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Abstract

This paper adopts a dynamic stochastic general equilibrium-vector autorgressive (DSGE-VAR) approach to examine the managed exchange-rate system at work in Singapore. We examine if the country has any reason to fear floating the exchange rate and adopting a Taylor rule. Our results show that, in terms of overall inflation volatility, the exchange rate rule has a comparative advantage over the Taylor rule when export-price shocks are the major sources of real volatility, while a Taylor rule dominates when domestic productivity shocks drive real volatility. The exchange-rate rule also dominates the Taylor rule for reducing inflation persistence.

Key words: Inflation targeting, Taylor rule, Exchange-rate management, DSGE-VAR estimation

JEL Classificaltion: E52, E62,F41

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1 Introduction

Should Singapore fear floating its exchange rate by adopting a Taylor rule? [1] Calvo and Reinhart (2002) noted that many emerging markets retain a preference for a managed float with much less flexibility than is commonly assumed by official exchange-rate classification schemes. Lack of credibility of the monetary authority or liability dollarization, they note, are major reasons emerging market countries would avoid floating and adopting a Taylor rule. However, there are other reasons which may be more relevant for a small, highly open and fast growing economy such as Singapore.

Reflecting the small open nature of its economy, Singapore has adopted in 1981 (effectively, but not officially) an inflation-targeting exchange rate centered monetary policy framework.[2] Given the open-economy trilemma, monetary policy can only achieve two of the following three dimensions: monetary policy independence, fixed exchange rates, and open capital accounts. As a major financial centre, Singapore has chosen free capital mobility. Hence, it can only choose to target either the exchange rate or some other monetary variable, but not both. The Monetary Authority of Singapore (MAS) has chosen to use the exchange rate as opposed to the more conventional benchmark policy interest rate as its policy operating tool since the early 1980s (MAS, 2000).

This is not surprising as the highly open and trade-dependent nature of the economy suggest that the exchange rate could be an effective tool for managing the state of the economy. Singapore is highly dependent on external demand which constitutes about seventy percent of aggregate demand. Moreover, domestic consumption has a high import content — out of every Singapore dollar spent domestically, about fifty cents are applied to imports. Being a price-taker in international markets, it is logical to assume that Singapore is highly susceptible to imported inflation. It would appear that Singapore has been well served by an unofficial "inflation-targeting" managed exchange rate-centered monetary policy framework with free capital mobility and with the domestic short-term interest rates determined by foreign interest rates, allowing for a time-varying risk premium.

Managing the exchange rate comes with a cost, namely, the fear of speculative attacks. With the exception of the Asian crisis period in 1997, the MAS has successfully deterred speculators from attacking the domestic currency over the past three decades. But it has been argued that it is the flexibility accorded by the managed exchange rate system that aided Singapore in escaping from the Asian crisis relatively unscathed. Singapore's acceptance of market driven depreciations in the wake of and amid the deepening of the Asian financial crisis deterred currency speculators from engineering over-depreciation in the domestic currency (Yip, 2005). In other words, it is as if the Singapore dollar was on a free float during this period.[3]

[1] The interest-rate feedback rule for inflation targeting was extensived analyzed by Taylor (1993) and is commonly known as the Taylor rule.

[2] In practice, the Monetary Authority of Singapore (MAS) adopts an intermediate exchange rate regime by targeting the Singapore dollar under a basket-band-crawl (BBC) system (Khor et al, 2004; Williamson, 1999). Under this managed float system, the Singapore dollar is related to a trade-weighted basket (termed TWI) of currencies of its major trading partners and competitors. Neither the component currencies, their assigned weights in the basket, the central rate, nor the band limits are disclosed by the MAS.

[3] Of course, Singapore's substantial amount of foreign reserves played a critical role in de-

The Asian financial crisis raised awareness that pegged exchange rates and its attendant insurance effect exacerbated boom-bust cycles associated with capital flows, thereby contributing to the crisis (Cossetti et al., 1999). This prompted many central banks in East Asia to shift their focus from exchange rate stability to price stability. In particular, crisis-hit countries like Indonesia, (South) Korea, Philippines and Thailand announced the explicit adoption of inflation targeting and the move towards using interest rates as the key monetary policy instrument. However, unless capital controls are imposed, the open economy trilemma dictates that countries that adopt inflation targeting should necessarily have a freely floating exchange rate regime as well. Should Singapore follow suit?[4]

The MAS' stated objective for monetary policy is "to ensure low inflation as a sound basis for sustained economic growth". In practice, then, the exchange rate became the policy instrument to stabilize inflation and output around their desired target levels while the interest rate was effectively tied to the foreign rate. An alternative set-up is to use the interest rate as the policy instrument, while the exchange rate adjust to market forces. Should Singapore float its currency and adopt a Taylor rule?

To determine if the conduct of monetary policy would have been more welfare enhancing had the interest rate been used as the policy operating instrument in place of the exchange rate requires counter-factual experiments and simulation analysis. This is the purpose of this paper.

In a VAR analysis of Singapore's monetary transmission mechanism, Chow (2005) found that the exchange rate was more influential than the interest rate as a source of macroeconomic fluctuations. However, the VAR methodology cannot be used to address the question of "what if" had Singapore adopted an alternative policy rule. This has to be examined in a framework where the estimated parameters are not intrinsically linked to the historical policy settings - the so-called Lucas critique of policy analysis. Hence the framework adopted in this paper, belongs to the class of models called dynamic stochastic general equilibrium (DSGE) or New Keynesian models of the small open economy.

In the next section we lay out a DSGE model of the Singapore economy with its current exchange-rate regime and with nominal and real frictions in the form of sticky wages and prices, habit persistence in consumption, and adjustment costs for investment. We then discuss the results of a Bayesian estimation of the model. Finally we undertake counterfactual simulations assuming a floating exchange rate system with a Taylor rule for the interest rate and perform welfare comparisons under the two monetary regimes. The last section concludes.

terring speculative attacks. Further, strong economic fundamentals such as consistent fiscal surplus, large current account surplus, maintenance of stable and consistent macroeconomic policies, and a robust financial system are important explanations why Singapore was relatively less affected by the Asian crisis.

[4]Some market participants have advocated a move to greater flexibility in the exchange rate to guard against the risk of policymakers misjudging the level of Singapore's equilibrium exchange rate. However, others have pointed out that increasing flexibility in the TWI would increase the risk of the Singapore dollar overshooting and is thus, destabilizing.

2 Model

We model the Singapore macro economy as the aggregate outcome of the interactions of four sectors. The household sector provides labour services, owns the capital stock, makes consumption and investment decisions, and holds domestic and foreign bonds. In supplying labor to the firms, the household sets its wage in a monopolistically competitive fashion. All financial interactions are subsumed into this sector. The production sector is mainly responsible for combining capital and labour to produce the goods. It sets the prices of domestic goods in a monopolisticlaly competitive way. The government sector buys domestic goods and services while collecting lump sum taxes from households, and implements the policies under consideration, namely exchange-rate management. The fourth sector is the external sector. Singapore is a small open economy and takes world prices and interest rates as given.

The equations of the model are standard in the literature, and we have focussed on behavior which capture the key features of the Singapore economy, namely its high degree of openness. We allow real-sector frictions, in the form of habit persistence in consumption and adjustment costs in investment. There are two forms of nominal stickiness, one in wage setting and the other in the setting of domestic final-goods prices.

2.1 Household sector

The intertemporal welfare (V) and utility function (U) for the household sector are:[5]

$$\begin{aligned} V &= E_0 \sum_{t=0}^{\infty} \beta^t U_t(C_t, L_t) \\ U_t(.) &= \frac{(C_t - \rho^c \overline{C}_{t-1})^{1-\eta}}{1-\eta} - \gamma \frac{L_t^{1+\varpi}}{1+\varpi} \end{aligned} \tag{1}$$

where β is the discount factor, C is consumption with habit persistence parameter ρ^c, L is labour services, η is the coefficient of relative risk aversion, ϖ is the Frisch labour supply elasticity, and γ is the disutility of labour. We assume that the habit process is an external one, so that the habit stock at time $t+i$ is based on the average past period's consumption, $\rho^c \overline{C}_{t+i-1}$, The symbol E_0 is the expectations operator at time $t = 0$.

The household budget equation can be written as:

$$W_t L_t + R_t^k K_t + \Gamma_t + T_t + R_{t-1} B_{t-1} + (R_{t-1}^* + H_{t-1}) S_t B_{t-1}^* = B_t + S_t B_t^* + P_t^c C_t + P_t^i I_t \tag{2}$$

where W is the wage rate, R^k is the nominal rental rate on capital K, Γ is distributed profits, T is taxes and transfers; B (B^*) are domestic (foreign) bonds while R (R^*) are the gross interest rates on domestic and foreign bonds with S as the exchange rate expressed as domestic to foreign currency and H is a risk premium. The price index of consumption is given by P^c, and for investment goods by P^i. The financial assets are state-contingent with one

[5] Since the relationships between the micro (many households, differentiated labour, and monopolistic competition) and their macro (aggregate) counterparts are well-known, we have only presented the aggregate equations here.

period maturity. Following Devereux, Lane and Xu (2006), we assume that capital evolves according to the following law of motion:

$$K_t = \left[\frac{I_t}{K_{t-1}} - \frac{\phi}{2} \left(\frac{I_t}{K_{t-1}} - \delta \right)^2 \right] K_{t-1} + (1-\delta) K_{t-1} \tag{3}$$

where δ is the depreciation rate and ϕ is an adjustment cost factor, $\phi > 0$.

The household purchases consumption C_t and investment goods I_t,as well as goverhment and foreign bonds and pays lump sum taxes, T_t. It rents capital and supplies labor to firms, and receives wage income $W_t L_t$ and rental income from capital, $R_t^k K_t$.

The household sector takes P^i, P^c, W, R^k, R, R^*, and S as given and the paths for consumption (C), capital (K), domestic (B) and foreign (B^*) bond holdings are obtained by solving the Lagrangean problem (maximize present value of utility (1) subject to the budget constraint (2) and the law of motion for capital (3)). This yields the Euler equations below:

$$\frac{(C_t - \rho^c C_{t-1})^{-\eta}}{P_t^c} = \beta \frac{(C_{t+1} - \rho^c C_t)^{-\eta}}{P_{t+1}^c} R_t \tag{4}$$

$$R_t S_t = (R_t^* + H_t) S_{t+1} \tag{5}$$

$$Q_t \left[1 - \phi \left(\frac{I_t}{K_{t-1}} - \delta \right) \right] = \left[\frac{(C_t - \rho^c C_{t-1})^{-\eta}}{P_t^c} \right] P_t^i \tag{6}$$

$$Q_t = \left[\frac{(C_t - \rho^c C_{t-1})^{-\eta}}{P_t^c} \right] R_t^k + \beta Q_{t+1} \left[\begin{array}{c} \frac{\phi}{2} \left(\frac{I_{t+1}^2}{K_t^2} \right) \\ -\frac{\phi}{2} \delta^2 + (1-\delta) \end{array} \right] \tag{7}$$

Household expenditures are for consumption (C) or for investment (I) at respective prices P^c, P^i. Consumption and investment goods are mainly, but not totally, imported and they are modeled respectively as CES functions:

$$C_t = \left[(1-\theta_c)^{1/\mu_c} \left(C_t^d \right)^{(\mu_c - 1)/\mu_c} + \theta_c^{1/\mu_c} \left(C_t^m \right)^{(\mu_c - 1)/\mu_c} \right]^{\mu_c/(1-\mu_c)} \tag{8}$$

$$C_t^d = (1-\theta_c) \left(\frac{P_t^d}{P_t^c} \right)^{-\mu_c} C_t \tag{9}$$

$$C_t^m = \theta_c \left(\frac{P_t^m}{P_t^c} \right)^{-\mu_c} C_t \tag{10}$$

$$P_t^c = \left[(1-\theta_c) \left(P_t^d \right)^{1-\mu_c} + \theta_c \left(P_t^m \right)^{1-\mu_c} \right]^{1/(1-\mu_c)} \tag{11}$$

$$I_t = \left[(1-\theta_i)^{1/\mu_i} \left(I_t^d \right)^{(\mu_i - 1)/\mu_i} + \theta_i^{1/\mu_i} \left(I_t^m \right)^{(\mu_i - 1)/\mu_i} \right]^{\mu_i/(1-\mu_i)} \tag{12}$$

$$I_t^d = (1-\theta_i) \left(\frac{P_t^d}{P_t^i} \right)^{-\mu_i} I_t \tag{13}$$

$$I_t^m = \theta_i \left(\frac{P_t^m}{P_t^i} \right)^{-\mu_i} I_t \tag{14}$$

$$P_t^i = \left[(1-\theta_i) \left(P_t^d \right)^{1-\mu_i} + \theta_i \left(P_t^m \right)^{1-\mu_i} \right]^{1/(1-\mu_i)} \tag{15}$$

where θ_c, θ_i are the respective share parameters and μ_c, μ_i represent the intratemporal elasticities of substitution for consumption and investment.. The world price for the imported consumption and investment goods are highly correlated and we have represented this as P^m.

The Singaporean labour market does not clear, and wages are modeled as staggered contracts with a fraction $(1-\xi_w)$ renegotiated each period. Each household chooses the optimal wage W_t^o by maximizing the expected discounted utility subject to the demand for its labor $L_t^h = \left(\frac{W_t^o}{W_t}\right)^{-\zeta_w} L_t$ where ζ_w is a parameter governing the degree of substitution. This behavior is modeled in a similar manner to the Calvo sticky prices and the model is written in recursive form as:

$$W_t^{num} = (W_t)^{\zeta_w + \zeta_w \varpi} \left(L_t^{1+\varpi}\right) + \xi_w \beta . W_{t+1}^{num} \quad (16)$$

$$W_t^{den} = \left(\frac{(C_t - \rho^c C_{t-1})^{-\eta}}{P_t^c}\right) (W_t)^{\zeta} L_t + \xi_w \beta . W_{t+1}^{den} \quad (17)$$

$$(W_t^o)^{1+\zeta_w \varpi} = \frac{W_t^{num}}{W_t^{den}} \quad (18)$$

$$W_t = \left[\xi_w (W_{t-1})^{1-\zeta_w} + (1-\xi_w)(W_t^o)^{1-\zeta_w}\right]^{\frac{1}{1-\zeta_w}} \quad (19)$$

where, W_t^{num} and W_t^{den} are auxiliary variables in the formula.

2.2 Production sector

Aggregate demand (Y_t) comes from domestic consumption, government spending (G), exports (X) and investment:[6]

$$Y_t = C_t^d + G_t + X_t + I_t^d \quad (20)$$

Aggregate supply is a function of capital and labor:

$$Y_t = K_t^{\alpha} (Z_t L_t)^{1-\alpha} \quad (21)$$

$$\log(Z_t) = \log(Z_{t-1}) + \epsilon_t^z; \quad \epsilon_t^z \sim N(0, \sigma_z^2) \quad (22)$$

where Z_t is an economy-wide unit-root technology shock and α is a parameter that determines the degree of capital intensity for production. The profits of the firms are given by the following relationships, and distributed to the households:

$$\Gamma_t = P_t Y_t - W_t L_t - R_t^k K_t$$

Maximizing profits also implies the following relationship:

$$\frac{\alpha W_t}{(1-\alpha) R_t^k} = \frac{K_t}{L_t} \quad (23)$$

[6] To simplify the analysis, we assume that output is transformed into goods for different end-users and that the markets are segmented.

We assume sticky monopolistically competitive firms and they set the price for goods sold both domestically and in foreign markets. According to the Calvo price setting world, there are forward-looking price setters and backward looking setters. Assuming at time t that ξ_p is the probability of persistence, with demand for the product from firm j given by $Y_t \left(P_t^j / P_t\right)^{-\zeta_p}$, the optimal price, P_t^o can be written in recursive formulation as follows:[7]

$$A_t = \frac{\left(R_t^k\right)^{\alpha} W_t^{1-\alpha}}{Z_t} \left(\frac{1}{(\alpha)^{\alpha}(1-\alpha)^{1-\alpha}}\right) \tag{24}$$

$$P_t^o = \frac{P_t^{num}}{P_t^{den}} \tag{25}$$

$$P_t^{num} = Y_t \left(P_t\right)^{\zeta_p} A_t + \beta \xi_p P_{t+1}^{num} \tag{26}$$

$$P_t^{den} = Y_t \left(P_t\right)^{\zeta_p} + \beta \xi_p P_{t+1}^{den} \tag{27}$$

$$P_t = \left[\xi_p \left(P_{t-1}\right)^{1-\zeta_p} + \left(1-\xi_p\right)\left(P_t^o\right)^{1-\zeta_p}\right]^{\frac{1}{1-\zeta_p}} \tag{28}$$

where A is the marginal cost and ζ_p is a substitution parameter.

2.3 Government Sector

The Treasury/Central Bank receives taxes and borrows to finance government expenditure. The evolution of the domestic debt is:[8]

$$B_t = P_t^d G_t + B_{t-1} R_{t-1} + T_t \tag{29}$$

where government spending G_t is assumed to follow a simple exogenous autoregressive process and include a normally distributed innovation ϵ^g with variance σ_g^2 :

$$\log(G_t) = \rho^g \log(G_{t-1}) + (1-\rho^g)\log(\overline{G}) + \epsilon_t^g; \qquad \epsilon_t^g \sim N(0, \sigma_g^2) \tag{30}$$

The aim of monetary policy is to manage the exchange rate to "target" inflation, that is the exchange rate is engineered to appreciate (-) to manage domestic inflation. Following McCallum (2006)[9], we model the behavior of the Monetary Authority of Singapore as following an exchange rate rule:[10]

$$\log(S_{t+1}/S_t) = \rho^s \log(S_t/S_{t-1}) - (1-\rho^s)\psi(\log(\Pi_{t+1}^c/\overline{\Pi^c})); \qquad \psi > 0 \tag{31}$$

[7] For more details of the derivation see for example, Walsh (2003), chapter 5: Money, Output and Inflation in the Short-run

[8] We assume that the exogenous taxes prohibit that debt from becoming non-stationary.

[9] We note that this specification does not include an output-gap term. This does not mean that variations in growth are not considered, only that they are considered via their impact on inflation.

[10] In its semiannual monetary policy cycle, the MAS would announce the exchange rate policy stance through a Monetary Policy Statement. Apart from changes to the crawl in the central parity, there could be a re-centering of the policy band. Another form of adjustment is through changing the width of the band of fluctuations. Essentially, the exchange rate is used as an intermediate monetary policy instrument to achieve the primary objective of non-inflationary growth. In a sense, monetary policy is operated in Singapore as sort of a hybrid between the BBC and inflation targeting. In practice, an adjustable band is used to track the movement of its instrument, while setting its instrument in a way to hit intermediate targets as a means to control inflation and achieve non-inflationary growth (Khor et al. 2004). In this way, the BBC system can be operated to achieve the same objectives as inflation targeting.

The parameter ρ_s measures the persistence and ψ is a reaction coefficient, specified so that the exchange rate appreciates when inflation rises. The gross inflation is for the consumer price index, with $\Pi^c_{t+1} = P^c_{t+1}/P^c_t$.[11]

2.4 External Sector

Singapore is a very open economy and highly susceptible to international factors. Since it is a very small open economy we have modeled the external forces as autoregressive processes. The foreign interest rate R^* is assumed to follow the following autoregressive process (in log terms):

$$\log(R^*_t) = \rho^{r*} \log(R^*_{t-1}) + (1-\rho^{r*}) \log(\overline{R^*}) + \epsilon^{r*}_t \quad \epsilon^{r*}_t \tilde{} N(0, \sigma^2_{r*}) \tag{32}$$

To ensure that the small open economy is closed, we follow Schmitt-Grohe and Uribe (2003) and allow the risk premium to react to the deviation of foreign debt:

$$\log(H_t) = \rho^h \log(H_{t-1}) + (1-\rho^h)\left(\overline{H} + \varphi \log(B^*_t/\overline{B^*_t})\right) + \epsilon^h_t; \qquad \epsilon^h_t \sim N(0, \sigma^2_h) \tag{33}$$

with $\varphi < 0$; the greater the deviation of foreign assets from the steady-state level, the lower the risk premium. Foreign assets evolve as follows:

$$P^x_t X_t - P^m_t (I^m_t + C^m_t) = S_t(B^*_t - B^*_{t-1}(R^*_{t-1} + H_{t-1})) \tag{34}$$

$$P^m_t = S_t P^{m^*}_t \tag{35}$$

$$P^x_t = S_t P^{x^*}_t \tag{36}$$

and the feedback loop from debt to risk premium ensures that foreign debt do not become indeterminate. Following evidence reported in Chew, Ouliaris and Meng (2009), we assume full pass-through of exchange-rate changes to the domestic prices of imported goods. The demand for export goods by trading partners is modeled in a similar way to the Singaporean demand for imported goods:

$$X_t = \theta_f \left(\frac{P^x_t}{P^w_t}\right)^{-\mu_f} Y^*_t \tag{37}$$

where θ_f represents the share of imported goods in the trading partners' total expenditure, μ_f is the intratemporal elasticity of substitution for domestic and imported components, Y^*_t is a measure of the GDP of trading partners, and P^w_t is the world price index, normalized to unity.

The Singapore economy is sensitive to world prices and world output. These processes, namely the trading partners' GDP Y^*, import prices $P^{m^*}_t$, and export

[11] Note that the term $(1-\rho_s)\log(\overline{S})$ has been dropped because $\log(\overline{S}) = 0$.

prices $P_t^{x^*}$ are all modeled to follow an autoregressive stochastic process:[12]

$$\log(Y_t^*) = \rho^{y*}\log(Y_{t-1}^*) + (1-\rho^{y*})\log(\overline{Y}^*) + \epsilon_t^{y*}; \quad \epsilon_t^{y*} \sim N(0,\sigma_{y*}^2) \tag{38}$$

$$\log(P_t^{m*}) = \rho^{pm*}\log(P_{t-1}^{m^*}) + (1-\rho^{pm*})\log(\overline{P^{m*}}) + \epsilon_t^{pm*}; \quad \epsilon_t^{m*} \sim N(0,\sigma_{pm*}^2) \tag{39}$$

$$\log(P_t^{x*}) = \rho^{px*}\log(P_{t-1}^{x*}) + (1-\rho^{px*})\log(\overline{P^{x*}}) + \epsilon_t^{px*}; \quad \epsilon_t^{x*} \sim N(0,\sigma_{px*}^2) \tag{40}$$

In summary, the model contains 7 processes and a number of autoregressive, reaction and deep parameters. We turn now to the estimation of the log-linearised model.

2.5 Log-Linear Model

Following standard practice, the model described above is log-linearised. Then since the original variables are non-stationary, we adopt the practice of transforming the variables so that the estimated model contains stationary variables. There are two types of manipulations; the first is to detrend real variables by productivity ($\widetilde{y}_t = \log(Y_t/Z_t)$) and the second is to recast price variables into relative terms (that is, work with $\pi_t = \log(P_t/P_{t-1})$).

Another point to mention is the index of openness. Singapore is a very open economy and based on equation (20), we obtain a price relationship:

$$P_t = P_t^d(1-\Theta) + P_t^x\Theta \tag{41}$$

where Θ is a measure of the share of exports in economic activity (see Monacelli and Gali, 2005).[13]

3 Empirical Analysis

We estimate the model for seven stochastic shocks: for government spending, foreign trading partners' weighted GDP, import and export price inflation, foreign interest rates, the risk premium, and productivity. We use seven observables: government spending, weighted GDP of trading partners[14], import price inflation, the foreign interest rate, the risk premium (calculated as the domestic interest differential less the realized change in the exchange rate), domestic GDP growth and inflation. With the exception of the foreign interest rate (LIBOR) and the risk premium, all of the observables are in log first differences. The estimation is carried out for the sample period 1985.1-2009.4.

[12] In the empirical section, we have also modelled these processes to allow for some cross-effects in a VAR framework. We find that the cross-terms were not significant.

[13] The coefficient γ drops out in the log-linear model, but an estimate can be derived from the steady state conditions. The estimate is used in computing utility/welfare in the counterfactual experiments.

[14] This series is constructed by Abeyshinghe and Forbes (2005) and the data source is http://www.fas.nus.edu.sg/ecs/esu/data.html. It is an export share weighted average of the real GDPs of the following countries: Hong Kong, Indonesia, Malaysia, Philippines, Thailand, Taiwan, USA and OECD as one group. To allow for changes in the country composition of Singapore trade, the export shares are computed as 12-quarter moving average.

The results are presented in the following sections. The estimated parameters were based on two methodologies (the DSGE and the DSGE-VAR) as a check for robustness of estimates. We examine the shocks, the impulse response functions and the conditional variance decompositions. Using information from the extracted implied shocks, we also interpret how they have contributed to the changes in the growth of GDP and inflation over the sample period.

3.1 Estimation: DSGE and DSGE/VAR

We estimate the model for Singapore in a pure DSGE framework as well as in a DSGE/VAR framework, following Del Negro, Marco and Schorfheide (2004, 2010), Adjemian, Darracq and Moyen (2008), and An and Kang (2009). The intuition for using the hybrid DSGE/VAR approach comes from recognizing that a pure DSGE model could suffer from specification errors, and that the explanatory power of the model could be improved by the use of a non-structural VAR model. The weight of the pure VAR, relative to the pure DSGE model, is given by the ratio $1/(1+\lambda)$. If $\lambda = 0$, the pure VAR model explains all the variation in the data, and if $\lambda = \infty$, the pure DSGE explains the variation in the data without any input from the VAR[15]. The advantage of using the hybrid DSGE/VAR Bayesian model is thus to provide a specification test of the DSGE model relative to the widely used non-structural alternative, the VAR, with $0 < \lambda < \infty$ indicating the merit of the DSGE relative to the VAR.

Table 1: Marginal Likelihood

	DSGE	DSGE/VAR
	$--$	$\lambda = 1.303$
Laplace Approximation	2127.049	2185.322
Modified Harmonic Mean	2124.905	2182.981

Table 1 shows the relative fit of the DSGE model to a VAR model. The best fit gives the median $\lambda = 1.303$ by both the Laplace and Harmonic Mean measurements of the Marginal Likelihood. We note, as expected, that the DSGE/VAR has a higher marginal likelihood than the pure DSGE model. Given this result, we make use of the DSGE/VAR parameters for more detailed model analysis.

[15]However, we also note that stimating a pure DSGE is not identical to estimation of a DSGE/VAR with $\lambda = \infty$, since the DSGE/VAR relies on a finite lag structure.

3.2 Parameter and Volatility Estimates

All of the structural parameters (for example behavioural parameters η, ϖ, dynamic parameters ρ^g, ρ^{r*}, standard deviations of the shocks parameters σ_z^2, σ_g^2, were estimated, except for the discount factor β which is calibrated for a steady-state annual gross interest rate of 1.04.[16] In the log-linearized model, we specified the steady-state share of consumption to GDP at 0.6, and the steady-state share of government spending to GDP at 0.1. These ratios are the mean values of actual data. The net export ratio is 0.3.

Table 2 shows the priors and the posterior estimates under the pure DSGE and the DSGE/VAR framework for the median $\lambda = 1.303$. The table contains the median and mean values of the Bayesian estimates for 200,000 simulations in four blocks. We also show the infimum and supremum of each estimate for a 95% confidence interval.

The priors are those commonly used in Bayesian models. We follow closely the specifications of Teo (2009) who estimated a DSGE model for Taiwan. We set the intratemporal elasticity of substitution for investment and for foreign demand, μ_i and μ_f at 1.5 but specified the intratemporal elasticity for consumption, μ_c at 5, following evidence for this parameter presented by Alolfson, Laseen, Linde and Villani (2007). We set the prior for the adjustment cost coefficient for investment, ϕ, at 200, in order to ensure that the volatility of investment matched the observed volatility in the data.

With respect to the differences between the DSGE and DSGE/VAR estimates, the parameters ρ^g, ρ^{y*} for the autoregressive process for government spending and foreign GDP growth show more persistence in the pure DSGE than in the DSGE/VAR framework. For the remaining parameters, Table 2 shows that the 95% confidence interval estimates for the DSGE and DSGE/VAR frameworks have a considerable degree of overlap.

Another point to note is with respect to the degrees of price and wage stickiness. The Calvo price stickiness parameter estimate is much lower than those commonly found in models of the US or UK, but its 95% confidence interval is within the corresponding confidence interval for Taiwan [0.48 0.77], reported by Teo (2009). It would appear, however that wages are a lot more flexible than prices in the Singapore economy. Reforms were implemented in the Singapore labour market (around late 1980s) to promote a more flexible wage system by encouraging companies to pay both a base rate and a variable component linked to productivity and profitability.

Table 2 also contains the volatility estimates. We see that in general, with the exception of σ_{px*}, the estimated volatilities are slightly lower in the DSGE/VAR model than in the DSGE model.

[16] Since the model is in log-linear deviations, there is no need to calibrate the model for parameters which affect the steady state, as suggested by Christiano, Motto, and Rostagno (2007). We also abstract from tax effects because they are small and only affect the bond accummulation equation. The shares are sample averages.

Table 2: Prior and Posterior Estimates

Coefficient Estimates

	Priors			Posteriors				Posteriors			
				DSGE				DSGE/VAR			
	Dist	Mean	Std.Dev.	Median	Mean	.025	.975	Median	Mean	.025	.975
ρ^g	Beta	0.500	0.200	0.905	0.902	0.867	0.937	0.653	0.649	0.517	0.777
ρ^{y*}	Beta	0.500	0.200	0.899	0.897	0.860	0.932	0.735	0.732	0.627	0.832
ρ^r	Beta	0.500	0.200	0.958	0.956	0.931	0.985	0.933	0.927	0.872	0.974
ρ^{px*}	Beta	0.500	0.200	0.948	0.947	0.924	0.972	0.849	0.842	0.749	0.935
ρ^{pm*}	Beta	0.500	0.200	0.211	0.211	0.095	0.316	0.199	0.201	0.067	0.326
ρ^s	Beta	0.500	0.200	0.098	0.104	0.023	0.180	0.145	0.158	0.030	0.282
ρ^h	Beta	0.500	0.200	0.422	0.424	0.278	0.569	0.251	0.253	0.088	0.410
φ	Beta	0.010	0.100	0.005	0.005	0.002	0.008	0.006	0.007	0.002	0.013
θ_c	Beta	0.500	0.200	0.487	0.487	0.406	0.568	0.497	0.496	0.413	0.577
θ_i	Beta	0.800	0.200	0.803	0.799	0.709	0.889	0.797	0.799	0.721	0.881
ξ_p	Beta	0.500	0.200	0.439	0.441	0.333	0.545	0.435	0.435	0.321	0.554
ξ_w	Beta	0.500	0.200	0.290	0.290	0.191	0.379	0.244	0.246	0.163	0.333
ζ_w	Normal	6.000	1.000	5.659	5.662	3.920	7.468	5.600	5.626	3.869	7.537
η	Normal	2.500	0.200	2.677	2.682	2.395	2.995	2.582	2.578	2.255	2.925
ϖ	Beta	0.500	0.200	0.145	0.176	0.019	0.339	0.164	0.233	0.009	0.514
α	Beta	0.500	0.050	0.416	0.415	0.340	0.496	0.444	0.445	0.362	0.523
ψ	Normal	1.500	0.200	1.541	1.558	1.195	1.900	1.726	1.754	1.277	2.194
δ	Beta	0.020	0.005	0.019	0.019	0.011	0.027	0.020	0.020	0.013	0.028
μ_c	Normal	5.000	0.500	2.286	2.305	2.012	2.619	2.304	2.312	2.061	2.573
μ_i	Normal	1.500	0.200	1.247	1.261	1.004	1.497	1.254	1.249	1.017	1.453
μ_f	Normal	1.500	0.200	1.388	1.395	1.165	1.640	1.321	1.332	1.069	1.573
ϕ	Normal	200	50	246.057	245.166	162.138	324.906	251.387	251.325	165.709	337.836
ρ^c	Beta	0.500	0.200	0.768	0.756	0.637	0.887	0.741	0.736	0.605	0.869
Θ	Normal	0.700	0.300	0.695	0.696	0.663	0.723	0.698	0.698	0.663	0.726
λ	Uniform	[0 5]		–	–	–	–	1.304	1.330	0.996	1.654

Volatility Estimates

	Priors			Posteriors				Posteriors			
				DSGE				DSGE/VAR			
	Dist	Mean	Std.Dev.	Median	Mean	.025	.975	Median	Mean	.025	.975
σ^z	Inv.gamma	0.01	0.5	0.005	0.005	0.004	0.006	0.004	0.004	0.003	0.005
σ^g	Inv.gamma	0.01	0.5	0.025	0.025	0.022	0.028	0.019	0.019	0.016	0.022
σ^{y^*}	Inv.gamma	0.01	0.5	0.007	0.007	0.006	0.008	0.004	0.004	0.004	0.005
σ^r	Inv.gamma	0.01	0.5	0.002	0.002	0.001	0.002	0.001	0.001	0.001	0.001
σ^{p^x}	Inv.gamma	0.01	0.5	0.004	0.004	0.003	0.006	0.008	0.009	0.004	0.013
σ^{p^m}	Inv.gamma	0.01	0.5	0.024	0.024	0.021	0.026	0.018	0.018	0.015	0.021
σ^q	Inv.gamma	0.01	0.5	0.015	0.015	0.013	0.017	0.012	0.012	0.010	0.014

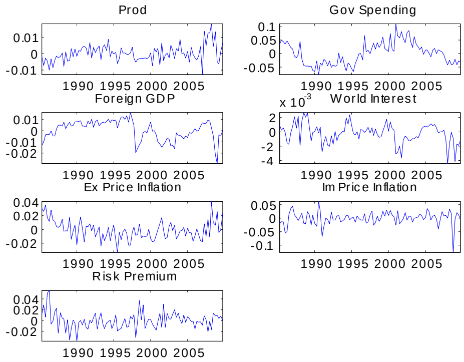

Figure 1: Smoothed Shocks from the DSGE/VAR Model

3.3 Estimated Shocks

Figure 1 pictures the smoothed shocks extracted from the estimation of the DSGE/VAR model and they appear to confirm a priori perceptions. As reflected in the negative shocks in foreign GDP, the Singapore economy was hit by a succession of external shocks from mid 1990s to early 2000. These include the 1996-97 downturn in the global electronics industry, the 1997-98 Asian financial crisis, the 2001 burst of information technology bubble and the 2003 outbreak of the SARS respiratory disease. In response to the various episodes of economic slowdown, the government introduced cost-cutting measures and bring forward various social infrastructure projects. Hence, government shocks appears to be a driver from mid 1990s until early 2000.

Export demand was on an uptrend from mid 2000s till the lead up to the global financial crisis, not least because of the growing importance of China as a market for Singaporean goods as well as intensifying trade linkages in the region through an expansion of cross border production networks. In fact, changes in external demand accounted for approximately 75% of the changes in Singapore's real total demand during this period. This helps explain the climb in export prices prior to 2008. Following the onset of the global financial crisis (accompanied by a huge drop in foreign GDP), the Singapore economy experienced a sharp contraction with GDP growth plunging to -9.5% in the first quarter of 2009. The propensity to import goods for domestic production or consumption in Singapore is also very high and estimated to be around 0.8. Reflecting the very high propensity to import, import prices collapsed following the onset of the global financial crisis.

As for the shocks to productivity, there is a noticeable surge prior to the lead up of the global financial crisis. This could be partly attributed to the influx of foreign labour including high skilled ones into Singapore over that period. For instance, permanent residents grew by 8.1% between 2004 and 2009 while non-local workers make up 35% of the workforce by 2009.

With respect to the other shocks, the model shows the declines in world interest rates after 2000 and again in 2008. There was a huge shock to the risk premium in the mid 1980s as Singapore entered into a deep recession in

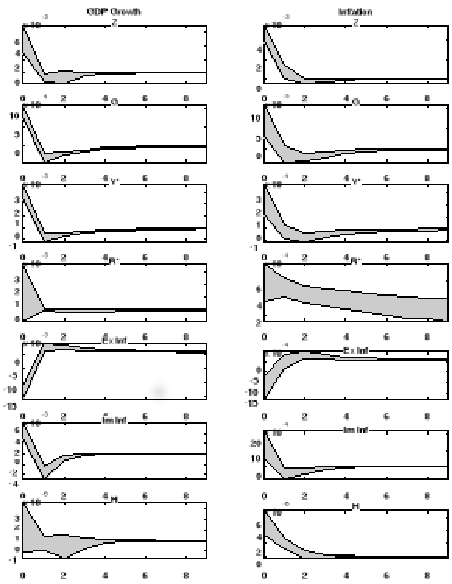

Figure 2: Impulse Response Paths for GDP and Inflation

1985 caused by uncompetitive exports and high labour costs. Subsequently, the uncertainty around late 1990s can be attributed to the onset of the 1997-98 Asian financial crisis.

3.4 Impulse Response Paths

Figure 2 shows the response paths generated by shocks for GDP and inflation. The grey areas represent 95% uncertainty bands. The results are in keeping with theoretical propositions. Productivity, government spending, and foreign GDP unambigiously positively affect GDP growth, while foreign interest rates and the risk premium have negligible impact effects (the confidence bands include zero even in the short run). An increase in export price inflation has negative effects on GDP growth through the export demand channel while a positive shock to import price inflation results in a switch in demand to domestic products by consumers.

For inflation, we see that an increase in demand via either government spending or foreign GDP lead to higher inflation. Import price inflation, foreign interest rates and the risk premium generate higher inflation through the cost channel. Since most of the inflation in Singapore is imported, it is not surprising that higher inflation would be positively related to higher foreign interest rates, which in turn are related to higher world inflation. An increase in export price inflation causes a fall in foreign demand, which leads to a fall in domestic inflation. Productivity shocks generate higher inflation in this model because the demand effects dominate supply effects.

3.5 Conditional Variance Decomposition

Table 3 gives the conditional variance decomposition of GDP and inflation for the seven shocks of the model for horizons of one, four, eight, twelve, sixteen and twenty quarters. The results show that export-price inflation shocks dominate the variability of GDP at all of the horizons, explaining about seventy-five percent of the total variation. The only other shocks that matter, in decreasing order of importance, are import-price inflation (affecting the cost of investment goods), productivity, and foreign GDP. Government spending and the risk premium have negligible effects. For inflation, productivity shocks matters the most, with some contribution from import and export price inflation and world interest rate shocks.

Table 3: Variance Decomposition

Shock:	1	4	8	12	16	20
			GDP			
ϵ^z	0.080	0.074	0.073	0.072	0.072	0.072
ϵ^g	0.003	0.004	0.004	0.004	0.004	0.004
ϵ^{y^*}	0.044	0.045	0.045	0.045	0.045	0.045
ϵ^{r*}	0.008	0.008	0.008	0.008	0.008	0.008
ϵ^{px*}	0.773	0.734	0.737	0.738	0.738	0.738
ϵ^{pm*}	0.091	0.136	0.134	0.134	0.134	0.134
ϵ^h	0.000	0.000	0.000	0.000	0.000	0.000
			Inflation			
ϵ^z	0.811	0.775	0.756	0.745	0.739	0.736
ϵ^g	0.000	0.000	0.000	0.000	0.000	0.000
ϵ^{y^*}	0.003	0.003	0.003	0.003	0.003	0.003
ϵ^{r*}	0.020	0.050	0.071	0.084	0.091	0.095
ϵ^{px*}	0.066	0.065	0.066	0.065	0.065	0.065
ϵ^{pm*}	0.100	0.107	0.104	0.103	0.102	0.102
ϵ^h	0.000	0.000	0.000	0.000	0.000	0.000

3.6 Historical Shock Decomposition

To gauge the relative importance of each of the exogenous shocks for key endogenous variables of the model, and when, during the sample periods, particular shocks become more important we turn to the historical shock decomposition.

Figure 3 pictures the historical shock decomposition for GDP growth and inflation for specific periods. We first focus on the historical decomposition of output. As discussed earlier in section 3.1.3, Singapore went into deep recession in 1985 as high wage costs eroded export competitiveness. This is reflected in the negative shocks from productivity and export prices at the beginning of the sample period. The subsequent recovery was aided by a boost to external demand, with foreign GDP playing an important positive role in the late 1980s, as well as a rebound in export price. However, the role of foreign GDP turned negative as the recession in the US and parts of Europe in the early 1990s dampened growth in Singapore in that period. Meanwhile, the large import price shocks in the early 1990s can be attributed to high oil prices precipitated by the 1991 Gulf war.

In the mid 1990s, the contribution of government spending increased as the Singapore government responded to the economic downswing triggered by the global electronics downturn. Towards the end of 1990s, there was a large negative shock to foreign interest rate at the outbreak of the Asian financial crisis. The Singapore economy was hit by a close sequence of external shocks in the early 2000s which prompted the government to implement counter-cyclical measures and boost spending. Hence, both the foreign GDP and government spending played important roles in this period. With the influx of skilled foreign labour from mid 2000's up till the onset of the global financial crisis, shocks to productivity became more important after 2005. At the onset of the global financial crisis, foreign interest rate, external demand and export prices collapsed. The noticeable negative effect of export price inflation in 2008/09 stand out very clearly, much more than import price inflation. Overall, the role of the export price inflation shocks are more substantial than the contribution of shocks to government spending, foreign GDP, and foreign interest rate. The contribution of risk premium shocks to growth is of least importance.

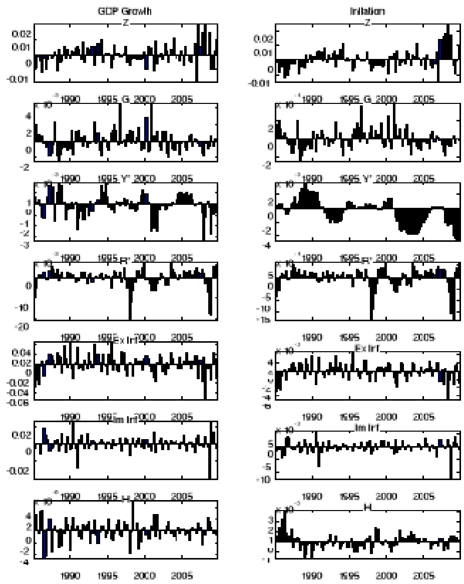

Figure 3: Historical Decomposition of GDP and Inflation

With respect to inflation, we see the strong contribution of productivity driving inflation after 2005. Due to the high import content in all expenditure components, we expect imported inflation to play an important role in Singapore's inflation. Similarly, the openness of the Singapore economy suggests that external demand will contribute significantly to Singapore's aggregate demand, which subsequently adds to domestic price pressures. However, the historical decomposition shows that collapse of foreign GDP of trading partners, and shocks emanating from import prices, especially in the early 1990's (after the Gulf War), and in 2008, at the time of the financial crisis, are of lesser magnitudes. This is a reflection of the central bank's ability to maintain price stability through the use of the exchange rate as a policy tool to target low inflation. Firstly, an exchange rate appreciation has a direct effect on domestic prices by lowering the prices of imported services as well as imported intermediate and final products. Secondly, a reduction in aggregate demand caused by an appreciation of the local currency, alleviates inflationary pressures indirectly through the easing of domestic costs such as wages. The central bank managed the exchange rate in response to shocks to import price inflation and external demand conditions throughout the sample period.

4 Counterfactual Taylor Rule

A key consideration in the use of the interest rate variable in the conduct of monetary policy is whether the Singapore economy is interest rate sensitive. Singapore's extensive network of international financial and trade linkages with

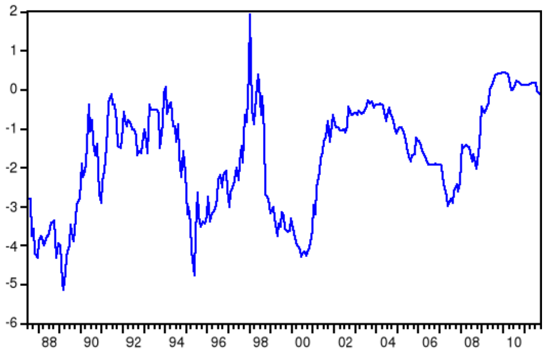

Figure 4: Interest Differentials between Singaporian Dollar and LIBOR

the attendant huge and rapid capital flows and a very liberal policy towards foreign direct investment could result in an economy that is not responsive to interest rate changes.

Figure 4, which depicts the ex post three-month uncovered interest differential between the LIBOR and Singapore, reveals that the differentials are quite different from zero. As pointed out by Yip (2003) they are substantially larger in magnitude compared with corresponding figures from Hong Kong. Hence, the fluctuations in the differentials suggest some scope for managing the domestic interest rate, so that the MAS can exercise a degree of control over domestic interest rates by varying the amount of liquidity injections.

It is natural to ask then, if Singapore would do better with an inflation targeting rule based on a Taylor rule? The typical formulation of the Taylor rule has the interest rate as a function of its own lag, as well as a function of inflation from its target rate, and an output gap measure:

$$\begin{aligned} \log(R_t) &= \rho^r \log(R_{t-1}) + (1-\rho^r)\rho^\pi(\log(\Pi_t^c/\overline{\Pi^c})) \\ &\quad +(1-\rho^r)\rho^y(\log(Y_t/Y_t^{flex})) \\ 0 &\leq \rho^r \leq 1; \quad \rho^\pi > 1, \quad \rho^y \geq 0 \end{aligned} \tag{42}$$

where Π_t^c is the gross consumption price inflation rate, $\overline{\Pi^c}$ is the target (steady-state) inflation rate, Y_t is GDP, Y_t^{flex} is the level of output in a flexible wage and price economy, while ρ^r is the smoothing coefficient, ρ^π is the inflation coefficient, ρ^y is the output gap coefficient, with the gap defined as $(\log(Y_t/Y_t^{flex}))$. Determinacy of inflation requires that the inflation rate coefficient be great than unity, hence $\rho^\pi > 1$.

Given that we acknowledge a certain degree of model misspecification, by making use of the DSGE/VAR estimates of the model, further assumptions are needed for counterfactual simulation. Del Negro and Schorfheide (2010) explore two alternatives in the context of the DSGE/VAR framework. One is to assume that the discrepancies between the DSGE and empirical VAR model are policy invariant. The second is to take misspecification into account through draws on the prior distributions of the parameters, conditional on the counterfactual policy regime. Given that the DSGE and DSGE/VAR parameter confidence intervals show a considerable degree of overlap, as noted in our discussion of the results presented in Table 2, we assume that the relatively small degree of misspecification is policy invariant.

Since the Taylor rule is the counterfactual, we obtain the coefficient values for this policy alternative from optimization of the welfare function, given by equation (1), conditional on the parameters obtained from the DSGE/VAR model. From numerical optimization of the model, the following estimates emerge for the couterfactual optimal Taylor rule: $\widehat{\rho}^{r} = 0.15$, $\widehat{\rho}^{\pi} = 1.025$, $\widehat{\rho}^{y} = 0.425$.

We compare the performance of the model using the actual and counterfactual optimal Taylor rule in three ways. First we examine the paths of inflation and the output gap over the estimation period, assuming that both regimes are subjected to the same set of smoothed shocks. Second, we examine the impulse response paths for inflation and the output gap, for all of the shocks, under the two regimes. Third, we examine the distributions of inflation and output gap volatility, over 1000 stochastic realizations, with the sample size equal to the historical sample.

4.1 Comparisons

4.1.1 Historical and Counterfactual Simulations

Figures 5 and 6 picture the paths of inflation and the output gap predicted by the model when the smoothed shocks (for productivity, the world interest rate, the risk premium, government spending, world GDP, and export and import price inflation) are used as the innovations in the model.

We see that the two paths are quite close. The standard deviation of inflation in the counterfactual regime is higher than under the actual exchange rate regime (0.089 vs 0.067), while the output gap volatilities are virtually the same (0.025 in both regimes). Figure 5a shows that the drop in the output gap under the counterfactual regime at the time of the Asian crisis is slightly less, but following the world crisis of 2008, we see that the swings in the output gap are of equal magnitude under both regimes. The reason is that the main cause of the drop in demand is the collapse of foreign GDP, which neither the exchange rate nor the domestic interest rate could stabilize in any way.

4.1.2 Impulse Response Paths

Figure 7 pictures the impulse response paths of inflation and the output gap under the actual and counterfactual policy regimes for the seven shocks estimated for the model. While the paths are generally close, we see a number of differences in the initial response. In response to a productivity shock, inflation rises under the exchange-rate rule but falls under the Taylor rule. The reason for the different response is that the productivity shock also increases the output gap. Since the Taylor rule responds to the output gap, with an increase in the interest rate, inflation will fall following the productivity shocks in this regime. We also see that inflation is more responsive to an import-price inflation shock under the Taylor rule than the base regime. The reason is that in the base exchange rate regime, inflation targeting can diminish the effects of import price inflation changes on domestic-currency prices more quickly than the interest rate rule, since the exchange rate is a component of domestic inflation..

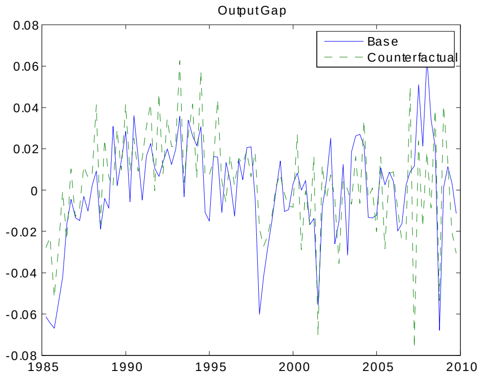

Figure 5: Output Gap under Actual and Counterfactual Policy Regimes

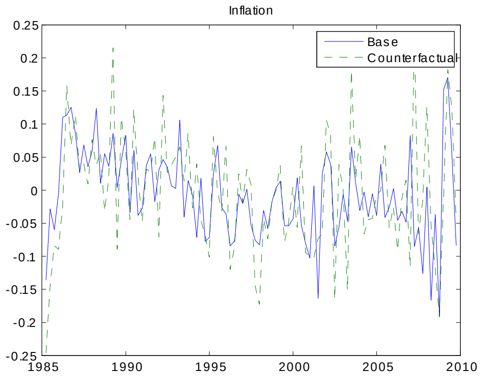

Figure 6: Inflation under Actual and Counterfactual Policy Regimes

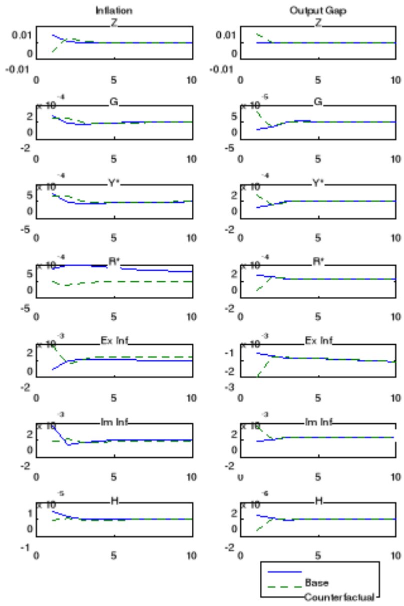

Figure 7: Impulse Response Paths of Inflation and Output Gap under Actual and Counterfactual Policy Regimes

The impulse response analysis suggests that one rule may be more useful than another for stabilizing inflation, depending on the nature of the shocks affecting the economy. If productivity shocks dominate, the Taylor rule appears to be more effective, but if foreign price shocks dominate, the exchange-rate rule is preferable. We discuss this in greater detail below, where we take up the comparative advantage of the two instruments for productivity and foreign inflation shocks.

4.1.3 Stochastic Simulations

So far, we have examined the response of the model to the historical smoothed shocks or to a one period shock, with all other innovations held at zero. For a more complete picture, we examine the volatilities (based on second moments) of inflation and the output gap, as well as the two alternative policy instruments, the rate of depreciation of the exchange rate and the interest rate, for 1000 stochastic simulations based on random draws of the shocks from their underlying distributions. Each draw was the size of the historical sample.

Figure 8 pictures the distributions of the volatility measures. We see a clear volatility trade-off in the choice of policy instrument. Under the exchange-rate rule, the depreciation is much less volatile and the interest rate more volatile, than under an interest-rate based rule.

We see that there is a slight increase in the volatility of inflation if the monetary authority switches from an exchange-rate based inflation targeting regime to an interest-rate based regime, but since the policy is aimed at managing infla-

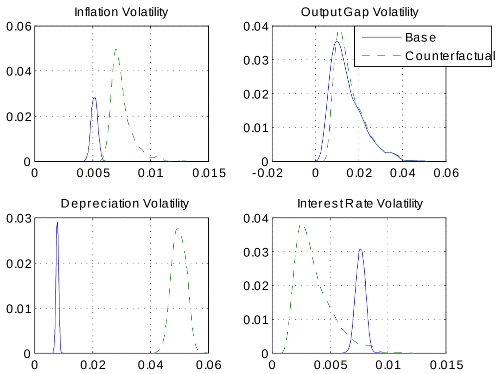

Figure 8: Volatility Distributions of Inflation, Output Gap, Depreciation and the Interest Rate under Actual and Counterfactual Regimes

tion, the differences will be small. What is surprising is the result for the output gap - there is virtually no difference between the volatilities under both regime even though the comparison is between an *estimated* exchange rate depreciation rule with an *optimal* Taylor rule.

To understand this result, we derived an optimal (welfare-maximing) depreciation rule, given the shocks of the model, and we find that the optimal rule delivers an output gap coefficient of zero, with a lower coefficient on inflation (1.05) and a larger smoothing coefficient on lagged depreciation (0.675) than the corresponding estimated coefficients of 1.72 and 0.145. In other words, the base exchange rate rule is close to the optimal rule. Thus, the counterfactual Taylor rule and the exchange-rate rule represent simple optimal rules, with nearly identical results on the output gap.

To interpret the differences in the welfare between the two regimes, we calculate the implied habit-adjusted consumption compensation index required to equalize the welfare of the representative household in the two regimes, following Schmidt-Grohe and Uribe (2007). A positive value implies that the household in the counterfactual scenario is worse off and needs a positive habit-adjusted consumption compensation to have the same welfare as the household 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.

The mean compensation from the stochastic simulations is -0.0025%, implying that the household is only very minimally worse off, a quarter of a percent of a percent, of a unit of habit-adjusted consumption, under the base exchange rate regime relative to the counterfactual Taylor rule.

4.2 A Comparative Advantage for Policy Regimes?

The analysis thus far show that the optimal (welfare-maximizing) Taylor rule, based on the lagged interest rate, inflation and the output gap, reduces inflation in the wake of a productivity shock, while the empirically-estimated exchange rate depreciation rule lowers inflation in the wake of an export price shock. We also see in Table 6 that real GDP volatility was largely explained by export-price volatility (74 percent) relative to productivity (4 percent). For stabilizing welfare, not just inflation, it makes sense for the MAS to make use of the exchange-rate depreciation rule rather than the Taylor rule, especially if export price shocks dominate. If, however, GDP were driven much more by productivity relative to export price shocks, our analysis suggests that the Taylor rule might make more sense as a policy regime.

To assess the relative performance or comparative advantage of the two policy regimes, we simulated the estimated model with the two optimal rules, for the case of pure export price shocks and for the case of pure productivity shocks. The volatility measures for inflation, output gap, and the two policy instruments (the interest rate and exchange rate) are computed.

Table 4 shows the comparative advantage of the two policy regimes. We see that the Taylor rule does a much better job in terms of inflation volatility for recurring productivity shocks. But, there is a volatility trade-off with a switch to an interest rate rule (compared to the exchange rate rule), in that inflation volatility falls but output-gap volatility increases. However, for recurring shocks to export prices, we see that switching from a Taylor rule to a depreciation rule reduces by almost half the volatility of inflation, while the output-gap volatility slightly falls. The overall results suggests that a policy regime based on inflation-targeting exchange-rate management has a decided comparative advantage over the Taylor rule when the economy is subject to recurrent export price shocks.

Table 4: Comparing Policy Regimes: Volatility

Shocks	π	$\log(Y/Y^{flex})$	r	Δs
		Exchange Rate Rule		
ϵ^{z}	0.0244	0.0011	0.0247	0.0246
ϵ^{px*}	0.0029	0.0177	0.0028	0.0028
		Taylor Rule		
ϵ^{z}	0.0172	0.0144	0.0038	0.1214
ϵ^{px*}	0.0047	0.0179	0.0041	0.0161

Gerlach and Tillman (2012) have argued that policy regime changes should also be evaluated on the basis of their effect on inflation persistence. They found that Asian countries which have switched to an inflation-targeting regime (with a Taylor rule) have reduced inflation persistence. What then are the effects of alternative "inflation-targeting" regimes on inflation persistence in Singapore? Following Gerlach and Tillman, we use the following regression equation to estimate the persistence coefficient γ :

$$\pi_t = \gamma \pi_{t-1} + \sum_{i=1}^{k} \delta_i \Delta \pi_{t-i} + \varepsilon_t$$

where π_t is inflation, and ε_t is a normally-distributed innovation with variance σ_{ε}^2.

We first estimate the persistence coefficient γ for the actual data, and obtain a bootstrapped 95% confidence interval. We then simulate the model (using the estimated standard errors of all of the shocks), under the two policy regimes, to find the mean, median and confidence intervals of inflation persistence.

Table 5: Inflation Persistence

	$\widehat{\gamma}$	$\widehat{\gamma}_{mean}$	$\widehat{\gamma}_{median}$	$\widehat{\gamma}_{.025}$	$\widehat{\gamma}_{.975}$
Actual Inflation	0.51			0.17	0.85
Exchange-Rate Rule		0.26	0.30	-0.40	0.71
Taylor Rule		0.85	0.94	0.12	1.06

Table 5 shows a confidence interval of [0.17 0.85] for inflation persistence for actual observed data. Based on simulated data, the mean and median of the persistence coefficient for the exchange-rate rule lie at the lower end of the actual distribution, while the mean and median under the Taylor-rule regime lie at the upper end of the actual distribution. These results indicate that the inflation-targeting regime with the exchange-rate rule has a comparative advantage over the Taylor rule inflation-targeting regime for achieving lower inflation persistence.

5 Conclusion

This paper has laid out a dynamic stochastic general equilibrium model of the Singapore economy. We estimated the model with seven stochastic shocks and seven observable variables. The shocks are to productivity, government spending, foreign interest rates, foreign GDP, import and export price inflation and the risk premium. The observables used in the Bayesian estimation are domestic GDP growth, CPI inflation, government spending, foreign interest rates, foreign GDP growth, import price inflation and the risk premium. The sample period is from 1985 to 2009.

The Monetary Authority of Singapore (MAS) adopted an exchange-rate instrument to manage inflation for this period. This paper shows that there is no reason for Singapore to have any fear of floating. Given the structure of the shocks impinging on the economy, welfare differences would be very minor. The only trade-off would be in the volatility of the alternative policy instruments. If the MAS abandoned the current exchange-rate rule, there would be greater exchange-rate volatility and less interest-rate volatility, but not much else would change. This result should not be surprising, since our Bayesian estimates shows that the degree of price and wage flexibility is relatively high in comparison with most advanced economies. With high nominal flexibility, it should make little or no difference which type of monetary regime is adopted.

However, this paper also shows that the choice of an exchange rate rule makes eminent sense, when export price shocks dominate domestic productivity shocks as the source of real sector volatility. The exchange-rate rule appears to have a comparative advantage over the Taylor rule for stabilizing both inflation and the output gap in this situation. It also has a comparative advantage for achieving lower inflation persistence relative to a Taylor rule.

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