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DISSERTATION

Bank Discrimination in A Two-Sector New Keynesian Model: A Simulation of the Chinese Economy

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Contents

Abstract

Bank discrimination against private firms leads to credit misallocation between the private sector and the public sector and can ultimately result in resource misallocation, given that private enterprises are overall more productive than state-owned enterprises. In order to study the business cycle implications of bank discrimination, a two-sector New Keynesian dynamic stochastic general equilibrium model is developed in this dissertation, and bank discrimination is featured in the way that private enterprises are subject to collateral constraints in external financing while state-owned enterprises are not. Based on the analysis of the impulse responses to a positive productivity shock to the economy, a positive productivity shock to the private sector, a contractionary credit shock to the private sector and a contractionary monetary policy shock, this research finds that private firms may be significantly constrained by bank discrimination in the credit market when faced with productivity shocks and credit shocks but can be less sensitive to monetary policy shocks.

1 Introduction

From the 1980s, we have witnessed the rapid growth of private enterprises in the Chinese economy. In the developing credit markets, however, state-owned enterprises are endowed with a superior financial status, and private enterprises are significantly discriminated against in credit acquiring despite private enterprises' higher overall productivity (Hsieh & Song, 2015). This dissertation aims to explore the business cycle implications of bank discrimination in the Chinese economy based on a two-sector New Keynesian dynamic stochastic general equilibrium model.

In China, state-owned enterprises are usually implicitly guaranteed by the government and financially supported by policy loans (Xu & Lu, 2001; Lu et al., 2005). Compared to state-owned enterprises, it is well documented in empirical studies (Brandt & Li, 2003; Lu et al., 2005) that private enterprises are usually subject to higher loan standards and tighter collateral constraints than state-owned enterprises and are thus far less likely to obtain credit. Bank discrimination leads to credit misallocation, especially in deteriorating credit markets, and can ultimately result in resource misallocation given that state-owned enterprises are overall less productive than private enterprises.

In order to study the business cycle implications of bank discrimination, a two-sector New Keynesian model is developed to feature the Chinese economy. The model divides firms into two sectors, the private sector and the state-owned sector, and bank discrimination is featured in the way that private enterprises are subject to collateral constraints in external financing while state-owned enterprises are not. Four types of exogenous stochastic shocks (a positive productivity shock to the economy, a positive productivity shock to the private sector, a contractionary credit shock to the private sector and a contractionary monetary policy shock) are simulated in the model so as to study the influence of bank discrimination on private enterprises in a deteriorating credit market.

The research succeeding this dissertation will further incorporate an imperfectly competitive banking sector to generate different interest rates for agents and thus to better feature the credit market. Moreover, the government in the model will be modified with an "appropriating technology" so that the government managing state-owned enterprises faces a policy trade-off between government spending and firm growth, which is closer to the reality. Ultimately, it is expected that the proposed two-sector model can be utilized for the welfare analysis of monetary policies in China, such as the dual-track interest rate system and the Loan Prime Rate (LPR) reform.

The rest of this dissertation is organized as follows: Section 2 briefly introduces the institutional background of bank discrimination in China; Section 3 summarizes the literature related to this dissertation and the succeeding research; Section 4 features the model economy and proposes potential improvements in the succeeding research; Section 5 calibrates the two-sector model for the Chinese economy and analyzes the business cycle implications of bank discrimination by simulating four shocks to the economy; finally, Section 6 concludes.

2 Institutional Background

Before the 1980s, state-owned economy and collective economy had been the majority in the Chinese socialist economy. However, the "Reform and Opening Up" policy in 1978 initiated an economic reform on private economy, and the 1982 constitutional amendment established the position of private economy as a "legitimate component of socialist economy" and a "complement to state-owned economy". In 1997, the 15th Chinese Communist Party Congress took a step further and referred to private economy as an "essential component of socialist market economy". With this dramatic change in the "official attitude" towards the economic composition, the Chinese economy has witnessed tremendous development of the private sector in the following decades.

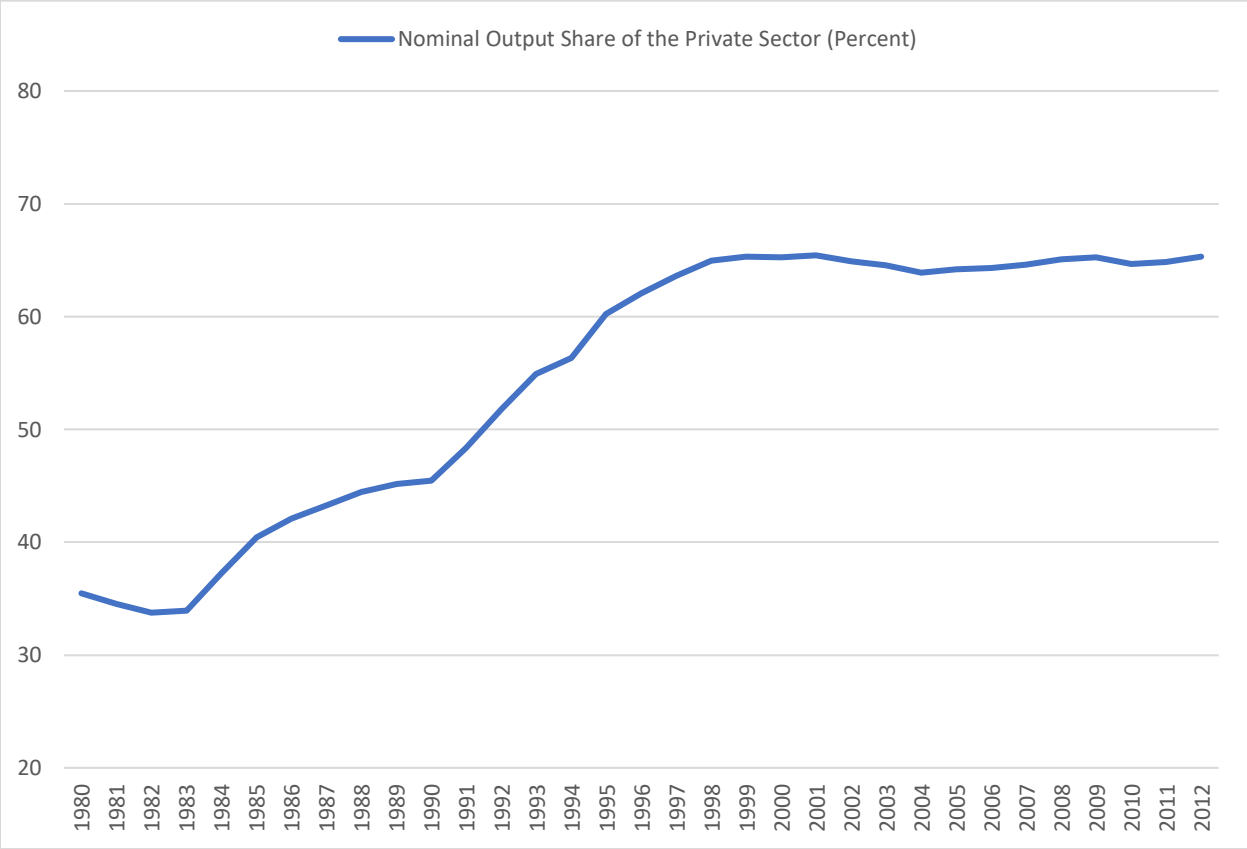

Figure 1: Nominal output share of the private sector (measured in percentage).
Source: Holz (2014).

On one hand, countless new private enterprises were established in response to the new economic focus on private economy. On the other hand, under the policy of "grasping the large and letting go of the small" in 1998 (Hsieh & Song, 2015), a large number of small and medium-sized state-owned enterprises were privatized, while many unprofitable state-owned enterprises, no matter large or small, were restructured or even eliminated in order to stimulate the dynamics in the Chinese economy; even more collective township and village enterprises were privatized during the 1990s (Brandt & Li, 2003). Holz (2014) constructs industrial output series for the Chinese economy from 1980 to 2012 both economy-wide and merely for the public sector, and it can be derived that the industrial output share of the private sector increased from around 35% in early 1980s to approximately 65% in late 1990s and remained at around 65% afterwards (Figure 1).

Admittedly, private economy has experienced pronounced growth in recent decades, but bank discrimination against the private sector in China is well documented in the literature: private enterprises are faced with more difficulties and constraints than state-owned and collective enterprises in obtaining loans from the banking system. According to Brandt & Li (2003) and Lu et al. (2005), controlling for other factors of enterprises, private enterprises are usually subject to higher loan standards and tighter collateral constraints than state-owned enterprises and are thus far less likely to obtain bank loans; some essential state-owned enterprises with considerable default risks can even manage to acquire more bank loans than many private enterprises with better financial condition. Given that the private sector's share in bank loans was around 45% in 2012, Guo et al. (2018) argue that private enterprises can only "obtain a disproportionate share of credit" from the banking system. Moreover, Song et al. (2011) and Guo et al. (2018) document that state-owned enterprises can finance up to 30% of their investments with bank loans, compared to around 10% for private enterprises.

Bank discrimination in the Chinese economy may arise from ex ante or ex post government intervention (Xu & Lu, 2001; Lu et al., 2005). On one hand, state-owned banks in China are

encouraged or obliged to provide credit to state-owned enterprises via policy loans. Though policy loans are usually made from legitimate political consideration, they sometimes end up with lower quality compared to commercial loans. On the other hand, state-owned enterprises (and state-owned banks) are often implicitly endorsed by the government via potential bailouts, which may take place in the form of restructuring the targeted firm and taking over its non-performing loans. Once anticipated, these potential bailouts can significantly weaken banks' risk management and increase the moral hazard of state-owned enterprises.

The consequent soft budget constraint on state-owned banks and enterprises can cause credit misallocation favoring the state-owned sector (Lu et al., 2005) and generate a "crowding-out effect on the private sector" (Guo et al., 2018). Also, it could be one of the sources of the lower total factor productivity of state-owned enterprises: Hsieh and Song (2015) find that the total factor productivity in the state-owned sector was only around 65 percent of that in the private sector from 1998 to 2007.

Along with the tremendous development of the private sector, the Chinese economy has also witnessed the formation of a dual-track interest rate system (Chen & Lin, 2019; Wang et al., 2019) in the developing credit market: a set of benchmark interest rates issued by the central bank and market interest rates operate contemporaneously in the economy; commercial banks, especially large state-owned banks, usually operate with benchmark rates while significantly higher market rates are mainly determined by shadow banking.

Bank discrimination in the credit market, as a major force, has consolidated the interest rate wedge in the dual-track interest rate system in China. In the asymmetrically deteriorating credit market during the last decade, state-owned enterprises can still manage to acquire sufficient credit from commercial banks near benchmark interest rates, while private enterprises, especially the small- and medium-scale ones, are usually forced to rely heavily on internal financing (e.g., retained earnings) (Song et al., 2011) or resort to shadow banking with market interest rates (Lu et al., 2015). Therefore,

private investments, which are often more productive, have been partially crowded out by investments of state-owned enterprises, leading to credit misallocation and a widely acknowledged phenomenon called “the state-owned sector advances while the private sector retreats” (Chen & Lin, 2019).

In order to further marketize interest rates and, more importantly, to alleviate the credit burden on small- and medium-scale private enterprises, the Loan Prime Rate (LPR) reform was launched in 2013 and furthered in 2019.: the benchmark lending rate has been replaced by the LPR, which is now collectively proposed by 18 major commercial banks based on a marketized guiding rate, the Mid-term Lending Facility (MLF) rate. The People’s Bank of China has been using targeted MLF or targeted required reserve ratio cuts to deliver credit (through commercial banks) precisely to small- and medium-scale private enterprises at rates close to the LPR (which is also the new benchmark rate for state-owned enterprises’ financing), so that more competitive private enterprises can obtain less expensive loans from the credit market.

3 Literature Review

This dissertation is mainly related to two strands of literature: first, the sources and implications of bank discrimination against private enterprises in the Chinese economy; second, Dynamic Stochastic General Equilibrium models focusing on the interaction between credit frictions and macroeconomic fluctuations. The succeeding research will expand to other strands of literature including the separation of ownership and control within companies and the interest rate reforms in China.

The literature on bank discrimination in China mainly attributes this biased lending problem to the superior financial status of state-owned enterprises (Brandt & Li, 2003; Allen et al., 2005) and argues that bank discrimination can lead to credit misallocation between the public sector and the private sector (Song et al., 2011). Brandt & Li (2003) show that private enterprises are subject to higher loan standards than state-owned enterprises and thus are disadvantaged in obtaining bank loans, and Allen et al. (2005) demonstrate that state-owned enterprises have easier access to credit and a significantly higher percentage of bank loans in external finance. In order to study the influence of bank discrimination on long-term economic growth, Song et al. (2011) propose a two-sector Overlapping Generation model in which only private enterprises are faced with credit constraints, and the model accounts quantitatively for China's economic transition.

After the interaction of credit frictions and macroeconomic fluctuations is introduced into a general equilibrium framework, we have seen a growing literature on dynamic models in which credit frictions amplify or propagate macroeconomic fluctuations. Bernanke et al. (1999) deploy a costly state verification framework, which exhibits a "financial accelerator" mechanism, in a New Keynesian model to study asymmetric information and agency costs in credit markets. Iacoviello (2005) then adds collateral constraints against real estate values (Kiyotaki & Moore, 1997) and nominal debts into a New Keynesian setup and demonstrate that "the model features an accelerator of demand shocks, and a 'decelerator' of supply shocks". Based on Iacoviello (2005), Gerali et al. (2010) introduces an

imperfectly competitive banking sector into the model with a Dixit-Stigliz framework to study the supply side of credit markets; Andres et al. (2013) substitute the assumption of interest rate stickiness with fully flexible rates in the imperfectly competitive banking sector to understand the nature of optimal monetary policy within this framework.

Deviating from the focus of the literature on the implications of bank discrimination for long-term economic growth (Song et al., 2011), Guo et al. (2018) propose a two-sector New Keynesian model, in which both the private sector and the state-owned sector are subject to collateral constraints while private enterprises are faced with lower loan-to-value ratio, and find that bank discrimination can cause resource misallocation by crowding out more productive private enterprises. Guo et al. (2018) claim that the asymmetric collateral constraints act as a "financial accelerator mechanism" in response to expansionary economic shocks, since expansionary economic shocks may increase the nominal value of collateral and state-owned enterprises with higher loan-to-value ratio are able to borrow even more from the banking sector. This research aims to improve the two-sector New Keynesian model with asymmetric credit constraints for the succeeding research on the interaction of bank discrimination and macroeconomic fluctuations.

In recent years, the LPR reform has attracted enormous attention from academia as an important step in the Chinese interest rate reform from the dual-track interest rate system towards full interest rate liberalization. Wang et al. (2019) demonstrates that the dual-track interest rate system in China serves as a gradual form of interest rate liberalization and can lead to aggregate profit gain and a Pareto improvement (reform without losers). Consistent with Liu et al. (2021), Wang et al. (2019) further argues that full interest rate liberalization, which eliminates the interest rate wedge between benchmark interest rate and market interest rate, alone may not guarantee a Pareto improvement, unless other policy reforms are also implemented to alleviate credit discrimination and improve private enterprises' access to credit. However, Chen & Lin (2019) claims that the interest rate wedge in the dual-track interest rate system can still distort capital allocation, and that full interest rate

liberalization can alleviate cross-sector capital misallocation but have an ambiguous net effect on aggregate productivity due to within-sector changes. The succeeding research hopes to study the implications of the dual-track interest rate system and the LPR reform, which can be considered as a step towards full interest rate liberalization, on credit allocation within a New Keynesian framework.

Besides incorporating a monopolistically competitive banking sector into the two-sector model proposed in this research following Gerali et al. (2010) and Andres et al. (2013), the succeeding research will refer to the literature on the separation of ownership and control within companies for featuring the government managing state-owned enterprises. Albuquerue & Wang (2008) stand out from the literature by developing an asset pricing model to study the welfare implications of imperfect investor protection. With the separation of ownership and control within firms, the model allows controlling shareholders to extract private benefits from outside shareholders.

4 The Model Economy

The two-sector New Keynesian model in this dissertation considers a discrete-time infinite-horizon economy populated by households, entrepreneurs (owning private firms and private capital producers), a government (managing state-owned firms and state-owned capital producers), retailers (together with wholesale producers and final producers) and a central bank. Households, entrepreneurs and the government seek to maximize their life-time utility based on their flows of funds, and retailers maximize their profits which are ultimately rebated to households.

Households work to achieve the balance between wage and leisure, consume the final goods in the economy and finance the investments of firms by holding their interest-bearing bonds. As in Iacoviello (2005), households are more patient than entrepreneurs and the government in the sense that households have higher discount factors (and accordingly lower discount rates), which give rise to non-zero bond holdings.

Intermediate producers are divided into two sectors: private firms in the private sector are owned by entrepreneurs, while state-owned firms in the state-owned sector are managed by the government. Private firms hire household labor and combine it with collateralizable capital to produce a homogeneous private intermediate good. In order to finance their production, private firms issue interest-bearing bonds to households under a collateral constraint as in Gerali et al. (2010) of a loan-to-value ratio less than one, which implies that entrepreneurs cannot borrow more than a certain proportion of their firms' capital value (explained in Section 4.2).

State-owned firms also hire household labor and combine it with collateralizable capital to produce a homogeneous state-owned intermediate good. State-owned firms issue interest-bearing bonds to households with a loan-to-value ratio equal to one, which implies that state-owned firms are not collateral-constrained (over-financing is not considered in this model). This difference in loan-to-

value ratio between private firms and state-owned firms resemble, to some extent, the bank discrimination against the private sector in the Chinese economy. Besides managing state-owned firms, the government also decides on the amount to spend on final goods as government spending.

Capital producers are introduced into the model so as to derive a market price for capital. Private capital producers and state-owned capital producers are ultimately owned by entrepreneurs and the government, respectively, hence the profits (or loss) of the capital producers are internalized into private firms and state-owned firms.

In order to motivate nominal rigidity, we introduce retailers together with wholesale producers and final producers into the model as in Bernanke et al. (1999). Wholesale producers purchase private intermediate goods and state-owned intermediate goods from private firms and state-owned firms, respectively, and aggregate these two types of intermediate goods into a homogeneous wholesale good. Then, retailers buy wholesale goods from wholesale producers, differentiate the wholesale goods at no cost into retail goods and sell the retail goods to final producers. Retailers in monopolistic competition have a certain degree of pricing power and are subject to Calvo-type staggered price adjustments (Calvo, 1983). Finally, final producers aggregate the retail goods into a homogeneous final good which is consumed by agents and utilized by capital producers as investments.

All entities in the economy are subject to the monetary policy proposed and conducted by the central bank, which is the monetary authority in the economy. In this model, the monetary policy is formulated in the form of a Taylor-type nominal interest rate rule (Taylor, 1993 & 1999) with inflation and output targeting.

4.1 Households

Infinite-lived households seek to maximize the expected present value of their life-time utility as follows:

$$max\, E_0 \sum_{t=0}^{\infty} (\beta^H)^t U^H(c_t^H, n_t) \tag{4.1.1}$$

where

$$U^H(c_t^H, n_t) = ln\, c_t^H - \mu \frac{n_t^{1+\eta}}{1+\eta}. \tag{4.1.2}$$

c_t^H is households' consumption of final goods and n_t is labor supply. The parameter β^H denotes households' discount factor, μ measures the weight of labor/leisure decision in the utility function (and determines the steady-state working hours) and η denotes the inverse elasticity of labor supply.

Households are bound to the following budget constraint in each period:

$$c_t^H + b_t = w_t n_t + (1 + R_{t-1}) \frac{b_{t-1}}{1+\pi_t} + \Pi_t^R \tag{4.1.3}$$

where $b_t = B_t/P_t$ is households' bond holdings in real terms, $w_t = W_t/P_t$ is the real wage, R_{t-1} denotes the nominal interest rate on bonds between $t-1$ and t, $\pi_t = P_t/P_{t-1}$ denotes the gross inflation rate between $t-1$ and t and Π_t^R is the lump-sum profits/dividends rebated from retailers (explained in Section 4.4). Financial obligations are set in nominal terms: in period t, households lend in nominal terms $-B_t$ (or borrow B_t) and receive back $R_{t-1}B_{t-1}/P_t$, or in real terms $(1 + R_{t-1})b_{t-1}/(1 + \pi_t)$, since B_{t-1} has matured. Note that in aggregation households only lend to firms and do not borrow (explained in Section 4.2).

By solving the optimization problem of households, we obtain the first-order conditions as follows:

$$MU_{c,t}^H = \beta^H E_t \left(MU_{c,t+1}^H \frac{1+R_t}{1+\pi_{t+1}} \right) \tag{4.1.4}$$

$$\mu n_t^{\eta} = MU_{c,t}^H w_t \tag{4.1.5}$$

given the definition that $MU_{c,t}^H = (c_t^H)^{-1}$. Equation (4.1.4) is households' consumption Euler equation and equation (4.1.5) determines the optimal labor supply.

4.2 Entrepreneurs & Private Firms

Private firms combine (sector-specific) capital and labor as inputs to produce a homogeneous private intermediate good using a Cobb-Douglas constant return-to-scale production technology:

$$y_{p,t}^{I} = A_{p,t} k_{p,t-1}^{\alpha} n_{p,t}^{1-\alpha} \tag{4.2.1}$$

in which α denotes the capital-output ratio in the production of intermediate goods, $A_{p,t}$ denotes the total factor productivity of the private sector and $k_{p,t}$ and $n_{p,t}$ are the capital and labor demand.

$A_{p,t}$ fluctuates around the reference total factor productivity level A_t according to

$$A_{p,t} = \chi_{p,t} A_t \tag{4.2.2}$$

where $\chi_{p,t}$ is subject to a $AR(1)$ process:

$$ln\, \chi_{p,t} = \left(1 - \rho_{\chi}\right) ln\, \overline{\chi_p} + \rho_{\chi}\, ln\, \chi_{p,t-1} + e_{\chi,t}^{P} \tag{4.2.3}$$

in which ρ_{χ} measures the persistence of sector-specific productivity shocks, $e_{\chi,t}^{P}$ denotes an exogenous productivity shock to the private sector (with zero mean and standard deviation σ_{χ}^{P}) and $\overline{\chi_p}$ equals to one implying that the average productivity level of the private sector is equal to A_t.

A_t is also subject to an $AR(1)$ process:

$$ln\, A_t = \rho_A\, ln\, A_{t-1} + e_{A,t} \tag{4.2.4}$$

where ρ_A measures the persistence of economy-wide productivity shocks and $e_{A,t}$ denotes an exogenous productivity shock to the whole economy (with zero mean and standard deviation σ_A).

Infinite-lived entrepreneurs seek to maximize the expected present value of their life-time utility as follows:

$$max\, E_0 \sum_{t=0}^{\infty} (\beta^E)^t U^E(c_t^E) \tag{4.2.5}$$

where

$$U^E(c_t^E) = ln\, c_t^E\,. \tag{4.2.6}$$

c_t^E is entrepreneurs' consumption of final goods and β^E denotes entrepreneurs' discount factor.

Entrepreneurs are bound to the following budget constraint in each period:

$$c_t^E + w_t n_{p,t} + (1 + R_{t-1})\frac{b_{p,t-1}}{1+\pi_t} + q_{p,t}k_{p,t} = p_{p,t}^I y_{p,t}^I + b_{p,t} + q_{p,t}(1-\delta)k_{p,t-1} + \Pi_{p,t}^K \tag{4.2.7}$$

where $b_{p,t} = B_{p,t}/P_t$ is the bonds issued by private firms in real terms, $q_{p,t} = Q_{p,t}/P_t$ is the real price of capital in the private sector, $p_{p,t}^I = P_{p,t}^I/P_t$ is the real price of private intermediate goods and δ denotes the depreciation rate of capital. In period t, private firms sell their last-period undepreciated capital $(1-\delta)k_{p,t-1}$ to private capital producers at the price $q_{p,t}$ and then purchase back new capital $k_{p,t}$ at the same price. $\Pi_{p,t}^K$ is the profits of entrepreneurs' private capital producers (explained in Section 4.5).

In period t, entrepreneurs borrow in real terms b_t (or lend $-b_t$) and settle the matured bonds with interests $(1 + R_{t-1})b_{p,t-1}/(1+\pi_t)$. Following Gerali et al. (2010), we assume that entrepreneurs are subject to a collateral constraint in borrowing:

$$(1 + R_t)b_{p,t} \le m_{p,t}E_t\left[q_{p,t+1}(1+\pi_{t+1})(1-\delta)k_{p,t}\right] \tag{4.2.8}$$

where $m_{p,t}$ is the stochastic loan-to-value ratio for private firms (explained in Section 4.8). Different from Iacoviello (2005) where entrepreneurs borrow against real estate, this assumption implies that the amount entrepreneurs can manage to borrow from the economy is constrained by the value of their private firms' collateralized capital. Gerali et al. (2010) argue that compared to that in Iacoviello (2005), this assumption "seems a more realistic choice, as overall balance-sheet conditions give the soundness and creditworthiness of a firm".

Moreover, following Iacoviello (2005), we assume that entrepreneurs' discount factor β^E (as well as the government's discount factor β^G described in Section 4.3) is lower that households' discount

factor β^H, namely $\beta^E < \beta^H$ (and $\beta^G < \beta^H$). The assumption that entrepreneurs (and the government) discount the future more heavily than households has two implications: first, households only lend to firms and do not borrow while firms only borrow; second, given the size of shocks being "sufficiently small" as in Iacoviello (2005), the borrowing constraint of entrepreneurs (and the government) would bind in a neighborhood of the steady state. Therefore, we can update equation (4.2.8) with a binding borrowing constraint:

$$(1 + R_t)b_{p,t} = m_{p,t}E_t\left[q_{p,t+1}(1 + \pi_{t+1})(1 - \delta)k_{p,t}\right]. \tag{4.2.9}$$

By solving the optimization problem of entrepreneurs, we obtain the first-order conditions as follows:

$$MU^E_{c,t} = \beta^E E_t\left(MU^E_{c,t+1}\frac{1 + R_t}{1 + \pi_{t+1}}\right) + \varphi_{p,t}(1 + R_t) \tag{4.2.10}$$

$$MU^E_{c,t}q_{p,t} = E_t\left\{\beta^E MU^E_{c,t+1}\left[\alpha p^I_{p,t+1}\frac{y^I_{p,t+1}}{k_{p,t}} + (1 - \delta)q_{p,t+1}\right] + \varphi_{p,t}m_{p,t}(1 - \delta)(1 + \pi_{t+1})q_{p,t+1}\right\} \tag{4.2.11}$$

$$w_t = (1 - \alpha)p^I_{p,t}\frac{y^I_{p,t}}{n_{p,t}} \tag{4.2.12}$$

given the definitions that $MU^E_{c,t} = (c^E_t)^{-1}$ and that $\varphi_{p,t}$ is the period t shadow value of private firms' borrowing constraint (4.2.9). Equation (4.2.10) is entrepreneurs' consumption Euler equation, equation (4.2.11) determines the optimal capital demand and equation (4.2.12) determines the optimal labor demand.

4.3 The Government & State-owned Firms

State-owned firms also combine (sector-specific) capital and labor as inputs to produce a homogeneous state-owned intermediate good using a Cobb-Douglas constant return-to-scale production technology:

$$y^I_{s,t} = A_{s,t}k^{\alpha}_{s,t-1}n^{1-\alpha}_{s,t}. \tag{4.3.1}$$

Different from $A_{p,t}$, $A_{s,t}$ fluctuates around a level lower than A_t according to

$$A_{s,t} = \chi_{s,t} A_t \tag{4.3.2}$$

where $\chi_{s,t}$ is subject to a $AR(1)$ process:

$$ln\, \chi_{s,t} = \left(1 - \rho_\chi\right) ln\, \overline{\chi_s} + \rho_\chi\, ln\, \chi_{s,t-1} + e^S_{\chi,t} \tag{4.3.3}$$

in which $\overline{\chi_s}$ is less than one implying that state-owned firms are less productive than private firms on average.

The government seeks to maximize the expected present value of its utility as follows:

$$max\, E_0 \sum_{t=0}^{\infty} (\beta^G)^t U^G(g_t) \tag{4.3.4}$$

where

$$U^G(g_t) = ln\, g_t\,. \tag{4.3.5}$$

g_t is government spending on final goods and the government's discount factor β^G is lower than households' discount factor β^H.

The government is bound to the following budget constraint in each period:

$$g_t + w_t n_{s,t} + (1 + R_{t-1}) \frac{b_{s,t-1}}{1 + \pi_t} + q_{s,t} k_{s,t} = p^I_{s,t} y^I_{s,t} + b_{s,t} + q_{s,t}(1 - \delta) k_{s,t-1} + \Pi^K_{s,t} \tag{4.3.6}$$

where $\Pi^K_{s,t}$ is the profits of state-owned capital producers managed by the government (explained in Section 4.5).

Different from private firms, state-owned firms are assumed to operate without collateral constraint. Given that $\beta^G < \beta^H$ and that over-financing is not considered in this model, state-owned firms' bond supply is determined by a binding borrowing constraint:

$$(1 + R_t) b_{s,t} = m_s E_t\left[q_{s,t+1}(1 + \pi_{t+1})(1 - \delta) k_{s,t}\right] \tag{4.3.7}$$

where the loan-to-value ratio for state-owned firms m_s is equal to one.

By solving the optimization problem of the government, we obtain the first-order conditions as follows:

$$MU_{g,t} = \beta^G E_t \left(MU_{g,t+1} \frac{1+R_t}{1+\pi_{t+1}} \right) + \varphi_{s,t}(1+R_t) \tag{4.3.8}$$

$$MU_{g,t} q_{s,t} = E_t \left\{ \beta^G MU_{g,t+1} \left[\alpha p^I_{s,t+1} \frac{y^I_{s,t+1}}{k_{s,t}} + (1-\delta) q_{s,t+1} \right] + \varphi_{s,t} m_s (1-\delta)(1+\pi_{t+1}) q_{s,t+1} \right\} \tag{4.3.9}$$

$$w_t = (1-\alpha) p^I_{s,t} \frac{y^I_{s,t}}{n_{s,t}} \tag{4.3.10}$$

given the definitions that $MU_{g,t} = (g_t)^{-1}$ and that $\varphi_{s,t}$ is the period t shadow value of state-owned firms' borrowing constraint (4.3.7). Equation (4.3.8) is the Euler equation for government spending, equation (4.3.9) determines the optimal capital demand and equation (4.3.10) determines the optimal labor demand.

4.4 Wholesale Producers, Retailers & Final Producers

The intermediate goods $y^I_{x,t}$ (where $x \in \{p, s\}$) are marketed from private firms and state-owned firms to wholesale producers at the real price $p^I_{x,t}$. Then wholesale producers aggregate these two types of intermediate goods into a homogeneous wholesale good y^W_t using a Cobb-Douglas constant return-to-scale production technology:

$$y^W_t = \left(y^I_{p,t}\right)^{\sigma} \left(y^I_{s,t}\right)^{1-\sigma} \tag{4.4.1}$$

where σ is the gross output share of private intermediate goods, which could be determined by the nominal output share of the private sector in the economy derived from Holz (2014).

Wholesale producers operate in a perfectly competitive manner and thus earns no profit, which implies:

$$p^W_t y^W_t = p^I_{p,t} y^I_{p,t} + p^I_{s,t} y^I_{s,t} \tag{4.4.2}$$

where p^W_t is the real price of the wholesale goods.

Combining equations (4.4.1) and (4.4.2) we know that the cost on each type of intermediate goods accounts for a fixed proportion (determined by σ) of the gross output of wholesale producers:

$$p_{p,t}^{I} y_{p,t}^{I} = \sigma p_t^W y_t^W \tag{4.4.3}$$

$$p_{s,t}^{I} y_{s,t}^{I} = (1-\sigma) p_t^W y_t^W. \tag{4.4.4}$$

Subsequently, a continuum of retailers purchase wholesale goods y_t^W from wholesale producers at the price p_t^W, differentiate the wholesale goods at no cost into retail goods $y_t(i)$:

$$y_t^W = \int_0^1 y_t(i)\ \mathrm{d}i \tag{4.4.5}$$

then sell the retail goods to final producers at the nominal price $P_t(i)$, where retailers are indexed by $i \in [0,1]$.

Finally, final producers transform the retail goods $y_t(i)$ into a homogeneous final good y_t using a CES production technology:

$$y_t = \left[\int_0^1 y_t(i)^{\frac{\varepsilon-1}{\varepsilon}}\ \mathrm{d}i\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{4.4.6}$$

where ε denotes the elasticity of substitution between the differentiated retail goods $y_t(i)$.

Similar to wholesale producers, final producers also operate in a perfectly competitive manner and set the nominal price P_t for final goods according to:

$$P_t y_t = \int_0^1 P_t(i) y_t(i)\ \mathrm{d}i. \tag{4.4.7}$$

Hence, each retailer faces an individual demand curve:

$$y_t(i) = \left[\frac{P_t(i)}{P_t}\right]^{-\varepsilon} y_t \tag{4.4.8}$$

and the nominal price of final goods P_t can be indexed by the nominal prices of differentiated retail goods $P_t(i)$:

$$P_t = \left[\int_0^1 P_t(i)^{1-\varepsilon}\ \mathrm{d}i\right]^{\frac{1}{1-\varepsilon}}. \tag{4.4.9}$$

The profits of each retailer in period t can be given by

$$\Pi_t^R(i) = \frac{P_t(i)}{P_t} y_t(i) - p_t^W y_t(i) \tag{4.4.10}$$

and these profits are finally rebated to households as dividends. Therefore, the aggregate profits/dividends rebated to households is

$$\Pi_t^R = \int_0^1 \Pi_t^R(i)\ \mathrm{d}i = y_t - p_t^W y_t^W. \tag{4.4.11}$$

Retailers operate in a monopolistically competitive manner and have a certain degree of pricing power. Following Bernanke et al. (1999), we assume retailers are subject to Calvo-type staggered price adjustments: a retailer can only adjust its price $P_t(i)$ with fixed probability $1-\theta$, and this leads to a dynamic price-setting problem since it may be stuck with a certain price for multiple periods. If a retailer gets the opportunity to adjust its price in period t, it discounts the profits in period $t+j$ by both $\Lambda_{t,t+j}^H = (\beta^H)^j \frac{MU_{c,t+j}^H}{MU_{c,t}^H}$, households' stochastic discount factor (since the profits are finally rebated to households as dividends), and θ^j, the probability that the price set in period t still remains in effect in period $t+j$. Therefore, the dynamic price-setting problem of an updating retailer i in period t can be given by:

$$\max E_t \sum_{j=0}^{\infty} \theta^j \Lambda_{t,t+j}^H \left[\frac{P_t(i)}{P_{t+j}} y_{t+j}(i) - p_{t+j}^W y_{t+j}(i)\right]. \tag{4.4.12}$$

After substituting $y_{t+j}(i)$ with equation (4.4.8) and multiplying out, we have:

$$\max E_t \sum_{j=0}^{\infty} \theta^j \Lambda_{t,t+j}^H \left\{\left[\frac{P_t(i)}{P_{t+j}}\right]^{1-\varepsilon} y_{t+j} - p_{t+j}^W \left[\frac{P_t(i)}{P_{t+j}}\right]^{-\varepsilon} y_{t+j}\right\}. \tag{4.4.13}$$

By transforming the first order condition with regard to $P_t(i)$ we obtain:

$$P_t^* = \frac{\varepsilon}{\varepsilon - 1} \frac{E_t \sum_{j=0}^{\infty} (\beta^H \theta)^j M U_{c,t+j}^H p_{t+j}^W P_{t+j}^{\varepsilon} y_{t+j}}{E_t \sum_{j=0}^{\infty} (\beta^H \theta)^j M U_{c,t+j}^H P_{t+j}^{\varepsilon-1} y_{t+j}} \tag{4.4.14}$$

where P_t^* refers to the optimal price to be set by the updating retailer i in period t.

We can rewrite the expression for optimal price (4.4.14) in recursive form:

$$P_t^* = \frac{\varepsilon}{\varepsilon - 1} P_t \frac{u_t}{l_t} \tag{4.4.15}$$

where

$$u_t = M U_{c,t}^H p_t^W y_t + \beta^H \theta E_t (1 + \pi_{t+1})^{\varepsilon} u_{t+1} \tag{4.4.16}$$

$$l_t = M U_{c,t}^H y_t + \beta^H \theta E_t (1 + \pi_{t+1})^{\varepsilon-1} l_{t+1}. \tag{4.4.17}$$

By dividing the recursive form expression for optimal price (4.4.15) by P_{t-1} we obtain:

$$1 + \pi_t^* = \frac{\varepsilon}{\varepsilon - 1} (1 + \pi_t) \frac{u_t}{l_t} \tag{4.4.18}$$

where $\pi_t^* = P_t^*/P_{t-1}$ refers to the optimizing inflation rate expected by the updating retailer i.

After transforming the price index (4.4.9) using properties of Calvo pricing, we have:

$$P_t^{1-\varepsilon} = \int_0^1 P_t(i)^{1-\varepsilon} \, \mathrm{d}i = \int_0^{1-\theta} (P_t^*)^{1-\varepsilon} \, \mathrm{d}i + \int_{1-\theta}^1 P_{t-1}(i)^{1-\varepsilon} \, \mathrm{d}i = (1-\theta)(P_t^*)^{1-\varepsilon} + \theta P_{t-1}^{1-\varepsilon} \tag{4.4.19}$$

and divided by $P_{t-1}^{1-\varepsilon}$:

$$(1 + \pi_t)^{1-\varepsilon} = (1-\theta)(1 + \pi_t^*)^{1-\varepsilon} + \theta. \tag{4.4.20}$$

The optimal inflation rate evolves according to equation (4.4.20), with which we have successfully got rid of the heterogeneity of retailers.

By combining retailers' differentiation technology (4.4.5) and demand curve (4.4.8) we obtain:

$$y_t^W = \int_0^1 y_t(i) \, \mathrm{d}i = \int_0^1 \left[\frac{P_t(i)}{P_t}\right]^{-\varepsilon} y_t \, \mathrm{d}i = y_t \int_0^1 \left[\frac{P_t(i)}{P_t}\right]^{-\varepsilon} \mathrm{d}i. \tag{4.4.21}$$

Define price dispersion v_t as:

$$v_t = \int_0^1 \left[\frac{P_t(i)}{P_t}\right]^{-\varepsilon} \mathrm{d}i \tag{4.4.22}$$

which can be transformed using properties of Calvo pricing to yield:

$$v_t = (1-\theta)(1+\pi_t)^{\varepsilon}(1+\pi_t^*)^{-\varepsilon} + (1+\pi_t)^{\varepsilon}\int_{1-\theta}^{1}\left[\frac{P_{t-1}(i)}{P_{t-1}}\right]^{-\varepsilon} \mathrm{d}i. \tag{4.4.23}$$

Therefore, we obtain the recursive form price dispersion in terms of inflation rates:

$$v_t = (1-\theta)(1+\pi_t)^{\varepsilon}(1+\pi_t^*)^{-\varepsilon} + \theta(1+\pi_t)^{\varepsilon}v_{t-1} \tag{4.4.24}$$

and now we have successfully got rid of nominal prices, since price dispersion v_t and inflation rates π_t and π_t^* are being tracked instead of the individual nominal prices $P_t(i)$ for retail goods.

Therefore, the demand of wholesale goods can be derived:

$$y_t^W = v_t y_t. \tag{4.4.25}$$

4.5 Capital Producers

Perfectly competitive capital producers produce sector-specific capital for intermediate producers and are ultimately owned by entrepreneurs and the government, so the profits (or loss) of capital producers are internalized into the flows of funds of private firms and state-owned firms.

Private capital producers purchase last-period undepreciated private capital $(1-\delta)k_{p,t-1}$ at the nominal price $Q_{p,t}$ (or equivalently the real price $q_{p,t}$) from private firms and $i_{p,t}$ units of final goods from final producers at the nominal price P_t, combines these two inputs to produce new capital $k_{p,t}$ and then sell the new capital back to private firms at the nominal price $Q_{p,t}$. Hence the profits of private capital producers in period t is

$$\Pi_{p,t}^K = q_{p,t}\Delta k_{p,t} - i_{p,t} \tag{4.5.1}$$

where $\Delta k_{p,t} = k_{p,t} - (1-\delta)k_{p,t-1}$ is the amount of newly produced private capital.

Private capital producers seek to maximize the expected present value of their profits with

entrepreneurs' stochastic discount factor $\Lambda_{0,t}^{E} = (\beta^{E})^{t} \frac{MU_{c,t}^{E}}{MU_{c,0}^{E}}$ (since the profits are finally internalized into private firms' flow of funds):

$$\max E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^{E} \Pi_{p,t}^{K} \tag{4.5.2}$$

subject to investment adjustment costs implying

$$\Delta k_{p,t} = \left[1 - \frac{\kappa}{2}\left(\frac{i_{p,t}}{i_{p,t-1}} - 1\right)^{2}\right] i_{p,t} \tag{4.5.3}$$

where κ measures the level of costs incurred by investment adjustment.

By solving the optimization problem of private capital producers, we obtain the first-order condition:

$$\begin{aligned} MU_{c,t}^{E}\left\{1 - q_{p,t}\left[1 - \frac{\kappa}{2}\left(\frac{i_{p,t}}{i_{p,t-1}} - 1\right)^{2} - \kappa\left(\frac{i_{p,t}}{i_{p,t-1}} - 1\right)\frac{i_{p,t}}{i_{p,t-1}}\right]\right\} \\ = \beta^{E} E_t\left[MU_{c,t+1}^{E} q_{p,t+1} \kappa\left(\frac{i_{p,t+1}}{i_{p,t}} - 1\right)\left(\frac{i_{p,t+1}}{i_{p,t}}\right)^{2}\right] \end{aligned} \tag{4.5.4}$$

which determines the optimal level of investment of private capital producers.

Similar to private capital producers, state-owned capital producers earn profits

$$\Pi_{s,t}^{K} = q_{s,t} \Delta k_{s,t} - i_{s,t} \tag{4.5.5}$$

by providing state-owned firms with newly produced state-owned capital $\Delta k_{s,t} = k_{s,t} - (1 - \delta) k_{s,t-1}$, and seek to maximize the expected present value of its profits with the government's stochastic discount factor $\Lambda_{0,t}^{G} = (\beta^{G})^{t} \frac{MU_{g,t}}{MU_{g,0}}$:

$$\max E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^{G} \Pi_{s,t}^{K} \tag{4.5.6}$$

subject to

$$\Delta k_{s,t} = \left[1 - \frac{\kappa}{2}\left(\frac{i_{s,t}}{i_{s,t-1}} - 1\right)^{2}\right] i_{s,t}. \tag{4.5.7}$$

By solving the optimization problem of state-owned capital producers, we obtain the first-order condition:

$$MU_{g,t}\left\{1-q_{s,t}\left[1-\frac{\kappa}{2}\left(\frac{i_{s,t}}{i_{s,t-1}}-1\right)^2-\kappa\left(\frac{i_{s,t}}{i_{s,t-1}}-1\right)\frac{i_{s,t}}{i_{s,t-1}}\right]\right\}$$
$$=\beta^G E_t\left[MU_{g,t+1}q_{s,t+1}\kappa\left(\frac{i_{s,t+1}}{i_{s,t}}-1\right)\left(\frac{i_{s,t+1}}{i_{s,t}}\right)^2\right] \tag{4.5.8}$$

which determines the optimal level of investment of state-owned capital producers.

4.6 Market Clearing

In the perfectly competitive labor market, the labor supply from households equals the labor demand of firms:

$$n_t = n_{p,t} + n_{s,t}. \tag{4.6.1}$$

In the financial market, bonds issued by firms are hold by households:

$$b_t = b_{p,t} + b_{s,t}. \tag{4.6.2}$$

The market clearing condition for the final goods is:

$$y_t = c_t^H + c_t^E + g_t + i_{p,t} + i_{s,t} \tag{4.6.3}$$

which implies that the gross output of final goods is either consumed by agents (as consumption or government spending) or employed by capital producers as investments.

4.7 Monetary Policy

All entities in the economy are subject to the monetary policy proposed and conducted by the central bank, and the monetary policy is formulated according to a Taylor-type nominal interest rate policy rule with inflation and output targeting:

$$R_t = (1-\rho_R)\overline{R} + \rho_R R_{t-1} + (1-\rho_R)\rho_\pi(\pi_{t-1} - \overline{\pi}) + (1-\rho_R)\rho_y(ln\, y_{t-1} - ln\, \overline{y}) + e_{R,t} \qquad (4.7.1)$$

where ρ_R measures the persistence of monetary policy shocks, ρ_π is an inflation-targeting parameter, ρ_y is an output-targeting parameter and $e_{R,t}$ denotes an exogenous monetary policy shock with zero mean and standard deviation σ_R. $\overline{R}$, $\overline{\pi}$ and $\overline{y}$ are the steady-state nominal interest rate, inflation rate and output, respectively. Note that we assume that the central bank adopts a backward-looking Taylor rule as in Iacoviello (2005).

4.8 Borrowing Constraints & Credit Shocks

State-owned firm face no collateral constraint when issuing bonds to households. Given that over-financing is not considered in this model, state-owned firms are just constrained by their capital value in borrowing (via bonds) and thus operate with a constant loan-to-value ratio m_s equal to one.

However, private firms face a collateral constraint (4.2.8) when issuing bonds and can only borrow against their capital value with a stochastic loan-to-value ratio $m_{p,t}$ which is subject to an $AR(1)$ process:

$$\ln m_{p,t} = (1-\rho_m)\ln \overline{m_p} + \rho_m \ln m_{p,t-1} + e^P_{m,t} \qquad (4.2.9)$$

in which ρ_m measures the persistence of sector-specific credit shocks, $e^P_{m,t}$ denotes an exogenous credit shock to the private sector (with zero mean and standard deviation σ^P_m) and $\overline{m_p}$ is the average loan-to-value ratio for private firms.

Therefore, state-owned firms can always maintain a relatively loose and stable credit condition, while private firms with collateral constraints are even subject to sector-specific credit shocks in the financial market. This assumption resembles, to some extent, the bank discrimination against private firms in the asymmetrically deteriorating credit market in China.

4.9* Succeeding Research Plan

4.9.1 Government Appropriation

Based on the proposed two-sector model with asymmetric credit constraints, the succeeding research will further assume that the government taxes households, private firms and state-owned firms as in Andres et al. (2013) and then decides on the amount to spend on final goods as government spending. Inspired by the private benefit of controlling shareholders in Albuquerue & Wang (2008), we assume that the government can appropriate a fraction from the gross output of state-owned firms for government spending by incurring a cost (which is a dead loss to the economy).

Households are bound to the following budget constraint instead of equation (4.1.3):

$$c_t^H + b_t = (1 - \tau^H) w_t n_t + (1 + R_{t-1}) \frac{b_{t-1}}{1 + \pi_t} + \Pi_t^R \tag{4.9.1}$$

in which households are taxed by the government on their wage income at the rate τ^H.

Entrepreneurs are bound to the following budget constraint instead of equation (4.2.7):

$$c_t^E + (1 + R_{t-1}) \frac{b_{p,t-1}}{1 + \pi_t} + q_{p,t} k_{p,t} = (1 - \tau^P)\left(p_{p,t}^I y_{p,t}^I - w_t n_{p,t}\right) + b_{p,t} + q_{p,t}(1 - \delta) k_{p,t-1} + \Pi_{p,t}^K \tag{4.9.2}$$

in which entrepreneurs are taxed by the government on private firms' gross output net of wage payments at the rate τ^P.

The government decides on the amount of government spending g_t using funds from taxing households, private firms and state-owned firms and appropriating the gross output of state-owned firms. We assume that the government can appropriate a fraction s_t from the gross output of state-owned firms by incurring a quadratic cost $\frac{\gamma}{2}s_t^2 p_{s,t}^I y_{s,t}^I$ as the stealing cost in Albuquerue & Wang (2008), so we have the expression for the appropriation a_t:

$$a_t = s_t p_{s,t}^I y_{s,t}^I - \frac{\gamma}{2}s_t^2 p_{s,t}^I y_{s,t}^I. \tag{4.9.3}$$

Therefore, state-owned firms are bound to the following budget constraint instead of equation (4.3.6):

$$(1+R_{t-1})\frac{b_{s,t-1}}{1+\pi_t} + q_{s,t}k_{s,t} = (1-\tau^S)\left[(1-s_t)p_{s,t}^I y_{s,t}^I - w_t n_{s,t}\right] + b_{s,t} + q_{s,t}(1-\delta)k_{s,t-1} + \Pi_{s,t}^K. \tag{4.9.4}$$

State-owned firms are taxed by the government on their gross output (after appropriation) net of wage payments at the rate τ^S, hence we can obtain the expression for government spending g_t:

$$g_t = \tau^H w_t n_t + \tau^P\left(p_{p,t}^I y_{p,t}^I - w_t n_{p,t}\right) + \tau^S\left[(1-s_t)p_{s,t}^I y_{s,t}^I - w_t n_{s,t}\right] + a_t. \tag{4.9.5}$$

4.9.2 Other Potential Improvements

Following Gerali et al. (2010) and Andres et al. (2013), the succeeding research will also incorporate a monopolistically competitive banking sector into the two-sector model proposed in this research. The banking sector with monopolistic power is assumed to generate not only a credit spread between deposit rate (riskless rate) and lending rate but also an interest rate wedge between benchmark interest rate and market interest rate so that the dual-track interest rate system can be featured in the economy.

As for monetary policy rule, it is a canonical method to utilize a Taylor-type interest rate rule (Taylor, 1993 & 1999) in New Keynesian models. However, Li & Liu (2017) claim that with developing financial markets and credit markets, the monetary policy in the Chinese economy is more of a quantity policy rule, which is mainly targeted on money supply, than a price policy rule, which is primarily targeted on interest rates. In order to study the optimal monetary policy and related welfare implications within a two-sector economy incorporating bank discrimination, the succeeding research is likely to adopt a money supply rule instead of the Taylor-type interest rate rule in this research.

5 Empirical Analysis

In this research, the two-sector model is calibrated using parameters estimated with the historical data of the Chinese economy and those borrowed from the literature on New Keynesian models with credit frictions or modelling the Chinese economy. The business cycle implications of bank discrimination are discussed with the simulation of a positive productivity shock to the economy, a positive productivity shock to the private sector, a contractionary credit shock to the private sector and a contractionary monetary policy shock in the model. In addition, the succeeding research will follow the fashion in the literature and use Bayesian method to estimate the model with quarterly data in order to acquire customized parameter values.

5.1 Calibration

Some parameters in the model are estimated to match certain steady-state moments and ratios derived from the historical data of the Chinese economy.

The annualized nominal interest rate is set at 3.5 percent to match the average annualized 3-month Shanghai Interbank Offered Rate (SHIBOR) from Q1 2007 to Q4 2019 (CEIC China Premium Database, Figure 2), and thus the steady-state quarterly nominal interest rate $\overline{R}$ is approximately 0.875 percent.

Similarly, the annualized inflation rate is set at 2.5 percent to match the quarterly Consumer Price Index (CPI) in China from Q1 2007 to Q4 2019 (CEIC China Premium Database, Figure 2), and hence the steady-state quarterly inflation rate $\overline{\pi}$ is approximately 0.625 percent.

Households' discount factor β^H is calibrated to match the historical data of real interest rate, namely

the difference between nominal interest rate and inflation rate. Therefore, the value of β^H is set at 0.9975 so that the annualized real interest rate in this model is roughly 1 percent, which is consistent with the historical data of nominal interest rate and inflation rate. Moreover, entrepreneurs' discount factor β^E and the government's discount factor β^G are set at 0.9925 and 0.995, respectively, implying that entrepreneurs discount the future more heavily than the government.

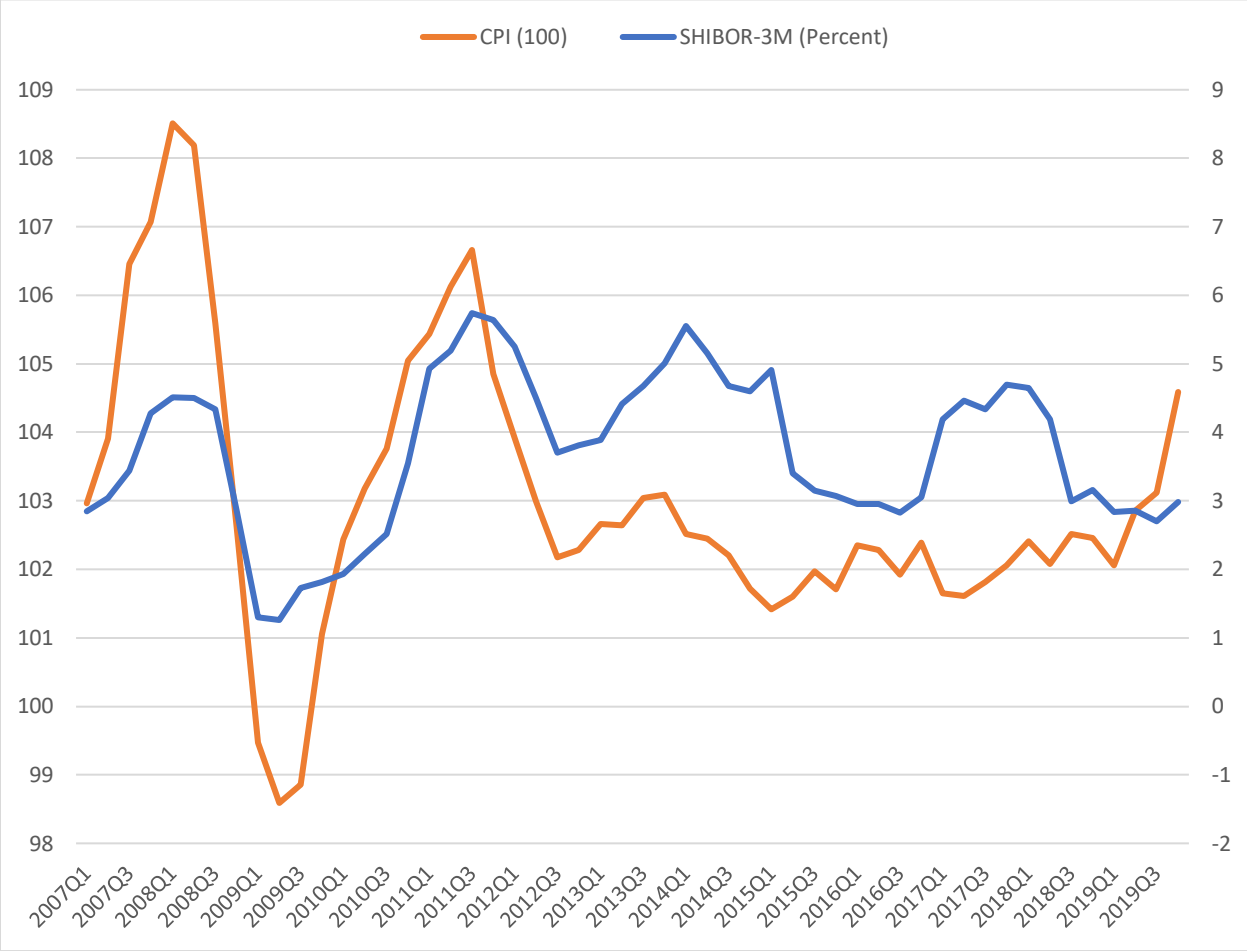

Figure 2: Consumer Price Index (CPI) (measured in an index of 100) and 3-Month Shanghai Interbank Offered Rate (SHIBOR-3M) (measured in percentage) from Q1 2007 to Q4 2019.
Source: CEIC China Premium Database.

Following Li and Liu (2017), the quarterly depreciation rate of capital δ is set at 3.5 percent. This implies an annualized depreciation rate of 14 percent, which is consistent with a capital turnover cycle of approximately 7 quarters in the Chinese economy.

As shown in Figure 1, it can be derived from Holz (2014) that the nominal output share of the private sector in the Chinese economy has been quite stable at around 65 percent since the late 1990s. Therefore, the gross output share of private intermediate goods in the aggregation of wholesale goods σ is set at 0.65.

Parameter	Description	Value
β^H	Households' discount factor	0.9975
β^E	Entrepreneurs' discount factor	0.9925
β^G	The Government's discount factor	0.995
η	Inverse elasticity of labor supply	0.01
δ	Depreciation rate of capital	0.035
σ	The gross output share of private intermediate goods in the aggregation of wholesale goods	0.65
α	Capital-output ratio in the production of intermediate goods	0.4
κ	Level of investment adjustment costs	10
ε	Elasticity of substitution between retail goods	6
θ	Degree of nominal price rigidity	0.75
ρ_A	Persistence of productivity shocks	0.8
σ_A	Standard deviation of productivity shocks	0.01
$\overline{\chi_p}$	Average total factor productivity level of the private sector	1
$\overline{\chi_s}$	Average total factor productivity level of the state-owned sector	0.65
ρ_m	Persistence of credit shocks	0.8
σ_m	Standard deviation of credit shocks	0.01
m_s	Loan-to-value ratio of state-owned firms	1
$\overline{m_p}$	Average loan-to-value ratio of private firms	0.5
ρ_R	Persistence of monetary policy shocks	0.75

ρ_π	Inflation-targeting parameter in the nominal interest rate rule	1.25
ρ_y	Output-targeting parameter in the nominal interest rate rule	0
σ_R	Standard deviation of monetary policy shocks	0.001
$\overline{R}$	Steady-state quarterly nominal interest rate	0.00875
$\overline{\pi}$	Steady-state quarterly inflation rate	0.00625

Table 1: Summary of calibrated parameters.

The values of other parameters are borrowed from the literature on New Keynesian models with credit frictions or modelling the Chinese economy.

Following Li and Liu (2017), the capital-output ratio in the production of intermediate goods α is set at 0.4.

Hsieh and Song (2015) demonstrate that the total factor productivity in the state-owned sector is approximately 65 percent of that in the private sector from 1998 to 2007, hence the average total factor productivity level of the private sector $\overline{\chi_p}$ is normalized to 1 and that of the state-owned sector $\overline{\chi_s}$ is set at 0.65 accordingly. The reference level of total factor productivity A_t and sector-specific productivity parameters $\chi_{p,t}$ and $\chi_{s,t}$ are subject to productivity shocks with persistence ρ_A of 0.8 and a standard deviation σ_A of 0.01, respectively.

Given that over-financing is not considered in this model, state-owned firms under no collateral constraint finance externally with a loan-to-value ratio m_s of 1. Private firms are assumed to operate under a collateral constraint with a stochastic loan-to-value ratio $m_{p,t}$ with an average level of $\overline{m_p}$ equal to 0.5, which implies that private firms can only borrow against half of their collateral values. The credit shocks to $m_{p,t}$ are featured with persistence ρ_m of 0.8 and a standard deviation σ_m of 0.01.

Following Gerali et al. (2010), the level of investment adjustment costs κ is set at 10, and the

elasticity of substitution between retail goods ε is set at 6, implying a markup of 1.2 for retailers.

Following Iacoviello (2005), the degree of nominal price rigidity θ is set at 0.75, which implies roughly a fourth of retailers have the opportunity to adjust their prices in a certain quarter; the inverse elasticity of labor supply η is calibrated at 0.01, implying "a virtually flat labor supply curve"; the Taylor-type interest rate rule is featured with persistence ρ_R of 0.75, an inflation-targeting parameter ρ_π of 1.25 and an output-targeting parameter ρ_y of 0; the standard deviation of monetary policy shocks σ_R is set at 0.001.

Table 1 summarizes the values of the calibrated parameters.

5.2 Simulation

In order to investigate the business cycle implications of bank discrimination, we simulate a positive productivity shock to the economy, a positive productivity shock to the private sector, a contractionary credit shock to the private sector and a contractionary monetary policy shock in this two-sector model with asymmetric credit constraints. Without collateral constraint, state-owned firms can borrow against all their capital value; while private firms are assumed to finance externally with a loan-to-value ratio of 0.5 and thus can only collateralize half of their capital.

Figure 3 reports the impulse responses to a positive productivity shock to the economy with a standard deviation of 0.01. Since investment adjustments incur extra costs, output, investments and loans increase in a hump-shaped manner. Inflation falls and the central bank lowers the nominal interest rate accordingly in a backward-looking manner. Retailers adjust prices in a staggered manner, so the profits rebated from retailers to households increases. Combined with a wage increase, households decide to work less while enjoying a hump-shaped consumption increase. State-owned

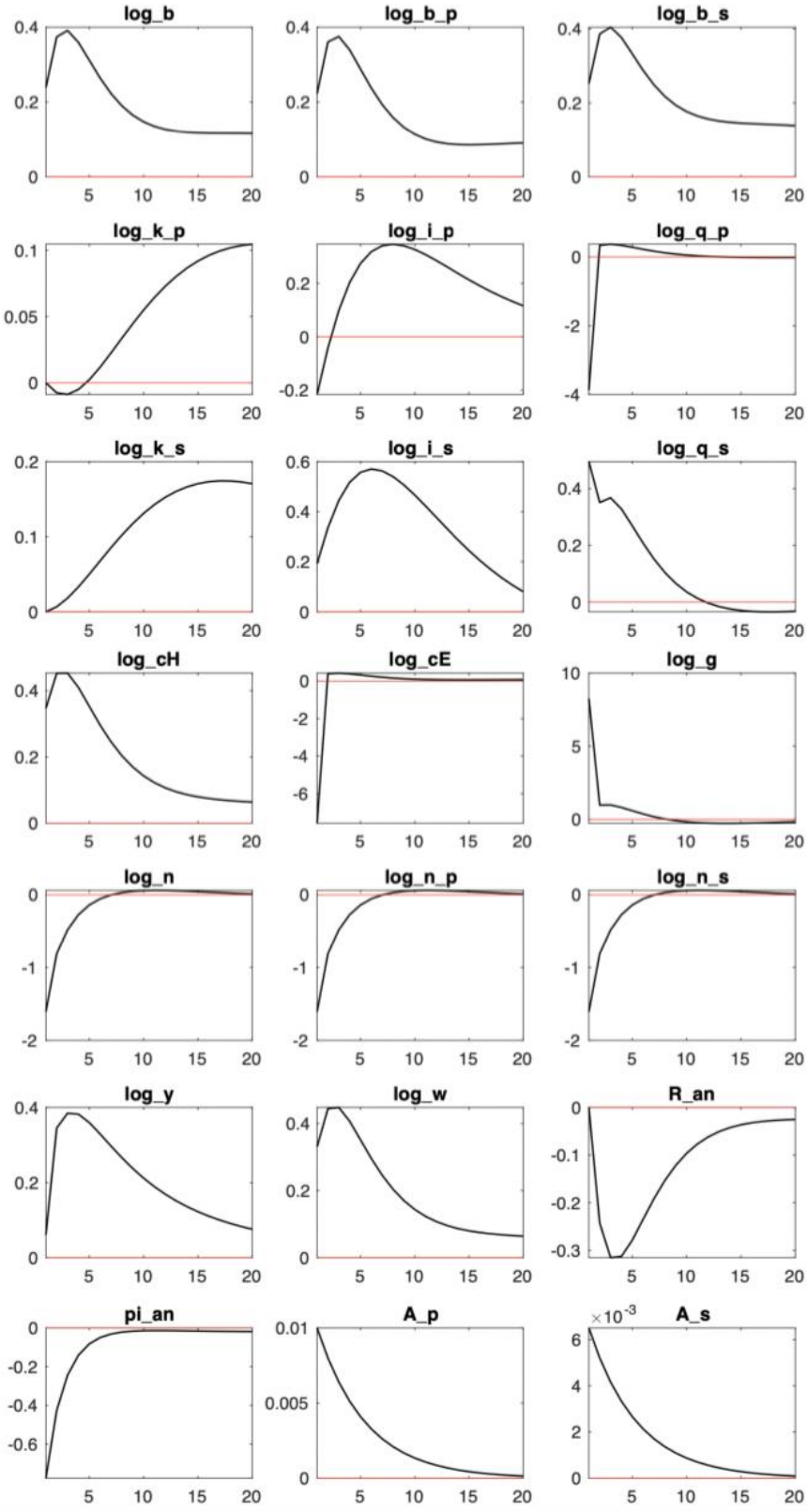

Figure 3: Impulse responses to a positive productivity shock.

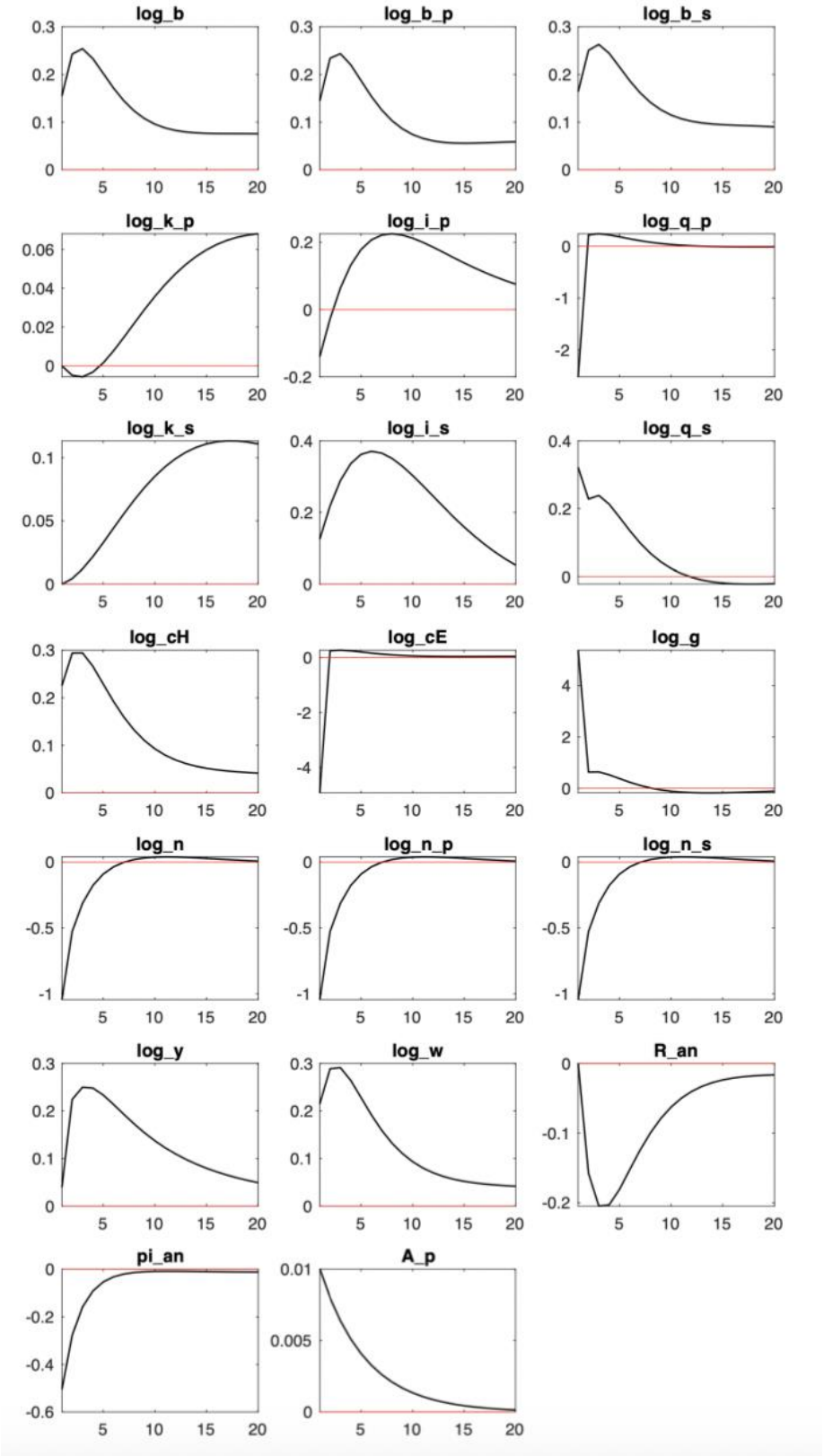

Figure 4: Impulse responses to a positive productivity shock to the private sector.

firms raise investments and accumulate capital, which leads to an increase in the capital price for the state-owned sector and an increase in government spending. However, due to the revenue decline and the binding collateral constraint, entrepreneurs lower consumption and investment initially but increase both shortly afterwards since the central bank lowers the nominal interest rate from the second quarter and turns around the credit condition of private firms. Accordingly, the capital price for the private sector declines in the first quarter and rises from the second quarter.

Figure 4 shows the impulse responses to a positive productivity shock to the private sector with a standard deviation of 0.01. The state-owned sector also benefits from the productivity increase in the private sector and faces higher demand together with higher price. Consequently, the impulse responses are quite similar to those to a positive productivity shock to the whole economy, except that most variables deviate less from the steady-state levels. It is worth emphasizing that even with an asymmetric productivity increase, private firms as well as entrepreneurs will suffer from the revenue decline and the binding collateral constraint before the central bank adjusts the nominal interest rate.

Figure 5 depicts the impulse responses to a contractionary credit shock to the private sector with a standard deviation of 0.01. The decline in the loan-to-value ratio of private firms results in an instant decrease in the demand for private investments and thus for final goods and intermediate goods. Shortly after the shock, inflation and output fall. Even though state-owned firms initially borrow more, households' overall bond holdings and private firms' loans decline. Households initially decide to work less and consume more with the wealth from matured bonds, higher wage and the profits incurred by the staggered price adjustments of retailers. Government spending is much lowered, and the state-owned investments also decline which leads to a decrease in the capital price for the state-owned sector. Entrepreneurs also consume much less, and the decline in the demand for private investments leads to a pronounced decrease in the capital price for the private sector. In response to the decline in inflation and the economic downturn, the central bank decreases the nominal interest

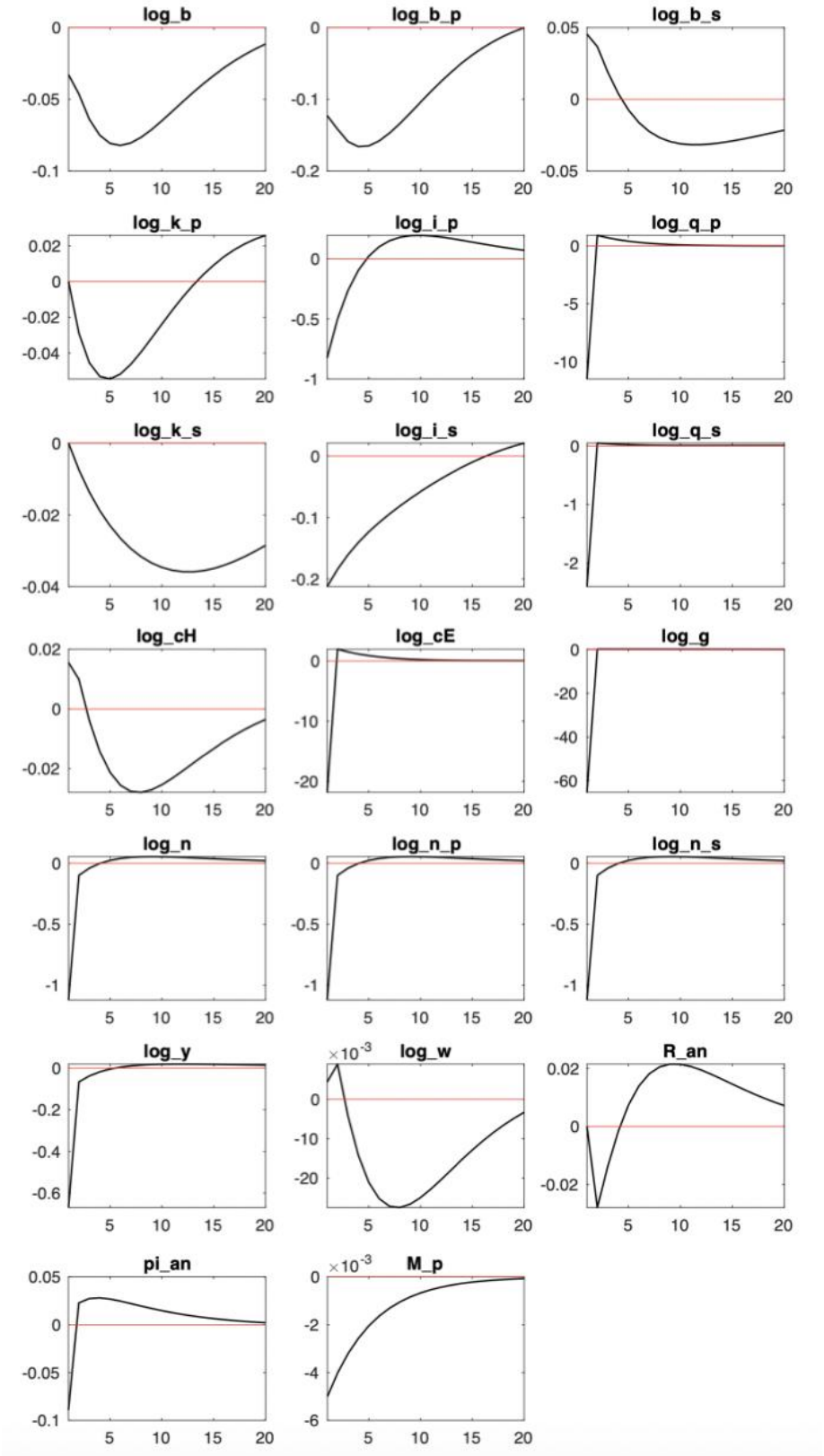

Figure 5: Impulse responses to a contractionary credit shock to the private sector.

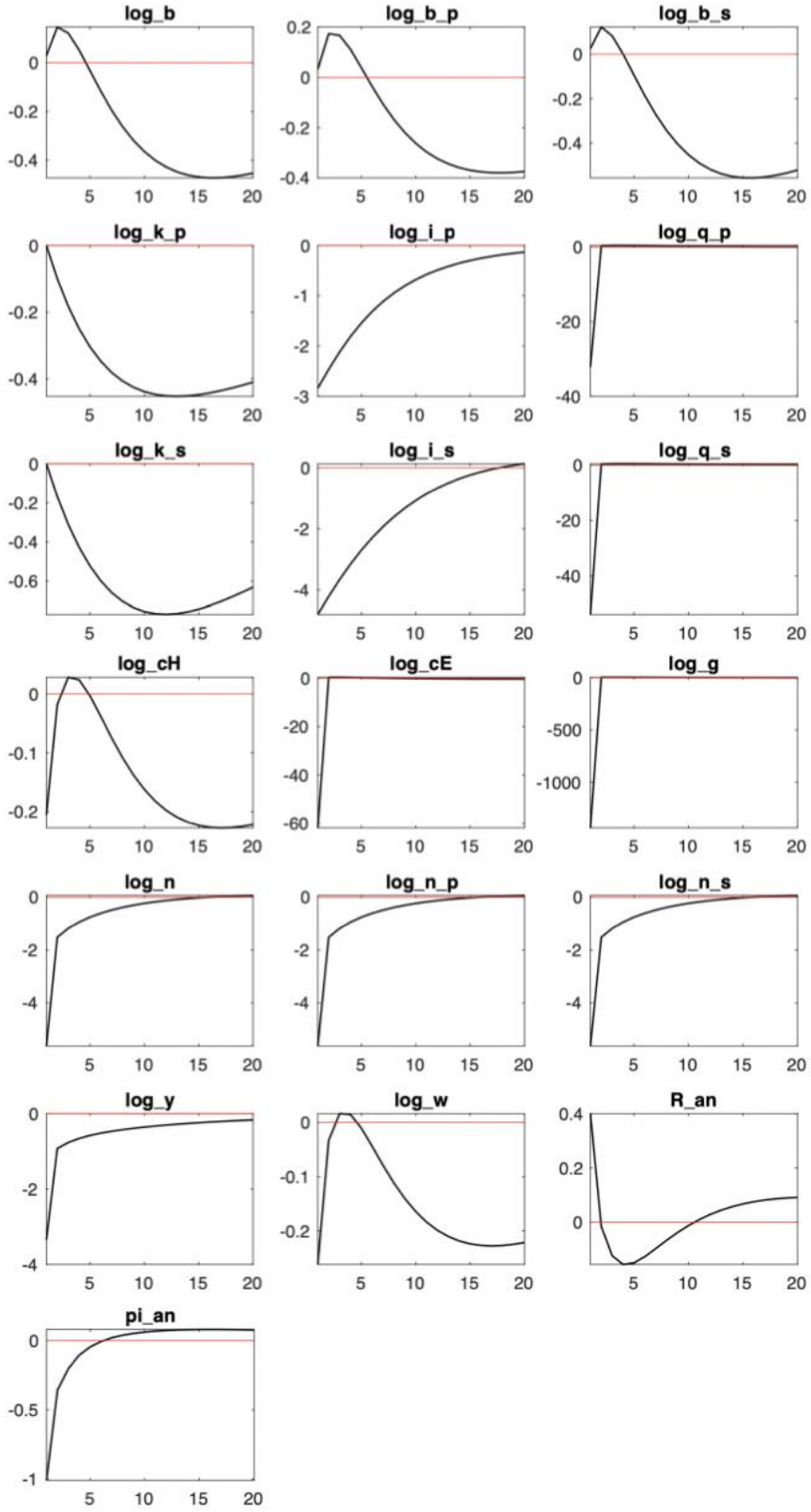

Figure 6: Impulse responses to a contractionary monetary policy shock.

rate for several quarters and increases the nominal interest rate after the inflation turns positive in order to control inflation. With the intervention of the central bank, most variables deviate much less after the first quarter, including output and labor supply. Due to the economic downturn, households' wage and consumption and state-owned firms' loan start to decrease in a few quarters subsequent to the shock.

Figure 6 demonstrates the impulse responses to a contractionary monetary policy shock with a standard deviation of 0.01. An increase in real and nominal interest rate lowers inflation and output, and the central bank lowers the nominal interest rate instantly in response to the decline in inflation and the economic downturn. Households work and consume less on impact and restore much of labor supply and all consumption after the intervention of the central bank. Entrepreneurs and the government consume much less and lower the investments for private firms and state-owned firms, respectively, leading to a decline in capital price for both sectors. It is worth mentioning that both sectors borrow even more from households on impact in order to settle their matured loans, given that they both have lower demand and thus lower revenue. After a few quarters, households' consumption, wage and bond holdings start to decrease because of the economic downturn.

It can be concluded from the analysis of the shocks above that private firms under bank discrimination may significantly suffer from the collateral constraints when faced with productivity shocks and credit shocks but can be less sensitive to monetary policy shocks.

6 Conclusion

In this dissertation, a two-sector New Keynesian model with asymmetric credit constraints is proposed and calibrated to explore the business cycle implications of bank discrimination in the Chinese economy. Bank discrimination is featured in that private enterprises are subject to collateral constraints in external financing while state-owned enterprises are not. Four types of exogenous stochastic shocks (a positive productivity shock to the economy, a positive productivity shock to the private sector, a contractionary credit shock to the private sector and a contractionary monetary policy shock) are simulated in the model, and the analysis of impulse responses indicates that private firms may be significantly constrained by bank discrimination in the credit market when faced with productivity shocks and credit shocks but can be less sensitive to monetary policy shocks.

However, the calibration of this model to match the features of the Chinese economy is still far from complete. For example, the government together with state-owned firms reacts to the credit shock and the monetary policy shock in an unreasonable manner regarding certain variables, such as government spending and loans. On one hand, the author will further calibrate this model before proceeding to the succeeding research plan. On the other hand, it might be promising to follow Smets & Wouters (2003 & 2007) and employ Bayesian method in parameter estimation.

Moreover, the model proposed in this dissertation just serves as the baseline model to incorporate other frameworks in order to better feature bank discrimination in the Chinese economy. Following Gerali et al. (2010) and Andres et al. (2013), the succeeding research will incorporate a monopolistically competitive banking sector into the proposed model. The banking sector with monopolistic power is assumed to generate not only a credit spread between deposit rate (riskless rate) and lending rate but also an interest rate wedge between benchmark interest rate and market interest rate so that the dual-track interest rate system can be featured in the economy. Besides, the succeeding research will follow the “stealing technology” in Albuquerue & Wang (2008) and assume

that the government managing state-owned enterprises faces a policy trade-off between government spending and firm growth and hopefully this framework can features a more sensible government together with state-owned firms.

Lastly, the model in this dissertation adopts a Taylor-type interest rate rule to simulate the monetary policy in the economy, which is common in the literature. However, Li and Liu (2017) argue that the monetary policy in China is targeted more closely on money supply rather than interest rate. Therefore, the proposed model could probably be improved by replacing the Taylor-type interest rate rule with a money supply rule.

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