# Optimal Monetary Policy in a DSGE Model of China's Economy with a Shadow Banking Sector[1]

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**Abstract**

This paper develops a model of the Chinese economy using a DSGE framework that accommodates a banking sector and money. The model is used to shed light on the period of the Global Financial Crisis. It differs from other applications in the use of indirect inference to estimate and test the fitted model. Officially mandated bank lending and government spending were used to supplement monetary policy to aggressively offset shocks to demand. This paper examines the efficiency of monetary policy in terms of the reduction in the frequency of severe economic slowdowns. We find that monetary policy can be used more vigorously to stabilise the economy, making direct banking controls and fiscal activism unnecessary and a price level targeting monetary policy is the most efficient, compared with a conventional Taylor rule, a Friedman rule or a nominal GDP targeting rule

**Keywords**: DSGE Model; China Shadow Banking; Severe Economic Slowdowns; Indirect Inference; Monetary Policy.

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## 1 Introduction

The last four decades have witnessed the remarkable economic growth of China. With rapid accumulation of capital, monetary policy has been playing growing importance in Chinese economy (Sun, 2013; Chen, Ren and Zha, 2018; etc.). Owing to their excellent empirical fitting and attractive model flexibility in addressing important policy issues, dynamic stochastic general equilibrium (DSGE) models have been widely used for the purpose of monetary policy analysis (Christiano, Trabandt, and Walentin, 2010; and Christiano, Eichenbaum and Trabandt, 2018). As such, in recent years there have been a number of investigations into the evaluation of relative performance of alternative monetary policy rules for China utilizing the DSGE framework. For example, Li and Meng (2006) discuss quantity based monetary policy rules, Xi and He, (2010) and Ma, (2015) discuss price based rules, Wu and Lian (2016) analyze hybrid rules, and Li and Liu (2017) compare the relative performance of alternative quantity and price rules.[3]

As noted by Chen et. al. (2018), China's unprecedented multitrillion RMB stimulus package originated in 2008 to cope with the global finance crisis (GFC). The following contractionary monetary policy 2009-2015 gave further impetus to the expansion of the shadow banking sector. The growth of the Chinese shadow banking sector after the GFC, has prompted a number of Chinese scholars to examine its role in deflecting monetary policy. Qiu and Zhou (2014) is perhaps the first systematic investigation into the role of shadow banking in the monetary transmission mechanism using a DSGE framework. They argued that Chinese shadow banking is counter cyclical and will reduce the effectiveness of monetary policy. Liu, Hao and Tian (2014) and Lin, Cao and Xiao (2016) also study Chinese shadow banking using the DSGE framework and claim that shadow banking is pro cyclical. Funke, Mihaylovski and Zhu (2015) analyzed the impacts of interest rate liberalization on monetary policy transmission. Gao, Chen, Zeng and Gong (2018) find a counter cyclical pattern of Chinese shadow banking with a structural vector autoregressive (VAR) model, and contended that shadow banking dampens the effects of monetary policy by substituting between commercial and shadow bank financing. These equilibrium results are largely in accordance with the reduced form analysis of Chen et. al. (2018) with a panel VAR on the distortionary effect of shadow banking on monetary policy.

Unlike the existing monetary DSGE models of Chinese shadow banking, this paper follows Smets and Wouter (2007, henceforth SW)'s Bayesian DSGE

[3] See Chen et. al. (2018) for a review of the unique features and history of evolution of China's monetary policy.

model to evaluate the sources of Chinese macroeconomic fluctuations with a shadow banking sector. [4] Specifically, we employ a variant of the SW model due to Le et al. (2011). The model is augmented with the quantity of credit and money in a way we explain in detail below. The basic idea is that the monetary base (M0) acts as collateral for loans because it is entirely liquid and riskless. Hence it is a powerful agent of credit growth in a way that has hitherto been relatively neglected in DSGE models.

In an earlier paper (Le, Meenagh, Matthews, Minford and Xiao, 2014, henceforth LMMMX) we explored such an approach and reported some success. In this paper we take matters further by adding a fuller monetary sector. In the previous paper we incorporated the Bernanke et al. (1999, henceforth BGG) model of the banking system but paid no explicit attention to balance sheets, the quantity of money and bank credit. Here we try to develop a framework that allows us to comment on policy relating monetary quantities and bank credit (including the activity of the shadow banking system) as opposed to just interest rates.

The focus of this paper is empirical. In contrast to the mainstream Bayesian application, we apply an innovative testing procedure (indirect inference, to be introduced below) to this theoretical set-up, and check whether China's macroeconomic fluctuations can be explained by this theory. China was not immune to the GFC. As LMMMX show, China also experienced a severe loss of output in the GFC in the sense of the Lucas Wedge and suffered a strong growth slowdown and has not recouped this loss nor reached its previous trend growth rate. The purpose of this paper is to investigate whether the evolution of Chinese economy in this period can be plausibly explained within our set up and to evaluate the efficacy of monetary stabilisation policies. The objective is to use the estimated model to evaluate the efficiency of monetary policy as exercised by the Peoples Bank of China (PBOC) in a target framework.

To anticipate our results, we estimate a version of this model to fit the Chinese economy covering the period of the GFC. We use the model to evaluate alternative monetary stabilisation rules and find that a price level targeting and nominal GDP targeting rules are superior to the Taylor rule with an inflation targeting priority or a Friedman monetary rule. In terms of minimising the frequency of severe economic slowdowns (henceforth SES), the most efficient monetary policy rule the PBOC should adopt is a simple price level targeting rule.

In our empirical analysis we use the indirect inference procedure to test the model on some initial starting parameter values, and then allow the parameters to move freely until they maximise the criterion of replicating the data

[4] Li and Liu (2017) also used the Smets and Wouter (2007) Bayesian DSGE framework for studying the relative performance of China's monetary policy rules without shadow banking.

behaviour. [5] This allows us to test the model itself rather than a particular set of parameter values that could be at fault. The main advantage for using indirect inference over the Bayesian maximum likelihood is that it tests the overall ability of the model to replicate key aspects of data behaviour, which are not guaranteed results with Bayesian estimation. Another advantage of the indirect inference is that it works on the original data directly, while the usual estimation method of maximum likelihood or Bayesian usually have to work on the de-trended data thus engender potential information loss as the macro time series data are often nonstationary (Del Negro et al., 2015; Kollmann et al., 2016; Fernandez-Villaverde et al., 2017). Meanwhile, with indirect inference we can simulate the frequency of SES by bootstrap, thus providing additional insights on the probability distribution of the adverse consequences.

It can be argued that the model, developed out of the SW framework is only suitable for a large closed economy as characterised by the USA. Since China has a large export sector (26% of GDP) and a similarly large import sector, one might think that it cannot be modelled as a closed economy. However, China's export and import sector have developed rapidly because of decisions to invest in new infrastructure in cities and transportation; once these decisions were taken, the resulting output of goods was sold on world markets at the prices needed to absorb it. Nevertheless, as there is some degree of price and wage rigidity in China, there will be effects of world demand in the short run. Because the industrial structure is largely dominated by multi-national companies, imports too are closely related to the export volumes. Thus we would argue that net imports can reasonably be modelled as exogenous processes in China; this is how they enter in the SW model, as an exogenous error process in the goods market-clearing equation whereby output equals demand for goods.

An alternative argument is that the Chinese economy does not function fully as a developed market economy and that the modelling of the economy must include the distortions of a dominant state sector (Zheng, Storesletten and Zilibotti, 2011) that stifles the growth of private enterprise through state capital (Huang, 2008) and distortions in the labour market (Dollar and Jones, 2013) and a controlled banking system (Funke et al. 2015). While there is merit in this argument, we argue that it misses the point of using a model as an analytical aid to think about the determinants of the business cycle. In reality no economy developed or otherwise behaves fully as the SW framework describes. The purpose of using a DSGE model of a variant of the SW framework is to use it to isolate the principal factors that drive the business cycle in China even with distorted markets.

The rest of this paper is as follows: in the next section we set out the model in outline, incorporating the modified BGG framework to the SW model. In the

[5] For a review of the method of indirect inference and why it is relevant for testing with DSGE models, see Gourieroux, Monfort and Renault (1993), Le et al. (2011), Le et al. (2014), Le et al. (2016a) and Le et al. (2016b).

third section, we set out the empirical results for the model. The model is used to analyse the banking crisis and to speculate on the causes of future SES. In the penultimate section we consider how monetary policy could be reformed to minimise the occurrence of SES, independently of the regulative solutions now widely being suggested. Our final section concludes, with some reflections on the implications for China's monetary policy.

## 2 The Model

One of the main faults of the first type of calibrated DSGE model, the real business cycle (RBC) model, was its failure to capture the stylised features of the labour market observed in actual data. Employment was found to be not nearly volatile enough in the RBC model compared with observed data, and the correlation between real wages and output was found to be much too high (see, for example, King, Plosser and Rebelo, 1988). In the New-Keynesian tradition, the SW marks a major development in macro-econometric modelling based on the DSGE framework. Its main aim is to construct and estimate a DSGE model in which prices and wages, and hence real wages, are sticky due to nominal and real frictions in both the goods and labour markets, and to examine the consequent effects of monetary policy which is set through a Taylor rule. The SW model contains a full range of structural shocks. These are: for total factor productivity, the risk premium, investment-specific technology, the wage mark-up, the price mark-up, exogenous spending and monetary policy. These shocks are generally assumed to have an autoregressive structure. The model finds that aggregate demand has hump-shaped responses to nominal and real shocks.

We utilise the New Keynesian framework as described by SW in our analysis of the Chinese economy including shadow banking. In particular, we use the model proposed by Le et al. (2014), which extended the original SW model in the following ways. First, it allows for the final goods and labour being sold and supplied to, respectively, in both perfectly competitive and imperfectly competitive markets. Secondly, it incorporates the financial accelerator mechanism (Bernanke et al., 1999) to allow for the analysis of banking/financial sector. Lastly, to make the model more realistic in the light of recent developments in the monetary scene, it allows for the effects of aggressive open market operations ("Quantitative Easing", henceforth QE) and the increase of intrusive regulation of banks. The increase in banking regulation raises the cost of lending to firms. In a modelling sense the extra regulation is added as a credit friction, $\xi$. To add QE to the model we assume that firms are required to put up collateral which is a fraction of their net worth. How does this relate to QE? We assume that as base money (M0) is issued it is acquired by firms from banks to be held as collateral. This is like Williamson (2013). The extension we make in this paper is to include 2 types of intermediate-goods producing firms, SOEs (State-owned enterprises) and SMEs (Small and Medium-sized enterprises). They produce using capital and labour and sell their intermediate goods to the retailer at the marginal costs. They hire labour from the households and buy capital from capital producers. SOEs are assumed to be riskless because of the implicit state guarantee. The banks would lend to these firms at the risk-free rate. However, SMEs are riskier firms but more productive than the SOEs. Banks still want to lend to SMEs, but they do so through the off-balance sheet route of supplying wealth management products which effectively place funds in the shadow banking sector.

There are many ways that banks can perform this lending channel. One way they can do it is to lend at the risk-free rate plus the mark up to high-value individuals or intermediary firms, who then pass it on, together with a slice of their own capital to risky SMEs. These intermediaries share the risks with SME firms to who they are lending. The banks pay a risk-free rate on their savings and lend on risky loans to SMEs. We can think of this as banks charging SMEs a higher premium than the rate at which they lend to SOEs. SMEs could reduce the premium by having a high net worth and/or pledging some of their cash collateral. Since the SMEs can reduce their cost of borrowing by having cash, it would acquire all cash issued by the central bank. In the model, this means that SOEs borrow at a lower rate and SMEs borrow at a higher rate, which is the SOEs borrowing rate plus the credit premium. The premium depends on the net worth of the SME, price of capital and the cash collateral. Therefore, the SMEs risk premium is

$$E_t cy_{t+1} - \left(r_t - E_t \pi_{t+1}\right) = \chi\left(qq_t^{SME} + k_t^{SME} - n_t^{SME}\right) - \psi_1 m_t + \xi_t + epr_t \tag{1}$$

i.e. the risk premium is reduced with a higher cash collateral ($m_t$) and a higher net worth relative to the gross value of capital (-($qq_t^{SME} + k_t^{SME} - n_t^{SME}$)), it rises with more regulations and exogenous shocks. There is also an assumption that every period a fixed death rate $(1-\theta)$ happens so that the stock of firms is kept constant by an equal birth rate of new firms, and the net worth remains below the demand for capital. This means that the SMEs net worth is the past net worth of surviving firms plus their total return on capital minus the expected return (which is paid out in borrowing costs to the bank) on the externally financed part of their capital stock — equivalent to the following in natural logs,

$$n_t^{SME} = \theta n_{t-1}^{SME} + \frac{K^{SME}}{N^{SME}}\left(cy_t - E_{t-1}cy_t\right) + E_{t-1}cy_t + enw_t \tag{2}$$

,where $\frac{K^{SME}}{N^{SME}}$ is the steady state ratio of SMEs' capital expenditures to SMEs net worth, $\theta$ is the survival rate of SMEs, $cy_t$ is the return on capital, and $enw_t$ is a net worth shock.

Firms in each intermediate sector produce intermediate goods under perfect competition assumptions. The final goods producer would gather these intermediate goods following a CES production function into final goods. It then sells a part of final goods in the competitive market and it differentiates the rest and then marks up for sale in the market characterised by the nominal rigidities. Therefore, we assume that the monopolistic power, nominal price rigidities, is introduced at the retail level. For some derivations, see Appendix 1. Labour supply also works in the same way so that the aggregate wage index is a weighted average of the two sectors wage levels.

Finally, we model the rate on official lending to the banks by the central bank in accordance with a Taylor Rule. We assume that in normal times the central bank enforces this rule via discount window operations so that base money is endogenous — supporting the lending implied by the Taylor Rule[6]. The monetary authorities therefore have two instruments: *M0* and *r*. Due to data on regulations being unavailable, we merge the exogenous credit shocks and regulations as one shock, thus a higher shock in the risk premium equation can be partly due to more regulations on the banking system. Regulations are also one of the instruments available to the central bank.

The full listing of the model is available in the Appendix.

## 3. Model Estimation and Variance Decomposition

The model that integrates the banking sector and money is estimated using the method of indirect inference as set out in Le et al. (2011)[7] for the 1991–2015 period using unfilted quarterly data. The estimated model is tested against the data using the main macroeconomic variables, output, inflation and the interest rate. The method tests whether the model can jointly match the time series properties of the data.

A word about the data, before moving on to a discussion of the results. As is often the case with China, some strong assumptions are made to move a theoretical model to an empirical framework. The data for real GDP output, inflation and the interest rate are obtained from the IMF data bank. Total annual investment data, and private investment data is obtained from the China Bureau of Statistics and interpolated for quarterly figures[8]. Private investment is assumed to be the investment of the SMEs and SOE investment is assumed to be the residual. The share of private sector output is obtained as annual data

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[6] For a more detailed statement of the model see the model listing in Appendix 1.

[7]For an in depth look at the benefits of using the method see Le et al. (2016a).

[7] Time series data on private sector investment are obtained directly from *China Statistical Yearbooks* up to 2015. The ownership structure of China's enterprises has changed dramatically since the early 1980's, and the definition of the term 'private' is not a constant. To resolve uncertainties regarding the construction of a private investment data series, China's National Bureau of Statistics published in 2012 an instruction document on its definition for China. For the early years where the private investment data are unavailable, we follow the instruction to construct the data series. Clearly due to the complexity of the ownership change situation, the private investment data might have non-negligible measurement errors hence can at best be viewed as a close proxy to the true level of investment.

from 2000-2015 and interpolated for quarterly estimates and spliced back to 1991 as a constant proportion the 2000 share. Again, private sector output is assumed to be generated by the SME sector.

The model is found to fit the data with the Wald statistic having a p-value of 0.053 showing that the model is not rejected at the conventional level of significance. Table 1 displays the parameter estimates. We also show impulse response functions to key variables and shocks in Figure 1. Note that the second set of impulse response function (IRF)'s in Figure 1 are due to a non-stationary productivity shock.

Table 1: Key Coefficient Estimates (1991Q1–2015Q4)

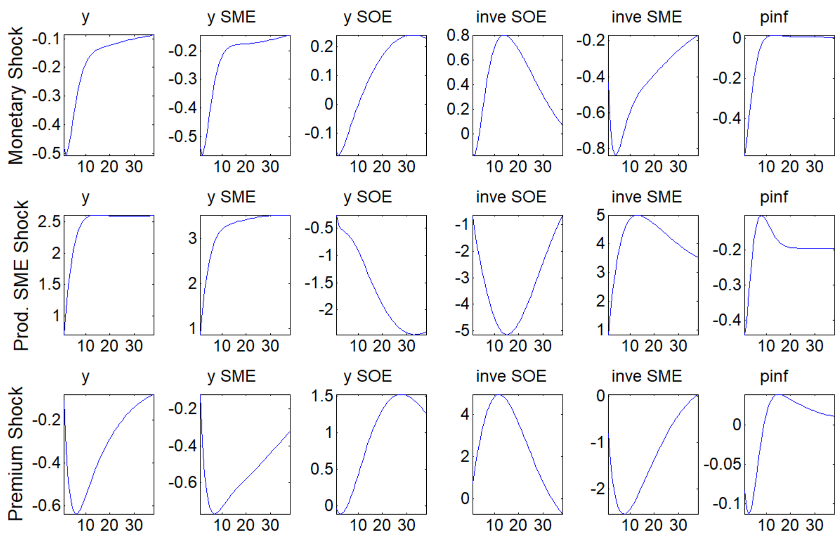
| | | |
|---|---|---|
| $\sigma_c$ | Elasticity of consumption | 1.1351 |
| $\varphi$ | Steady-state elasticity of capital adjustment | 9.8529 |
| $\lambda$ | External habit formation | 0.0004 |
| $\sigma_l$ | Elasticity of labour supply | 1.1919 |
| $\xi_p$ | Probability of not changing prices | 0.7497 |
| $\iota_p$ | Price indexation | 0.0254 |
| $\xi_w$ | Probability of not changing wages | 0.6178 |
| $\iota_w$ | Wage indexation | 0.1679 |
| $\eta$ | Substitution between demand for SOE and SME intermediate goods | 2.5428 |
| $\chi$ | Elasticity of the premium with respect to leverage | 0.0105 |
| $\psi_s$ | Elasticity of the premium to M0 | 0.0408 |
| $\psi_m$ | Monetary response | 0.0030 |
| $\rho$ | Interest rate smoothing | 0.9621 |
| $\rho_\pi$ | Taylor Rule response to inflation | 2.9494 |
| $\rho_y$ | Taylor Rule response to output | 0.1471 |
| $\rho_{\Delta y}$ | Taylor Rule response to change in output | 0.0558 |
| $\omega_\pi$ | NK weight on inflation | 0.7058 |
| $\omega_w$ | NK weight on wage | 0.8925 |
| | Wald | 18.3356 |
| | Trans | 1.5546 |
| | p-value | 0.053 |

We find that in China the labour and product markets are strongly competitive. The coefficient of wage indexation is 17% and price indexation for the SMEs is 2.5%. If one had to place China along the New Keynesian-New Classical spectrum it would therefore be closer to the New Classical end, with less nominal rigidity. The main differences for the model with money comes through the substitution of M0-based collateral in place of net worth. The feedback coefficient on M0 from the credit/money supply is set very small in estimation because otherwise it tends to destabilise the model.

The IRFs are more revealing. Figure 1 shows the IRFs for output by the SMEs, and SOEs respectively, investment by the two types of firms, and inflation. The first row shows the effect of a negative interest rate shock. Both output of the SMEs and SOEs decline driven by a fall in investment which is more pronounced for the SME sector. The second row shows a positive shock to productivity in the SME sector. Aggregate output increases even though there is a crowding out effect on SOE output. The third row shows a shock to the premium, which has an effect not dissimilar to the monetary shock.

These results are in contrast to Gao et. al. (2018) who argue that a negative monetary shock causes the banking system in China to substitute from bank credit to shadow bank credit. As monetary policy tightens, banks shift their assets off-balance sheet so as avoid capital constraints and to meet increased funding costs from the tightening monetary policy. Therefore a tightening of monetary policy causes a decrease in commercial bank lending and an increase in shadow bank lending. They argue that shadow bank credit is countercyclical to commercial bank credit and therefore dampens the effect of monetary shocks, whereas the results below suggest shadow bank credit reinforces monetary policy through its effect on the premium.

Figure 1: IRFs for Key Variables




Having found a set of parameters that are not rejected by the data, we now back out the structural residuals. As we are using unfiltered data we test whether the residuals are stationary, trend stationary, or non-stationary. The productivity residual has a unit root and we specify it in first differences. The other shocks we treat as either stationary or trend-stationary and allow the residual data to determine the AR parameters. Many of the residuals are highly persistent[9]. The

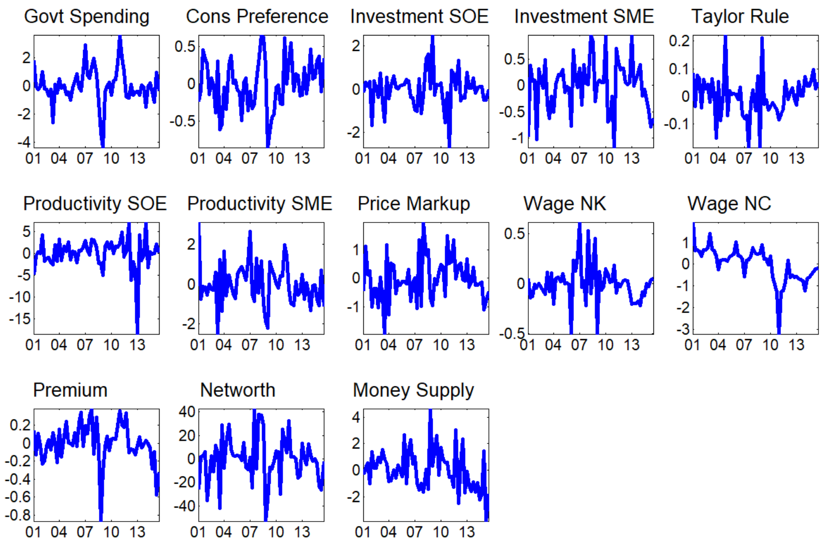
[9] Although the ADF and KPSS tests are consistent in several cases with unit roots, the fact that the model as a whole fits the data behaviour with the AR coefficients used here is evidence in their favour; had unit

error terms are interpreted as the shocks that hit the Chinese economy.

From Figure 2, we can see that the spike in investment by SOEs in 2009 coincides with China's equivalent of QE in the form infrastructure expenditure. This also coincides with negative spikes in the Taylor rule and the premium, and a positive spike in the money supply.

We go on to analyse the period of the GFC in China[10]. There are many shocks hitting the Chinese economy during the crisis period. Most of the major shocks are international but lead to domestic counterpart shocks. The Chinese authorities responded by ordering banks to lend for investment projects (mainly infrastructure). There is also a reaction to the crisis in government spending which with net exports constitutes the exogenous demand shock.

Figure 2: Innovations




We next look at the variance decomposition for the crisis episode. As we are using unfiltered data we need to analyse the non-stationary shock differently. We take the shocks in the episode and replay them by redrawing them randomly and repeatedly with replacement. The results of the variance decomposition are shown in Table 2 below.

We find that only 37% of the output variance is due to banking shocks (here essentially net worth, premium and the M0 shock[11]). The main effect of the

roots given a better fit, we would observe AR coefficients negligibly different from unity.

[10] As this is only a model of China we can't identify the causality of any international ramifications. These international effects will show up in the shocks. The commodity price shocks that enter through the 'price mark-up' here are themselves responding to the crisis. Also, the exogenous demand shock, which consists of government spending and net exports, contains the international downturn in world trade.

[11]We include the M0 error among the banking shocks because it parallels the behaviour of the credit premium shock in the US which was clearly a financial shock but also later embodied a strong policy

banking shocks in on investment by the SMEs. This is because it operates by disturbing the supply of credit; thus, for investment by the SMEs the share of financial shocks is very high (71%) and for investment by SOEs is 54%. This large effect doesn't fully carry over to GDP because interest rates react to them.

We have found that the financial shocks do play a role in China for this episode, but most of the variation comes from the other shocks. Most notably productivity, and SOE investment.

## 4 Monetary Policy Reforms

During the GFC the Chinese government used both a direct fiscal response in the form of higher government spending and a credit-direction response in which banks were directed to lend for investment. While the fiscal response was effective and when we simulated it in repeated samples, caused a dampening of output fluctuations, the credit/investment response caused dangerous instability in the form of rising excess capacity — this was the major finding of LMMMX. We now look, using our model with both money and credit, at whether the Chinese authorities could have made more effective use of monetary policy to dampen the impact of the GFC.

Table 2: Variance Decomposition for Crisis Period (2006 Q1-2015 Q4)

| | Y | y SME | y SOE | inv | inv SOE | inv SME |
|---|---|---|---|---|---|---|
| Govt Spending | 2.01 | 1.67 | 0.59 | 0.70 | 1.49 | 0.24 |
| Cons Preference | 3.14 | 1.82 | 1.57 | 5.46 | 3.66 | 1.97 |
| Investment SOE | 7.50 | 4.65 | 3.22 | 9.63 | 3.73 | 3.91 |
| Investment SME | 0.20 | 0.16 | 0.02 | 0.21 | 0.09 | 0.17 |
| Taylor Rule | 1.17 | 1.00 | 0.12 | 0.99 | 0.31 | 0.87 |
| Productivity SOE | 4.64 | 1.16 | 69.46 | 2.49 | 29.67 | 0.39 |
| Productivity SME | 43.80 | 43.60 | 3.77 | 22.38 | 7.12 | 20.98 |
| Price Markup | 0.25 | 0.22 | 0.04 | 0.22 | 0.09 | 0.21 |
| Wage NK | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Wage NC | 0.15 | 0.11 | 0.01 | 0.09 | 0.02 | 0.04 |
| Premium | 4.82 | 6.82 | 6.97 | 8.48 | 16.50 | 13.21 |
| Net worth | 22.74 | 28.31 | 12.16 | 33.06 | 31.51 | 41.73 |
| Money Supply | 9.58 | 10.48 | 2.07 | 16.30 | 5.82 | 16.27 |
| SOE shock | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Banking Shocks | 37.14 | 45.61 | 21.21 | 57.83 | 53.82 | 71.21 |
| Non-Banking Shocks | 62.86 | 54.39 | 78.79 | 42.17 | 46.18 | 28.79 |

response in the form of bank bailout. In China the credit premium shock was small because the banks are largely state banks with little perceived credit risk.

The model endows the authorities with two instruments, apart from regulation which we leave on one side as a last resort, given the distortionary impacts that it has. These instruments are Base money (Quantitative Easing, Open Market Operations) and interest-rate setting via a Taylor Rule. We assume in this model that the instruments can be independently chosen. Open market operations supply Base money (M0) in exchange for government bonds of all types, so setting the credit premium by affecting the supply of collateral. Interest rates are set by selling or buying short, government bonds for long.

According to the model, what are the general causes of SES? To understand how we approach this question, we analyse the bootstrap experience. We simulate potential scenarios by bootstrapping the shocks from the period 2006 Q1–2015 Q4, so we are specifically using the shocks from the period of the GFC. We can then analyse these scenarios to see how frequent SES are, and what types of shocks are needed to cause an SES.

Note that throughout the paper we use the term SES (severe economic slowdown) as a counterpart of crisis, which is often used in DSGE models of developed economies. Normally, a crisis could be defined as a severe interruption in output growth, a large part of which is permanent; and a financial crisis as a crisis in which there is also a financial collapse of some sort. However, the history of the period we take for our analysis has never experienced what would constitute a recession (2 quarters of negative growth) let alone a crisis in terms of a permanent fall in output for China. Indeed, the average growth rate for the estimation period for the model tops 9% per year. Bootstrapping the shocks even for the period of the GFC will generate very few instances of negative growth. Therefore, the term SES instead of crisis is more appropriate for dubbing Chinese economic fluctuations, while SES may be interpreted in the relative sense of growth falling below some target much lower than the historical average. From the perspective of maintaining consensus behind the government's policies for growth and market liberalisation the avoidance of SES whoever way defined, is of key importance, as clearly revealed in the Chinese government's strong response to the GFC.

Bootstrapping the shocks 1000 times we can identify the number of instances an SES occurs. We find that if we define an SES as an interruption of GDP growth such that output falls and does not recover to its past peak for at least 3 years (which for a China accustomed to regular 9% plus growth is a severe interruption), then we find that an SES on average will occur about every 100 years[12]. Using this definition of an SES we can say that SES is not a normal part of the Chinese economy. Of course, we are only analysing data from the

[12]This figure is obtained by defining the balanced growth path of the economy to 6% rather than the historic 9%.

last decade to include the period of the GFC. During this period the variance of shocks was considerably lower than in earlier post-war history. If we were to extend our sample to include this more volatile period, then no doubt it would change our estimates in detail.

However, if we are more liberal in our definition of an SES to mean a reduction in the growth rate to below 6% for 3 years, the frequency of SES alters radically. For a growth rate of 5% for 3 years the frequency of SES increases to 15 years, and a growth of 3% a year for 3 years, the frequency is every 23 years. We can surmise that an average frequency of SES of this order, implying a good chance of more frequent occurrence, would be unacceptable to Chinese policymakers.

### *4.1 Changes in the monetary regime*

The Great Recession showed that an economy with inflation targeting alone struggled to cope with big shocks to the economy and might even contribute to instability (Beckworth, 2014) because monetary policy was too tight (and may have been too loose in the boom that led up to it). In this section, we discuss some possible changes to the monetary regime that could improve economic stability, compared with the baseline regime (embedded in the model) of inflation targeting, minimal regulation and an accommodative M0 response to the money supply. Our focus with these alternative regimes is their capacity to reduce the number of SES.

We test whether supplementing the Taylor Rule with a powerful Friedman type money supply rule could help stabilise the economy. The reason for testing this is because prior to the financial crisis inflation expectations were strongly anchored by the inflation target, and so inflation did not respond to the substantial expansion of money and credit that was seen in the run-up to the Great Recession.

The optimal monetary reform takes the following form[13]

$$m_t = m_{t-1} + \rho_m y_{t-1} + \varepsilon_t^m \qquad (3)$$

We repeat our bootstrap simulation exercise incorporating this rule and compute the frequency of SES as defined above, namely a fall in output where output does not recover to its previous peak for 3 years, a fall in the growth rate of output to 3% a year or less for 3 years, and a fall in the growth rate to 5% or less for 3 years. The results are shown in Table 3 below. What Table 3 shows is the frequency of incidence in a particular time interval. So based on the residuals of the model and bearing in mind that China has not experienced a fall in output for a continuous period of 3 years within the sample period, column 1 says that using the Taylor rule China can expect a fall in output for a continuous period

[13]The best value of $\rho_m$ turned out to be zero and equation (3) translates to a simple monetary target rule, however a drift factor and be attached to it without any change to the results to produce a Friedman rule of a constant rate of growth of money.

of 3 years with recovery to its previous peak, one-in-every hundred years (one 1 per cent probability of occurrence). Moving to the next row, it says that China can expect an SES of growth less than 3 per cent for a continuous period of 3 years once every 23 years – or with 4.3% probability. The next row says that growth will fall below 6% for a period of 3 years, once every 15 years.

Following the decrease of interest rates, to close to the zero lower bound, in most developed economies there has been a renewed interest in price level targeting (PLT) as a better alternative monetary policy that can achieve price stability while also reducing the impact of the zero lower bound (Wolman, 2005; Vestin, 2006; Nakov, 2008; and Dib et al, 2008; for a recent survey see Hatcher and Minford, 2013). Under PLT, inflation expectations adjust to stabilise the economy: if an unanticipated shock pushes the price level below the target, people will expect higher than average inflation in the future to bring the price level back to the target. PLT has two advantages over inflation targeting. First, due to the automatic adjustment in inflation expectations, the central bank does not need to move interest rates aggressively in response to shocks (Cover and Pecorino, 2005), thus it reduces the likelihood of hitting the zero bound. Second, PLT can generate positive inflation expectations in a deflationary situation, lowering real interest rates even at the zero bound and so strengthen recovery. While China has not experienced a zero-lower bound, similar mechanisms work outside the zero bound: when the economy grows strongly pushing up the price level, inflation expectations fall sharply, so powerfully raising real interest rates; and when the economy is weak, pushing prices down, inflation expectations rise sharply, lowering real interest rates and promoting recovery.

The PLT rule is specified as follows:

$$r_t = \rho_1 r_{t-1} + (1-\rho_1)\left\{\rho_\pi\left(p_t - \overline{p}\right) + \rho_y (y_t - y^*)\right\} + \rho_{\Delta y}\left[\left(y_t - y^*\right) - \left(y_{t-1} - y^*\right)\right] + er_t \quad (4)$$

Under the zero-inflation steady state, the steady state price level is assumed constant here and normalised as $\overline{p} = 0$.

We are looking for an optimal PLT specification that provides the least frequency of SES under our bootstrap simulations. It turns out that the following PLT rule

$$r_t = 0.43 r_{t-1} + (1-0.43)\left\{0.11 p_t + 0.98(y_t - y^*)\right\} + 0.67\left(y_t - y_{t-1}\right) + er_t \quad (5)$$

, reduces the frequency of SES further (Table 3).

Another alternative rule that has been suggested in the literature is a rule that targets the level of nominal GDP (NGDP), rather than either a monetary aggregate or inflation (Sumner 2011, Nunes and Cole 2013). A similar proposal was made some time ago in a series of papers by McCallum (1988) and McCallum and Nelson (1999) who suggested a rule setting interest rates in response to deviations of nominal GDP growth from a target rate. McCallum argued that this rule would be superior to monetary targeting because of the large and unpredictable changes in payments technology and financial regulations. Compared with the later Taylor Rule McCallum's rule has interest rates responding as strongly to output growth deviations as to inflation deviations. However, the authors above suggest targeting the level of NGDP rather than its growth rate; the reasons are like those for PLT, except that in this case an expected future interest rate stimulus is triggered also by output falling below its trend (McCallum, 2011). A concern about this is that with a stochastic productivity trend monetary policy would be affected by permanent shifts in productivity; thus, the NGDP rule we use here allows for changes in the model's productivity trend — since this is hard for the central bank to estimate, the results for the NGDP rule shown here are 'best case'. Nevertheless, if this best case can be assumed, the NGDP rule generates expectations of very strong monetary responses in conditions of prolonged recession — analogous to Roosevelt's 1930s abandonment of the Gold Standard (Carney, 2012 and Woodford, 2012).

Implementing the NGDP target, the central bank would specify an intermediate target for the official interest rate. The rule might be written as follows:

$$r_t = \rho_1 r_{t-1} + \rho_y (y_t + p_t - \overline{y_t} - \overline{p}) + er_t \tag{6}$$

where $\overline{y} + \overline{p}$ is the target for NGDP, where $\overline{p} = 0$ and $\overline{y_t}$ follows the trend path in real output generated by productivity.

Given this general rule, we bootstrap our model and implied shocks to see whether implementing the NGDP targeting regime could help to stabilise the economy. We found that the rule in the form below also dramatically reduces the frequency of SES (Table 3):

$$r_t = 0.89 r_{t-1} + 4.94(p_t + y_t - \overline{y_t}) + er_t \tag{7}$$

To summarise our results, what we find is that the pure Taylor rule, and the Taylor rule supplemented with the Friedman money supply rule produce almost identical results in terms of reducing the frequency of SES[14]. We also find that we can reduce the frequency of SES to negligible levels if we implement the reforms to the Taylor Rule or to the Friedman M0 rule, by following either a nominal GDP target rule of a Price level target rule. Output variability is dramatically dampened, smoothing out the boom and bust cycle, and virtually eliminating SES, if we define SES as a drop in GDP that is not recovered for three years. Using these rules would also mean that there is no need for the

[14] The results of Table 3 can be contrasted with Li and Liu (2017) who explore the optimal monetary policy rule in a Bayesian DSGE model of China. Li and Liu (2017) augment the conventional Taylor rule with a monetary growth target and compare this against a conventional Taylor rule and a flexible monetary target rule. They find that a flexible monetary target rule and the augmented Taylor rule is superior to the conventional Taylor rule in terms of variance decomposition.

authorities to use heavy-handed and distortionary regulative controls on banks to avoid financial crisis.

Table 3: Frequency of SES in years under different monetary regimes, assuming a 6% balanced growth path

| Condition of SES | Taylor Rule | Monetary rule | NGDPT | PLT |
|---|---|---|---|---|
| Growth 0% or less | 100 | 85 | 155 | 552 |
| Growth 3% or less | 23 | 22 | 28 | 45 |
| Growth 5% or less | 15 | 15 | 17 | 20 |

## 5 Conclusions

This paper presents the results of an investigation into the behaviour of the Chinese economy over the period of the recent GFC with the aid of the well-known Smets-Wouters DSGE model, as modified by Le et al. (2011) to allow for greater heterogeneity in price/wage behaviour and including the banking/financial accelerator model of Bernanke et al. (1999). Furthermore, we have modified the BGG model to allow for the role of money, replacing net worth as collateral with the firm's holding of cash (M0) and the cash-conversion. This allows the model to generate monetary behaviour.

The methodology of this paper distinguishes itself from the mainstream of modelling the economy of China. Unlike the conventional approach, which is to apply Bayesian methods to a DSGE framework, we use the method of indirect inference. Here, the method of indirect inference is used to estimate the model using unfiltered data, allowing for non-stationary shocks. The model was not rejected by the data and a variance decomposition was conducted to establish what a typical SES generated by these shocks would be caused by. The decomposition focussed specifically on the GFC period and showed that about one-third of output variance is generated by banking (financial) shocks and over 40% sourced to productivity shocks in the SME sector

The model also tells us that China is not exempted from the SES that are regular occurrences in developed economies, and that she frequently will have as their by-product financial turmoil in the sense that the premium rises sharply. These SES will occur despite there being no extreme financial shocks such as occurred in the recent episode; so serious financial shocks are not required for SES to happen. Furthermore, extreme financial shocks on their own of the type identified in this sample do not cause SES; all they do is cause temporary recessions. Thus, both SES and financial turmoil result from non-financial shocks; naturally financial shocks if extreme enough will add an extra layer of recession.

We build on the results of an earlier paper where we found that the Chinese government's response to the GFC in the form of mandated credit provision across the economy risked generating severe excess capacity and consequent instability. In this paper we looked at alternative monetary responses to those in the prevailing regime. We found that a Friedman rule fared no better than a Taylor inflation target rule in stabilising output and avoiding recessions. However, we found that an interest rate rule with either a price level target or a nominal GDP target would have greatly stabilised the Chinese economy, reducing SES to a minimum.

The policy conclusion of this paper is that financial regulative responses to the instability of the economy, are misplaced because they cause market distortions and are also unnecessary, since monetary policy can do the job, if properly calibrated. This echoes the policy conclusion of Le et al. (2014a) for the US. In this respect, as in many others, the behaviour of the Chinese economy does not appear to be qualitatively different from that of the US economy. A simple interest rate reaction to a price level target that operates on the macro-economy is more efficient to other rules in terms of minimising the frequency of SES and is preferable to regulatory restrictions that create microeconomic distortions.

## References

Beckworth, D. (2014). Inflation Targeting: A monetary Policy Regime Whose Time Has Come and Gone, Memo. ***Mercatus Center George Mason University***.

Bernanke, B. S., Gertler, M., Gilchrist, S. (1999). The financial accelerator in a business cycle framework, ***Handbook of Macroeconomics***, vol. 1, edited by J.B. Taylor and M. Woodford, ch. 21, 1341–1393, Elsevier.

Carney, M. (2012). Guidance, Speech in front of CFA Society Toronto.

Chen, K., Ren, J., & Zha, T. (2018). The Nexus of Monetary Policy and Shadow Banking in China. ***American Economic Review***, 108(12), 3891–3936.

Christiano, L. J., Trabandt, M., & Walentin, K. (2010). DSGE Models for Monetary Policy Analysis. In ***Handbook of Monetary Economics***, pps. 285–367.

Christiano, L. J., Eichenbaum, M. S., & Trabandt, M. (2018). On DSGE Models. ***Journal of Economic Perspectives***, 32(3), 113–140.

Chow, G. (2007). ***China's Economic Transformation***. Blackwell Publishing.

Chow, G. (2011). Lessons from studying a simple macroeconometric model for China. ***Economic Let***ters, 112, 233–235.

Coase, R., Wang, N. (2012). ***How China became Capitalist***, Palgrave Macmillan.

Cover, J., Pecorino, P. (2005). Price and Output Stability under Price-Level Targeting, ***Southern Economic Journal***, 72(1), 152–166.

Del Negro, M., Giannoni, M. P. and Schorfheide, F. (2015). Inflation in the Great Recession and New Keynesian Models, ***American Economic Journal: Macroeconomics***, 7(1), 168-196.

Dib, A., Mendicino, C., Zhang, Y. (2008). Price level Targeting in a Small Open Economy with Financial Frictions: Welfare Analysis, *Bank of Canada Working Paper* 2009–17.

Dollar, D., Jones B. F. (2013). China: An Institutional View of an Unusual Economy. ***NBER Working Paper Series*** WP 19662.

Fernandez-Villaverde, J, Rubio-Ramirez, J and F Schorfheide (2017), Solution and Estimation Methods for DSGE Models, In ***Handbook of Macroeconomics***, Vol 2, Edited by John B. Taylor and Harald Uhlig, North Holland.

Funke, M., Mihaylovski, P. and H. Zhu (2015). Monetary policy trans-mission in China: A DSGE model with parallel shadow banking and interest rate control, ***Bank of Finland Discussion Paper***, 9/2015.

Gao, R., Chen, C., Zeng, H. and Gong, L., (2018). Credit Constraint, Shadow Banking and Monetary Policy Transmission in China, ***Economic Research Journal***, 12, 68–82.

Gourieroux, C., Monfort, A. (1995). Simulation Based Econometric Methods. CORE Lectures Series, Louvain-la-Neuve.

Gourieroux, C., Monfort, A., Renault, E. (1993). Indirect inference. ***Journal of Applied Econometrics*** 8, S85–S118.

Hatcher, M. H., Minford, P. (2013). Stabilization policy, rational expectations and price-level versus inflation targeting: S survey., Cardiff working paper E2013/14, ***Cardiff University, Cardiff Business School, Economics Section***. Also, CEPR discussion paper No 9820, ***CEPR***, London.

Huang Y. (2008). ***Capitalism with Chinese Characteristics: Enterpreneurship and the State***. Cambridge University Press.

Jian Z-H., Li, S., Zheng J-Y. (2010), Impact of Oil Price Shocks on China’s Economy: A DSGE-based Analysis, 17th International Conference on Management Science & Engineering, Melbourne Australia.

King, R.G., Plosser, C.I. ,Rebelo, S.T. (1988). Production, growth and business cycles : I. The basic neoclassical model. ***Journal of Monetary Economics***, 21(2-3), 195–232.

Kollmann, R., Pataracchia, B., Raciborski, R., Ratto, M., Roeger, W. and Vogel, L. (2016). The post-crisis slump in the Euro Area and the US: Evidence from an estimated three-region DSGE model, ***European Economic Review,*** 88, 21-44.

Le, V.P.M., Meenagh, D., Minford, P., Wickens, M. (2011). How much nominal rigidity is there in the US economy — testing a New Keynesian model using indirect inference. ***Journal of Economic Dynamics and Control,*** 35(12), 2078–2104.

Le, V.P.M., Matthews, K., Meenagh, D., Minford, P., Xiao, Z., (2014). Banking and the Macroeconomy in China: A Banking Crisis Deferred? ***Open Economies Review***, 2014, 25, (1), 123–161.

Le, V.P.M., Meenagh, D., Minford, P., Wickens, M., Xu, Y., (2016a). Testing macro models by indirect inference: A survey for users. ***Open Economies Review***, 2016, 27, (1), 1–38.

Le, V.P.M., Meenagh, D., Minford, P. (2016b). Monetarism rides again? US monetary policy in a world of Quantitative Easing. ***Journal of International Financial Markets, Institutions and Money***, vol 44, pp. 85–102.

Li B and Liu Q (2017). On the choice of monetary policy rules for China: A Bayesian DSGE approach. ***China Economic Review***, 2017, 44, 166-185

Li, C. & Meng, X., (2006). China's economic fluctuation: An analysis based on the New Keynesian monopolistic competition model. ***Economic Research Journal***, 10, 72–82.

Lin, L., Cao, Y. and Xiao, H., (2016). The Fragility of Financial System under the Growing Shadow Banking System in China, ***China Economic Quarterly***, 15(3), 1113–1136.

Liu, X., Hao, Y. and Tian, Y., 2014, Comparative Study on China's Monetary Policy Rules under Dual Structure of Shadow Banking and Formal Finance, ***Journal of Finance and Economics***, 29(1), 15-26.

Ma, Y., (2016). China's monetary and fiscal policy regime and its macroeconomic stability effects. ***China Economic Quarterly***, 15(1), 173–195.

McCallum, B.T. (1988). Robustness Properties of a Rule for Monetary Policy, ***Carnegie-Rochester Conference Series on Public Policy,*** 29: 173–204.

McCallum, B. T., Nelson, E. (1999). Nominal Inocme Targeting in an Open-Economy Optimising Model, ***Journal of Monetary Economics***, vol 43(3), pp. 553–578.

McCallum, B.T. (2011). Nominal GDP Targeting, Shadow Open Market Committee, October 21.

Minford, P, Theordoridis, K, Meenagh, D. (2009). Testing a model of the UK by the method of indirect inference. ***Open Economies Review***, 20(2), 265–291.

Nakov, A. (2008). Optimal and Simple Monetary Policy Rules with Zero Floor on the Nominal Interest Rate, ***International Journal of Central Banking***, 4(2), 73–128.

Nunes, M., Cole, B.M. (2013) ***Market Monetarism- roadmap to economic prosperity***, Kindle books, Amazon.

Qin, D., Cagas M –A., Ducanes, G., He, X., Liu, R., Liu, S., Magtibay-Ramos, N., Quising, P (2007), A Macroeconometric Model of the Chinese Economy. ***Economic Modelling***, 24, 814–822.

Qiu, X. and Zhou, Q. (2014). Shadow Banking and Monetary Policy Transmission, ***Economic Research Journal***, 5, 91–105.

Smets, F., Wouters, R. (2003). An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area. ***Journal of the European Economic Association***, 1(5), p1123–1175.

Smets, F., Wouters, R. (2007). Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach. ***American Economic Review,*** 97, 586–606.

Sun, R., (2013). Does monetary policy matter in China? A narrative approach. ***China Economic Review***, 26, 56–74.

Smith, A., (1993). Estimating nonlinear time-series models using simulated vector autoregressions. ***Journal of Applied Econometrics,*** 8, S63–S84.

Sumner, S. (2011). The case for NGDP targeting — lessons from the Great Depression, ***Adam Smith Institute***.

Sun, X., Zhang, J., Shao, Y., Yang, X. (2009), Chinese Small-scale Quarterly Macroeconomic Model under Indirect Regulation of Monetary Policy. 2009 International Joint Conference on Computational Sciences and Optimization, IEEE Conference Publication Vol 2.

Vestin, D. (2006). Price level versus inflation targeting, ***Journal of Monetary Economics***, 53, 1361–1376.

Williamson, S. (2013), Liquidity, Monetary Policy, and the Financial Crisis: A New Monetarist Approach. ***American Economic Review***, 102(6), 2570–2605.

Wolman, A.L. (2005). Real Implications of the Zero Bound on Nominal Intrest Rates, ***Journal of Money, Credit and Banking***, 37, 273–296.

Woodford, M. (2012). Methods of Policy Accommodation at the Interest Rate Lower Bound, Jackson Hole, Wyoming.

Wu, G. & Lian, F. (2016). A study on the transition of China's monetary policy: An exploration based on hybrid rules of quantity and price instruments. ***The Journal of World Economy***, 3, 3–25.

Xi, J. & He, Y. (2010). The welfare losses of China's monetary policy and the selection of intermediate target: A new Keynesian DSGE model. ***Journal of Finance and Economics***, 36(2), 89–98.

Zheng, S., Storeslatten, K., Zilibotti, F. (2011). Growing Like China. ***American Economic Review***, 101(1), 196–233.

**Appendix 1: The retailer's problem**

Firstly, the retailer demands intermediate goods to minimise their costs and its problem is:

$$\min TC = P_t^{WSOE} Y_t^{WSOE} + P_t^{WSME} Y_t^{WSME}$$
$$s.t. Y_t = \left[ a \left( Y_t^{SOE} \right)^{\rho_1} + (1-a) \left( Y_t^{SME} \right)^{\rho_1} \right]^{\frac{1}{\rho_1}},$$

, where $P_t^{WSOE}$ ($P_t^{WSME}$) is the price of the SOE (SME) intermediate goods, $Y_t^{WSOE}$ ($Y_t^{WSME}$) is the intermediate input into the retailer output.

Secondly, it would sell part of the output on the competitive market to the consumers at the marginal costs, this is the real marginal cost

$$mc_t = a^{\frac{1}{1-\rho}} \left( \frac{P_t^{WSOE}}{P_t} \right)^{\frac{\rho}{\rho-1}} + (1-a)^{\frac{1}{1-\rho}} \left( \frac{P_t^{WSME}}{P_t} \right)^{\frac{\rho}{\rho-1}},$$

and the retailer would repackage the rest of output differently and set the prices and sell at the markup over the marginal costs in a Calvo manner with partial indexation to the last period's inflation rate. The retailer sets reoptimized price $P_t^*$ so that in expectation discounted marginal revenue equals discounted marginal cost, given the constraint that the nominal price is fixed in period $i$ with probability $\theta^k$ to satisfy the following equation

$$E_t \sum_{i=0}^{\infty} \beta^i \xi_p^i \lambda_{t+i} Y_{t+i}(z) \left( \frac{P_t^*}{P_t} \left( \frac{P_{t-1+i} / P_{t-1}}{P_{t+i} / P_t} \right)^{\gamma_p} - \left[ 1 + \lambda_{p,t+i} \right] mc_{t+i} \right) = 0 .$$

Given that the fraction $\xi_p$ of retailers' products do not change their price in period t, the price evolves according to

$$P_t^{-\frac{1}{\lambda_{p,t}}} = \left[ \xi_p \left( P_{t-1} \left( \frac{P_{t-1}}{P_{t-2}} \right)^{\gamma_p} \right)^{-\frac{1}{\lambda_{p,t}}} + \left( 1 - \xi_p \right) \left( P_t^* \right)^{-\frac{1}{\lambda_{p,t}}} \right]$$

with the mark up shock, $\lambda_{p,t}$. The aggregate price is the weighted average of the prices in competitive and monopolistic competitive markets.

**Appendix 2: Model Listing**

Table A1: Variable definition

| Variable Name | Variable Definition |
|---|---|
| $c$ | Household consumption |
| $c^e$ | Entrepreneurial consumption |
| $r^L$ | Lending rate |
| $inn$ | Investment |
| $inn^{SOE}$ | Investment by SOEs |
| $inn^{SME}$ | Investment by SMEs |
| $qq$ | Tobin's Q |
| $qq^{SOE}$ | Q of SOE |
| $qq^{SME}$ | Q of SME |
| $k$ | Capital |
| $k^{SOE}$ | Capital of SOE |
| $k^{SME}$ | Capital of SOE |
| $rk$ | Return on capital |
| $w$ | Real wage |
| $\pi$ | Inflation |
| $l$ | Total hours worked |
| $n^{SOE}$ | SOE labour |
| $n^{SME}$ | SME labour |
| $y$ | Output |
| $y^{SOE}$ | Output of SOEs |
| $y^{SME}$ | Output of SMEs |
| $r$ | Nominal interest rate |
| $cy$ | Return on external finance |
| $nw$ | Net worth |
| $c^e$ | Entrepreneurial consumption |
| $m$ | M0 |
| $M$ | M2 |

Consumption Euler equation

$$c_t = \frac{\frac{\lambda}{\gamma}}{1+\frac{\lambda}{\gamma}} c_{t-1} + \frac{1}{1+\frac{\lambda}{\gamma}} E_t c_{t+1} + \frac{(\sigma_c - 1)\frac{W_* L_*}{C_*}}{\left(1+\frac{\lambda}{\gamma}\right)\sigma_c}\left(l_t - E_t l_{t+1}\right) - \left(\frac{1-\frac{\lambda}{\gamma}}{\left(1+\frac{\lambda}{\gamma}\right)\sigma_c}\right)\left(r_t - E_t \pi_{t+1}\right) + eb_t$$

Labour composite

$$l_t = \frac{N^{SOE}}{N} n_t^{SOE} + \frac{N^{SME}}{N} n_t^{SME}$$

SOE production function

$$y_t^{SOE} = \varphi[\alpha^{SOE} k_{t-1}^{SOE} + (1-\alpha^{SOE}) n_t^{SOE} + ea_t^{SOE}]$$

SOE Labour demand

$$n_t^{SOE} = pW_t^{SOE} + y_t^{SOE} - w_t$$

SOE Tobin Q equation (capital demand in SOE sector)

$$qq_t^{SOE} = \frac{1-\delta}{1-\delta+R_*^K} E_t qq_{t+1}^{SOE} + \frac{R_*^K}{1-\delta+R_*^K}\left(y_{t+1}^{SOE} - k_t^{SOE} + pW_{t+1}^{SOE}\right) - \left(r_t - \pi_{t+1}\right)$$

SOE Marginal product of capital

$$mpk_t^{SOE} = y_t^{SOE} - k_{t-1}^{SOE} + pW_t^{SOE}$$

Investment SOE Euler equation

$$inn_t^{SOE} = \frac{1}{1+\beta\gamma^{(1-\sigma_c)}} inn_{t-1}^{SOE} + \frac{\beta\gamma^{(1-\sigma_c)}}{1+\beta\gamma^{(1-\sigma_c)}} E_t inn_{t+1}^{SOE} + \frac{1}{\left(1+\beta\gamma^{(1-\sigma_c)}\right)\gamma^2\phi} qq_t^{SOE} + einn_t^{SOE}$$

SOE Capital Accumulation equation

$$k_t^{SOE} = \left(\frac{1-\delta}{\gamma}\right)k_{t-1}^{SOE} + \left(1-\frac{1-\delta}{\gamma}\right)inn_t^{SOE}$$
$$+\left(1-\frac{1-\delta}{\gamma}\right)\left(1+\beta\gamma^{(1-\sigma_c)}\right)\left(\gamma^2\right)(\phi)\left(einn_t^{SOE}\right)$$

SME production function

$$y_t^{SME} = \varphi[\alpha^{SME}k_{t-1}^{SME} + (1-\alpha^{SME})n_t^{SME} + ea_t^{SME}]$$

SME Labour demand

$$n_t^{SME} = pW_t^{SME} + y_t^{SME} - w_t$$

SME Tobin Q equation (capital demand in SME sector)

$$qq_t^{SME} = \frac{1-\delta}{1-\delta+R_*^K}E_t qq_{t+1}^{SME} + \frac{R_*^K}{1-\delta+R_*^K}\left(y_{t+1}^{SME} - k_t^{SME} + pW_{t+1}^{SME}\right) - \left(r_t - \pi_{t+1} + s_t\right)$$

SME Marginal product of capital

$$mpk_t^{SME} = y_t^{SME} - k_{t-1}^{SME} + pW_t^{SME}$$

Investment SME Euler equation

$$inn_t^{SME} = \frac{1}{1+\beta\gamma^{(1-\sigma_c)}}inn_{t-1}^{SME} + \frac{\beta\gamma^{(1-\sigma_c)}}{1+\beta\gamma^{(1-\sigma_c)}}E_t inn_{t+1}^{SME}$$
$$+\frac{1}{\left(1+\beta\gamma^{(1-\sigma_c)}\right)\gamma^2\phi}qq_t^{SME} + einn_t^{SME}$$

SME Capital Accumulation equation

$$k_t^{SME} = \left(\frac{1-\delta}{\gamma}\right)k_{t-1}^{SME} + \left(1-\frac{1-\delta}{\gamma}\right)inn_t^{SME}$$
$$+\left(1-\frac{1-\delta}{\gamma}\right)\left(1+\beta\gamma^{(1-\sigma_c)}\right)\gamma^2\phi\left(einn_t^{SME}\right)$$

Investment composite

$$inn_t = \frac{INV^{SOE}}{INV} inn_t^{SOE} + \frac{INV^{SME}}{INV} inn_t^{SME}$$

Premium

$$E_t cy_{t+1} - (r_t^L - E_t \pi_{t+1}) = s_t = \chi(qq_t + k_t^{SME} - nw_t) - \psi m_t + epr_t$$

Net worth

$$nw_t = \frac{K}{NW}(cy_t - E_{t-1} cy_t) + E_{t-1} cy_t + \theta n_{t-1} + enw_t$$

Entrepreneurial consumption

$$c_t^e = n_t$$

Monetary policy

$$r_t = \rho r_{t-1} + (1-\rho)\left(\rho_\pi \pi_t + \rho_y y_t + \rho_{\Delta y}(y_t - y_{t-1})\right) + em_t$$

M0

$$\Delta m_t = \psi_1 \Delta M_t + errm_{2t}$$

M2

$$M_t = (1 + \nu - \mu) k_t + \mu m_t - \nu n_t$$

Market Clearing condition in goods market

$$y_t = \frac{C}{Y} c_t + \frac{I}{Y} inn_t + c_y^e c_t^e + eg_t$$

Final Output

$$y_t = \frac{Y^{SOE}}{Y} y_t^{SOE} + \frac{Y^{SME}}{Y} y_t^{SME}$$

Demand for output from SOE

$$y_t^{SOE} = -\varepsilon p_t^{SOE} + y_t$$

Demand for output from SME

$$y_t^{SME} = -\varepsilon p_t^{SME} + y_t$$

New Keynesian goods and labour subsector:

Wage setting equation

$$w_t = \frac{\beta\gamma^{(1-\sigma_c)}}{1+\beta\gamma^{(1-\sigma_c)}} E_t w_{t+1} + \frac{1}{1+\beta\gamma^{(1-\sigma_c)}} w_{t-1} + \frac{\beta\gamma^{(1-\sigma_c)}}{1+\beta\gamma^{(1-\sigma_c)}} E_t \pi_{t+1} - \frac{1+\beta\gamma^{(1-\sigma_c)}\iota_w}{1+\beta\gamma^{(1-\sigma_c)}} \pi_t + \frac{\iota_w}{1+\beta\gamma^{(1-\sigma_c)}} \pi_{t-1} - \frac{1}{1+\beta\gamma^{(1-\sigma_c)}} \left( \frac{\left(1-\beta\gamma^{(1-\sigma_c)}\xi_w\right)(1-\xi_w)}{\left(1+\varepsilon_w(\varphi_w-1)\right)\xi_w} \right) \left( w_t - \sigma_l l_t - \left( \frac{1}{1-\frac{\lambda}{\gamma}} \right) \left( c_t - \frac{\lambda}{\gamma} c_{t-1} \right) \right) + ew_t$$

Final Price setting equation

$$\pi_t = \frac{\beta\gamma^{(1-\sigma_c)}}{1+\beta\gamma^{(1-\sigma_c)}\iota_P} E_t \pi_{t+1} - \frac{\iota_P}{1+\beta\gamma^{(1-\sigma_c)}\iota_P} \pi_{t-1} + \left( \frac{1}{1+\beta\gamma^{(1-\sigma_c)}\iota_P} \right) \left( \frac{\left(1-\beta\gamma^{(1-\sigma_c)}\xi_p\right)\left(1-\xi_p\right)}{\xi_p\left(\left(\varphi_p-1\right)\varepsilon_p+1\right)} \right) \left( \frac{Y^{SME}}{Y} pW_t^{SME} + \frac{Y^{SOE}}{Y} pW_t^{SOE} \right) + ep_t$$

Perfect competitive goods and labour subsector:

Marginal product of labour in SOE

$$\alpha^{SOE} mpk_t^{SOE} + (1-\alpha^{SOE}) w_t = ea_t^{SOE}$$

Marginal product of labour in SME

$$\alpha^{SME} mpk_t^{SME} + (1-\alpha^{SME}) w_t = ea_t^{SME}$$

Labour supply equation

$$\pi_t = E_{t-1}\pi_t + \sigma_L l_t + \left(\frac{1}{1-\frac{\lambda}{\gamma}}\right)\left(c_t - \frac{\lambda}{\gamma}c_{t-1}\right) + elabs_t$$