady state, however, it is no longer necessary to reallocate resources from POE firms to SOE firms because there will be no further increases in SOE productivity. Thus, the optimal required reserve ratio jumps to a new and higher level of $\tau_1^* = 82\%$.

Figure 6 and 7 displays the transition dynamics with $\tau^* = 0.59$, which is the welfare-maximizing level of required reserve ratio along the transition path. Under this optimal reserve requirement policy, the transition calls for a gradual reallocation of resources from the POE sector to the SOE sector, the productivity of which is assumed to be gradually rising. During the transition process, SOE output rises and POE output falls relative to the initial steady state. Accordingly, SOE leverage also increases while POE leverage decreases. The permanent improvement in SOE productivity and therefore aggregate productivity creates a wealth effect that raises consumption demand. Thus, both real GDP and inflation rises over time. Under the Taylor rule, the deposit rate also increases.

V. Conclusion

We have studied the role of adjusting reserve requirements as a policy instrument to offset or alleviate other distortions in a two-sector DSGE model with Chinese characteristics. The model builds on the standard financial accelerator model of Bernanke et al. (1999) and generalizes to include two key frictions: First, the model features segmented credit markets, in which SOE firms are able to obtain bank loans, while POE firms have to rely on shadow bank lending. Second, and more importantly, the government provides guarantees for bank loans to SOE firms, but not to shadow bank lending. We show that government guarantees of SOE loans are an important source of distortions and that adjustments in reserve requirements can be an effective second-best policy. In particular, our analysis here suggests that reserve requirements can be useful not just for alleviating steady-state distortions and stabilizing business cycle fluctuations, but also for accelerating the transition of the economy towards a more efficient new steady state following structural reforms that improve SOE productivity.

Our finding that under optimal policy the central bank uses reserve requirements to alleviate distortions caused by government guarantees of SOE loans suggests that the most effective reform would be to reduce or eliminate such guarantees. It also calls for coordination between fiscal and monetary policy.

Our model is a closed economy environment, where private firms rely on domestic shadow banking loans to finance their operation. This is a good approximation to China's current financial situation because China has maintained tight controls over the capital account, so that domestic firms cannot obtain foreign funding. However, the Chinese government has set out plans to loosen capital controls. Similar to the shadow banking sector in our model, having access to foreign funds would help to make POE financing more readily available and, to the extent that private firms are more productive than SOE firms, improve overall allocative efficiency in China. However, opening to foreign asset markets may also crowd out some domestic shadow banking activity, although risks may be better diversified with foreign lenders sharing risks. A full analysis of the consequences of opening the capital account in such an environment would require an open-economy model with these China-specific features. Future research along that line should be promising.

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Table 1. Calibrated values.

Variable	Description	Value
	A. Households	
β	Household discount rate	0.99
η	Inverse elasticity of labor	2
Ψ	Weight of labor disutility	23
σ_L	labor elasticity of substitution between SOEs and POEs	1
μ	share of labor hours worked in SOEs	0.67
Ω_k	Capital adjustment cost	3
δ	Physical capital depreciation rate	0.035
g	Steady state growth rate	$1 + 0.05/4$
π	Steady state inflation rate	$1 + 0.02/4$
	B. Retailers	
ϵ	Substitutability between retail goods	5
Ω_p	Price adjustment cost	22
	C. Firms	
k	Pareto distribution parameter of idiosyncratic productivity shock	2.14
ω_m	Pareto distribution parameter of idiosyncratic productivity shock	0.53
α	Production share of physical capital	0.5
θ	Production share of household labor	0.94
A_s	SOEs' TFP parameter	1
A_p	POEs' TFP parameter	1.23
m_s	SOEs' monitoring cost	0.15
m_p	POEs' monitoring cost	0.15
ξ_s	SOE manager's survival rate	0.98
ξ_p	POE manager's survival rate	0.62
	D. Monetary authority	
l_s	Loan loss coverage ratio of commercial banks	1
l_p	Loan loss coverage ratio of shadow banks	0
τ	Required reserve ratio	0.15
ρ_r	Interest rate smooth paramter	0
ψ_{rp}	Interest rate to inflation gap	2
ψry	Interest rate to output gap	0.5
	E. Steady state outcomes	
Y_s/Y_p	SOE output/POE output	0.4
W_s/W_p	SOE wage/POE wage	1
$F(\overline{\omega_s})$	SOE bankruptcy ratio	0.25/4
$F(\overline{\omega_p})$	POE bankruptcy ratio	0.25/4

Table 2. Volatilities and welfare under various policies.

Variables	Benchmark	Optimal rule in reserve requirement	Optimal rule in deposit rate	Optimal rule in both tools
Policy rule coefficients				
ψ_{rp}	2.0	2.0	6.7	133.4
ψ_{ry}	0.5	0.5	−0.1	−12.8
$\psi_{\tau p}$	0.0	−32.0	0.0	74.2
$\psi_{\tau y}$	0.0	13.2	0.0	−299.5
Volatilities and welfare				
GDP	1.903%	1.884%	1.956%	2.114%
π	1.084%	1.076%	0.063%	0.200%
C	1.386%	1.385%	1.759%	1.895%
H	0.636%	0.618%	0.302%	0.380%
R	1.252%	1.244%	0.586%	0.543%
Y_s	2.393%	2.231%	1.745%	3.228%
Y_p	2.403%	2.436%	2.323%	1.975%
$Welfare$	−0.112%	−0.108%	0.002%	0.138%

Note: For each variable X except for welfare, this table displays the standard deviation of the variable divided by its steady state value. This table expresses welfare as the permanent relative change in consumption (compared to the steady state), ξ, such that yields expected utility
$U((1+\xi)C, H) = E[U(C_t, H_t)]$

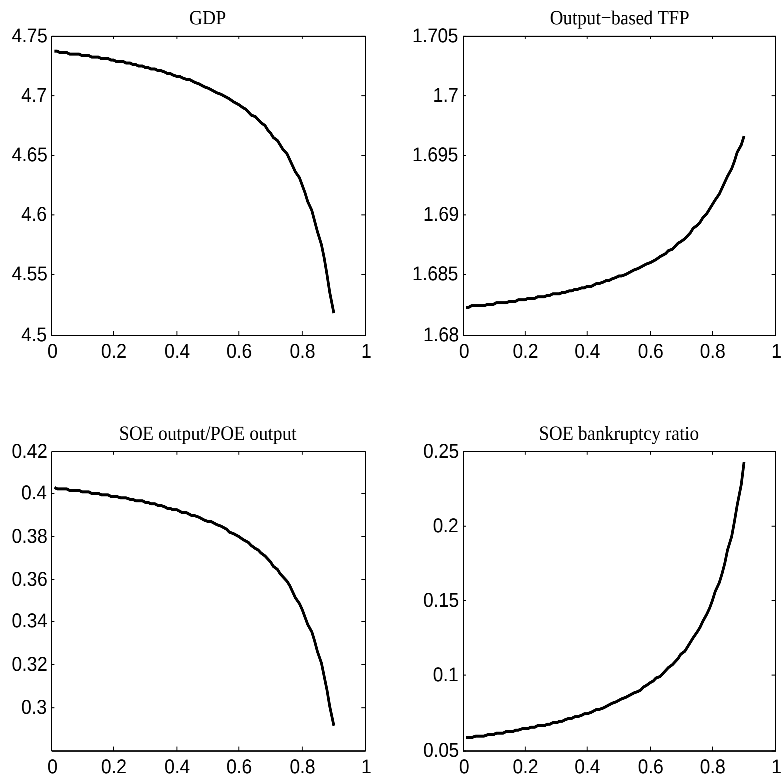

FIGURE 2. Relationship between the steady state and the required reseve ratio τ. The x-axis is the required reserve ratio τ. Variables are as follows: GDP GDP_t, Output-based TFP $\tilde{A}_{Y,t}$, relative ratio between SOEs' output and POEs' output $Y_{s,t}/Y_{p,t}$, SOEs' bankruptcy ratio $F(\overline{\omega}_{s,t})$.

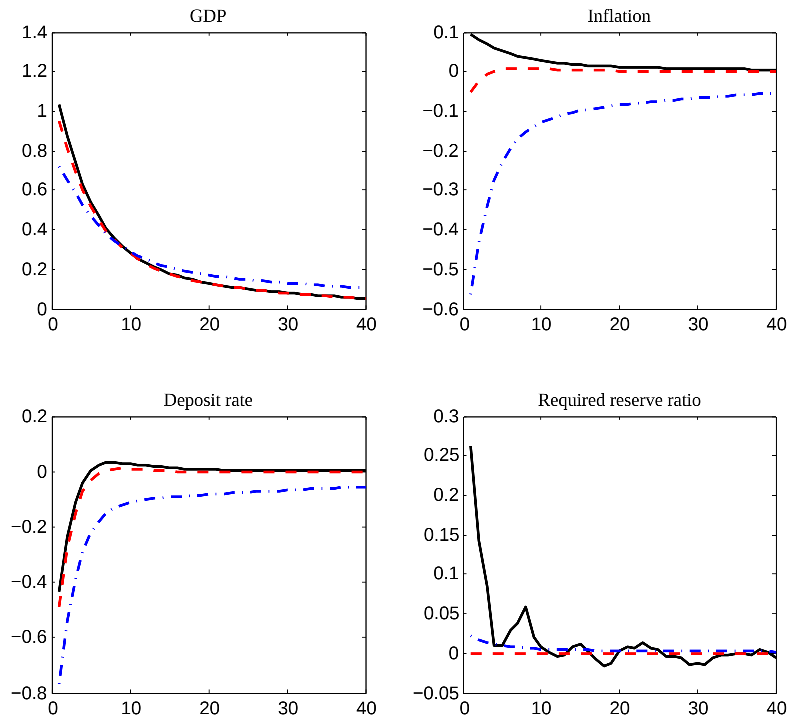

FIGURE 3. Dynamics of the aggregate economic variables in response to a one percent increase in the TFP shock $\epsilon_a = 0.01$ under various rules. Optimal rule in both tools: black solid; optimal interest rate rule: red dashed; optimal reserve requirement rule: blue dotted dashed. Units are the log percent deviation from the steady state except the required reserve ratio. Variables are as follows: GDP GDP_t, inflation π_t, deposit rate R_t, required reserve ratio τ_t.

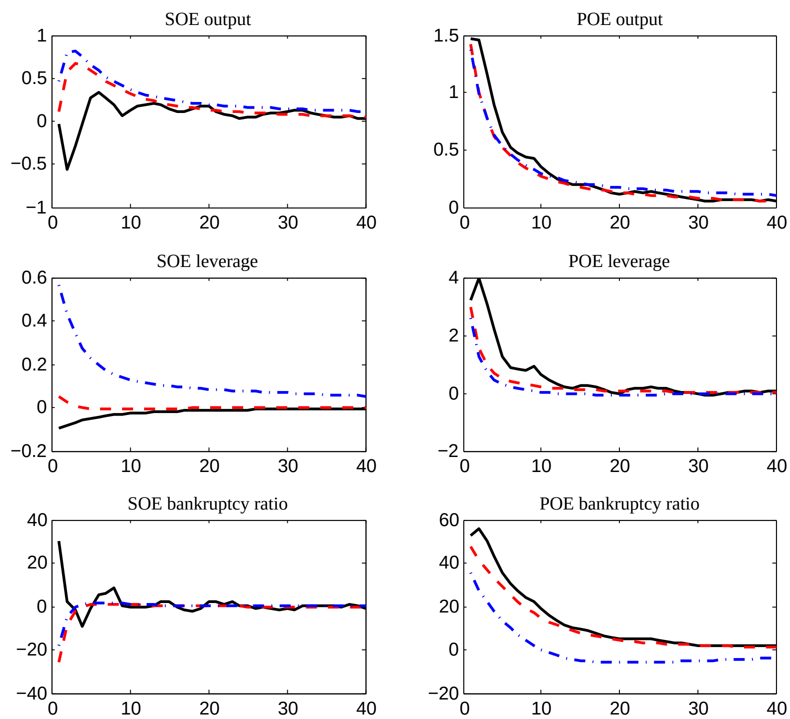

FIGURE 4. Dynamics of the SOE-specific and POE-specific variables in response to a one percent increase in TFP shock $\epsilon_a = 0.01$ under various rules. Optimal rule in both tools: black solid; optimal interest rate rule: red dashed; optimal reserve requirement rule: blue dotted dashed. Units are the log percent deviation from the steady state. Variables are as follows: SOE Output $Y_{s,t}$, POE Output $Y_{p,t}$, SOE leverage ratio $B_{s,t}/N_{s,t}$, POE leverage ratio $B_{p,t}/N_{p,t}$, SOE bankruptcy ratio $(\overline{\omega}_{s,t})$, POE bankruptcy ratio $F(\overline{\omega}_{p,t})$.

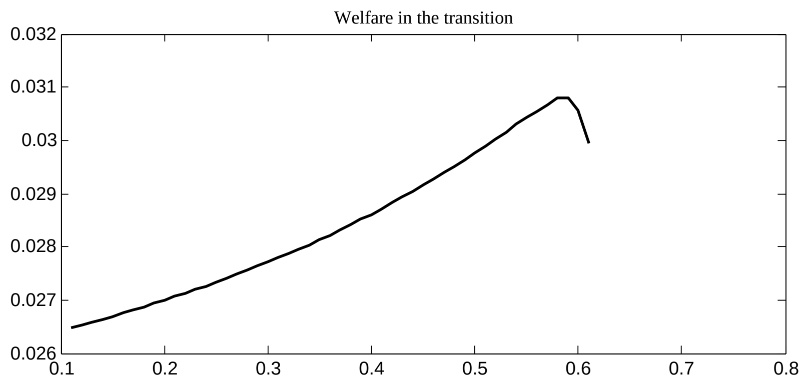

FIGURE 5. Relationships between welfare and required reserve ratio in the transition. The horizontal axis is the required reserve ratio τ'. The vertical axis is the welfare gains under each τ', expressed as consumption equivalent relative to the steady state under the benchmark calibration.

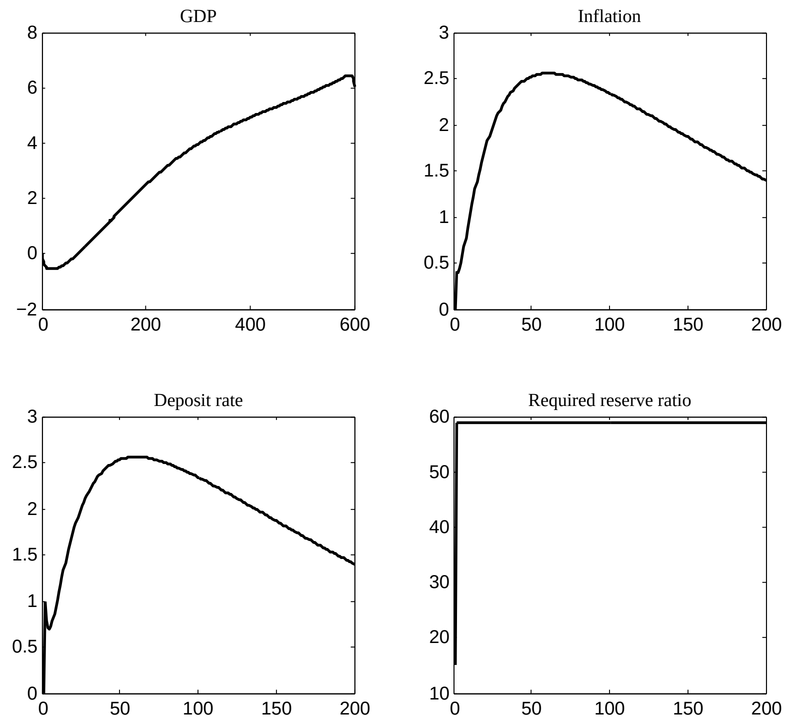

Figure 6. Transition dynamics of the aggregate economic variables in the transition where the SOE's TFP A_s increases gradually and converges to $A_s = 1.1$. Transition paths are computed based on the optimal required reserve ratio $\tau^* = 0.59$. Units are log percent deviations from the initial steady state except for the required reserve ratio. Variables are as follows: GDP GDP_t, inflation π_t, deposit rate R_t, required reserve ratio τ_t.

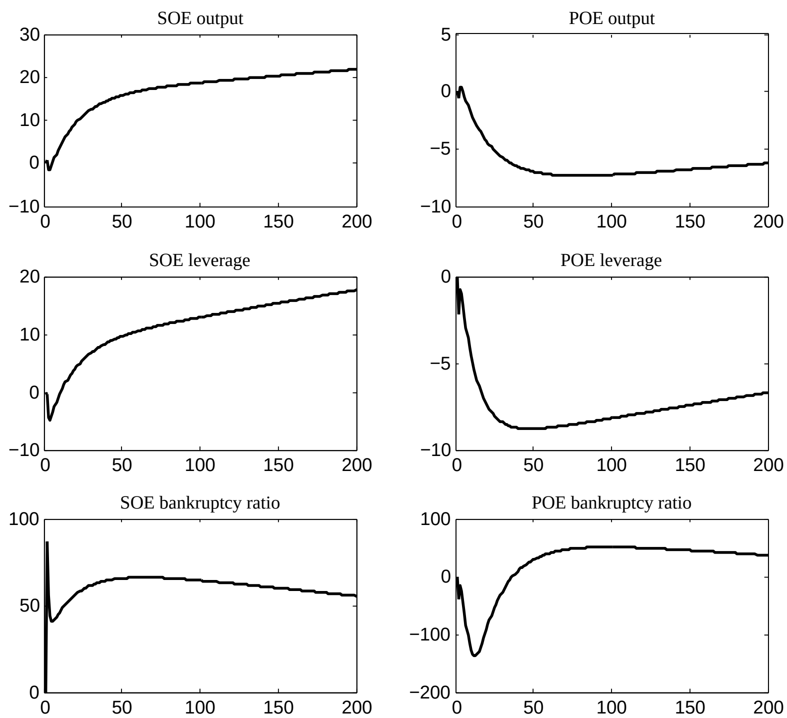

FIGURE 7. Transition dynamics of the SOE-specific and POE-specific variables in the transition where the SOE's TFP A_s increases gradually and converges to $A_s = 1.1$. Transition paths are computed based on the optimal required reserve ratio $\tau^* = 0.59$. Units are log percent deviations from the initial steady state except for the required reserve ratio. Variables are as follows: SOE Output $Y_{s,t}$, POE Output $Y_{p,t}$, SOE leverage ratio $B_{s,t}/N_{s,t}$, POE leverage ratio $B_{p,t}/N_{p,t}$, SOE bankruptcy ratio $(\overline{\omega}_{s,t})$, POE bankruptcy ratio $F(\overline{\omega}_{p,t})$.