Special Feature A

An Overview of the Satellite Model of Singapore[1]

Introduction

Macroeconomic models are stylised depictions of economic reality, as they attempt to replicate the main mechanisms of an entire economic system. Thus, a complex economic system can be made far more tractable in order to facilitate economic analysis. A fully elaborated model would also assemble various interpretations of the economy into a coherent whole, so that the implications of events and economic policies can be assessed in an internally consistent manner. Such features make models extremely useful for policymakers.

The origins of modern macroeconomic modelling can be traced back to the 1940s, when major modelling work was undertaken, especially with the adoption of simultaneous equation systems. Thereafter, modelling methodology made continuous progress in tandem with advances in economic and econometric research. For example, one weakness of older models was in the treatment of expectations. A powerful critique by Robert Lucas (1976) showed how tenuous the use of backward-looking or adaptive expectations was, since changes in the policy regime would surely lead to a revision of expectations. Economic agents anticipate the effects of these policy changes when forming their expectations, thus making adaptive expectations incompatible with reality. Combined with advances in computing technology and econometrics, the Lucas critique led to the widespread adoption of forward-looking or rational expectations. Newer modelling approaches, such as Dynamic Stochastic General Equilibrium (DSGE) models, in fact, build on this theoretical foundation and explicitly derive behavioural equations from microeconomic foundations.

In this Special Feature, we look at how macroeconomic modelling has evolved in MAS by focusing on the latest addition to our suite of models, the Satellite Model of Singapore (SMS). This model is then compared with our flagship model, the Monetary Model of Singapore (MMS), and its properties demonstrated by analysing the effects on the Singapore economy of a hypothetical foreign demand shock.

Evolution of Macroeconomic Modelling in MAS

Macroeconomic models have played an integral role in MAS' monetary policy since 1990, when the first comprehensive macroeconomic model, SINGMOD, was developed. In the following decade, the MMS, which incorporated new economic and econometric methodologies, was introduced.

The MMS is a Macro-Computable General Equilibrium (Macro-CGE) model.[2] It is able to analyse policy effects dynamically at both the economy and industry levels by using detailed information on all production activities from Singapore's input-output tables. The MMS also has the advantage of being able to model both short- and long-run dynamics, as its key behavioural equations are estimated using error-correction models.

[1] We are grateful to Douglas Laxton, Division Chief, Economic Modelling Division, Research Department, IMF and Werner Schule, Deputy Division Chief, Asia and Pacific Department, IMF for their assistance in the development of the SMS.

[2] CGE models are largely driven by theory and are based on the optimising behaviour of a variety of economic agents. As they evolved to include dynamic adjustment processes, these were subsequently labelled as Macro-CGE models.

In 2010, the SMS became the latest addition to MAS' suite of models. Developed in collaboration with the IMF, the SMS is a small quarterly macroeconomic model that provides a satellite view of the Singapore economy, making it more tractable for economic analysis.

The Satellite Model of Singapore (SMS)

Overview

The SMS is based on a theoretical foundation that lies midway between Dynamic Stochastic General Equilibrium (DSGE) models and reduced-form econometric models. Essentially, the SMS blends the New Keynesian concept of imperfect markets with DSGE models that incorporate rational expectations. Nominal and real rigidities are permitted by setting prices to adjust gradually to changing economic conditions. Under these assumptions, the economy may therefore fail to attain full employment in the short run. This suggests a "stabilisation" role for policy in the SMS, allowing it to be used as a suitable model for analysing monetary policy.

Although the SMS is not explicitly based on microeconomic foundations, many of its features are nonetheless motivated by economic theory. Moreover, the SMS also requires the model to be calibrated by the user, so that it more closely mimics existing economic conditions. As such, the SMS adopts a pragmatic approach, whereby modellers engage in theory but not fully for its own sake.

The SMS has three key behavioural equations: an aggregate demand or output gap equation; a price-setting or New Keynesian Phillips curve equation; and a monetary policy equation motivated by the Taylor rule.

The aggregate demand equation relates the level of real activity (in terms of the output gap) to previous and future real activity, the level of real activity in Singapore's trading partners,[3] the real exchange rate, and the short-term real interest rate. Within the model, the real exchange rate provides the crucial link between monetary policy and the real economy.

The Phillips curve captures the relationship between current inflation and the output gap, change in the real exchange rate, and expected and lagged inflation. This equation embodies some of the key ideas from the contemporary macroeconomic synthesis regarding the role of monetary policy, which is to provide a nominal anchor for inflation and to influence inflation through its effects on output and the exchange rate.

Following Parrado (2004), a modified Taylor-type monetary policy reaction function is adopted for Singapore based on changes in the Singapore dollar nominal effective exchange rate (S$NEER), rather than a short-term nominal interest rate. Changes to the S$NEER are then related to the deviation of the expected inflation rate from its target and the output gap.

Finally, a modified uncovered interest rate parity (UIP) equation and a dynamic version of Okun's Law, whereby the unemployment gap is related to the output gap, complete the main equation block of the model.

[3] Global output is modelled using the Global Projection Model (GPM), which is developed and maintained by the IMF. The latest version, GPM6, comprises six country/regional blocs that include all of Singapore's major trading partners. The GPM6 allows for interactions between the different regions through traditional trade channels as well as a financial channel. An important feature of the SMS is that it may be seamlessly integrated with the GPM6, allowing the external outlook to be fed directly into the SMS and permitting an analysis of external shocks to be introduced in a model-consistent manner.

Unlike the MMS, the SMS features only a basic supply side, in which variables such as potential output, the equilibrium real interest rate, and exchange rate, are modelled as simple stochastic processes and are derived using the Kalman filter.[4]

A noteworthy feature of SMS is that it uses a Bayesian estimation procedure, which places particular emphasis on the economic structure of the model rather than simply on the statistical goodness of fit. Accordingly, Bayesian estimation endows the model with a variety of information from the data, prior assumptions based on other studies and the judgment of the researchers and, to some extent, the structure of the model itself. The relative weights on the different sources of information are determined by examining the model's properties using impulse response functions (IRFs).[5]

Bayesian techniques are particularly well-suited to handle small data sets, enabling structural changes in the economy to be more effectively captured. This is especially useful in the context of Singapore, since long time series of macroeconomic data are hard to find.

Apart from forecasting key macroeconomic variables, the SMS is also used for policy simulations, such as analysing the impact of GDP and inflation shocks on the economy. The results from the simulations are then used in conjunction with the MMS to determine the appropriate monetary policy stance.

[4] The Kalman filter is a recursive algorithm that is widely used in economic models to provide estimates of latent (unobserved) variables that are conditional on a given information set and behaviour of the model parameters.

[5] IRFs show the reaction of variables to various shocks, and are useful for studying the interactions between variables in a dynamic model.

Comparison of MMS and SMS

This section highlights the similarities and differences between the MMS and SMS in terms of model structure and the modelling approach. Table 1 provides a summary of the key features of both models.

The MMS is a large model comprising 255 equations. Its building blocks are the national income identities and sectoral production functions, from which equations are obtained for households, firms, government, trade, labour market, production, prices, interest rates and monetary policy. These underlying relationships are derived from economic theory and are based on the optimising behaviour of the agents involved. The MMS also integrates the supply side of the economy with the respective expenditure (or demand) components and has a detailed sectoral breakdown.

In contrast, the SMS is a highly aggregated model with no sectoral or expenditure components. The SMS is much smaller with 37 equations, and its key properties are derived from the three New Keynesian core equations for aggregate demand, inflation, and the monetary policy reaction function.

Economic Properties of the Models

Despite these differences, the MMS and SMS have some common fundamental properties. Both are New Keynesian in the short run, but neoclassical in the long run.[6] More specifically, the long-run equilibrium path in both models assumes that:

Economic growth is steady.
In the MMS, real variables in the long run grow according to the rate of Harrod-neutral technological progress plus the rate of growth in the labour force. In the SMS, the economy converges to its potential growth rate.

The unemployment rate converges.
Both models assume that the unemployment rate converges to a non-accelerating inflation rate of unemployment (NAIRU).

Neutrality of money holds.
Monetary policy does not have an effect on real variables in the long run for both models. Also, the fundamental role of monetary policy in both models is to provide a nominal anchor for inflation.

The MMS and SMS also share some similar short-run dynamics. Output in the short run is demand-determined as a result of nominal and real rigidities. Also, both models incorporate expectations, with the MMS assuming rational expectations in the financial markets to exhibit forward-looking behaviour, while the SMS allows for both rational and adaptive expectations in its key relationships.[7]

[6] The neoclassical long-run properties in the MMS are consistent with a typical computable general equilibrium model that focuses on equilibrium steady states.

[7] For example, the Phillips curve equation in SMS is specified such that current inflation depends on expected and lagged inflation, the output gap, and the change in the exchange rate gap. Expected inflation is specified as the quarter-ahead inflation rate.

Table 1
Model Description

	MMS	SMS
Year of Model Development	1999*	2010
Frequency of Data	Quarterly	Quarterly
Size		
Total Number of Equations	255	37
Behavioural Equations	38	5
Key Blocks/Equations		
Trade	• Export and import demand functions for three sectors.	• Does not feature exports or imports. The trade channel is captured by including foreign real activity in the domestic output gap equation.
Sectoral	• Production functions for five sectors, with interlinkages.	• No sectoral breakdown.
Labour Market	• Labour demand, supply, and wage equations are estimated in a disequilibrium framework. Features an Inflation Expectations-Augmented Phillips curve.	• Okun's law allows real activity to affect the unemployment rate, but does not play a fundamental role in the model. Also features an Inflation Expectations-Augmented Phillips curve.
Households	• Ando-Modigliani Consumption Function	• No households.
Firms	• CES Production Functions • Tobin's 'q' Theory of Investment	• No firms.
Theoretical Underpinning	• New Keynesian in the short run; Neoclassical in the long run.	• New Keynesian in the short run; Neoclassical in the long run.
Econometric Approach		
Specification	• Error Correction Model	• Equation System
Estimation	• Ordinary Least Squares	• Bayesian estimation
Expectation	• Rational expectations in the financial markets. Adaptive expectations in others.	• Rational and adaptive expectations in key relationships.
Special Features	• Detailed modelling by sector and expenditure components.	• Can be integrated with GPM6. • Uses Taylor rule for optimal monetary policy.

* Note: The MMS has since undergone significant enhancements.

Analysing the Impact of a Foreign Demand Shock in SMS

In the October 2007 issue of the *Review*, we highlighted two structural macro-econometric models, the MMS and the ESU01 model developed at the National University of Singapore. [8] The different transmission mechanisms in each model were demonstrated by simulating an adverse foreign demand shock. In this section, we simulate a similar foreign demand shock in the SMS, and examine its impact on key macroeconomic variables.

In the SMS, an adverse foreign demand shock affects the aggregate demand equation directly. This results in a fall-off in aggregate demand, which then impacts inflation through the short-run Phillips curve. Figure 1 shows the transmission mechanism in SMS arising from a shock to external demand. If monetary policy is exogenous, the S$NEER will remain unchanged. The Taylor-type monetary policy reaction function, however, endows the SMS with a model-based monetary policy response to the shocks to the economy. Under this endogenous monetary policy setting, the S$NEER therefore adjusts in response to lower expected future inflation and a smaller output gap.

Simulation Results

A fall in foreign demand is introduced in the SMS through a change in the composite foreign gross domestic product (GDPF) index. The shock is assumed to be temporary—GDPF falls by 1% below baseline for four quarters, recovers by 0.25% in each of the subsequent four quarters, and finally reverts to the baseline by the end of the second year. Chart 1 shows our assumed path for GDPF. The impact of this shock on the key macroeconomic variables is then simulated under both exogenous and endogenous monetary policy settings.[9]

Under the exogenous monetary policy scenario, real domestic GDP falls by 1.2% from baseline in the first quarter with the shock having a maximum impact on real GDP after two quarters. (Chart 1) Faced with a lower level of economic activity, the unemployment rate rises and reaches a peak that is 0.3% point higher than baseline in the fourth quarter. The CPI, however, remains below baseline for an extended period due to the fall in external demand, reaching its trough at 1.2% below baseline in the fifth quarter.

Overall, real GDP declines by 1.3% in the first year compared to the baseline, and then recovers. (Table 2) CPI falls by 0.7% below baseline in the first year, and remains below baseline into the second year. The unemployment rate ticks up initially, before reverting to baseline by the end of the second year. Beyond the second year, the impact on the key macroeconomic variables dissipates in the long run due to the temporary nature of the GDPF shock.

However, when monetary policy is allowed to respond to the external shock (endogenous monetary policy), the impact on the macroeconomic variables is more muted. This occurs as the slope of the S$NEER adjusts according to the Taylor rule, hence stabilising output and inflation around their respective targets. The resulting looser monetary policy softens the impact of the adverse foreign demand shock, thereby capping the peak decline in GDP and CPI at 1.2% and 0.9% below the baseline respectively. (Chart 1) The peak deviation in the unemployment rate is also lower at 0.2% point above the baseline. Under the endogenous monetary policy setting, real GDP and CPI decline by 0.9% and 0.6% below baseline in the first year respectively. (Table 2)

[8] The ESU01 model was developed in 2001 by the Econometric Studies Unit of NUS and further refined in 2005. It can be utilised for economic analysis, policy simulation and forecasting. Details can be found in Abeysinghe and Choy (2007).

[9] For the exogenous monetary policy setting, the path of S$NEER was maintained at its baseline levels. When monetary policy is endogenous, the built-in monetary policy response function is enabled.

Figure 1
Transmission of a Foreign Demand Shock within the SMS

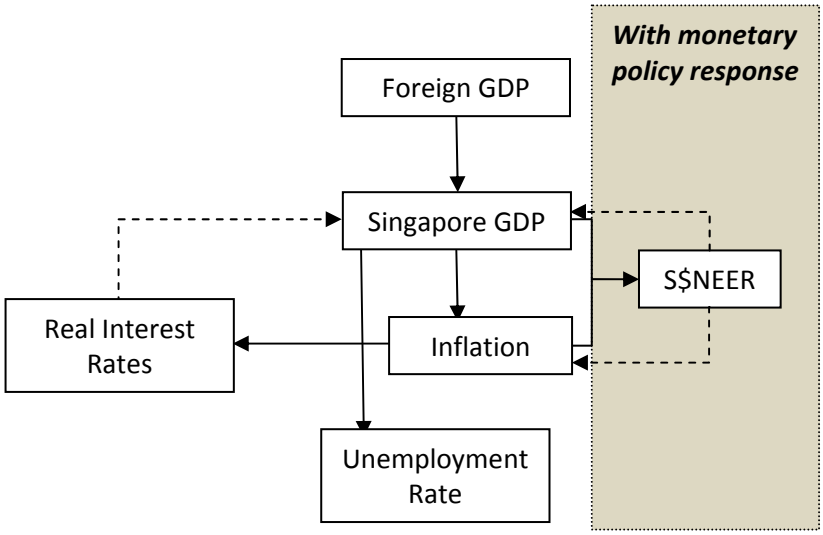

Chart 1
Macroeconomic Effects of a Foreign Demand Shock in the SMS

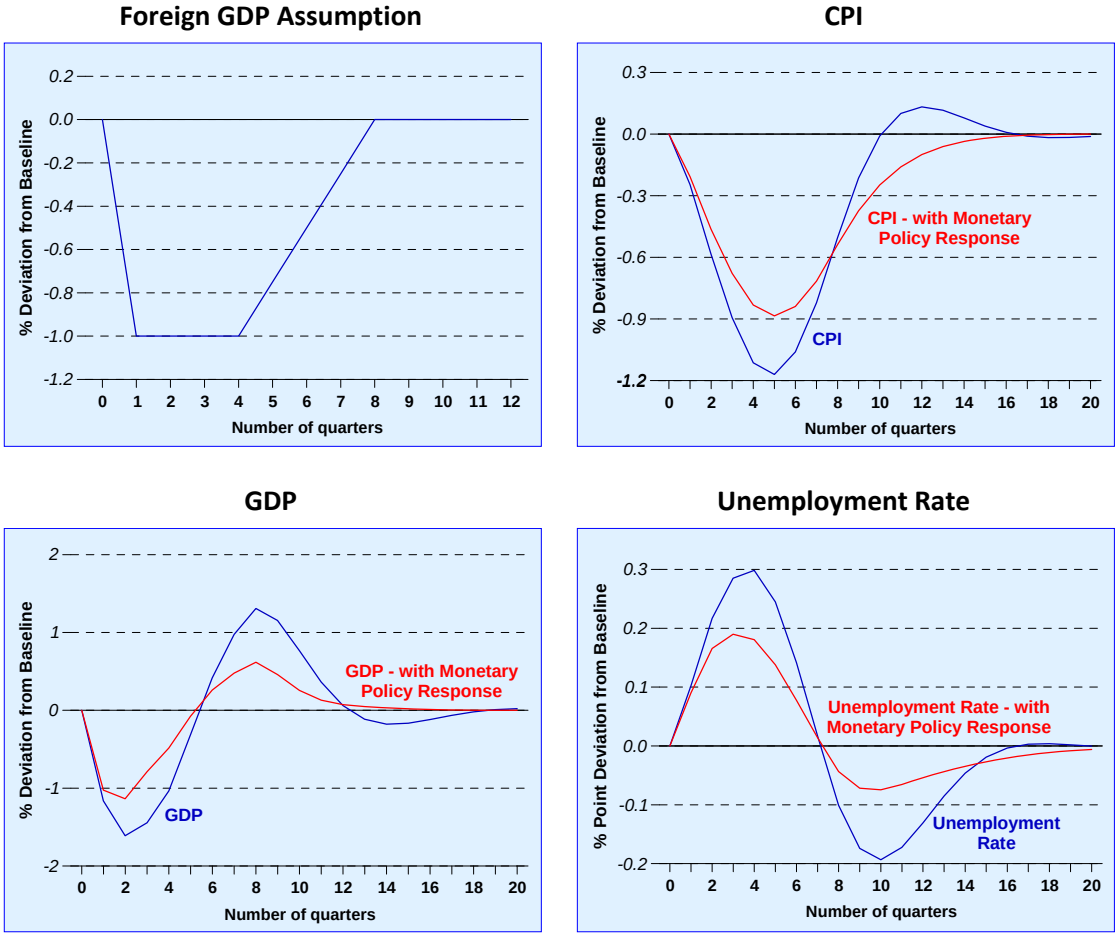

Table 2
Macroeconomic Effects of a Foreign Demand Shock in the SMS
(% deviations from baseline)

Model	Impact on	Year 1	Year 2
SMS	GDP	−1.31	0.59
	CPI	−0.71	−0.89
	Unemployment Rate*	0.23	0.08
SMS (with monetary policy response)	GDP	−0.86	0.32
	CPI	−0.55	−0.74
	Unemployment Rate*	0.16	0.05

* % point deviation.

Sum-up

The addition of SMS to MAS' suite of macro-econometric models resonates with our continued adherence to a pluralistic approach to modelling and our belief that no one model is superior in all possible circumstances. Notably, the key advantage of the SMS is its elegance in encapsulating key macroeconomic relationships within a tight model-consistent framework. The MMS, by comparison, has the advantage of scale and detail, enabling an extensive and detailed set of policy simulations to be carried out.

The SMS results in this Special Feature corroborate those obtained from a simulation conducted on the latest version of the MMS. Taken together, the two models highlight the range of possible outcomes in response to an adverse external demand shock. In both models, GDP falls by 1.2–1.3% below baseline in the first year, but recovers after 4–6 quarters. Similarly, the CPI also declines by 0.5–0.7% in the first year, reaching its trough after five quarters.

The SMS further augments MAS' analytical toolkit and, together with the MMS, will play an important role in our monetary policy formulation.

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