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台灣信用管道與最適貨幣政策之探討

The Credit Channel and Optimal Monetary Policy: The Case of Taiwan

何佩螢

Ho, Pei-Ying

指導教授：黃俞寧 博士

Advisor: Hwang, Yu-Ning, Ph.D.

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中文摘要

本文研究目的是在動態隨機一般均衡模型當中，加入銀行體系，並以台灣的參數值加以模擬，進一步討論台灣的最適貨幣政策。首先以均衡解進行分析，討論銀行體系如何影響台灣的經濟體，另外，本文探討四種貨幣政策，包含貨幣總數法則，利率法則，其中利率法則包含三種目標：CPI 膨脹率目標、國內商品物價膨脹目標及名目匯率目標，模擬結果發現央行使用貨幣總數法則對經濟體的福利大於其他法則，且有助於穩定產出、物價、匯率的波動，另外，提高資本的移動程度以及提高貿易開放程度並不會改變政策福利排序的結果。

關鍵字：DSGE、貨幣政策、銀行、信用管道

Abstract

The objective of this paper is to investigate the optimal monetary policy of Taiwan by using a micro-based dynamic stochastic general equilibrium (DSGE) model with the banking sector. The results of steady state show that how the banking sector affects the Taiwanese economy. Furthermore, comparing the performance of alternative monetary policies, the monetary aggregate growth rate rule leads to the highest welfare and lowest volatility of output, inflation rates and exchange rate. It may be the optimal monetary policy of Taiwan. Also, with high degree of capital market friction and highly open market, the rank of these rules is the same.

Keywords: DSGE, monetary policy, banking sector, credit channel

Contents

1. Introduction

1.1. Motivation

The objective of this paper is to investigate the optimal monetary policy of Taiwan with a micro-based dynamic stochastic general equilibrium (DSGE) model. In Taiwan, the goal of the Central Bank of the Republic of China [CBC]'s monetary policy includes three aspects: to promote price stability, to guide financial soundness, to maintain the internal and external value of the currency, and then to stimulate economic growth.[1] In line with the goals, the inflation rates and exchange rates have remained stable, particularly important to a country, like Taiwan, which strongly relies on trades.

According to "Purpose and Function of the CBC" (CBC, 2006), the CBC generally adopts the framework of monetary targeting and chooses the monetary aggregate, M2, to be the intermediate target. However, with the financial globalization and liberalization, it is harder to control the monetary aggregate to coincide with the desired goals. As a result, some literatures turn to the interest rate rule as the intermediate target, and compare the fitness of these two types of monetary policies by using empirical econometrics.[2] Hou (2005) and Chen and Wu (2010) also point out that the monetary aggregate may not be the single target for monetary policies. On the other hand, with a Dynamic Stochastic General Equilibrium (DSGE) model, Teo (2009) finds that the Taiwanese monetary policy is better described by a money supply growth rate rule than a Taylor-style interest rate rule.

While the empirical investigation of Taiwanese monetary policy is an important

[1] See "Purpose and Function of the CBC," (CBC, 2006)
[2] See Hsu (1999).

and interesting issue, few studies examine this issue theoretically, and the lack of microfoundation in the model leaves the study of optimal monetary policy aside. Teo (2010) uses a DSGE model with the inventory investment to examine the optimal monetary policy of Taiwan. He finds that monetary policy in Taiwan is the fixed exchange rate targeting. In his model, he discusses only the money supply growth rate rule, and households and firms can borrow without any friction.

The DSGE model is suited to analyze the policy because the optimization problems of individuals and the effect of policies change are captured by DSGE model.[3] We can analyze the welfare of various policies through DSGE model. In the past decade, there are considerable quantities of studies on optimal monetary policy using DSGE framework. For instance, Kollmann (2002), Schmitt-Grohé and Uribe (2007), Bergin, Shin and Tchakarov (2007). For the Taiwanese literature, Teo (2010) introduce inventory investment into a small open economy DSGE model and studies the optimal monetary policy to the Taiwanese case. Except for Teo (2010), the optimal monetary policy has been little studied in DSGE model for the case of Taiwan.

On the other hand, to examine the effects of monetary policy precisely, it is crucial to understand the mechanisms through which monetary policy affects the economy. In the traditional monetary view, the monetary authority adjusts the monetary aggregate or the interest rate to influence the cost of capital, thereby affects the decision of the business and households about the investment and consumption spending, and eventually changes the economic performance. However, it is difficult to explain the empirical finding of the economy's response to monetary policy shock solely with conventional interest rate effects.[4] [5] In recent years, many studies focus

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[3] See Teo (2009).
[4] Mishkin (1995, 2001) provided the detailed description about monetary transmission mechanism.
[5] Bernanke and Gertler (1995) observed some facts: the magnitude of the policy effect, the timing and the composition of the spending effects.

on the credit view which emphasizes the role of banking system in monetary transmission mechanism.[6] For the firms dependent on bank's loans, the tight monetary policy may reduce the net worth as well as the liquidity of assets, thereby rising the external financial premium (EFP), which is the difference between the internal and external financial costs of firms. The size of the EFP reflects the imperfect information and transaction costs in the credit market. Higher EFP will exacerbate the downturn in the economic activities. The deteriorating condition of the credit market may intensify the adverse effect of the contractionary monetary policy action. Therefore, the credit channel is not distinct to the traditional interest rate channel, but a factor that amplifies the conventional channel.

In the literature of Taiwan about the monetary policy with credit channel, Wang and Li (2004), Wu and Chen (2004), Wu (2004) examine whether the credit channel exists in the monetary transmission mechanism by using Vector Autoregression Model (VAR) and Structure VAR. All of them show that banking sector is crucial in the monetary policy transmission process. However, similar to the previous discussions, such econometric models lack the microfundation in the analysis of dynamic policy, so that the policy implication based on those models would potentially be quantitatively misleading.[7]

Furthermore, we face the serious financial crisis since subprime mortgage erupted in the U.S. In early 2007 to this year, Taiwan experienced recession. It highlights the importance of the healthy financial market condition in a modern economy. We want to realize the role of banking sector in the economy of Taiwan. Consequently, in this paper we include money and banking sector into the DSGE model in a small open economy to discuss the optimal monetary policy in Taiwan.

[6] See Bernanke and Blinder (1988) and Bernanke Gertler (1995).
[7] This is so called "Lucas critique."

1.2. Literature review

Now we review the literature of the credit channel, which is initiated by Bernanke and Blinder (1988), and introduce the related literature following it. Bernanke and Blinder (1988) address the importance of bank loan in the financial market and introduce credit to the closed-economy IS-LM model. They show that the credit channel reinforces the effects of monetary policy on output, as compared with the conventional IS-LM model.

Bernanke and Gertler (1995) demonstrate that the direct effects of monetary policy on interest rate are strengthened by endogenous changes in the EFP. The changes of EFP would deeper the impacts of shock on business cycle, which is referred to as the "financial accelerator." Edward and Végh (1997) extend the concept, including the banking sector to a theoretical model of a small open economy with predetermined exchange rates. They show that the banking sector affects the various shocks transmission mechanism and dramatically alter the real effects of macroeconomic disturbances. Claus (2007) extends Edward and Végh (1997) to a floating exchange rate and inflation targeting monetary authority. The finding suggests that the degree to which a country's financial system is intermediary based or market based does not matter. Chang (2008) combines the IS-LM framework of Bernanke and Blinder (1988) and the banking sector setting of Edward Végh (1997), developing a general equilibrium model of a small open economy with floating exchange rate regime. The main finding is that monetary policy's effect is depended on the sensitivity of banks and firms to loan and bond market interest rates.

Differing from the literatures mentioned above, Goodfriend and McCallum (2007) take money into account in the closed economy DSGE model with banking sector. They suggest that the omission of money considerations would mislead the effect of the financial accelerator. There are two sectors in the model: a goods-producing sector and a banking sector. Goods are produced with capital and labor as conventional, and the banking sector produces loans according to a production function by using inputs of monitoring effort and collaterals, which consists of government bonds and capital. In addition to the productivity shock to the goods-producing sector, there are two shocks exist in the banking sector. One is the shock to the monitoring effort, and the other is the shock to collateral, which can be characterized the cause of financial crisis. They find that there is the banking accelerator transmission effect in the model, and there also exits the banking attenuator effects in some cases. Hwang and Yang (2009) extend Goodfriend and McCallum (2007) to a small open economy. They show that the banking sector does influence the monetary transmission mechanism and the degree of openness will reinforce the economy's responses to financial shocks.

In the literature about Taiwan, Chen and Wu (2010) examine the monetary policy of Taiwan by using econometric method. They show that monetary aggregate rule is better to describe the monetary policy in the period of 1981-1997 and interest rate rule is better in 1998-1999. In theoretical analysis, Teo (2010) introduces the inventories in a small open economy DSGE model and calibrates to the case of Taiwan. He shows that for a high but reasonable value of elasticity of substitution for export, the money supply growth rate rule with a fixed exchange rate regime can be the optimal monetary policy in Taiwan.

In this paper, we adopt the model in Hwang and Yang (2009) to calibrate the model to the Taiwanese case. The results of the steady state show that money and banking do raise the EFP. In the welfare of monetary policies, we compare the monetary aggregate growth rule and the interest rate rule with CPI targeting, non-traded goods inflation rate targeting and exchange rate targeting, respectively. We show that the banking sector is an important role in Taiwanese economy. In costly banking sector, the liquidity service yield on collateral would affect some variables. Moreover, we investigate the performances of four types of monetary policies rules: monetary aggregate growth rate rule, interest rate rule with CPI targeting, interest rate rule with domestic goods inflation rate targeting, and exchange rate targeting rule. The results show that the monetary aggregate growth rate rule can be welfare superior to the other policies and stabilize the output, CPI inflation rate, domestic goods inflation rate and exchange rate. Also, highly capital mobility friction and highly trade openness would increase the welfare of Taiwanese economy.

The rest of this paper is organized as follows. In Section 2, we describe the model specification, first-order conditions and monetary policy. Next, in Section 3, we present the various interest rates relationship. Then, in Section 4, we solve the steady state solutions, discuss the steady state calibration and analyze the results of the steady state. We show the quantitative effects of money and banking sector in Taiwanese economy. The linearized model is listed in Section 5. In Section 6, we compare the performance of alternative monetary policies to examine the optimal monetary policy of Taiwan. Section 7 concludes.

2. The model

2.1. Goods market

The household consumes composite goods, which is composed of domestic goods C_t^d and imported goods C_t^m :

$$C_t = \left[\left(\alpha^d\right)^{1-\theta} \left(C_t^d\right)^{\frac{\theta-1}{\theta}} + \left(\alpha^m\right)^{1-\theta} \left(C_t^m\right)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}} \tag{1}$$

where $\alpha^m, \alpha^d > 0$ represent the ratio of import and domestic goods in consumption C_t, respectively. θ is the intratemporal elasticity of substitution between domestic goods and imported goods. Minimizing expenditure, we can obtain the demand function for domestic goods and imported goods as:

$$C_t^d(s) = \left(\frac{P_t^d(s)}{P_t^d} \right)^{-\nu} C_t^d \tag{2}$$

$$C_t^m(s) = \left(\frac{P_t^m(s)}{P_t^m} \right)^{-\nu} C_t^m \tag{3}$$

$$C_t^d = \alpha^d \left(\frac{P_t^d}{P_t} \right)^{-\theta} C_t \tag{4}$$

$$C_t^m = \left(\alpha^m\right) \left(\frac{P_t^m}{P_t} \right)^{-\theta} C_t \tag{5}$$

where $C_t^d(s)$ and $C_t^m(s)$ stand for the domestic goods and imported goods of variety s. ν is the elasticity of substitution between differential goods. $P_t^d(s)$ is the price of domestic goods of variety s in the domestic currency, and $P_t^m(s)$ is the price of imported goods of variety s in the foreign currency. $P_t^d\left[P_t^m\right]$ is the price index for domestic [imported] goods, and P_t is the aggregate price index of the small open economy. The price indices are given by following:

$$P_t^i = \left[\int_0^1 P_t^i(s)^{1-\nu} ds \right]^{\frac{1}{1-\nu}} \quad , \ i = d, m \tag{6}$$

$$P_t = \left[\alpha^d \left(P_t^d\right)^{1-\theta} + \left(\alpha^m\right)\left(e_t P_t^m\right)^{1-\theta} \right]^{\frac{1}{1-\theta}} \tag{7}$$

where e_t is the nominal exchange rate, expressed as units of domestic currency per 1 unit of foreign currency.

Goods s is sold both home and abroad. The export demand function $C_t^x(s)$ of variety s is assumed to resemble the domestic demand function Eq. (2):

$$C_t^x(s) = \left(\frac{P_t^x(s)}{P_t^x}\right)^{-\nu} C_t^x \tag{8}$$

$$C_t^x = \left(\frac{P_t^x}{P_t^*}\right)^{-\mu} \quad , \mu > 0 \tag{9}$$

where $P_t^x(s)$ is the firm's export price in foreign currency. P_t^x is the price index of export goods in the foreign currency, and P_t^* is the foreign price index. μ is the price elasticity of the aggregate exports.

In the model, identical goods will have the same price in different countries, so we assume the law of one price (LOOP) holds, which means that $P_t^d = e_t P_t^x$. However, it is not necessary for the Purchasing Power Parity (PPP) to hold.[8]

2.2. Household problem

Following Goodfriend and McCallum (2007), we simplified the model in terms of an optimizing problem for a representative household, which plays three rules in the economy: household, firm and bank operator. A representative household not only consumes composite goods, saves and supplies labor, but owns a monopolistic competitive firm and operates a competitive bank.

Assume the infinitely-lived household maximizes expected lifetime utility based on consumption bundle and leisure:

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[8] either $P_t = e_t P_t^*$ or $P_t \neq e_t P_t^*$

$$E_0\sum_{t=0}^{\infty}\beta^t\left[\phi\log\left(C_t\right)+\left(1-\phi\right)\log\left(1-n_t^s-m_t^s\right)\right] \tag{10}$$

where $\beta\in\left(0,1\right)$ is the household's subjective discount factor. ϕ stands for the share of consumption in the utility. n_t^s and m_t^s are labor supplies in the goods production and banking sectors, respectively.

Maximization is subject to two constraints. The first is the following market clearing condition.

$$K_t^{\eta}\left(A1_t n_t^d\right)^{1-\eta}-\alpha^d\left(\frac{P_t^d\left(s\right)}{P_t^d}\right)^{-\nu}\left(\frac{P_t^d}{P_t}\right)^{-\theta}C_t^A-\left(\frac{P_t^x\left(s\right)}{P_t^x}\right)^{-\nu}\left(\frac{P_t^x}{P_t^*}\right)^{-\mu}=0 \tag{11}$$

$$C_t^A=C_t+q_t\delta K_t \tag{12}$$

Under the monopolistic competition, firm products goods to satisfy the demand from domestic and foreign market. The first term is the goods production function. Firm uses capital goods K_t and labor demand n_t^d as input (where η is the capital share), and the productivity is affected by technology shock $A1_t$. To simplify the model, we assume that K_t equals to its steady-state value in each period. The second term is the domestic demand of a typical goods s. C_t^A stands for the aggregate consumption, which can be written as Eq. (12), where q_t is the real price of capital and δ is the depreciation rate. The third term is foreign demand of a typical goods s.

The other constraint is the following budget constraint expressed in real terms. The representative household's income includes net sale of capital goods, receipt of financial assets, wage for working in both sectors, revenue from selling production.

$$
\begin{aligned}
& q_t(1-\delta)K_t + \frac{B_t}{P_t} + \frac{e_t B_t^*}{P_t} + \frac{H_{t-1}}{P_t} + w_t\left(n_t^s + m_t^s\right) + \alpha^d\left(\frac{P_t^d(s)}{P_t^d}\right)^{1-\nu}\left(\frac{P_t^d}{P_t}\right)^{1-\theta} C_t^A \\
& + \left(\frac{e_t P_t^x(s)}{P_t}\right)\left(\frac{P_t^x(s)}{P_t^x}\right)^{-\nu}\left(\frac{P_t^x}{P_t^*}\right)^{-\mu} - w_t\left(n_t^d + m_t^d\right) - \frac{H_t}{P_t^A} - tax_t - q_t K_{t+1} \\
& - \frac{e_t B_{t+1}^*}{P_t\left(1+R_t^{B^*}\right)} - \frac{B_{t+1}}{P_t\left(1+R_t^B\right)} - C_t = 0
\end{aligned}
\qquad (13)
$$

w_t is the real wage, which is assumed to be identical in both sectors. n_t^d and m_t^d are the labor demanded in the goods production and banking sector, respectively. B_{t+1} is the domestic bond and B_{t+1}^* is the foreign currency bond. The nominal interest rates which B_{t+1} and B_{t+1}^* pay are denoted by R_t^B and $R_t^{B^*}$, respectively. tax_t is the lump-sum tax. H_t stands for the nominal holdings of base money at the end of t.

Following Kollmann (2002), we assume that foreign bond rate, $R_t^{B^*}$, equal to the world interest rate, R_t^*, plus a factor of $\sigma\left(B_{t+1}^*/P_t^*\right)/\chi$, which characterizes the friction on the international financial market:

$$
\left(1+R_t^{B^*}\right) = \left(1+R_t^*\right) - \frac{\sigma\left(B_{t+1}^*/P_t^*\right)}{\chi} \qquad (14)
$$

where σ is the parameter which captures the degree of capital mobility, a lower σ stands for higher capital mobility. χ is the steady state value of exports $\left(P_t^x/P_t^*\right)^{-\mu}$.

2.3. Bank

Before a household consumes goods, he has to hold enough deposit for payment. The concept is similar to “cash-in-advance” constraint. The transaction constraint is

$$
C_t = \frac{VD_t}{P_t} \qquad (15)
$$

where D_t is the deposits, and V is constant, representing the velocity of aggregate deposit.

The bank receives deposits from fund's suppliers, and then creates loan to fund's demander. Each bank's balance sheet can be written as:

$$H_t + L_t = D_t \tag{16}$$

where the asset term includes: total reserves H_t and loans to household L_t, and the nominal deposits D_t is liabilities. Let rr be the reserve ratio. The bank chooses rrD_t as reserves and $(1-rr)D_t$ as loan. Thus, the balance sheet can be rewritten as $rrD_t + L_t = D_t$ or $L_t = (1-rr)D_t$.

The bank creates "loan" by using labor for monitoring and collateral. We assume the loan production function following Cobb-Douglas form as:

$$\frac{L_t}{P_t} = F\left(b_{t+1} + A3_t kq_t K_{t+1}\right)^{\alpha}\left(A2_t m_t\right)^{1-\alpha} \tag{17}$$

m_t is the labor input for monitoring. $b_{t+1} + A3_t kq_t K_{t+1}$ is the collateral, which consists of the home government bonds and capital goods, with $b_{t+1} = B_{t+1} \big/ P_t^A\left(1+R_t^B\right)$. Note that the foreign bond cannot be used for collateral. α is the share of collateral in the loan production. F is constant, which stands for the efficiency of the banking sector. $0 < k < 1$ characterizes the inferiority of capital to bonds for collateral purposes, because capital goods need more monitoring effort than bonds to confirm the market value. $A2_t$ and $A3_t$ are shocks to the monitoring effort and collateral, respectively.

2.4. Government

The government budget constraint is as follows.

$$G_t - tax_t = \frac{H_t}{P_t} - \frac{H_{t-1}}{P_t} + \frac{B_{t+1}}{P_t\left(1+R_t^B\right)} - \frac{B_t}{P_t} \tag{18}$$

The government finances its expenditure, G_t, through levying lump-sum tax , tax_t, issuing base money and bond. Following Goodfriend and McCallum (2007), we set G_t to be zero.

2.5. The First-order condition

The household chooses 8 variables $\left\{m_t^s, m_t^d, n_t^s, n_t^d, K_{t+1}, B_{t+1}, B_{t+1}^*, P_t^d(s)\right\}$ to maximize Eq. (10), subject to the market clearing condition Eq. (11) and the budget constraint Eq. (13). Let ξ_t and λ_t denote the Lagrangian multipliers on Eqs. (11) and (13). In addition, we define

$$\Omega_t = \frac{\alpha C_t}{b_{t+1} + A3_t k q_t K_{t+1}} \tag{19}$$

The first order conditions are as follows.

w.r.t m_t^s [9]:

$$\frac{1-\phi}{1-n_t^s - m_t^s} = \lambda_t w_t \tag{20}$$

w.r.t n_t^d :

$$w_t = \left(\frac{\xi_t}{\lambda_t}\right) A1_t \left(1-\eta\right)\left(\frac{K_t}{A1_t n_t}\right)^{\eta} \tag{21}$$

w.r.t m_t^d :

$$w_t = \left(\frac{\phi}{C_t \lambda_t} - 1\right)\left(\frac{(1-\alpha)C_t}{m_t}\right) \tag{22}$$

w.r.t K_{t+1}:

$$\begin{aligned}&\left(\frac{\phi}{C_t \lambda_t} - 1\right)\Omega_t A3_t k q_t - q_t + \beta(1-\delta) E_t\left(\frac{\lambda_{t+1}}{\lambda_t} q_{t+1}\right)\\ &+\beta\eta E_t\left[\frac{\lambda_{t+1}\xi_{t+1}}{\lambda_t \lambda_{t+1}}\left(\frac{A1_{t+1} n_{t+1}}{K_{t+1}}\right)^{1-\eta}\right] = 0\end{aligned} \tag{23}$$

---

[9] The first order condition with respect to n_t^s is identical to Eq. (20).

w.r.t B_{t+1}:

$$\left(\frac{\phi}{C_t\lambda_t}-1\right)\Omega_t-1+\beta E_t\left[\frac{\lambda_{t+1}P_t}{\lambda_t P_{t+1}}\left(1+R_t^B\right)\right]=0 \tag{24}$$

w.r.t B_{t+1}^*:

$$-1+\beta E_t\left[\frac{\lambda_{t+1}P_t\, e_{t+1}}{\lambda_t P_{t+1}e_t}\left(1+R_t^{B^*}\right)\right]=0 \tag{25}$$

w.r.t $P_t^d(s)$:

$$\frac{\xi_t}{\lambda_t}=\frac{\nu-1}{\nu}\frac{P_t^d}{P_t} \tag{26}$$

$$b_{t+1}=\frac{B_{t+1}}{P_t\left(1+R_t^B\right)} \tag{27}$$

$$b_{t+1}^*=\frac{e_t B_{t+1}^*}{P_t\left(1+R_t^{B^*}\right)} \tag{28}$$

$$P_t^x=\frac{P_t^d}{e_t} \tag{29}$$

We assume that all the households are identical, so $P_t^d(s)=P_t^d$. Eq. (29) is the law of one price condition.

2.6. Exogenous variables

The exogenous processes in the model are all assumed to follow first-order autoregressive process:

$$A1_t=\left(1-\rho^1\right)A1+\rho^1 A1_{t-1}+\varepsilon_t^1, \qquad 0\le\rho^1<1 \tag{30}$$

$$A2_t=\left(1-\rho^2\right)A2+\rho^2 A2_{t-1}+\varepsilon_t^2, \qquad 0\le\rho^2<1 \tag{31}$$

$$A3_t=\left(1-\rho^3\right)A3+\rho^3 A3_{t-1}+\varepsilon_t^3, \qquad 0\le\rho^3<1 \tag{32}$$

$$P_t^*=\left(1-\rho^{P^*}\right)P^*+\rho^{P^*}P_{t-1}^*+\varepsilon_t^{P^*}, \qquad 0\le\rho^{P^*}<1 \tag{33}$$

$$P_t^m = \left(1-\rho^{P^m}\right)P^m + \rho^{P^m} P_{t-1}^m + \varepsilon_t^{P^m}, \qquad 0 \le \rho^{P^m} < 1 \tag{34}$$

$$R_t^* = \left(1-\rho^{R^*}\right)R^* + \rho^{R^*} R_{t-1}^* + \varepsilon_t^{R^*}, \qquad 0 \le \rho^{R^*} < 1 \tag{35}$$

where $\varepsilon_t^1, \varepsilon_t^2, \varepsilon_t^3, \varepsilon_t^{P^*}, \varepsilon_t^{P^m}, \varepsilon_t^{R^*}$ are independent white noises. The AR(1) coefficients of $A1_t, A2_t, A3_t$ are chosen to be 0.9. The persistence of the import prices and the world price are set to be 0.8 while the persistence of the foreign bond rate is set to be 0.95.

2.7. Policy

The monetary authority uses two alternative types of policy rules. The one is the monetary aggregate growth rate rule, and the other is the interest rate rule. We assume that the growth rate of base money bases on the following process:

$$\Delta h_t = \rho^H \Delta h_{t-1} + \varepsilon_t^H \tag{36}$$

where $\Delta h_t = \log(H_t) - \log(H_{t-1})$ is the growth rate of the stock of base money. $0 < \left|\rho^H\right| < 1$ represents the degree of money growth persistence. ε_t^H is shock to the stock of money.

The other monetary policy is the interest rate rule. The central bank uses the interbank interest rate as the monetary instrument, following the general form of Taylor rule (Taylor, 1993) with a lagged value of R_t^{IB} to reflect the effect of interest rate smoothing. Furthermore, the volatility of exchange rate may be an important factor in a small open economy, so we modify the form of interest rate rule in Goodfriend and McCallum (2007) by the following rule:[10]

[10] We refer to the similar form in Devereux, Lane and Xu (2006).

$$R_t^{IB} = \left(1-\alpha_R\right)\left[\alpha_0 + \alpha_p \Delta p_t + \alpha_{pd} \Delta p_t^d + \alpha_{mc} mc_t + \alpha_e \Delta e_t\right] + \alpha_R R_{t-1}^{IB} + \varepsilon_t^R \tag{37}$$

Here $\Delta p_t = \log\left(P_t\right) - \log\left(P_{t-1}\right)$ and $\Delta p_t^d = \log\left(P_t^d\right) - \log\left(P_{t-1}^d\right)$, so Δp_t and Δp_t^d are the CPI inflation rate and non-traded goods inflation rate, respectively. mc_t is the real marginal cost of goods production, measured as the output gap. $\Delta e_t = \log\left(e_t\right) - \log\left(e_{t-1}\right)$ denotes the volatility of exchange rate. $\alpha_p, \alpha_{pd}, \alpha_{mc}, \alpha_e > 0$ are policy parameters, which control the degree of CPI inflation targeting, non-traded goods inflation targeting, output gap targeting and exchange rate targeting, respectively. $0 \le \alpha_R < 1$ and ε_t^R is the shock to the interest rate rule.

3. Interest rates

3.1. Interest rates relationship

In this section, we introduce various interest rates and their relationship. R_t^T represents the uncollateralized lending rate, which resemble the pure intertemporal rate of interest in the conventional literature without banking sector, is used as a "benchmark" rate. R_t^T must satisfy the Euler equation as

$$1+R_t^T = E_t \frac{\lambda_t P_{t+1}}{\beta \lambda_{t+1} P_t} \tag{38}$$

We can obtain the relationship between R_t^T and R_t^B by substituting Eq. (24) into Eq. (38).

$$\frac{1+R_t^B}{1+R_t^T} = 1 - \left(\frac{\phi}{C_t \lambda_t} - 1\right)\Omega_t \tag{39}$$

The government bond rate will be equal to the pure intertemporal rate only if $\Omega_t = 0$[11] or $\left[\left(\phi/C_t\lambda_t\right)-1\right]=0$. According to our model, the two terms hold in highly efficient banking, not in costly banking system. Therefore, we denote the spread of government bond rate and intertemporal rate, $\left[\left(\phi/C_t\lambda_t\right)-1\right]\Omega_t$, as the liquidity service yield on bonds, LSY_t^B, or the risk premium bonds.

$$LSY_t^B = R_t^T - R_t^B = \left(\frac{\phi}{C_t\lambda_t}-1\right)\Omega_t \tag{40}$$

R_t^K is the return of another collateral--capital goods. We set the two collateral have the same risk properties, but capital is less valuable than bonds by the factor k. Consequently, the liquidity service yield on capital, LSY_t^K, will satisfy the following condition:

$$LSY_t^B = k \times LSY_t^K \tag{41}$$

The interbank rate R_t^{IB} is denoted the instrument of monetary policy for central bank. A typical bank can receive fund from other banks at the rate R_t^{IB}, and makes loan to households at the benchmark rate R_t^T without collateral or at the loan rate R_t^L with collateral. The spread between the loan rate and the interbank rate must cover all marginal cost that the bank incurs. The real marginal cost of loan production equals the real wage divided by marginal product of the labor effort in banking sector.[12] From Eq. (17), we can obtain the partial derivative of L_t/P_t with respect to m_t. Combing Eqs. (15)-(17), we find the relationship between the uncollateralized rate

[11] Ω_t is the partial derivative of consumption with respect to government bond as collateral, $\Omega_t = \partial C_t/\partial b_{t+1}$.

[12] $MC = \dfrac{w_t}{\partial\left(L_t/P_t\right)/\partial m_t} = \dfrac{Vw_t m_t}{(1-\alpha)(1-rr)C_t}$

and the interbank rate as

$$\left(1+R_t^T\right)=\left(1+R_t^{IB}\right)\left[1+\frac{Vw_t m_t}{(1-\alpha)(1-rr)C_t}\right] \tag{42}$$

With the collateral, the monitoring effort will decrease by the share of α, so the marginal cost of the loan production can be reduced by $(1-\alpha)$. The relationship between the collateralized rate and the interbank rate becomes

$$\left(1+R_t^L\right)=\left(1+R_t^{IB}\right)\left[1+\frac{Vw_t m_t}{(1-rr)C_t}\right] \tag{43}$$

Finally, R_t^D is the nominal deposit rate which the banks pay household for their deposit. The bank holds the fraction rr of deposit as the reserve without lending out. Therefore, the relationship between deposit rate and the interbank rate can be described as follows:

$$R_t^D=R_t^{IB}(1-rr) \tag{44}$$

3.2. External finance premium

The EFP is the difference between the external fund cost and the internal fund rate, which reflecting the real marginal cost of managing and monitoring effort in banking sector. From Eq. (43), we can obtain the EFP by taking the spread between R_t^L and R_t^{IB}. As mentioned above, the various interest rates are stated as the function of endogenous variables in the model. Consequently, the EFP can be obtained as

$$EFP_t=R_t^L-R_t^{IB}\approx\frac{Vw_t m_t}{(1-rr)C_t} \tag{45}$$

We can find the EFP is composed of endogenous variables C_t, w_t, m_t, so that the monetary and fiscal policy will affect the decision of the household. Further, the economic performance will be influenced.

4. Steady-state

4.1. Steady-state solution

In this section, we solve the steady-state solutions with zero-inflation and show the parameterization of the model. To simplicity, we assume that the price indices of the country $P = P^d = P^m = P^x = 1$, and foreign price index $P^* = 0.84$, which is calibrated to match Taiwanese data. Moreover, the price of capital goods $q = 1$, and the nominal exchange rate $e = 1$. Following Kollmann (2002), the foreign bond rate R^{B^*} and the world interest rate R^* are equal to 0.01 under perfect capital mobility. Following Goodfriend and McCallum (2007), boc is defined as a constant steady-state ratio of government bond to consumption. Therefore, Eq. (11)-(26) can be degenerated to nine equations for nine endogenous variables $C, m, n, \Omega, \lambda, w, K, b^*, R^B$. The steady-state solutions can be represented as below.

First, substitute Eqs. (15) and (16) into (17), then we can have

$$1 = \left(\frac{FV}{1-rr}\right)\left(boc + \frac{kqK}{C}\right)^{\alpha}\left(\frac{m}{C}\right)^{1-\alpha} \tag{46}$$

Then Eqs. (19)-(23) above can be stated as follows:

$$\Omega = \frac{\alpha}{boc + kq\left(\frac{K}{C}\right)} \tag{47}$$

$$\frac{1-\phi}{1-n-m} = w\lambda \tag{48}$$

$$w = \left(\frac{\phi}{C\lambda} - 1\right)\left(\frac{(1-\alpha)C}{m}\right) \tag{49}$$

$$w=\frac{(\upsilon-1)(1-\eta)}{\upsilon}\left(\frac{K}{n}\right)^{\eta} \tag{50}$$

$$\left(\frac{\phi}{C\lambda}-1\right)\Omega k-1+\beta\left[1-\delta+\frac{\eta(\upsilon-1)}{\upsilon}\left(\frac{K}{n}\right)^{\eta-1}\right]=0 \tag{51}$$

Next, the market clearing condition Eq. (11) can be stated as:

$$K^{\eta}n^{1-\eta}-\alpha^{d}C^{A}-\left(\frac{P^{x}}{P^{*}}\right)^{-\mu}=0 \tag{52}$$

Then, combining Eqs. (24) and (25), we have one relation associated with the home and foreign bond:

$$\left(\frac{\phi}{C\lambda}-1\right)\Omega+\beta\left(R^{B^{*}}-R^{B}\right)=0 \tag{53}$$

Finally, we derive the overall resource constraint from Eqs. (11)-(13) and (18):

$$b^{*}R^{B^{*}}=\alpha^{m}C^{A}-\left(\frac{P^{x}}{P^{*}}\right)^{-\mu} \tag{54}$$

Consequently, we obtain nine Eqs (46)-(54) to determine the nine steady-state values $\{C,m,n,\Omega,\lambda,w,K,b^{*},R^{B}\}$. Given these variables, we can solve for the steady-state values of interest rates $R^{T},R^{B},R^{IB},R^{L},R^{D}$ and the EFP by using Eqs. (38)-(39), (42)-(45).

4.2. Parameterization and Calibration

We calibrate the model to the case of Taiwan for the time period 1996Q1 to 2006Q4. The time period is quarterly. All parameters are summarized in Table 1. Following Goodfriend and McCallum (2007), we set the discount rate $\beta=0.99$ and $\eta=0.36$ to reflect the relative shares of capital in the goods production. The steady state price-marginal cost markup factor for goods is set at $\frac{\upsilon}{\upsilon-1}$=1.2 (i.e. $\upsilon=6$)

and the depreciation rate of capital is 0.025, following Teo (2009). ϕ is calibrated to be 0.49 to generate roughly 1/3 of available time working in both goods production and loan production. α^m is set to 0.43 so that the steady-state import to GDP ratio is 50%, consistent with the sample average in Taiwanese data. The elasticity of substitution between domestic goods and imported goods, θ, is set to 5, and the price elasticity of demand for export $\mu = 5$. Moreover, since we do not have the estimate of the capital mobility parameter for the Taiwanese case, we set $\sigma = 0.0019$ following Lane and Milesi-Ferretti (2001) which research for 21 OECD countries.

There are three parameters to be set is based on the average for the Taiwanese data from 1996Q1 to 2006Q4. First, we set the velocity of aggregate bank deposits at $V = 0.134$, measured as the ratio of real GDP to M2. Second, the reserve ratio $rr = 0.054$ measured as the ratio of reserve to M2. Third, the fiscal policy parameter, $boc = 1.194$, is computed by using values of Taiwanese amounts outstanding of government bond to consumption.

Finally, we calibrate the three parameters in the loan production function $\alpha = 0.7$, $k = 0.55$ and $F = 7.6$ to match the facts of Taiwan, which are explained below.

4.3. Steady-state analysis

Table 2 shows the steady-state results of the benchmark model. First of all, total available working time $m + n = 35.33\%$ is close to 1/3, consistent with the Taiwanese data. Moreover, the ratio of time worked in banking sector to total labor effort is $m/m + n = 2.7\%$, which is an acceptable value. In the steady state, the ratio of capital to output annually is $K/4y$=2.34, which is close to the ratio 2.13 in the Taiwanese data.

Now we turn to the various interest rates in the model. The steady-state values are obtained with zero inflation, so that all the interest rates are in the real term. The interbank rate R^{IB} and the government bond rate R^{B} are short-term interest rates in the model, which are calibrated as 0.92% and 1.72% per annum, respectively. A 1% per annum average short-term riskless real rate that is accepted in the finance literature, e.g. Campbell (1998).[13] The interbank rate is close to 1%. Although the government bond rate is less satisfactory, it is in an acceptable range.

Before analyzing the results of steady state, we run another case. We let the banking efficiency parameter $F = 80$ to illuminate the extent to which money and banking sector matters quantitatively. The outcome is summarized in the bottom panel of Table 2. In highly efficient banking, it is obvious that all interest rates converge to R^{T}, so there is the only one interest rate in the economy. The EFP and the labor effort in banking m decline to zero because the banking inputs less labor to monitoring effort and highly efficient banking system decreases the asymmetric information in financial market. The highly efficient banking resembles the traditional model without banking sector. However, the costly banking sector setting is closer to the real economy.

In costly banking sector, the collateral help to reduce the default risk. The interest rates become lower because the banking creates the liquidity service yield on collateral. As a result, the government bond rate R^{B} and R^{K} reduce below R^{T} by 2.2% p.a. and 1.24% p.a., respectively. The capital not only can be used as production input but serves as collateral. Thus the capital stock is 11.55% higher and government bond 0.38% higher in the costly banking sector than in highly efficient banking. Beside, R^{IB} declines 3.12% points p.a. below R^{T}, and the spread covers the real marginal cost of loan production. The results of steady state highlight the importance

[13] The average riskless real interest rate is low because there is the only modest uncertainty about inflation at a 3-month horizon.

of banking sector in Taiwanese economy.[14]

5. Linearization

5.1. Nominal rigidity

In the steady state analysis, the price indices are flexible. In the dynamic analysis, we set the prices are rigid in the short run and the firms take Calvo (1983) sluggish pricing strategy. Following Goodfriend and McCallum (2007), we adopt the price adjustment equation as below.

$$\Delta p_t^d = \beta E_t \Delta p_{t+1}^d + \kappa mc_t + u_t \tag{55}$$

Here we set the price adjustment based on P_t^d instead of P_t. mc_t is the real marginal cost of goods production. Under sticky price setting, Eq. (25) is not constant anymore and becomes as:

$$mc_t = \frac{\xi_t}{\lambda_t} \tag{56}$$

Following Goodfriend and McCallum (2007), κ is calibrated as 0.05.

5.2. Linearization

Before the dynamic analysis, we need to linearize the model in a suitable manner. We use symbols with a "hat" to denote the deviation from steady-state value, which means that $\hat{X} = \left(X_t - \bar{X}\right) / \bar{X}$. The variables without the subscript represent the steady state values. We linearize all the first order conditions and interest rate relationship. First of all, Eqs. (7), (11)-(14), (16)-(29) are linearized as the following

[14] We calibrate another case of less openness. Generally, the result is similar to those in Hwang and Yang (2009). Moreover, we set the reserve ratio to be 1, which resemble the case of no banking sector. The result is similar to the case of high efficient banking.

17 equations:

$$\hat{P}_t = \alpha^d \hat{P}_t^d + \alpha^m \left(\hat{P}_t^m + \hat{e}_t \right) \tag{57}$$

$$\begin{aligned} &(1-\eta) K^{\eta} n^{1-\eta} \left(a\hat{1}_t + \hat{n}_t \right) + \theta \alpha^d C^A \left(\frac{P^d}{P} \right)^{-\theta} \left(\hat{P}_t^d - \hat{P}_t \right) - \alpha^d \left(\frac{P^d}{P} \right)^{-\theta} C^A \widehat{C}_t^A \\ &+ \mu \left(\frac{P^x}{P^*} \right)^{-\mu} \left(\hat{P}_t^x - \hat{P}_t^* \right) = 0 \end{aligned} \tag{58}$$

$$C^A \widehat{C}_t^A = C\widehat{C}_t + \delta K \hat{q}_t \tag{59}$$

$$R^{B^*} \hat{R}_t^{B^*} = R^* \hat{R}_t^* - \frac{\sigma}{\chi} \left(\frac{B^*}{P^*} \right) \left(\hat{B}_{t+1}^* - \hat{P}_t^* \right) \tag{60}$$

$$\widehat{H}_t = \widehat{C}_t + \widehat{P}_t \tag{61}$$

$$\widehat{C}_t = (1-\alpha) \left(a\widehat{2}_t + \widehat{m}_t \right) + \left(\frac{\alpha b}{b+kK} \right) \hat{b}_{t+1} + \left(\frac{\alpha kK}{b+kK} \right) \left(a\widehat{3}_t + \widehat{q}_t \right) \tag{62}$$

$$\widehat{\Omega}_t = \widehat{C}_t - \left(\frac{b}{b+kK} \right) \widehat{b}_{t+1} - \left(\frac{kK}{b+kK} \right) \left(a\widehat{3}_t + \widehat{q}_t \right) \tag{63}$$

$$\hat{\lambda}_t + \widehat{w}_t = \left(\frac{n}{1-n-m} \right) \widehat{n}_t + \left(\frac{m}{1-n-m} \right) \widehat{m}_t \tag{64}$$

$$\widehat{w}_t + \widehat{m}_t + \left(\frac{(1-\alpha) C}{wm} \right) \widehat{C}_t + \left(1 + \frac{(1-\alpha) C}{wm} \right) \hat{\lambda}_t = 0 \tag{65}$$

$$\begin{aligned} m\hat{c}_t &= \widehat{w}_t + \hat{n}_t \\ &- \frac{1}{\alpha^d C^A + \left(\frac{P^x}{P^*} \right)^{-\mu}} \left[\alpha^d \theta C^A \left(\hat{P}_t - \hat{P}_t^d \right) + \alpha^d C^A \widehat{C}_t^A + \mu \left(\frac{P^x}{P^*} \right)^{-\mu} \left(\hat{P}_t^* - \hat{P}_t^x \right) \right] \end{aligned} \tag{66}$$

$$\left(\frac{\phi k\Omega}{\lambda C}\right)\hat{C}_t = k\Omega\left(\frac{\phi}{\lambda C}-1\right)\left(\hat{\Omega}_t + a\hat{3}_t\right) + \left[k\Omega\left(\frac{\phi}{\lambda C}-1\right)-1\right]\hat{q}_t + \beta\left(1-\delta\right)E_t\hat{q}_{t+1}$$
$$+\beta\left[1-\delta+\eta mc\left(\frac{n}{K}\right)^{1-\eta}\right]E_t\hat{\lambda}_{t+1}$$
$$+\left[\beta\eta mc\left(\frac{n}{K}\right)^{1-\eta}\right]E_t\left[m\hat{c}_{t+1}+\left(1-\eta\right)\left(\hat{n}_{t+1}+a\hat{1}_{t+1}\right)\right] \tag{67}$$
$$-\left[\frac{\phi k\Omega}{\lambda C}+\beta\left(1-\delta+\eta mc\left(\frac{n}{K}\right)^{1-\eta}\right)\right]\hat{\lambda}_t$$

$$\left(\frac{\phi}{C\lambda}-1\right)\Omega\hat{\Omega}_t - \left(\frac{\phi}{C\lambda}\Omega\right)\hat{C}_t - \left[\frac{\phi}{C\lambda}\Omega+\beta\left(1+R^B\right)\right]\hat{\lambda}_t + \beta R^B\hat{R}_t^B$$
$$+\beta\left(1+R^B\right)\left(E_t\hat{\lambda}_{t+1}+\hat{P}_t-E_t\hat{P}_{t+1}\right)=0 \tag{68}$$

$$\beta R^{B^*}\hat{R}_t^{B^*}+\beta\left(1+R^{B^*}\right)\left(E_t\hat{\lambda}_{t+1}+\hat{P}_t-E_t\hat{P}_{t+1}-\hat{\lambda}_t+E_t\hat{e}_{t+1}-\hat{e}_t\right)=0 \tag{69}$$

$$\hat{b}_{t+1}=\hat{B}_{t+1}-\hat{P}_t-\left(\frac{R^B}{1+R^B}\right)\hat{R}_t^B \tag{70}$$

$$\hat{b}_{t+1}^*=\hat{e}_t+\hat{B}_{t+1}^*-\hat{P}_t-\left(\frac{R^{B^*}}{1+R^{B^*}}\right)\hat{R}_t^{B^*} \tag{71}$$

$$\hat{P}_t^x=\hat{P}_t^d-\hat{e}_t \tag{72}$$

$$\hat{C}_t=\left(\frac{K}{C}\right)^{\eta}\left(\frac{n}{C}\right)^{1-\eta}\left[\hat{P}_t^d-\hat{P}_t+\left(1-\eta\right)\left(a\hat{1}_t+\hat{n}_t\right)\right]-\frac{\delta K}{C}\hat{q}_t+\frac{b^*R^{B^*}}{C}\hat{R}_{t-1}^{B^*}$$
$$+\frac{b^*\left(1+R^{B^*}\right)}{C}\left(\hat{e}_t-\hat{e}_{t-1}+\hat{b}_t^*+\hat{P}_{t-1}-\hat{P}_t\right)-\frac{b^*}{C}\hat{b}_{t+1}^* \quad (73)^{15}$$

Second, the interest rate relationship in section 3, Eq. (38), (39), (42) and (43), are linearized as follows:

$$R^T\hat{R}_t^T=\frac{1}{\beta}\left(\hat{\lambda}_t-E_t\hat{\lambda}_{t+1}+E_t\hat{P}_{t+1}-\hat{P}_t\right) \tag{74}$$

$$\left(\frac{R^B}{1+R^T}\right)\hat{R}_t^B-\left(\frac{R^T\left(1+R^B\right)}{\left(1+R^T\right)^2}\right)\hat{R}_t^T=\left[\left(1-\frac{\phi}{C\lambda}\right)\Omega\right]\hat{\Omega}_t+\left(\frac{\phi}{C\lambda}\Omega\right)\left(\hat{C}_t+\hat{\lambda}_t\right) \tag{75}$$

[15] This equation is the overall constraint, which combined Eqs. (11)-(13) and (18).

$$R^{T}\widehat{R}_{t}^{T}-\left(\frac{1+R^{T}}{1+R^{IB}}\right)R^{IB}\widehat{R}_{t}^{IB}=\left(1+R^{IB}\right)\left(\frac{Vmw}{(1-\alpha)(1-rr)C}\right)\left(\widehat{w}_{t}+\widehat{m}_{t}-\widehat{C}_{t}\right) \tag{76}$$

$$R^{L}\widehat{R}_{t}^{L}-\left(\frac{R^{IB}\left(1+R^{L}\right)}{\left(1+R^{IB}\right)}\right)\widehat{R}_{t}^{IB}=\left(1+R^{IB}\right)\left(\frac{Vmw}{(1-rr)C}\right)\left(\widehat{w}_{t}+\widehat{m}_{t}-\widehat{C}_{t}\right) \tag{77}$$

Moreover, we need to denote the variables correspond to monetary policy as below:

$$\Delta h_{t}=\widehat{H}_{t}-\widehat{H}_{t-1} \tag{78}$$

$$\Delta p_{t}=\widehat{P}_{t}-\widehat{P}_{t-1} \tag{79}$$

$$\Delta p_{t}^{d}=\widehat{P}_{t}^{d}-\widehat{P}_{t-1}^{d} \tag{80}$$

$$\Delta e_{t}=\widehat{e}_{t}-\widehat{e}_{t-1} \tag{81}$$

where Δh_t is the growth rate of the stock of high-powered money. Δp_t and Δp_t^d are the CPI inflation rate and non-traded goods inflation rate, respectively. Δe_t denotes the volatility of exchange rate.

There are 24 endogenous variables $\widehat{mc}_t, \widehat{\Omega}_t, \widehat{\lambda}_t, \widehat{\xi}_t, \widehat{w}_t, \widehat{n}_t, \widehat{m}_t, \widehat{C}_t, \widehat{C}_t^A, \widehat{q}_t, \widehat{e}_t, \widehat{P}_t, \widehat{P}_t^d$, $\widehat{P}_t^x, \widehat{R}_t^T, \widehat{R}_t^B, \widehat{R}_t^L, \widehat{R}_t^{IB}, \widehat{R}_t^{B^*}, \widehat{b}_{t+1}, \widehat{B}_{t+1}, \widehat{b}_{t+1}^*, \widehat{B}_{t+1}^*, \Delta\widehat{p}_t^d$ and 6 exogenous variables $a\widehat{1}_t, a\widehat{2}_t$, $a\widehat{3}_t, \widehat{P}_t^*, \widehat{P}_t^m, \widehat{R}_t^*$ in the linearized system. Thus, with the monetary policies, Eqs. (36)-(37), we can study the dynamic model and calculate the welfare.

6. Welfare analysis

As mentioned in Section 4, the DSGE model with banking sector could be better to characterize the Taiwanese economy than conventional model without banking setting. In this section, we investigate the performance of alternative monetary policy rules under external shocks by comparing the welfare and the volatility of key macroeconomic variables, and further suggest the optimal monetary policy of Taiwan.

Moreover, we consider some variation of the benchmark model to check for the robustness of the results. The results of welfare are computed by the software package, Dynare.

6.1. Welfare criterion

We use the expected lifetime utility of the representative household in period zero as the welfare measure:

$$CV_0 = E_0 \sum_{t=0}^{\infty} \beta^t \left[\phi \log(C_t) + (1-\phi) \log(1 - n_t - m_t) \right] \tag{82}$$

Following Schmitt-Grohé and Uribe (2007), we evaluate monetary policy by computing the welfare of a given policy regime.

$$CV_0^a = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \phi \log\left[\left(1 + \frac{\gamma^a}{100}\right) \bar{C} \right] + (1-\phi) \log(1 - \bar{n} - \bar{m}) \right\} \tag{83}$$

where $\bar{C}$, $\bar{n}$ and $\bar{m}$ are the steady-state value of consumption, labor in the goods production and banking sectors, respectively. γ^a is the fraction of steady-state consumption process that the household would increase to be as well off under the steady-state as under a regime a. Consequently, a higher value of γ^a means higher welfare level.

6.2. Welfare analysis

As mentioned in Section 2, we assume the central bank uses two types of monetary instrument. The first is the form of monetary aggregate growth rule Eq. (36), and ρ^H is assumed to be 0.99 (MA rule).[16] The second is the form of interest rate rule Eq. (37). In this rule, we consider three simple rules: strict consumer price index

[16] The coefficient ρ^H do not affect the result in the paper.

targeting (CPIT rule), strict domestic goods inflation targeting (DPT rule) and exchange rate targeting (ERT rule), respectively. The CPIT rule stresses the consumer price index targeting, with inflation response $\alpha_p = 50$, and with no effort to stabilize domestic goods inflation rate, output gap and exchange rate ($\alpha_{pd} = 0, \alpha_{mc} = 0, \alpha_e = 0$).[17] The DPT rule and ERT rule can be done in the same manner.

Table 3 reports the welfare measure of each monetary policy γ^a and the volatilities of some key macroeconomic variables (output, consumption, CPI inflation rate, domestic price inflation rate and exchange rate). When the economy encounters the external shocks, we find that MA is the best rule, followed by CPIT rule, ERT rule while DPT rule is the worst. It is worth noting that MA rule leads to lowest standard deviations of all variables except consumption. That is, MA rule helps to reduce the volatilities of output, inflations and exchange rate, and further reach the goal of stabilizing the economy.

6.3. Sensitivity analysis

6.3.1. Degree of capital mobility

In the benchmark model, we assume that the degree of capital mobility $\sigma = 0.0019$, which is the estimate for 21 developed countries. However, Taiwan is less developed than those countries. Thus, we try to increase the friction of capital mobility $\sigma = 0.01$ to investigate how the results change. As can be seen from Table 3, the rank of monetary policies is the same with the benchmark model. Also, the standard deviations of all variables are similar to the benchmark model. The only difference is that the welfares of all four rules become slightly higher than the

[17] Following Goodfriend and McCallum (2007), we set the policy parameters to be 50. We found that higher values of policy parameter have no effect on the rank of monetary policies.

benchmark model. The intuition for this result is that less open financial market keeps the foreign bond's holders from incurring the market risks which may decrease the value of financial asset.

6.3.2. Degree of trade openness

With globalization, the degree of Taiwanese openness becomes higher than before. Besides, there is a hot issue currently in Taiwan over Economic Cooperation Framework Agreement (ECFA), which is essentially the free trade agreement. One of those controversial topics is the impact of trade openness. In Section 4, α^m is set to 0.43 so that the steady-state import to GDP ratio is 50%, consistent with the sample average in Taiwanese data during the period. Now we consider the case of highly open market for $\alpha^m = 0.53$, which will lead to the ratio of import over GDP to be 70%. The results are listed in the bottom of Table 3. The MA rule generates the highest welfare among all policies, and there is slight difference in welfare and standard deviations among CPIT, DPT and ERT rules. The MA rule still stabilizes output, inflation rates and exchange rate except consumption. The ranking of these rules is the same with the benchmark model. Moreover, we found that the welfare of higher trade openness is significantly greater than the benchmark model ($\alpha^m = 0.43$), particularly under the MA rule.

In general, the MA rule dominates other rules, which not only cause higher welfare but stabilize the output, two types of inflation rates and exchange rate. Thus, considering the banking sector to the model, the monetary aggregate growth rate rule may be the optimal monetary policy of Taiwan.[18]

[18] We try another case of higher k. The result shows that the MA rule is still the optimal monetary policy in Taiwan.

7. Conclusion

In this paper, we investigate the optimal monetary policy of Taiwan by using a micro-based dynamic stochastic general equilibrium (DSGE) model with the banking sector. The discussions focus on two aspects. First, we analyze the results of steady state. We find that the banking sector is an important role in Taiwanese economy. In costly banking sector, the liquidity service yield on collateral would affect some variables. Second, we investigate the performances of four types of monetary policies rules: monetary aggregate growth rate rule, interest rate rule with CPI targeting, interest rate rule with domestic goods inflation rate targeting, and interest rate rule with exchange rate targeting. The results show that the monetary aggregate growth rate rule can be welfare superior to the other policies and stabilize the output, CPI, domestic goods price inflation rate and exchange rate. Also, highly capital mobility friction and highly trade openess would increase the welfare of Taiwanese economy.

We conclude this paper by providing some interesting issues for future research. First of all, the house and foreign bond could be included as collateral. It would be interesting to examine whether the monetary policy should react to the asset price. Furthermore, we discuss the simple rules of monetary policy in this paper. In reality, the central bank may use more complex instrument to carry out the monetary policy. It would be interesting to consider mixed strategy.

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Appendix

Table 1 Parameter values (on quarterly basis)

Parameter	Description	Value
ϕ	The importance of consumption in the utility function	0.49
η	Capital share in goods production	0.36
β	Discount rate	0.99
δ	Depreciation rate of capital	0.025
boc	Real government bond / consumption bundle	1.194
V	Velocity of aggregate bank deposits	0.134
rr	Reserve rate	0.054
α	Collateral share in loan production	0.7
F	Efficiency parameter of banking sector	7.6
k	Inferiority of capital to bonds for collateral purposes	0.55
α^m	Ratio of import goods to aggregate consumption in the steady state	0.43
α^d	Ratio of domestic goods to aggregate consumption in the steady state	0.57
υ	Elasticity of substitution among different variety of goods	6
θ	Elasticity of substitution between domestic goods and imported goods	5
μ	Price elasticity of demand for export	5
P^*	The rest of the world price index	0.84
σ	The degree of capital mobility	0.0019

Table 2 Steady-state values

Benchmark calibration (quarterly data; zero inflation; $F = 7.6$)					
w	C	C^A	m	n	
1.8792	1.1064	1.3905	0.0097	0.3436	
b	b^*	Ω	K	λ	
1.3217	17.9727	0.1023	11.3626	0.4197	
R^T	R^{IB}	R^L	R^B	R^K	EFP
0.01	0.0022	0.0046	0.0043	0.0069	0.0024
Highly efficient banking ($F = 80$)					
w	C	C^A	m	n	
1.7829	1.1023	1.3570	0.000	0.3564	
b	b^*	Ω	K	λ	
1.3167	16.5306	0.1115	10.1857	0.4444	
R^T	R^{IB}	R^L	R^B	R^K	EFP
0.01	0.01	0.01	0.01	0.01	0.000

Table 3 Welfare and Standard deviations

	MA	CPIT	DPT	ERT
Benchmark model (policy parameter=50)				
Welfare γ^a	0.173277	0.111891	0.108199	0.110957
Standard deviations				
Output	0.0342	0.0506	0.0482	0.0498
Consumption	0.0231	0.0093	0.0079	0.0087
CPI inflation rate	0.0100	0.0130	0.0126	0.0128
Non-traded goods inflation rate	0.0045	0.0084	0.0080	0.0082
Exchange rate	0.0084	0.0115	0.0111	0.0114
Highly capital mobility friction ($\sigma = 0.01$)				
Welfare γ^a	0.173291	0.113516	0.109371	0.112572
Standard deviations				
Output	0.0344	0.0508	0.0482	0.0500
Consumption	0.0231	0.0089	0.0074	0.0083
CPI inflation rate	0.0100	0.0130	0.0125	0.0128
Non-traded goods inflation rate	0.0044	0.0083	0.0079	0.0082
Exchange rate	0.0083	0.0115	0.0110	0.0113
Highly openness ($\alpha^m = 0.53$)				
Welfare γ^a	0.20401	0.119365	0.119214	0.119333
Standard deviations				
Output	0.0524	0.0688	0.0687	0.0688
Consumption	0.0311	0.0037	0.0037	0.0037
CPI inflation rate	0.0149	0.0177	0.0177	0.0177
Non-traded goods inflation rate	0.0058	0.0101	0.0101	0.0101
Exchange rate	0.0138	0.0166	0.0166	0.0166

Note. ① MA is the monetary aggregate growth rate rule. CPIT refers to the interest rate rule with CPI targeting. DPT refers to the interest rate rule with domestic goods inflation rate targeting. ERT refers to the interest rate rule with exchange rate targeting. ② In the benchmark model, we set $\sigma = 0.0019$ and $\alpha^m = 0.43$.