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Estimating a small open economy DSGE model with indeterminacy: Evidence from China

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ABSTRACT

Considering that monetary policy instability may cause indeterminacy of the macroeconomic equilibrium, this paper derives the boundary condition between determinacy and indeterminacy in a small open economy DSGE model, and then uses this model to investigate China's monetary policy and macroeconomic fluctuations under indeterminacy during the period from 1992 to 2011. The empirical results show that the nominal interest rate reacts not only to inflation and output gap, but also to the changes in RMB exchange rate. Moreover, the indeterminacy in the macro-dynamics indicates the instability in China's monetary policy, and it stems from two sources, the sunspot shock and the indeterminate propagation of fundamental shocks. In addition, we find that the monetary policy shock affects macroeconomic dynamics significantly in the short run, while in the long run, it only influences nominal variables, such as the inflation and the exchange rate, but not the real output.

1. Introduction

Over the last decades, economists, central bankers and financial market analysts have shown increasing interest in monetary policy analysis.[1] One of the most prominent studies is the well-known *Taylor rule*, which was proposed as a guideline to evaluate and describe central bank policy actions intuitively. As shown in Taylor (1993), the central bank could adjust the interest rate according to inflation deviation (the deviation of inflation rate from its target) and output gap (the deviation of real output from its potential value). From then on, economists extended the original rule to various Taylor-type rules and applied them to examine monetary policy reaction functions in different countries (Clarida et al., 1998, 2000; Taylor, 2001). However, amongst these single-equation models, they fail to establish a clear link between the conduct of monetary policy and the performance of the economy, which makes the model economy far away from the real world, and hence the relevant concluding remarks might be inaccurate and unreliable.

Recently economists are increasingly making use of dynamic stochastic general equilibrium (DSGE) models for macroeconomic analysis and monetary policy evaluation in academic research, especially at central banks. For example, the European Central Bank uses the DSGE model developed by Smets and Wouters (2003) to analyze the economy of the Euro zone as a whole. In fact, compared to other structural models such as vector autoregression (VAR), structural VAR, and simultaneous equation model, the DSGE model has three apparent advantages: Firstly, it provides a theoretical discipline on the structure of the model economy, in which it relates the reduced-form parameters to the structural parameters, and connects the short-run dynamics with the long-run equilibrium; secondly, it shows a more suitable framework for analyzing social welfare and designing an optimal policy, as the agents' utility in the economy can be taken as a measure of welfare explicitly; lastly, it makes use of the micro-founded model for monetary policy analysis more appropriately, i.e. less subject to the *Lucas critique*. Furthermore, as shown in An and Schorfheide (2007) and Chib and Ramamurthy (2010), no matter how complicated the DSGE model is, the standardized Bayesian method can be used to realize the model estimation quickly.

Although a large fraction of DSGE models are assumed to a closed economy (Justiniano et al., 2010; Rabanal, 2007), more and more studies have considered the open economy version of the DSGE model to

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[1] By now there is a large and growing amount of macroeconomist work on DSGE models from theoretical perspective and empirical methodology. This includes Lubik and Schorfheide (2003, 2004, 2007), Fernádez-Villaverde and Rubio-Ramírez (2005, 2007), and Farmer et al. (2010, 2011). Subsequently, DSGE models have been elaborated by many central banks, such as Smets and Wouters (2003) for EMU, SIGMA for the US, BEQM for England, TOTEM for Canada, AINO for Finland, and so on. In addition, Belaygorod and Dueker (2009) is one of the successes in the financial industry.

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examine monetary policy and concern important factors in open economy, such as exchange rate and terms of trade. For example, Galí and Monacelli (2005) extended the DSGE model to a small open economy setting, and analyzed the macroeconomic implications of three alternative rule-based policy regimes from a theoretical point of view. Bergin (2003) was the first one to extend the small open economy model in the empirical direction. Lubik and Schorfheide (2007) examined whether central banks target exchange rates, and found that the central banks of Australia and New Zealand don't, whereas the Bank of Canada and the Bank of England do include the nominal exchange rate in their policy rules. Using the model in Lubik and Schorfheide (2007) and the economic data in Chile, Caputo and Liendo (2005) found that the inflation persistence played an important role for small open economy, and Del Negro and Schorfheide (2009) assessed the robustness of conclusions to the presence of model misspecification. Dib (2010) found that small open economy and closed economy models in Canada lead to qualitatively similar structural parameter estimates and the effects of monetary policy shocks and other domestic shocks.

However, it's worth mentioning that most DSGE models in the existing literature are estimated at the boundary of the determinacy region. As a matter of fact, in order to solve DSGE models and keep them tractable, most economists typically use linear rational expectations (LRE) models as local approximation. Depending on the number of stable eigenvalues in the LRE model, the numerical solution might be non-existent, exhibit unique or multiple equilibria, and the unique and multiple equilibria are often referred to as determinacy and indeterminacy, respectively. More importantly, the dynamic response of the economy under indeterminacy would show some specific characteristics, such as sunspot shock and indeterminate propagation of fundamental shocks, which would not be present under determinacy.

Essentially, indeterminacy can arise if the central bank follows a Taylor-type rule and does not raise interest rates aggressively enough in response to an increase in inflation. For example, Lubik and Schorfheide (2004) firstly applied the standard new Keynesian monetary DSGE model to test the indeterminacy.[2] They found that the US monetary policy before 1979 contributes to the aggregate instability and that the policy becomes more stabilizing during the Volcker–Greenspan period. Treadwell (2009) used the same model to access the role of monetary policy across the G7 countries preceding and during the *Great Inflation*. Belaygorod and Dueker (2009) implemented a change point methodology to extend the model to encompass a sample period that includes both determinacy and indeterminacy. To the best of our knowledge, the indeterminacy is mostly concerned in the prototypical monetary DSGE model, whereas it's not taken seriously in the limited empirical papers within the framework of small open economy DSGE model.

This paper extends the small open economy DSGE model developed by Lubik and Schorfheide (2007) to the parameter space which allows for both determinacy and indeterminacy, and gives the general solution in a standard form. Besides, based on the empirical findings showing the unstable behavior of China's monetary policy,[3] we estimate the small open economy DSGE model with indeterminacy for China, and investigate the monetary policy and macroeconomic fluctuations.[4] Obviously, there are two contributions in this paper. One is to derive the boundary condition between determinacy and indeterminacy, and present the numerical solution for a small open economy DSGE model. The other one is to re-examine the monetary policy reaction function, especially test whether the PBC includes RMB exchange rate in its policy rule, and investigate monetary policy effect and macroeconomic fluctuations in a more accurate way.

The remainder of this paper is organized as follows. In Section 2, we outline a log-linearized small open economy DSGE model, discuss the determinacy and indeterminacy, and then present the numerical solution for a canonical linear rational expectations (LRE) model. Section 3 briefly shows the econometric approach, data description and choice of prior. In Section 4, we report the estimation results and analyze the macroeconomic dynamics using impulse response functions and variance decompositions. Section 5 offers some concluding remarks.

2. Small open economy DSGE model and its numerical solution

2.1. Small open economy DSGE model

Following Lubik and Schorfheide (2007) and Del Negro and Schorfheide (2009), in this paper we consider a small open economy model, which includes two economies, home (China) and rest-of-the-world (world). The consumption Euler equation can be rewritten as an open economy IS curve,

$$y_t = E_t(y_{t+1}) - (\tau+\lambda)(R_t - E_t\pi_{t+1}) - \rho_z z_t - \alpha(\tau+\lambda)E_t(\Delta q_{t+1}) + \frac{\lambda}{\tau}E_t(\Delta y^*_{t+1}) \ , \tag{1}$$

where $0<\alpha<1$ is the import share, and the equation reduces to its closed economy variant when $\alpha=0$. τ is the intertemporal substitution elasticity and $\lambda=\alpha(2-\alpha)(1-\tau)$. R_t, π_t and y_t denote the interest rate, CPI inflation rate and aggregate real output, respectively. z_t is the growth rate of an underlying non-stationary technology process A_t, q_t is the terms of trade, defined as the relative price of exports in terms of imports, and y^*_t is the world output. In order to obtain stationarity of the model, all real variables are expressed in terms of percentage deviations from A_t.

The optimal price setting strategy of domestic firms leads to the following Phillips curve,

$$\pi_t = \beta E_t\pi_{t+1} + \alpha\beta E_t\Delta q_{t+1} - \alpha\Delta q_t + \frac{K}{\tau+\lambda}(y_t - \bar{y}_t) \ , \tag{2}$$

[2] After estimating monetary policy reaction functions of reduced form, Clarida et al. (2000) suggested that the monetary policy rule in the US before 1979 is destabilizing and it leaves open the possibility of bursts of inflation and output. Recently Mavroeidis (2010) used identification robust methods to reexamine the empirical findings and confirmed that the policy before Volcker leads to indeterminacy, but the model is not accurately identifiable after 1979.

[3] For example Xie and Luo (2002) employed the historical analysis and reaction function method to conduct an empirical analysis of China's monetary policy in the framework of Taylor rule and draw the conclusion that this rule can accurately measure the operation level of China's monetary policy.

[4] In this paper, we assume a small open economy for China in that it does not have strong market power in the international market until now. In literature a small economy is a country that is a price taker in the international market, and it is not closely related to the total output, market size or territory area. The small open economies include not only small countries, i.e. Chile, Mexico and New Zealand, but also several big countries, i.e. Australia, Canada and England.