Special Feature A

Impact of a Foreign Demand Shock on the Singapore Economy — Perspectives from Two Macroeconometric Models[1]

Introduction

Quantitative macroeconometric models of national economies have gone through several generations of theoretical development and empirical calibration to become a standard tool in the analysis and design of macroeconomic policies. Having been temporarily eclipsed during the 1980s by new developments in econometric modelling, there has been an apparent "revival" since the 1990s in macromodelling by public policy institutions, such as central banks, and the incorporation of the results of macroeconometric models in their policymaking process.

In Singapore, econometric modelling forms an integral part of the academic and policymaking scene. Several academic and public policy institutions – National University of Singapore (NUS), Nanyang Technological University (NTU) and MAS – maintain macroeconometric models for forecasting and policy evaluation. It is rare for one model to be superior in all circumstances, and alternative models are needed for different purposes. A comparison of existing models will thus help to enhance our understanding of key relationships and linkages in the Singapore economy, as well as contribute to improved modelling practices.

This Special Feature undertakes a detailed comparison of two extant macroeconometric models of the Singapore economy – the MAS Monetary Model of Singapore (MMS) and the NUS Econometric Studies Unit Model (ESU01).[2] Our focus is on drawing out the different perspectives and insights provided by these two models on the impact of a negative demand shock on the Singapore economy.

The MMS was formally introduced in 2000 for use in forecasting and policy simulation. In particular, it plays a key role in the central bank's monetary policy formulation process, where it is used extensively to simulate alternative policy paths under different scenarios. The ESU01 model was constructed 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. While both models were constructed for broadly similar purposes, policy analysis features more prominently as an objective of the MMS while the ESU01 is designed primarily for structural analysis and forecasting.

[1] This feature was written in collaboration with Tilak Abeysinghe, Department of Economics, National University of Singapore and Choy Keen Meng, Division of Economics, Nanyang Technological University.

[2] MMS was featured in MAS (2000) and in Enzler *et al.* (2005). A complete documentation of the ESU01 model is presented in the recently published book by its architects (Abeysinghe and Choy, 2007).

The next section describes the similarities and differences between the MMS and ESU01 in terms of model structures and modelling approaches, thereby showing also where they complement each other.

We then compare the two models' responses to a negative demand shock by tracing the impact through their respective transmission mechanisms.

Comparison of the Models

Overview

Table 1 summarises the features of both the MMS and the ESU01 models. Both are structural macroeconometric models of the Singapore economy and are derived from strong theoretical foundations to ensure that their systemic properties are consistent with widely-accepted theories and models. The parameters in the two models are estimated econometrically from quarterly time series data, although MMS also relies on calibration techniques to some extent.

The MMS is a macro computable general equilibrium model that is essentially derived from microeconomic optimisation theory, while the ESU01 is an economic system built on behavioural relationships which are mostly, albeit not exclusively, motivated by standard macroeconomic theory. Broadly speaking, the equations in both models can be placed into four blocks: trade, industrial sector, labour market and domestic demand. In both models, the supply side is integrated with the expenditure or demand side. However, they differ in the modelling of the long run. In the case of MMS, the economy converges to a steady state growth path dictated by supply-side constraints, while the ESU01 converges to long-run equilibrium relationships that bind key macroeconomic variables together.

In terms of the approach to econometric modelling, both models are specified according to an error correction framework. Error correction models ensure that both the short- and long-run aspects of behavioural relationships are taken into consideration, thus allowing maximum flexibility for the equation dynamics to fit Singapore data.

The modelling of the production sectors in the MMS and ESU01 draws upon the Singapore Input-Output Tables, which is one of the best sources of detailed information on the economy. The MMS utilises these tables to compute price elasticities, such as those pertaining to sector-specific exports and imports. In addition, these tables are an important ingredient in the calibration of the sectoral parameters in both models.

Trade Block

As Singapore is a small and very open economy, both models emphasise the pivotal role of the external economic environment through clearly defined processes. In general, since the volumes of Singapore's imports and exports are small relative to world trade, export and import prices are assumed to be determined by global markets. Foreign prices and the exchange rate also have a significant impact on domestic prices since imports account for a large part of domestic expenditures on consumption and capital requirements.

Beyond these common features, distinct differences are found in the design of the trade blocks of the two models. Export and import demand functions are modelled for various *sectors* in the MMS such as manufacturing, and financial and business services. By comparison, in the ESU01, export and import functions are estimated for disaggregated trade *categories* such as non-oil exports and retained imports. (Table 1)

Sectoral Block

Given the richness of Singapore's data on the industrial and service sectors, both the MMS and ESU01 take advantage of this information in the choice of modelling strategies for the sectoral block.

Table 1
Model Description

	MMS	ESU01
Date of Model Development	1999	2001
Frequency of Data	Quarterly	Quarterly
Size		
Total Number of Equations	248	62
Behavioural Equations	38	36
Key Blocks		
Trade	Export and import demand functions for three sectors: • Manufacturing • Finance & Business Services • Other Goods and Services	Equations for export and import categories: • Non-oil domestic exports (NODX) • Oil domestic exports • Re-exports • Service exports • Retained imports • Service imports
Sectoral	Production functions for five sectors: • Manufacturing • Finance & Business Services • Construction • Housing Services • Other Goods and Services	Supply functions for six sectors: • Manufacturing • Finance & Business Services • Construction • Transport & Communications • Commerce • Others
Domestic Demand		
Households	Ando-Modigliani Consumption Function	Parsimonious specification of the consumption function to fit historical data
Firms	• CES Production Functions • Tobin's 'q' Theory of Investment	• Supply functions in the sectoral block based on final demand • Forward-looking variables in investment equations to incorporate agents' anticipations
Labour Market	Inflation Expectations Augmented Phillips Curve	Disequilibrium term in real wage equation incorporates influence of foreign workers
Theoretical Underpinning	• Keynesian in the short run • Neoclassical in the long run	• Demand driven with long-run cointegrating restrictions
Econometric Approach		
Specification Estimation	Error Correction Model • Ordinary Least Squares	Error Correction Model • Ordinary Least Squares • Autoregressive Distributed Lag • Johansen's Maximum Likelihood
Expectations	Explicitly Modelled	Implicitly Modelled
Financial Markets	Rational Expectations	
Goods/Factors Markets	Adaptive Expectations	
Special Features	• Detailed decision-making processes of factors of production • Rational expectations in the financial markets	• Trade equations take into account both demand and supply factors • CPI equation incorporates Balassa-Samuelson effect

In the MMS, GDP on the supply side is disaggregated into five sectors. Each sector has its own production function derived from optimisation theory to obtain fully-consistent equations for employment, investment, export supply, import demand and pricing. The decision-making processes with regard to the demand for primary factors are embedded in these equations. The *production* functions allow for substitution between the primary factors, capital and labour, given a Constant Elasticity of Substitution production technology. In addition, these functions incorporate the rate of technological progress by means of labour and capital efficiency indices.

Instead of explicitly estimating production functions, the ESU01 model employs a novel approach to estimate *supply* functions for the six sectors covered. Specifically, the value added of each sector is made dependent on the final demand for the sector's output, thereby creating linkages between the domestic demand and trade blocks in the model.

To summarise so far, the two models differ mainly in the emphasis given to the sectoral and trade blocks. The MMS pays particular attention to the modelling of the sectoral block. By contrast, the ESU01 focuses on Singapore's trade relationships with the rest of the world. Hence, an exogenous shock transmission mechanism in MMS works through the production side of the economy via the sectoral block whereas in the ESU01, an external disturbance is propagated through the expenditure side of the economy via the trade equations. This key difference in transmission mechanisms will be explored further through a simulation experiment in the next section.

Labour Market Block

Both the MMS and ESU01 adopt a structural approach to the modelling of the labour market, in which labour demand, supply and wage equations are estimated in a disequilibrium framework. The aggregate wage equations resemble a Phillips curve in that the wage rate depends on some form of capacity constraint (also known as the disequilibrium term). However, there is a clear distinction between the two econometric specifications. In the MMS, the disequilibrium term in the wage equation is the unemployment rate. The ESU01, on the other hand, utilises the gap between the actual and market-clearing real wage as the disequilibrium term. This attempts to explicitly account for the influence of foreign workers in the wage adjustment process through their impact on labour supply.[3]

Domestic Demand Block

In the MMS and the ESU01, the domestic demand block comprises the behavioural equations for private consumption and investment. However, government spending is assumed to be an exogenous policy variable in both models.

The MMS includes an Ando-Modigliani consumption function in which equilibrium private consumption is determined by current labour income and non-human wealth. Consumers are then assumed to allocate their equilibrium consumption spending between consumer goods produced by the four sectors.[4] This in turn provides the consumption demand for each of the four sectors, taking into account the private sector's intertemporal budget constraint. In contrast, the ESU01 takes an empirical approach in searching for the most parsimonious specification of the consumption function that can incorporate the observed decline in the average propensity to consume in Singapore.

In MMS, a Tobin's 'q' style model of private business investment is adopted in each sector. This recognises the costs involved in adjusting the capital stock and allows it to adjust gradually to a new equilibrium level where the actual and required rates of return on capital are equal. The ESU01 does not utilise conventional investment models. Instead, since fixed capital formation is predominantly driven by expected demand and profitability, the ESU01 includes two forward-looking expectations-laden variables in its specification and estimation of investment

[3] Until January 2007, all foreign workers had to leave Singapore if they were unemployed. Hence, the inflow or outflow of foreign workers had an impact on wages by affecting the labour supply. Since the beginning of 2007, a limited number of foreign workers can remain unemployed in Singapore for up to six months.

[4] The construction sector does not produce consumer goods.

functions: Net investment commitments in the manufacturing sector, and building contracts awarded in the construction sector. This greatly simplifies the task of incorporating agents' expectations into the modelling of private capital expenditures.

Treatment of Expectations

In response to the Lucas critique, the MMS incorporates forward-looking or rational expectations in the financial markets. This property enables the model to capture the widely-recognised fact that financial markets respond virtually instantaneously to all kinds of new, relevant information. Rational expectations in financial markets are modelled through two key relationships – uncovered interest rate parity and the term structure of interest rates. The MMS assumes that expectations are mainly backward-looking in other markets.

To address the Lucas critique, the ESU01 models expectations implicitly by including current and lagged variables in estimated equations and using proxies for agents' expectations as in the investment equations discussed above. Another solution was to add policy variables directly into the regressions and to ensure that the parameter estimates remain invariant under structural and policy shifts.

Long-run Properties

The primary objective of the MMS is policy simulation. As such, the medium- to long-run properties of the model are more important than the short-run behaviour of the economy. In contrast, the ESU01 model places more emphasis on cointegration relationships and short-run dynamics.

The MMS is Keynesian in the short run and neoclassical in the long run.[5] Thus, the model incorporates a formal structure for the economy, with well-defined long-run properties to ensure that the economy reverts to its steady-state balanced growth path, determined by technical progress and the rate of growth in the labour force. In particular, all variables in the model settle to their long-run equilibrium levels and are mutually consistent, i.e. they all "add up".

The MMS also models the fiscal policy rule using the government's intertemporal budget constraint to account for the distinctive feature that the Singapore government is a net creditor over time. This ensures a sustainable fiscal policy in the long run.

In comparison, the ESU01 does not have explicit steady-state restrictions, reflecting the model-builders' concern that the imposition of such restrictions may result in misleading inferences from policy simulations. In their place are empirically-tested cointegration restrictions, which are themselves long-run equilibrium relationships derived from economic theory. These relations also provide guidance in the specification of the model's behavioural equations. In the short run, the ESU01 model is essentially demand-driven, with inventories acting as a buffer against shortfalls and excesses in aggregate demand.

[5] In a Keynesian short run, firms maximise profit subject to the constraints of domestic demand and the capital stock that they have in place. Over time, the price of domestic demand gradually adjusts to its marginal cost of production, thus relaxing the domestic demand constraint. In the long run, the Tobin's 'q' formulation for business investment results in the lifting of the constraint on capital. This yields a neoclassical long run of profit maximisation subject only to the production technology constraint.

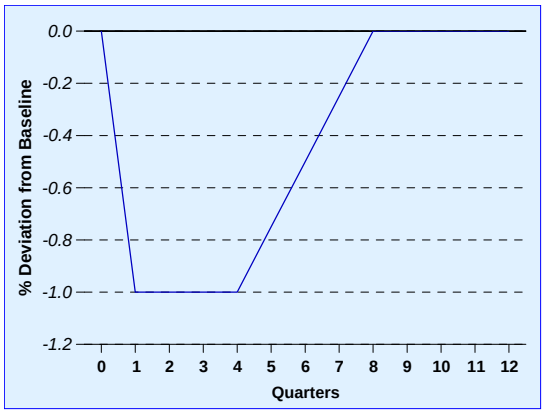
Analysing the Impact of a Foreign Demand Shock

In this section, we illustrate the different transmission mechanisms of the two models by simulating an adverse foreign demand shock. Figures 1 and 2 depict how the shock is transmitted through the Singapore economy in the MMS and ESU01 respectively.

A fall in foreign demand is introduced by changing the composite foreign GDP index that serves as a proxy for external demand in the two models. The shock is assumed to be temporary: foreign GDP is reduced by 1% below baseline for four quarters before recovering by 0.25% in each successive quarter to the baseline level by the end of the second year. Chart 1 shows the alternative path assumed for the foreign GDP index under the simulation.

An important caveat is that while we have attempted to analyse a common demand shock via a controlled 1% decline in the composite foreign GDP index across the models, the different ways in which the index is constructed in the respective models imply that the stimuli provided by the shock and its impact on the economy are only broadly comparable.[6] Therefore, we do not aim to compare the differences in multiplier effects on key economic indicators arising from the shock. Rather, the emphasis is on highlighting the different transmission channels and the dynamic properties embedded in each model.

Chart 1
(Weighted) Foreign GDP Assumption



[6] The foreign GDP indices used in the MMS and ESU01 models are not identical because the coverage of countries and the weights given to them are different.

Transmission Mechanism in MMS

In the MMS, the slowdown in economic activity in Singapore's main trading partners affects exports immediately and severely, with knock-on effects on investment and consumption. Chart 2 illustrates the impact on key macroeconomic indicators over time.

The shock is transmitted through the MMS via two main channels – the direct short-run effect and the profit-maximisation response by producers. (Figure 1) The first transmission channel is the immediate short-run effect of a decline in foreign GDP on manufacturing exports and output as export orders fall. NODX declines sharply by 2.0% in the immediate quarter, reaching a trough of 2.9% below baseline by the first quarter after the shock.

The second transmission channel is via the profit-maximising decisions of producers in the various sectors, as they adjust their overall production and pricing decisions in response to the decline in external demand.[7] This subsequently reduces their demand for domestic and imported intermediate inputs, resulting in further negative spillovers to the rest of the economy. Production for domestic and export markets thus adjust to a lower (short-run) equilibrium level, as does the demand for imports.

Producers reduce their own derived demand for labour, causing employment and, subsequently, wages to decrease. Employment falls by 0.14% in the immediate quarter with lower employment levels persisting for about six quarters after the shock. The unemployment rate reaches a peak of 0.15% point above the baseline in the second quarter. Households are then impacted as lower wages lead to a decline in private disposable income and hence private consumption.

Concomitantly, the actual rate of return on capital falls against the backdrop of a weaker economic environment. Non-residential investment falls by as much as 2.0% as a consequence.

Overall, real GDP declines by an average of 1.2% compared to the baseline scenario in the first year, with the manufacturing sector being the most adversely affected given its strong exposure to external demand. The CPI declines by 0.3% over the same period as cost and price pressures ease in the factor and product markets.

The economy begins to recover after the fourth quarter in tandem with the improvement in the external environment and as producers re-adjust their output levels in response to lower production costs. In particular, the collapse in demand in the earlier periods lowers the cost of inputs, including that of labour. This results in a reduction in sales/output prices, thereby stimulating domestic demand. The pickup in domestic demand, coupled with the relatively lower cost of labour, induces producers to increase their demand for labour inputs. Subsequently, the unemployment rate falls by 0.2% point below the baseline rate 10 quarters after the shock and investment slowly recovers to about 2.4% above the baseline level two years after the initial shock.

The domestic economic recovery is further boosted by the improvement in external demand into the second year, supporting a pickup in export activity. NODX and overall exports recover to 2.6% and 1.9% respectively above baseline levels two years after the shock. Accordingly, real GDP improves to an average of 1.4% above baseline in the second year.

As the foreign demand shock is assumed to be temporary, the impact on key macroeconomic variables dissipates in the long run.

[7] For the short-run profit maximisation problem, it is assumed that in each industry, firms choose their inputs of labour, intermediates and imports to maximise profit from domestic sales and exports, while taking their stocks of capital as fixed. Instead of the traditional closed-economy production function that relates output to inputs of capital and labour, the open-economy production function used in MMS extends the production function by deriving exports and domestic sales.

Figure 1
Transmission Mechanism of a Foreign Demand Shock in the MMS

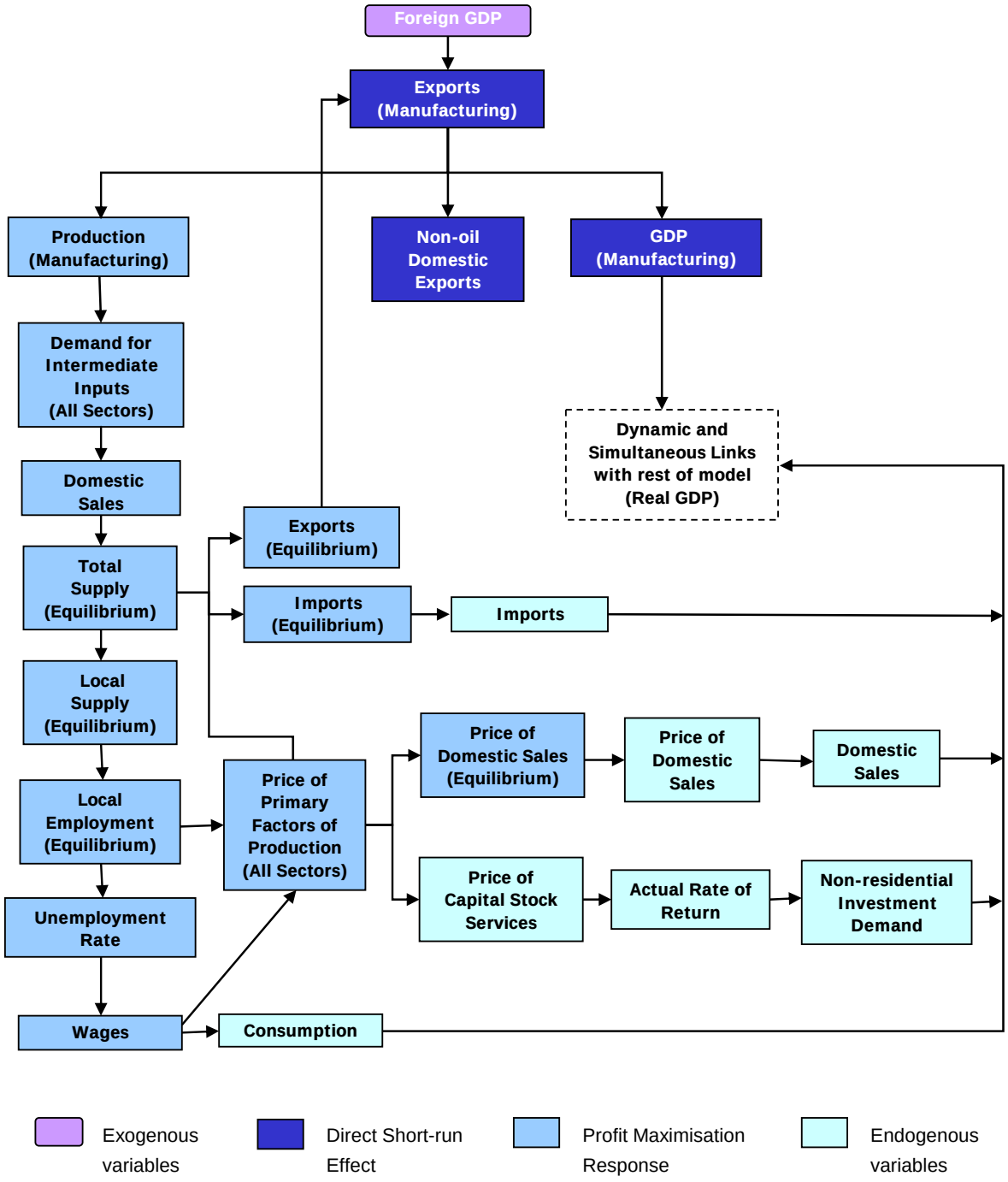
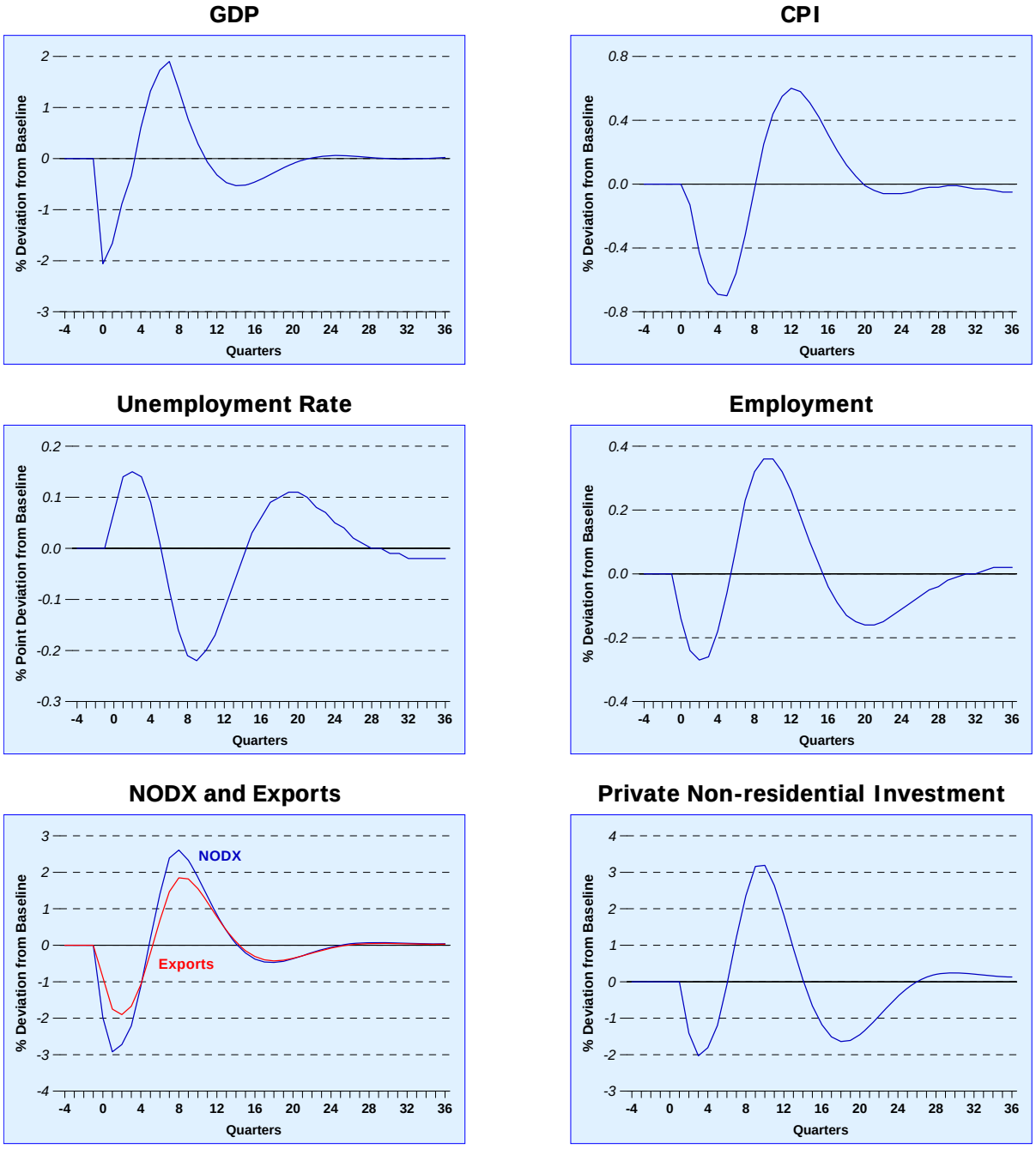


Chart 2
Macroeconomic Effects of a Foreign Demand Shock in the MMS



Transmission Mechanism in the ESU01

The transmission mechanism that serves to propagate the effects of a foreign demand impulse in the ESU01 model is shown in Figure 2.

A decline in foreign GDP has a negative hump-shaped impact on all the modelled trade categories, namely NODX, oil exports, services exports and re-exports. NODX, for example, are lower by 2.8% compared to the baseline scenario at the end of the first year after the shock, after which a gradual recovery towards the baseline begins. (Chart 3) The other export components fall by smaller amounts but share the same dynamic responses, except in the case of services exports, which drop immediately and sharply by 2.3%. As a result, Singapore's total exports will be curtailed by an average quantum of 1.2% over 10 quarters.

The reduction in external demand in turn depresses the final demand for the goods and services produced by the various sectors of the economy. In response, firms cut their output across the board. However, the brunt of the foreign shock is not surprisingly borne by the manufacturing and commerce sectors, in view of the heavy dependence of industrial enterprises on merchandise exports and commercial firms on both services exports and re-exports.

The cutbacks in sectoral production cause real GDP to spiral down after one year to 0.7% below the level that would have prevailed in the baseline scenario. Weaker income growth leads to lower private consumption expenditures and business investment spending, with outlays on new machinery and equipment falling by 1.2%. These spillover effects on domestic demand depress aggregate and sectoral output further through multiplier effects. They also partly account for the long-drawn-out impact of the foreign income shock on real GDP that is apparent in Chart 3. From a sectoral perspective, the persistent effects can be traced to the output of the service industries, which cater to both external and domestic demand.

The contraction in aggregate demand has further repercussions on the labour market. After a lag of 1-2 quarters caused by adjustment frictions, employment creation slows down as firms react by reducing their demand for labour. The maximum impact of about -0.4% is felt after six quarters, although job losses persist for another two years. Reflecting this, the overall unemployment rate moves up by 0.2-0.3% point in the second year.

At the same time, a fall in nominal wages lowers economy-wide unit labour costs (ULC) and the manufacturing sector's unit business costs (UBC), with salutary effects. The decline in UBC partially restores Singapore's export competitiveness, thereby hastening the economy's recovery to its long-run baseline equilibrium. By the end of the third year, GDP would have rebounded to just 0.2% off its baseline solution as the effects of the foreign shock peter out. In comparison, a lower ULC translates eventually into a more subdued inflation rate. Compared to the baseline path, the CPI would also have been lower by 0.1-0.2% after 10 quarters as a consequence of the foreign demand shock.

Figure 2
Transmission Mechanism of a Foreign Demand Shock in the ESU01

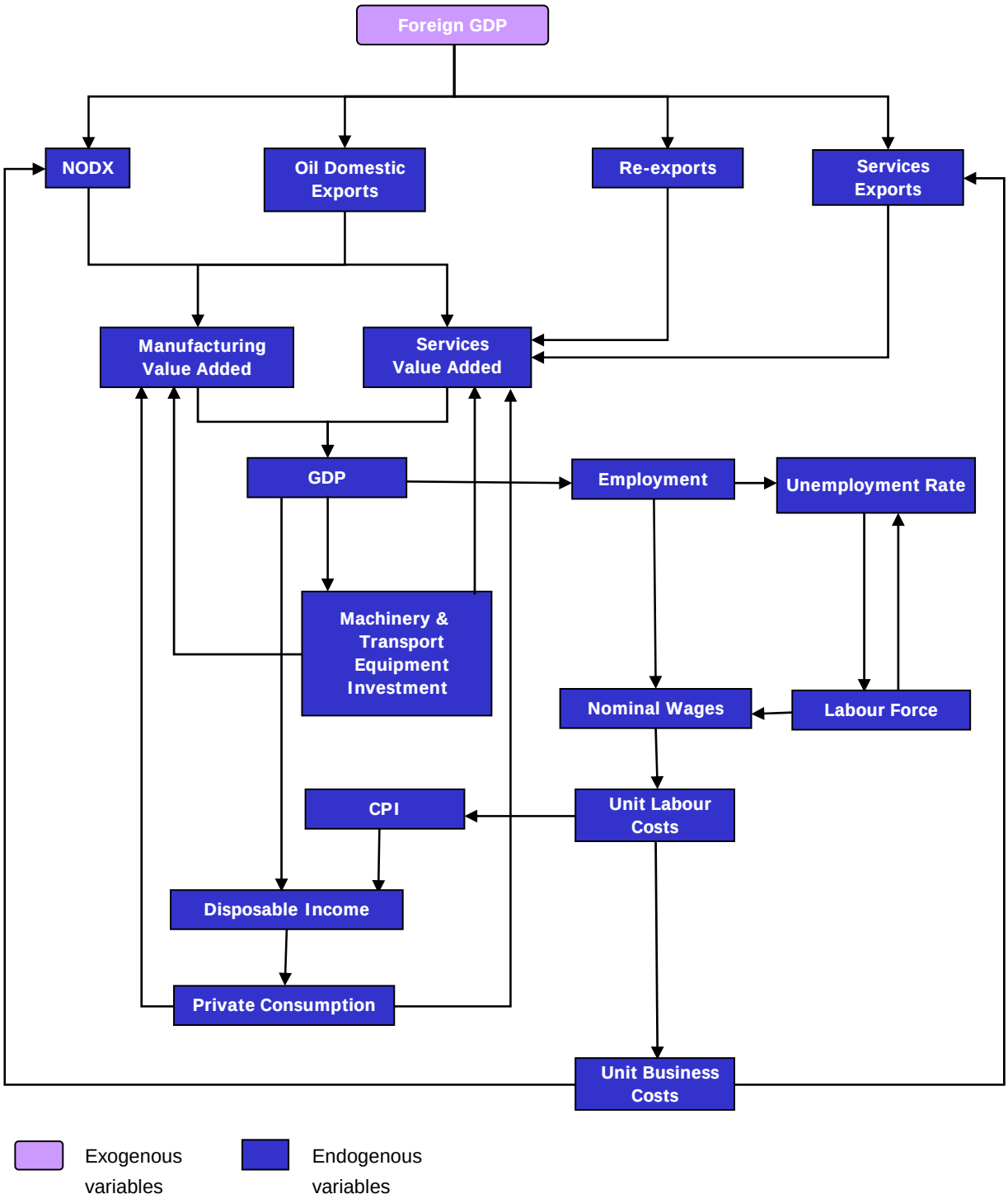
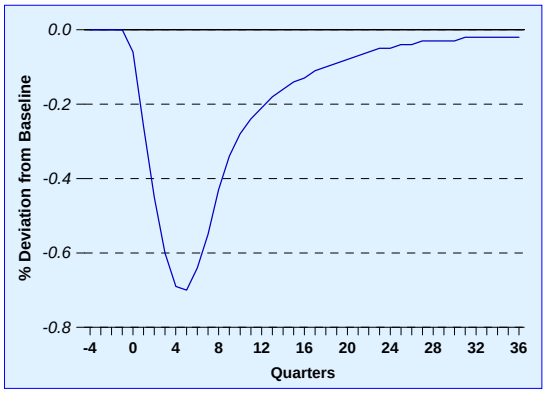
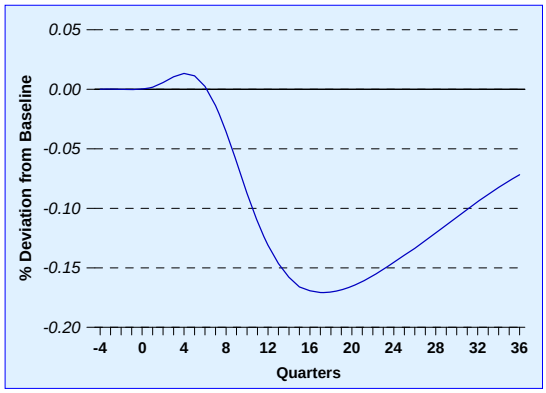


Chart 3
Macroeconomic Effects of a Foreign Demand Shock in the ESU01

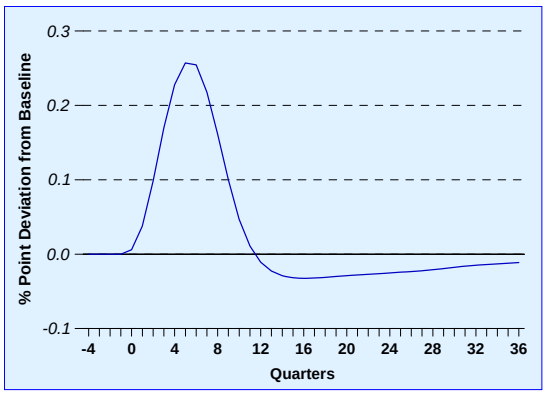
GDP



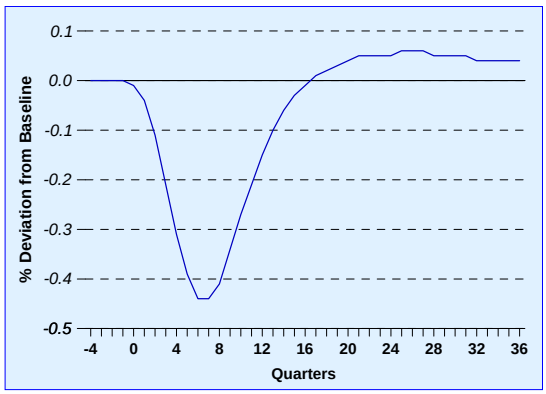
CPI



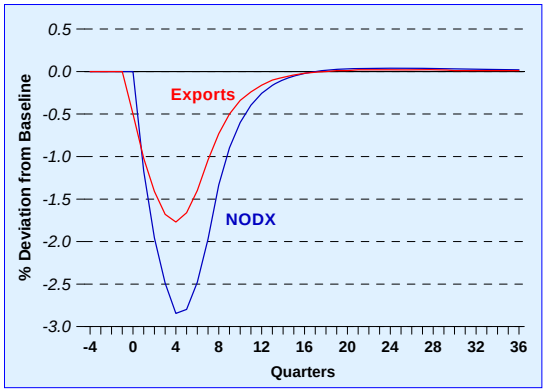
Unemployment Rate



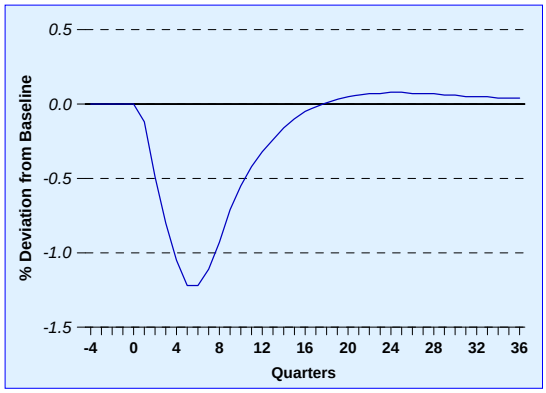
Employment



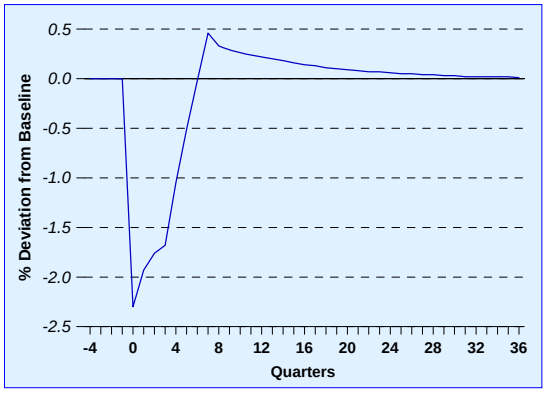
NODX and Exports



Private Machinery & Tpt Equipment Inv



Services Exports



Discussion

The simulations have revealed interesting similarities and differences in the responses of the MMS and the ESU01 to an external shock. These in turn are reflective of the different modelling approaches and structures reviewed in the earlier section.

The MMS places a greater emphasis on the modelling of the production side of the economy. Accordingly, a fall in demand and subsequent price changes – a direct outcome of a worsening in global economic conditions – signal to producers the need to re-adjust their profit maximising level of output. This leads to a ripple effect on other derived demand decisions, causing spillovers on the rest of the economy.

In comparison, the ESU01 stresses the linkages in the expenditure-based trade block of equations through which the negative demand shock impacts the rest of the economy. Specifically, the impact from the trade block is transmitted through to domestic demand, then to the sectoral and labour market blocks.

Notwithstanding the caveat above on the differences between the MMS and ESU01 with regard to the definition of the composite foreign GDP variable, there are many similarities between the two models in the dynamic responses of the economy to the external shock. Specifically, the hump-shaped decline and recovery exhibited by many economic variables is shared by both models. In terms of magnitudes, an inspection of Charts 2 and 3 suggests that the negative impact of the foreign demand shock is broadly similar across the various sectors. Moreover, the delayed changes in employment, unemployment rate and the general price level in both models indicate that these are lagging indicators of economic activity.

That said, it does appear that the MMS exhibits a stronger and quicker impact on domestic real GDP compared to the ESU01 model. The more distinct hump-shaped impact profile in the latter points to a deteriorating phase in economic activity before the maximum impact point is reached. The relatively larger swings evident in the MMS dynamic transition profile are in themselves a reflection of differential adjustment speeds within sectors and markets in the model, as well as the stronger role for stock-flow adjustments emanating from the investment equation. (see discussion above) Nevertheless, it is reassuring that both models place some emphasis on the role of self-adjusting market-driven processes in steering the economy back to its pre-shock level.

Both models, therefore, chart a well-defined transmission path for the effects of an external shock in a small open economy. They illustrate vividly the reach and pervasiveness of such a shock as it permeates through the domestic economy and highlight Singapore's heavy dependence on export demand in driving domestic economic activity. The quantitative results from the MMS and the ESU01 also establish a range of plausible multiplier estimates that will be useful in the policymaking and forecasting process.[8]

[8] In this Special Feature, the multiplier for a given endogenous variable is defined to be the percent difference between the shock and baseline levels for a given 1% change in the exogenous variable.

Sum-up

This Special Feature has reviewed two macroeconometric models of the Singapore economy – the MMS and ESU01.

Both models provide a well-structured representation of the entire economy while keeping track of the individual relationships and linkages among all the key variables in the economy. They thus help to provide greater clarity in macroeconomic analysis, although from different perspectives.

Comparative exercises, such as the one reported in this Special Feature, provide the opportunity to improve and fine-tune our economic models. Mishkin (2007) summarises this point rather well: "Active, and sometimes bitter, debates about which modelling approaches are the right ones are ongoing in macroeconomics, and there often is not a consensus on the best model. As a result, central banks must express some degree of humility regarding their knowledge of the structural relationships..."

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