

Monetary Growth Targeting, the Taylor Rule and Share-Market Stability: The Taiwanese Experience

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Abstract

This paper applies counterfactual simulation experiments based on Bayesian estimates of an open-economy DSGE model of Taiwan. We assess the monetary targeting framework of the Central Bank of the Republic of China relative to a pure inflation targeting Taylor rule. We find that welfare changes may be positive or negative, but very small, at most less than 0.6 percent of consumption. However, switching to a Taylor rule leads to significantly greater volatility in Tobin's Q. Given the importance of share-price stability for overall financial market performance, monetary targeting emerges as the more prudential framework for monetary policy.

JEL Classification: E52, E62, F41

1 Introduction

Since 1992 the Central Bank of the Republic of China (Taiwan) (thereafter CBC) has been officially targeting the growth rate of broad money through base money instruments. According to the "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. It appears that the Central Bank of the Republic of China (Taiwan) has thus bucked the trend of inflation targeting or exchange-rate managing among national monetary authorities in East Asia. Monetary targets remain alive and well in Taiwan, despite the oft quoted phrase of John Crow, former Governor of the Bank of Canada, that we (central bankers) "have not abandoned monetary targets, they abandoned us"[see King (1996), p.4].

Elsewhere in the region, the Central Bank of the Republic of Korea and the Bangko Sentral ng Pilipinas have adopted inflation targeting with flexible

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exchange rates and interest rate instruments after the East Asian crisis. By contrast, the Monetary Authority of Singapore has followed an exchange-rate targeting framework, while the Hong Kong Monetary Authority has maintained its currency board since 1984.

In the past decade, inflation targeting rule has received wide attention. Amid much debate about the causes of the Great Moderation, for example, Giannone, Lenza, and Reichlin (2008), argue that the underlying cause of the Great Moderation was more than good luck (due to favorable shocks). Rather, it was due to a change in the way the shocks were propagated, through the establishment of a better, more credible monetary policy framework. As noted by King (1996), while broad money targeting can provide credibility, inflation targeting is more direct, since it focuses on the ultimate target, and thus is more transparent. Since headline inflation is readily available to the public, accountability of central bank performance comes to the central of the stage in this framework.

While most of the countries operate interest rate rules, the monetary experiences of Taiwan have demonstrated that monetary targets work well. The macroeconomic fundamentals have remained relatively stable. A comparison between Taiwan and Korea (which has implemented inflation targeting rule since 1998), in Table 1, shows that the standard deviations of the GDP growth rate, CPI inflation and share price inflation are lower in Taiwan than in Korea based during the 1998-2007 period. Based on the experience of these two fast growing economies within the East Asia region, there is no empirical evidence that monetary targeting regimes fare worse than inflation-targeting regimes.

Table 1:
Macroeconomic Volatility: Taiwan vs. South Korea

	<u>Percentage Growth Rate:</u>		
	GDP	CPI	Share Index
	<u>Standard Deviation:</u>		
Taiwan	0.0169	0.0035	0.0777
South Korea	0.0553	0.0664	0.0898

Of course, these are only two sets of experiences. To investigate this issue further, this paper investigates the benefit and cost of the monetary targeting relative to a counterfactual Taylor rule inflation-targeting regime in Taiwan, with a dynamic stochastic general equilibrium models estimated with Bayesian methods. A previous study by Hou (2005), using data between 1991 and 2003, found that a rule to control the growth rate of the reserve money outperformed an interest-rate rule for stabilizing income and prices. Hou's model was based on a relatively simple New Keynesian model and the results were based on parameters estimated by classical methods. While the official position of the CBC is that its policy comes from a monetary-targeting framework, Hsu (1999) argued that the interest rate has been an important ancillary instrument, while

Chen and Wu (2010) found some evidence of switching between interest and monetary-growth rate rules, but they argue that monetary aggregate rules can well characterize the monetary policy of the CBC before 1998. More recently, however Teo (2009) used Bayesian estimation of a DSGE model to test the hypothesis of a monetary-targeting regime against alternative regimes based on the Taylor rule or exchange-rate targeting. Based on posterior odds ratios, the evidence strongly favored the monetary targeting regime for Taiwan. While Teo's work empirically establishes the use of the monetary targeting regime as the *de facto* policy framework of Taiwan, he did not perform any comparison of the macroeconomic performance of the *de facto* regime with counterfactual inflation or exchange-rate targeting regimes. This is the aim of this paper.

Scharnagl, Gerberding and Seitz (2010) argued that including broad money growth rates in a Taylor rule outperforms pure inflation targeting in a Taylor rule, for the Euro area. These authors make use of an estimated closed economy New Keynesian framework. They base their argument on the reality of measurement error of real-time output used by central bank policy-makers, and thus output-gap uncertainty, in the pure Taylor-rule framework.

In contrast to Scharnagl, Gerberding, and Seitz, we use an open-economy model which includes investment and capital accumulation. We include the financial sector for the liquidity injection by the central bank's monetary aggregate policy with the targeted growth rate of reserve money. On the other hand, the counterfactual experiments focusing on the CPI inflation targeting, away from broad money targeting, neglected the asset price inflation during the period of the Great Moderation. One of the key results we show in this paper is that a monetary targeting framework delivers much lower volatility in Tobin's Q , an indicator or shadow price of assets. Ironically, the focus on inflation targeting, which is more transparent and provides accountability, is also more limited than broad money targeting in providing stability to the share prices in the economy and financial markets in general. The economy can be stabilized through the control of the growth rate of broad money which is the primary source of liquidity to the economy.

Thus, the case of Taiwan may have given us a good example of monetary aggregate targeting as an alternative monetary policy, especially after the widespread financial crisis which has raised questions about the advisability of inflation targeting with interest rate rules, which of course have a zero lower bound. The next section of the paper presents the model we use for Bayesian estimation and simulation. We then discuss the Bayesian estimates. After that, we take up comparative policy simulations, for the base case of monetary targeting and for the counterfactual case of inflation targeting with the domestic interest rate.

2 The Model

2.1 Household Preferences and Endowments

Households own capital for rental and supply labor to both these export and home-goods firms. Capital for rental to the firms depreciates at the rate δ . When households accumulate or decumulate capital beyond the steady state level, they pay adjustment costs. The following law of motion is specified for capital, with adjustment costs given by AC_t^x , and ϕ_x is the adjustment cost parameter.

$$K_t^x = (1 - \delta)K_{t-1}^x + I_t^x \quad (1)$$

$$AC_t^x = \left(\frac{\phi_x (I_t^x - \delta \bar{K}^x)^2}{2K_t^x} \right) \quad (2)$$

We assume that all of investment goods are imported from abroad, and that the price P^f is the relevant price for these goods. The variable \bar{K}^x is the steady state level of the capital stock for export-goods producing firms.

The household consumption at time t , C_t , is a CES bundle of both domestic consumption goods, C_t^d and imported goods, C_t^f .

$$C_t = \left[(1 - \gamma_1)^{\frac{1}{\theta_1}} (C_t^d)^{\frac{\theta_1 - 1}{\theta_1}} + (\gamma_1)^{\frac{1}{\theta_1}} (C_t^f)^{\frac{\theta_1 - 1}{\theta_1}} \right]^{\frac{\theta_1}{\theta_1 - 1}} \quad (3)$$

The demand for each component of consumption is a function of the overall consumption index and the price of the respective component relative to the general price level, P :

$$C_t^d = (1 - \gamma_1) \left(\frac{P_t^d}{P_t} \right)^{-\theta_1} C_t \quad (4)$$

$$C_t^f = \gamma_1 \left(\frac{P_t^f}{P_t} \right)^{-\theta_1} C_t \quad (5)$$

The parameters γ_1 and $(1 - \gamma_1)$ are the relative shares of foreign and domestic goods in the overall consumption index, while θ_1 is the price elasticity of demand for each consumption component.

Domestically-produced goods are composed of both non-traded home goods and export goods (some of which are consumed domestically). The following CES aggregator is used for domestically-produced consumption goods:

$$C_t^d = \left[(1 - \gamma_2)^{\frac{1}{\theta_2}} (C_t^h)^{\frac{\theta_2 - 1}{\theta_2}} + (\gamma_2)^{\frac{1}{\theta_2}} (C_t^x)^{\frac{\theta_2 - 1}{\theta_2}} \right]^{\frac{\theta_2}{\theta_2 - 1}} \quad (6)$$

The relative demands for the home non-traded goods and the export goods are given by the following equations:

$$C_t^h = (1 - \gamma_2) \left(\frac{P_t^h}{P_t^d} \right)^{-\theta_2} C_t^d \quad (7)$$

$$C_t^x = \gamma_2 \left(\frac{P_t^x}{P_t^d} \right)^{-\theta_2} C_t^d \quad (8)$$

where the parameters γ_2 and $(1 - \gamma_2)$ are the shares of the export and non-traded goods in domestic production of consumption goods, and θ_2 is the price elasticity of demand.

The domestically-produced price index is given by the following CES aggregator:

$$P_t^d = \left[(1 - \gamma_2) (P_t^h)^{1-\theta_2} + \gamma_2 (P_t^x)^{1-\theta_2} \right]^{\frac{1}{1-\theta_2}} \quad (9)$$

In the same manner, the overall price index, of course, is a CES function of the price of foreign and domestic consumption goods:

$$P_t = \left[(1 - \gamma_1) (P_t^d)^{1-\theta_1} + \gamma_1 (P_t^f)^{1-\theta_1} \right]^{\frac{1}{1-\theta_1}} \quad (10)$$

In addition to buying consumption goods, households put deposits M_t in the bank and receive dividends from the export and non-traded or home-goods producing firms. Total dividends is given by Π_t , with $\Pi_t = \Pi_t^x + \Pi_t^h$. The household pays taxes on labor income $\tau W_t L_t$ and on consumption $\tau_c C_t$. The following equation gives the household budget constraint (P_t^f is the price of imported goods):

$$\begin{aligned} & W_t L_t + (1 + R_{t-1}^m) M_{t-1} + \Pi_t + P_t^{k^x} K_t^x \\ &= P_t C_t (1 + \tau_c) + M_t + \tau W_t L_t + P_t^f I_t^x + P_t^f \left(\frac{\phi_x (I_t^x - \delta_2 \bar{K}^x)^2}{2K_t^x} \right) \end{aligned} \quad (11)$$

We assume that government spending G is bundled with consumption for utility in CES aggregator. We do this to indicate that there is a reason for government spending to take place, that such spending creates externalities for consumption, in the form of infrastructure, public utilities and other services which enhance household utility:

$$\tilde{C}_t = [\phi C_t^{-\frac{1}{\sigma}} + (1 - \phi) G_{t-1}^{-\frac{1}{\sigma}}]^{-\frac{1}{\sigma}} \quad (12)$$

However, household utility does not simply come from the current consumption bundle. Rather, habit persistence applies to this consumption index when it enters the specific utility function, so that the relevant consumption index is

deflated by the Habit Stock, H_t . The Habit Stock is a function of the lagged average consumption bundle, raised to the power ϱ , the habit persistence parameter:

$$H_t = \bar{C}_{t-1}^\varrho \quad (13)$$

Overall utility is a positive function of the consumption bundle, the habit stock and a negative function of labor:

$$U(\tilde{C}_t/H_{t+l}, L_t) = Z_t^C \frac{(\tilde{C}_t/H_t)^{1-\eta}}{1-\eta} - \gamma \frac{L_t^{1+\varpi}}{1+\varpi} \quad (14)$$

The parameter η is the relative risk aversion coefficient, while γ is the disutility of labor, and ϖ the Frisch labor supply elasticity. The variable Z_t^C is a shock to the utility of consumption and evolves according to the following process:

$$\ln(Z_t^C) = \rho_C \ln(Z_{t-1}^C) + (1 - \rho_C) \ln(\bar{Z}^C) + \epsilon_{Z^C,t} \quad (15)$$

$$\epsilon_{Z^C,t} \sim N(0, \sigma_{Z^C}^2) \quad (16)$$

The household chooses the paths of consumption, labor, deposits, investment and capital, to maximize the present value of its utility function subject to the budget constraint and the law of motion for capital. Thus, the objective function of the household is given by the following expression:

$$\underset{\{C_t, L_t, M_t, I_t^h, K_t^h, I_t^x, K_t^x\}}{Max} E_t \sum_{l=0}^{\infty} \beta^l U(\tilde{C}_{t+l}/H_{t+l}, L_{t+l}) \quad (17)$$

where the parameter β represents the constant, exogenous discount factor. This optimization is subject to the two constraints:

1.

$$\begin{aligned} & W_t L_t + (1 + R_{t-1}^m) M_{t-1} + \Pi_t + P_t^{k^x} K_t^x \\ = & P_t C_t (1 + \tau_c) + M_t + \tau W_t L_t + P_t^f I_t^x + P_t^f \left(\frac{\phi_x (I_t^x - \delta \bar{K}^x)^2}{2K_t^x} \right) \end{aligned} \quad (18)$$

$$K_t^x = (1 - \delta) K_{t-1}^x + I_t^x \quad (19)$$

The variable $P_t^{k^x}$ is the price of the capital to the export-goods producing firm, while W_t is the nominal wage rate.

The household optimization is represented by the intertemporal Lagrangean:

$$\begin{aligned}
\underset{\{C_t, L_t, M_t, I_t^h, K_t^h, I_t^x, K_t^x\}}{\text{Max}} \mathcal{L} &= E_t \sum_{\iota=0}^{\infty} \beta^{\iota} \left\{ -\Lambda_{t+\iota} \left[\begin{array}{l} U(\tilde{C}_{t+\iota}/H_{t+\iota}, L_{t+\iota}) \\ P_{t+\iota} C_{t+\iota} (1 + \tau_c) + M_{t+\iota} \\ -(1 + R_{t-1+\iota}^m) M_{t-1+\iota} \\ + P_{t+\iota}^f I_{t+\iota}^x + \\ P_{t+\iota}^f \frac{\phi_x (I_{t+\iota}^x - \delta \bar{K}^x)^2}{2 K_{t+\iota}^x} \\ + (\tau - 1) W_{t+\iota} L_{t+\iota} - \Pi_{t+\iota} \\ - P_{t+\iota}^k K_{t+\iota}^x \\ - Q_{t+\iota}^x (K_{t+\iota}^x - I_{t+\iota}^x - (1 - \delta) K_{t-1+\iota}^x) \end{array} \right] \right\} \quad (20)
\end{aligned}$$

Note that there are three Lagrange multipliers, one, $\Lambda_{t+\iota}$, is the familiar marginal utility of income or wealth, while Q_{t+i}^x , known as Tobin's Q, is the shadow price of capital for the export-goods sector.

Optimizing the Bellman equation with respect to the decision variables $C_t, L_t, M_t, I_t^h, K_t^h$ yields the following set of First-Order Conditions for the representative household:

$$\Lambda_t P_t = \phi \left(\tilde{C}_t \right)^{1-\varkappa-\eta} (H_t)^{\eta-1} (C_t)^{-\varkappa-1} Z_t^C \quad (21)$$

$$\gamma L_t^{\varpi} = \Lambda_t (1 - \tau) W_t \quad (22)$$

$$\Lambda_t = \beta E_t \Lambda_{t+1} (1 + R_t^m) \quad (23)$$

$$Q_t^x = \beta E_t \left(\Lambda_{t+1} \left(P_{t+1}^k + \beta P_{t+1}^f \frac{\left(\phi_x [I_{t+1}^x - \delta \bar{K}^x] \right)^2}{2 (K_t^x)^2} \right) + \beta Q_{t+1}^x (1 - \delta) \right) \quad (24)$$

$$I_t^x = \delta_1 \bar{K}^x + \frac{K_t^x}{\phi_x} \left(\frac{Q_t^x}{\Lambda_t} - P_t^f \right) \quad (25)$$

The first equation, Eq. (21), simply tells us that the marginal utility of wealth is equal to the marginal utility of consumption divided by the price level. The second equation, Eq. (22), states that the marginal disutility of labor is equal to the after tax marginal utility of consumption provided by the after-tax wage. The third equation is the Keynes-Ramsey rule for optimal saving: the marginal utility of wealth today should be equal to the discounted marginal utility tomorrow, multiplied by the gross rate of return on saving (in the form of deposits).

The equation for Tobin's Q tells us that the value of capital today is the discounted marginal utility of capital tomorrow, multiplied by the return to capital, in addition to the reduced value of adjustment costs in the future (due to the higher level of capital) and the discounted value of capital tomorrow, net of depreciation.

Finally, the investment equation tells us that investment will be equal to the steady state investment, $\delta_1 \bar{K}^x$, when $\frac{Q_t^x}{\Lambda_t} = P_t^f$. Any increase in Tobin's Q_t^x ,

relative to the marginal utility of income and the price of investment goods, will trigger increases in investment.

3 Production and Technology

3.1 Nontraded Home-Goods Firms

The home-good producing firms use the following CES technology:

$$Y_t^h = Z_t^h \left[(1 - \alpha_1) (L_t^h)^{-\kappa_1} + \alpha_1 (\bar{K}^h)^{-\kappa_1} \right]^{-\frac{1}{\kappa_1}} \quad (26)$$

The parameter α_1 is the share of the fixed capital stock in the CES production function, while the coefficient κ_1 is the CES aggregator. α_1 is assumed to be zero in calibration to characterize the labor-intensive nontradable industries such as services.

The technology shock is given by Z_t^h , which follows the autoregressive process:

$$\begin{aligned} \ln(Z_t^h) &= \rho_{Z^h} \ln(Z_{t-1}^h) + (1 - \rho_{Z^h}) \ln(\bar{Z}^h) + \epsilon_{Z^h,t} & (27) \\ \epsilon_{Z^h,t} &\sim N(0, \sigma_{Z^h}^2) & (28) \end{aligned}$$

The demand for the home good can be both for domestic consumption, as well for government consumption spending:

$$Y_t^h = C_t^h + G_t \quad (29)$$

We assume that the firm faces a liquidity constraint. It must borrow an amount N_t^h from banks each quarter to pay a fraction μ_h of its wage bill, at the borrowing rate R_t^n :

$$N_t^h = \mu_h W_t L_t^h, \quad (30)$$

The total profits (or dividends) of the export firm is given by the following identity:

$$\Pi_t^h = P_t^h Y_t^h - (1 + \mu_h R_t^n) W_t L_t^h \quad (31)$$

Maximizing profits with respect to the use of labor, we have the following first-order conditions for the firm:

$$\frac{\partial Y_t^h}{\partial L_t^h} = (1 + \mu_h R_t^n) \frac{W_t}{P_t^h} \quad (32)$$

In the CES technology, we have the following expressions:

$$\frac{\partial Y_t^h}{\partial L_t^h} = (Z_t^h)^{-\kappa_1} (1 - \alpha_1) \left(\frac{Y_t^h}{L_t^h} \right)^{1+\kappa_1} \quad (33)$$

You can see that with $\kappa_1 = 0$, the first order conditions reduce to the Cobb-Douglas marginal productivity conditions.

3.2 Export Goods

The firm producing export goods faces a similar production function:

$$Y_t^x = Z_t^x \left[(1 - \alpha_2) (L_t^x)^{-\kappa_2} + \alpha_2 (K_t^x)^{-\kappa_2} \right]^{-\frac{1}{\kappa_2}} \quad (34)$$

There is an export demand shock Z^x which follows the autoregressive process:

$$\ln(Z_t^x) = \rho_{Z^x} \ln(Z_{t-1}^x) + (1 - \rho_{Z^x}) \ln(\bar{Z}^x) + \epsilon_{Z^x,t} \quad (35)$$

$$\epsilon_{Z^x,t} \sim N(0, \sigma_{Z^x}^2) \quad (36)$$

Foreign export demand is also subject to a stochastic shock, $\epsilon_{C^*,t}$ at time t .

$$C_t^* = \rho_{C^*} C_{t-1}^* + (1 - \rho_{C^*}) \bar{C}^* + \epsilon_{C^*,t} \quad (37)$$

$$\epsilon_{C^*,t} \sim N(0, \sigma_{C^*}^2) \quad (38)$$

Under a small open economy setting we also assume that the price of the export good in domestic currency is simply equal to the exchange rate S_t multiplied by the world export price, P_t^{x*} . We assume that the world export price follows the following exogenous stochastic process:

$$\ln(P_t^{x*}) = \rho_{P^{x*}} \ln(P_{t-1}^{x*}) + (1 - \rho_{P^{x*}}) \ln(\bar{P}_t^{x*}) + \epsilon_{P^{x*},t} \quad (39)$$

$$\epsilon_{P^{x*},t} \sim N(0, \sigma_{P^{x*}}^2) \quad (40)$$

Total demand for the export good is composed of the local demand (for consumption purposes) as well as the foreign demand:

$$Y_t^x = C_t^x + C_t^*$$

These firms face a liquidity constraint for meeting their wage bill:

$$N_t^x = \mu_x W_t L_t^x \quad (41)$$

The profits of the export-goods firms are given by the following relation:

$$\Pi_t^x = P_t^x Y_t^x - (1 + \mu_x R_t^n) W_t L_t^x - P_t^{k^x} K_t^x \quad (42)$$

Optimizing profits implies the following first-order condition for cost minimization:

$$\frac{\partial Y_t^x}{\partial L_t^x} = (1 + \mu_x R_t^n) \frac{W_t}{P_t^x} \quad (43)$$

$$\frac{\partial Y_t^x}{\partial K_t^x} = \frac{P_t^{k^x}}{P_t^x} \quad (44)$$

3.3 Labor Mobility and Capital Immobility

We assume that labor can move between the home-goods and export sectors. This implies the following equality for real labor productivity in each sector:

$$\frac{\partial Y_t^x}{\partial L_t^x} \frac{P_t^x}{(1 + \mu_x R_t^n)} = \frac{\partial Y_t^h}{\partial L_t^h} \frac{P_t^h}{(1 + \mu_h R_t^n)}$$

3.4 Calvo Pricing for Home Goods

The pricing for home-goods firms is different from that of export firms. We assume monopolistically competitive firms in the home-goods market which implement the Calvo-typed staggered pricing.

Let the marginal cost at time t be given by the following expression:

$$A_t = \frac{(1 + \mu_1 R_t^n) W_t}{(A^h Z_t^h)^{\kappa_1} (1 - \alpha_1) \left(\frac{Y_t^h}{L_t^h}\right)^{1 + \kappa_1}} \quad (45)$$

In the Calvo price setting world, there are forward-looking price setters and backward looking setters. Assuming at time t a probability of persistence of the price at ξ , with demand for the product from firm j given by $Y_t^h (P_t^h)^\zeta$, the expected marginal cost, in recursive formulation, is presented by the expression for A_t^{num} . The expected demand, for the given price, is given by the variable A_t^{den} .

$$A_t^{num} = Y_t^h (P_t^h)^\zeta A_t + \beta \xi A_{t+1}^{num} \quad (46)$$

$$A_t^{den} = Y_t^h (P_t^h)^\zeta + \beta \xi A_{t+1}^{den} \quad (47)$$

$$P_t^o = \frac{A_t^{num}}{A_t^{den}} \quad (48)$$

$$P_t^{h,b} = P_{t-1}^h \left(\frac{P_{t-1}}{P_{t-2}}\right)^{\kappa^i} (1 + \tilde{\pi}_t)^{\kappa^\pi} \quad (49)$$

$$P_t^h = \left[\xi (P_t^{h,b})^{1-\zeta} + (1 - \xi) (P_t^o)^{1-\zeta} \right]^{\frac{1}{1-\zeta}} \quad (50)$$

The backward looking price setters do not keep the price fixed. They will set their price equal to the price at the previous period, P_{t-1}^h multiplied by the previous period's inflation, $\left(\frac{P_{t-1}}{P_{t-2}}\right)$ raised to an indexation parameter κ^i , and by the gross inflation target announced by the central bank, $(1 + \tilde{\pi}_t)$, representing monetary policy statements, relative to inflation targets, raised to a parameter κ^π .

3.5 Importing Firms

Imported goods Y^f are used for both consumption C^f and for investment in the export-goods I^x .

$$Y_t^f = C_t^f + I_t^x \quad (51)$$

The importing firms do not produce these goods. However, they have to borrow a fraction μ_f of the cost of these imported goods in order to bring them to the home market for domestic consumers and investors:

$$N_t^f = \mu_f (S_t P_t^{f*} Y_t^f) \quad (52)$$

where P_t^{f*} is the world price of the import goods and S_t is the exchange rate. The domestic cost of the imported goods is given by:

$$P_t^f = (1 + \mu_f R_t^n) S_t P_t^{f*} \quad (53)$$

4 The Financial Sector and Policies

4.1 The Financial Sector

Banks lend to all three types of firms:

$$N_t = N_t^x + N_t^h + N_t^f \quad (54)$$

In addition to these firms, the banks lend to the government B_t^g and receive a risk-free interest rate R_t .

They borrow from foreign financial centers the amount B^f and pay a risk premium above the domestic interest rate when such foreign debt exceeds a steady-state level \bar{B}^f :

$$\Phi_t = \max \left\{ 0, \varphi \left[e^{(|B_{t-1}^f - \bar{B}^f|)} - 1 \right] B_{t-1}^f \right\} \quad (55)$$

The banks thus pay a gross interest rate $R_t^* + \Phi_t$ on their outstanding dollar-denominated debt B_{t-1}^f to foreign financial centers,

In addition to paying deposits the interest rate R_t^m we assume that banks are also required to set aside a required ratio of reserves on outstanding deposits, $\phi_M M_t$. The relevant opportunity cost of holding these reserves is of course the amount the banks can earn by holding risk-free government bonds, $\phi_M R_t M_t$. In addition, banks are required to set aside a fraction of capital against their outstanding loans, $\phi_N N_t$. As in the case of the required reserves against deposits, the opportunity cost is given by $\phi_N R_t N_t$.

The gross profit of the banking sector is given by the following balance-sheet identity:

$$\begin{aligned}
\Pi_t^B &= (1 + R_{t-1})B_{t-1}^g + (1 + R_{t-1}^n)N_{t-1} + S_t B_t^f + M_t & (56) \\
&\quad - (1 + R_{t-1}^* + \Phi_{t-1})B_{t-1}^f S_t - (1 + R_{t-1}^m)M_{t-1} \\
&\quad - B_t^g - N_t - \phi_M R_{t-1} M_{t-1} - \phi_N R_{t-1} N_{t-1}
\end{aligned}$$

The bank maximizes its present discounted value of its profits, given by V_t^B , with respect to its portfolio of assets (loans to the government and firms, B_t^g and N_t) and liabilities (deposits from households and borrowing from foreign financial centers M_t and B_t^f).

$$\underset{\{B_t^g, N_t, M_t, B_t^f\}}{\text{Max}} \quad V_t^B = \Pi_t^B + \beta V_{t+1}^B$$

This set of first-order conditions leads to the familiar set of spreads for interest rates, as well as the interest-parity equation:

$$R_t = R_t^n - \phi_N \quad (57)$$

$$R_t = R_t^m + \phi_M \quad (58)$$

$$(1 + R_t)S_t = (1 + R_t^* + \Phi_t + \Phi_t' B_t^f)S_{t+1} \quad (59)$$

The foreign interest rate evolves according to the following law of motion:

$$\begin{aligned}
R_t^* &= \rho_{R^*} R_{t-1}^* + (1 - \rho_{R^*}) \bar{R}^* + \epsilon_{R^*,t} \\
\epsilon_{R^*,t} &\sim N(0, \sigma_{R^*}^2)
\end{aligned}$$

4.2 The Monetary Policy

We assume that the liquidity provision to the banking sector, which causes the change in the reserve of the banking sector ΔRES , adjusts to the target for the rate of growth of deposits in the banking sector.¹

$$\begin{aligned}
\Delta RES_t &= \rho_{RES} \Delta RES_{t-1} - (1 - \rho_{RES}) \rho_M [\Delta M_t - \mu] + \epsilon_{M,t} \\
\epsilon_{M,t} &\sim N(0, \sigma_M^2)
\end{aligned}$$

where μ is the target rate of deposit growth, ρ_{RES} is the smoothing parameter and ρ_M is the reaction coefficient, with $\rho_M > 1$. There is also a shock to monetary policy, $\epsilon_{M,t}$, normally distributed with variance σ_M^2 .

¹In the absence of currency, M_t is equivalent to the measure of broad money in this model.

The interest rate adjusts in this case to equilibrate the balance sheet of the financial sector.

$$R_t = \frac{N_t + B_t + (1 + R_t^* + \Phi_{t-1})B_{t-1}^f S_{t-1} + (1 - \phi_M)M_{t-1} - \Delta RES_t - M_t - B_t^f S_t - (1 - \phi_N)N_{t-1} - B_{t-1}}{B_{t-1} + N_{t-1}(1 - \phi_N) - M_{t-1}(1 - \phi_M)}$$

Basically this equation states that the flow returns to the system from government bonds and loans to firms, less interest payments on deposits, should be sufficient to finance new loans to firms and the government, as well as payments on foreign debt, net of new deposits and reserve injections by the central bank..

Thus, *ceteris paribus*, an increase in bond issues or loan demand by firms, or foreign interest rates would increase the domestic interest rate, while an increase in deposits or reserves would decrease the interest rate.

In the counterfactual scenario of an inflation targeting Taylor rule, the interest rate adjusts in the following way:

$$R_t = \rho_r R_{t-1} + (1 - \rho_r)\rho_\pi \hat{\pi}_t + (1 - \rho_r)\bar{R} + \epsilon_{M,t} \quad (60)$$

$$\epsilon_{M,t} \sim N(0, \sigma_M^2) \quad (61)$$

The coefficients ρ_r and ρ_π are the smoothing parameter and inflation coefficient, with $0 < \rho_r < 1$ and $\rho_\pi > 1$. \bar{R} is the steady state interest rate, equal to the steady state foreign interest rate R^* and $\hat{\pi}_t$ is the deviation of actual inflation from the target rate of inflation. Again we assume a shock to monetary policy given by $\epsilon_{M,t}$, normally distributed with variance σ_M^2 . Given that the central bank sets the interest rate, it provides reserves (or takes out reserves) to the banking sector through open market operations to insure a balance-sheet equilibrium:

$$\begin{aligned} \Delta RES_t &= N_t + B_t + (1 + R_t^* + \Phi_{t-1})B_{t-1}^f S_{t-1} \\ &\quad + (1 + R_t - \phi_M - \phi_M R_t)M_{t-1} - B_t^f S_t \\ &\quad - (1 + R_t + \phi_N - \phi_N R_t)N_{t-1} - M_t - (1 + R_t)B_{t-1} \end{aligned} \quad (62)$$

4.3 Fiscal Policy

The government takes in taxes from the households and engage in spending on traded goods. We assume that spending may be either pro-cyclical or counter-cyclical, depending on the value of ρ_{GY} , that there is smoothing in government consumption, and there is a stochastic component to spending:

$$G_t = (1 - \rho_G)\bar{G} + \rho_G G_{t-1} + (1 - \rho_G)\rho_{GY}(Y_{t-1} - \bar{Y}) + \epsilon_{G,t} \quad (63)$$

$$\epsilon_{G,t} \sim N(0, \sigma_G^2) \quad (64)$$

Given its source of labor and consumption tax revenue, the fiscal borrowing requirement is given by the following identities:

$$TAX_t = \tau W_t L_t + \tau_c P_t C_t \quad (65)$$

$$B_t^g = (1 + R_{t-1})B_{t-1}^g + P_t^h G_t - TAX_t \quad (66)$$

4.4 Foreign Assets and Interest Rates

The aggregate foreign borrowing or asset accumulation evolves through the following identity:

$$S_t B_t^f = [1 + R_{t-1}^* + \Phi_{t-1}] S_t B_{t-1}^f + P_t^f (C_t^f + I_t^h + I_t^x) - P_t^x (C_t^*) \quad (67)$$

It should be noted that the risk premium embedded in the accumulation of foreign debt effected closes this open economy model, so that the domestic consumption and foreign debt levels do not become indeterminate. There are other ways to close the open economy model, such as adjustment costs on foreign debt accumulation, or an endogenous discount factor [see Schmitt-Grohé and Uribe (2003)] We think that the incorporation of a time-varying endogenous risk premium is a more intuitive way to close this model.

5 Bayesian Estimation

5.1 Calibrated Parameters and Priors

We calibrate the parameters in accordance with the steady state by using the Taiwan's quarterly data from the beginning of 1998 through the end of 2007, before the outbreak of the subprime crisis, for the characterization of the macroeconomic fundamentals in Taiwan.

The discount parameter β follows the value used by most conventional models. The habit persistence parameter ϱ is consistent with most of the empirical estimations.² Since all the capital goods used in productions are assumed to be imported from abroad, we specify a higher value for the depreciation than the conventional value, and a relatively low value for the adjustment cost parameter ϕ_K . $\theta_1 > \theta_2$ is assumed to indicate a higher intratemporal elasticity between consumption of home and foreign goods in the total consumption index than the elasticity of intratemporal substitution between consumption of export and home goods in the domestic consumption index.

The ratios of consumption of foreign goods in the aggregate consumption, γ_1 and the share of export-goods consumption in the total domestic consumption basket, γ_2 , are assumed to be 0.3 and 0.1 respectively, for an approximated

² According to Teo (2009), the estimated habit persistence parameter of Taiwan is approximately 0.8.

characterization of Taiwan’s consumption pattern. In this model, the steady-state values are quite sensitive to the tax rates. The income and consumption tax rates τ, τ_C are assumed to be slightly higher than the applicable tax rates in Taiwan, which can be approximately 0.15 on average for the income tax and 0.05 for consumption tax respectively. The parameters are specified to generate the steady-state consumption share in GDP to be 0.68, close to 0.7 in the data, and 0.23 of the share of the government expenditure in the GDP to be consistent with 0.2 that the data indicate.

Since the financial system is well established in Taiwan, thus we assume relatively low financial friction parameters. $\mu_i, i = 1, ..3$, which representing the borrowing needs of the export, home-goods and importing firms, were all set equal at a value of 1. The capital coefficient in the export production function, α_2 , is set to to replicate the shares of capital and labor in the economy. Finally the banking reserve and lending cost parameters ϕ_M, ϕ_N , are set to replicate observed low spreads in the financial sector.

Table 2: Calibrated Parameters

<u>Symbol</u>	<u>Definition</u>	<u>Values</u>
β	discount factor	0.99
ϱ	habit parameter	0.8
δ	capital depreciation	0.06
ϕ_x	adjustment cost	0.005
γ_1	foreign cons. in total cons. index	0.3
γ_2	con. of export good in dom.cons. index	0.1
η	relative risk aversion parameter	5.0
ϖ	labor supply elasticity	0.5
γ_L	disutility of labor	0.5
ϕ_C	consumption in CES utility	0.95
\varkappa	CES utility coefficient	-0.1
θ_1	intra-temporal substitution elasticity, total cons	2.5
θ_2	intra-temporal substitution elasticity, domestic cons	1.5
τ, τ_C	tax rates on labor income and consumption	0.2, 0.1
μ_h, μ_x, μ_f	financial friction parameters	1, 1, 1
ζ	substitution elasticity for differentiated goods	6
κ	CES substitution parameter in production	-0.1
α_1	capital coefficient in non-traded goods	0
α_2	capital coefficient in traded goods	0.3
ϕ_M, ϕ_N	deposit and lending costs for banks	0.1, 0.15

Table 2 shows the prior distributions with the means and standard errors as well as values for the infima and suprema of the distributions.

We make use of relatively flat priors for the standard deviations of the shocks in the model. We estimate volatilities for the shocks to government spending, terms of trade, export demand, consumption, monetary policy, export productivity, home-goods productivity, and the foreign interest rate. The coefficients we estimate relate to stochastic process for government spending as well as its pro or counter-cyclical behavior, and the persistence coefficient for shocks to

export demand, terms of trade, foreign interest, consumption, productivity in export and home-goods industries, and the parameters for the monetary rule.

The observables we use for the Bayesian estimation are for consumption, inflation, deposits, the foreign interest rate, the terms of trade, government spending, export demand, and the exchange rates. The data are quarterly from 1998Q1 to 2007Q4. With the exception of the interest rate, all variables are in log first-differences.

Table 3:
Bayesian Priors: Parameters and Distributions

<u>Volatility</u>	<u>Name</u>	<u>Distribution</u>	<u>Mean</u>	<u>Std Dev</u>	<u>Inf</u>	<u>Sup</u>
σ_G	Gov. Spending	Inv. Gamma	.001	2	.005	.5
σ_{Z^x}	Export Prod.	Inv. Gamma	.001	2	.005	.5
$\sigma_{P^{x*}}$	Terms of Trade	Inv. Gamma	.001	2	.005	.5
σ_{R^*}	For. Interest	Inv. Gamma	.001	2	.005	.5
σ_{C^*}	Exports	Inv. Gamma	.001	2	.005	.5
σ_C	Consumption	Inv. Gamma	.001	2	.005	.5
σ_M	Monetary Rule	Inv. Gamma	.001	2	.005	.5
σ_{Z^h}	Home Goods Prod	Inv. Gamma	.001	2	.005	.5
<u>Coefficient</u>						
ρ_{RES}	Money Lag	Beta	.5	.2	.1	.9
ρ_M	Money Target Coeff.	Normal	1	.2	.5	2
ρ_G	Gov. Spending	Beta	.5	.2	.01	.95
ρ_{GY}	Gov. Spending	Normal	0	.1	-.3	.3
$\rho_{P^{x*}}$	Terms of Trade	Beta	.5	.2	.01	.95
ρ_{R^*}	For. Interest	Beta	.5	.2	.01	.95
ρ_{C^*}	Export	Beta	.5	.2	.01	.95
ρ_{Z^h}	Home Goods	Beta	.5	.2	.01	.95
ρ_{Z^x}	Home Goods	Beta	.5	.2	.01	.95
ξ	Calvo Pricing	Beta	.5	.2	.01	.95

5.2 Volatility and Parameter Estimates

The results show relatively low persistence in the conduct of monetary policy. There is relatively higher persistence for the shocks to export productivity than to home-good productivity. The Calvo coefficient is relatively high, showing the same degree of stickiness found in the models of the United States or the Euro Area.

The estimated volatilities are all relatively small, with the exception of the shocks to the foreign interest rate and to monetary policy.

Table 4: Parameter and Volatility Estimates

Coefficient	Mean	Inf	Sup
ρ_{RES}	0.1716	0.1127	0.2373
ρ_M	1.5026	1.4870	1.5189
ρ_{Z^h}	0.6790	0.6329	0.7264
ρ_G	0.5190	0.3723	0.6527
ρ_{GY}	0.5469	0.4852	0.6190
$\rho_{P^{x*}}$	0.6510	0.5601	0.7572
ρ_{R^*}	0.9459	0.9418	0.9499
ρ_{Z^x}	0.9035	0.8388	0.9597
ρ_{C^*}	0.5527	0.4496	0.6680
ξ	0.8830	0.8656	0.8999
Volatility			
σ_G	0.0186	0.0146	0.0230
σ_M	0.2861	0.2407	0.3372
$\sigma_{P^{x*}}$	0.0180	0.0146	0.0210
σ_{R^*}	0.2512	0.2071	0.2943
σ_{C^*}	0.0241	0.0196	0.0280
σ_{Z^x}	0.0093	0.0054	0.0136
σ_C	0.0638	0.0505	0.0766
σ_{Z^h}	0.0491	0.0401	0.0580

5.3 Variance Decomposition

Of course, these estimates tell us nothing about the relative importance of each of the exogenous shocks for key endogenous variables of the model. Table 5 gives the mean of the variance decomposition of the Bayesian estimation. A number of results are expected, for example, that the shock to consumption volatility explains almost half of the volatility of consumption itself. However, the most important shocks are those to export and home goods production as well as to terms of trade, for both inflation, the exchange rate and inflation. Given the highly open nature of the economy, shocks to export productivity explain more of inflation volatility than do shocks to the home goods productivity.

Table 5: Variance Decomposition

DSGE Variable	σ_G	σ_M	$\sigma_{P^{x*}}$	σ_{R^*}	σ_{C^*}	σ_{Z^*}	σ_C	σ_{Z^h}
\hat{c}	0.0053	0.0021	0.0789	0.0040	0.0386	0.1304	0.4934	0.2474
$\hat{\pi}$	0.0249	0.0058	0.0711	0.0179	0.0629	0.3579	0.3282	0.1313
\hat{s}	0.0076	0.0012	0.1808	0.0084	0.0835	0.2593	0.0188	0.4404

6 Counterfactual Simulations

For the counterfactual simulations, we used 1000 experiments for a recurring shock to real export demand, for sample size of 100, with a second-order per-

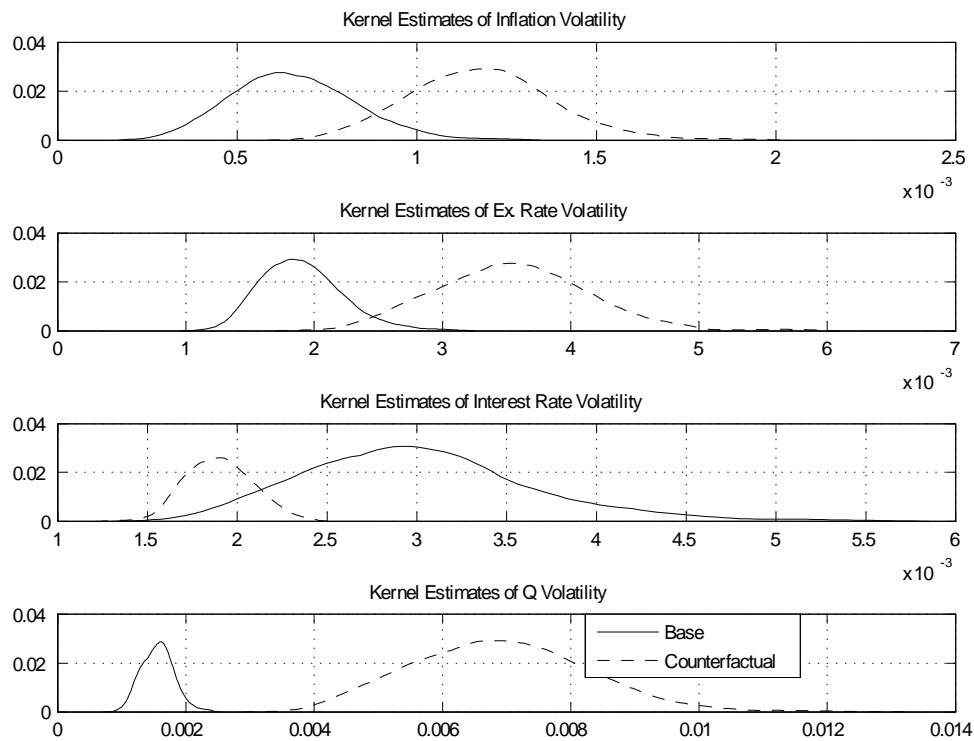


Figure 1: Inflation, Exchange Rate, Interest Rate and Q Volatility under Base and Counterfactual Simulations

turbation solution algorithm. We then computed the Epanechnikov kernel distributions for the standard deviations of key variables, as well as for overall welfare.

6.1 Recurring Shocks to Export Demand

Figure 1 pictures the distributions of the volatility measures of inflation, the exchange rate, the domestic interest rate and Tobin's Q under the base scenario of monetary targeting and the counterfactual Taylor rule inflation targeting. We see that abandoning the money target rule in favor of the interest rate rule leads to increases in volatility of Tobin's Q of several orders of magnitude. For the other variables, there is some in the volatility distributions under both regimes, indicating that either regime can generate the same realized standard deviations of these variables.

Figure 2 pictures the kernel estimates of consumption, investment, and employment volatility. We see a significant increase in the volatilities of consump-

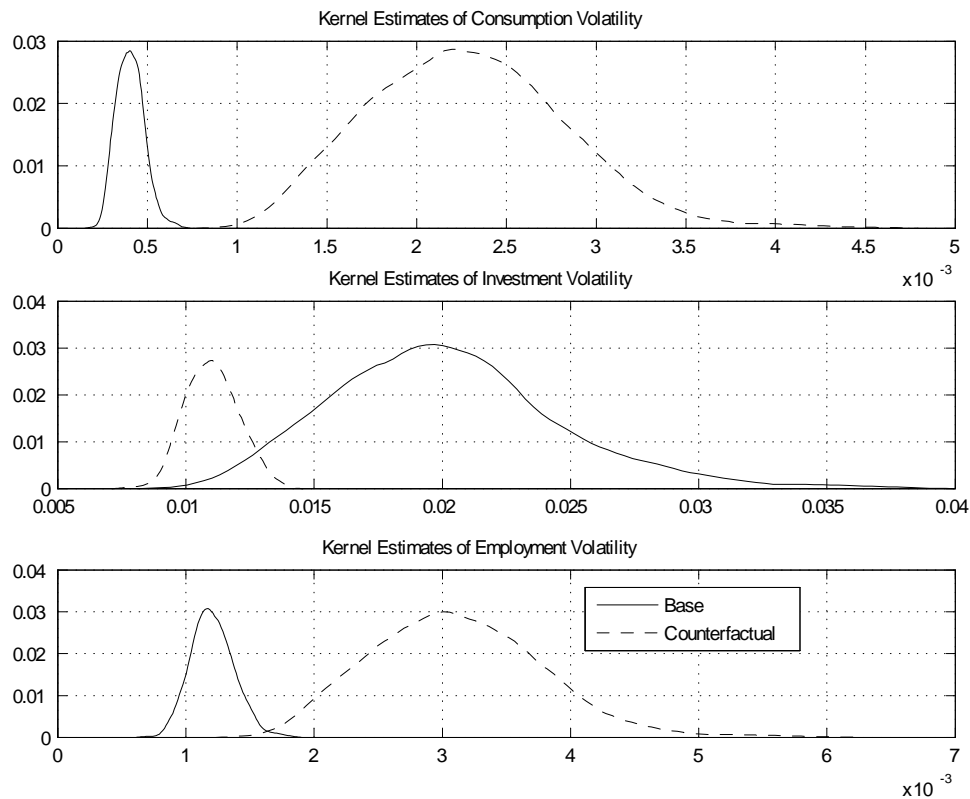


Figure 2: Consumption, Investment and Employment Volatility Under Base Policy and Counterfactual Taylor Rule

tion and employment but a decrease in the volatility of employment were Taiwan to switch to inflation targeting. The intuition for this result is that higher interest rate movements trigger greater consumption and employment volatility. Due to adjustment costs, more variable short term interest rates do not trigger significant differences in the volatility in investment.

Figure 3 pictures the distribution of the volatility of liquidity expansion, deposits by households and lending by the banking sector. The inflation targeting policy leads to lower volatility in central bank liquidity injections, but higher volatility in deposits. The distributions for loan volatility overlap with great dispersion in the case of the money targeting regime.

Figure 4 pictures the distribution of welfare. We see practically no difference. We see that the welfare distribution under the base scenario is more tightly centered around its mean. The inflation-targeting scenario shows that welfare is more widely distributed, either positively or negatively.

To better interpret the differences in the welfare distributions, we calculate

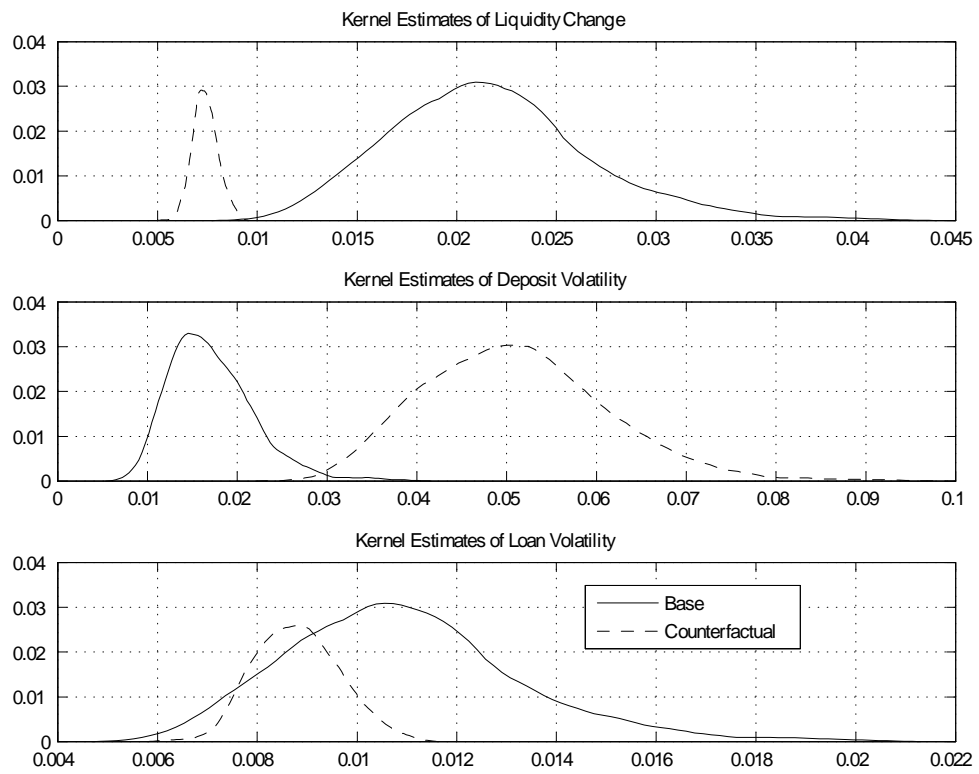


Figure 3: Base Money, Deposit and Loan Volatility under Base and Counterfactual Simulations

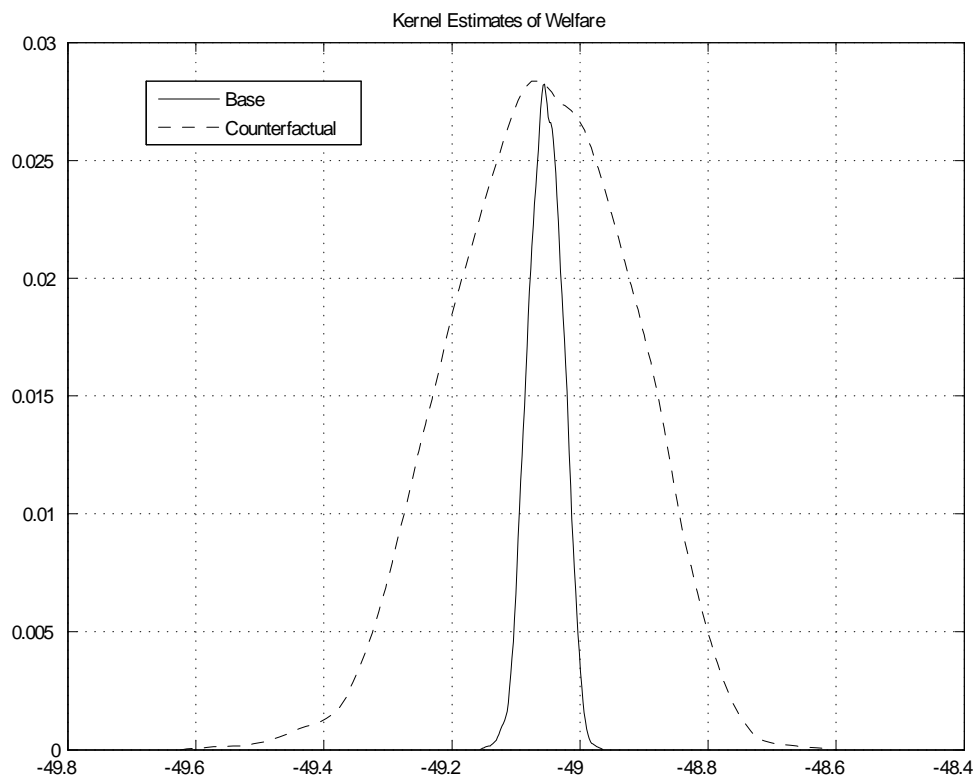


Figure 4: Welfare Distributions Under Base and Counterfactual Simulations

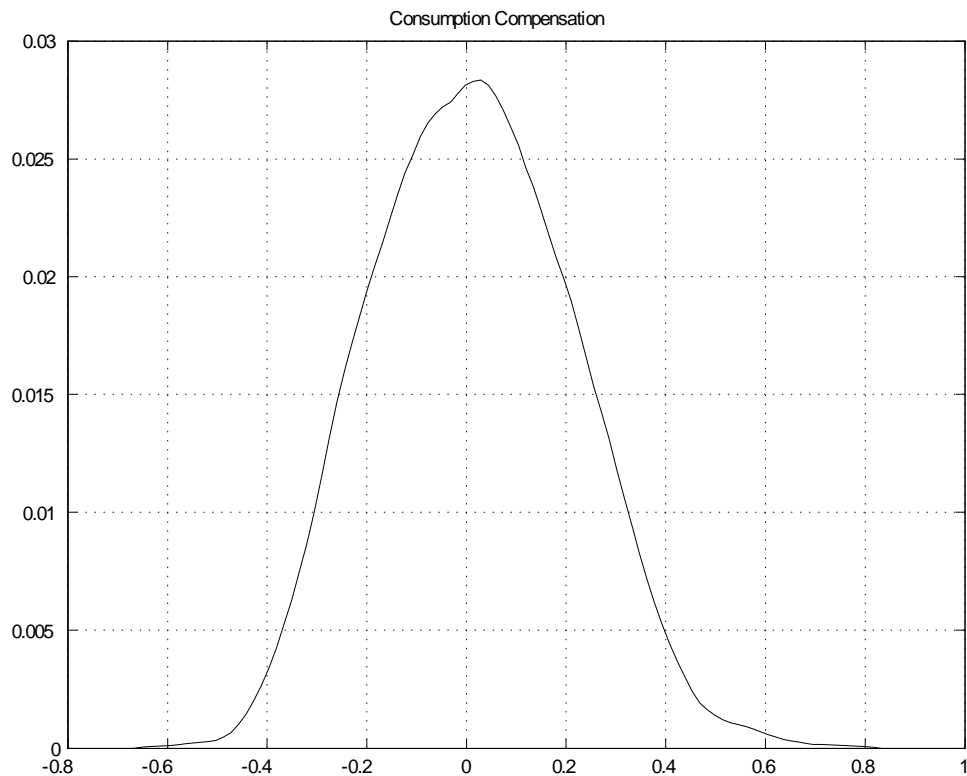


Figure 5: Consumption Compensation for Welfare Equalization in Base and Counterfactual Simulations

the implied consumption compensation required to equalize the welfare of the representative household in the two regimes, suggested by Schmidt-Grohe and Uribe (2004). A positive value implies that the household in the counterfactual scenario is worse off and needs a positive consumption compensation to have the same welfare as households in the base scenario. A negative value means that the household is better off in the counterfactual scenario, and would have to have consumption reduced to be equal to the welfare realized in the base scenario.

Figure 5 shows, at most, that the percentage gain or loss for a representative household between the two regimes would be .6% of a unit of consumption, so that the welfare difference is negligible.

7 Conclusion

Our counterfactual simulation experiments, based on calibrated and Bayesian parameter estimates for Taiwan, suggests that there would be little to gain or lose in welfare, by abandoning monetary targets in favor of inflation targets. The clear-cut difference would be a marked increase in the volatility of Tobin's Q if inflation targeting were to replace monetary targeting.

Our Taylor rule was a simple Taylor rule for inflation targets alone. We did not take into account that the Taylor rule could be amended to include Q -targeting. Clearly a Taylor-type inflation targeting program can be modified to include expanded sets of price indices. But if the standard argument for the Taylor rule is its transparency and simplicity, then such a modification would make this rule less attractive. The key result of this paper is that a simple monetary targeting framework does as well as a Taylor rule for welfare and greatly reduces share price volatility.

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