Monetary Authority of Singapore

Two Decades of Macromodelling at the MAS

MAS Staff Paper No. 39

July 2005

TWO DECADES OF MACROMODELLING AT THE MAS

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JULY 2005

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JEL CLASSIFICATION NUMBER: C5, E1, E2

KEYWORDS: MACROECONOMETRIC MODELS, SINGAPORE ECONOMY, SMALL OPEN ECONOMY MODELS

ABSTRACT

This paper provides an overview of the macromodelling work undertaken at the Economic Policy Department (EPD). EPD has been engaged in macromodelling since at least 1986. Our efforts in this area were sparked by the increasing recognition of the need for a quantitative tool to assess the macroeconomic impact of policy options on the Singapore economy. The first flagship macroeconomic model, Singmod, became fully operational in 1990. Singmod is essentially a structural model incorporating both short-run Keynesian and long-run neoclassical properties. It served as the Department's main tool for forecasting and policy simulations throughout the 1990s. In February 2000, the Monetary Model of Singapore (MMS) was officially launched and has now become the main model for forecasting and policy analysis. With the introduction of the MMS and the complementary role played by Singmod and other sectoral forecasting tools, quantitative work in EPD has become more rigorous and the models have come to play an integral part in macroeconomic policy analysis in the MAS. This paper also discusses the qualities that EPD strives to build into our models to ensure their continued relevance to policy-making in the MAS.

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1. INTRODUCTION

1.1 MACROECONOMIC MODELS IN ECONOMIC POLICY

1.1.1 Economic analysis is both a science and an art. Science involves the use of rigorous economic theory and sophisticated econometric methods, while art is brought to bear in judgemental assessment of available evidence and their application to policy issues. In practice, a key scientific approach to economic analysis in central banks has taken the form of macroeconometric modelling of the economy. Economists build economic models to tackle practical problems and design them as tools for thinking about economic issues. Models are consistent and systematic frameworks that help simplify complex linkages in the economy, allowing economists to overcome the limitations of the human mind and obtain a more complete representation of the economy. General to specific modelling provides a framework for the interpretation and analysis of quantitative data and allows a prediction of the likely state of the economy based on varying assumptions about economic policy and the external environment. A fully elaborated model ensures that all such inputs are accommodated in a precise and systematic way to yield internally consistent estimates of the outcomes.

1.1.2 Models also act as vehicles for communication. They represent economists' perception of macroeconomic behaviour, and provide a framework for discussions about the structure of the economy and the influence of fiscal and monetary policies on key macroeconomic variables. Hence, models ensure clarity and precision in macroeconomic analysis. Additionally, models help maintain a degree of consistency between economists and policymakers.

1.1.3 However, modellers may also have different perspectives on how the economy works, just as different artists may have varied interpretations of the same subject. Each particular view has its individual strengths and weaknesses. Thus, there is no single best way to specify an empirical model. This, in turn, has given birth to various econometric models, reflecting different economic opinions and policy concerns. As a result, many models are used, each with a different purpose in mind. We have taken the approach of systematically comparing the different models and learning from our comparisons.

1.2 ROLES OF MACROECONOMIC MODELS

1.2.1 The use of macroeconomic models for *forecasting, contingency simulations* and *policy analysis* is indispensable. Based on realistic assumptions, models simplify the complicated linkages in the economy and remove the unnecessary "noise", thus providing us with a consistent and systematic framework for accomplishing these three purposes.

A Forecasting Tool

1.2.2 Forecasting is central to macroeconomic policy. As forecasting tools, macroeconomic models are useful in giving us possible snapshots of the near and distant future. However, forecasting macroeconomic variables is a challenging task. Currency crises, natural and man-made disasters, new discoveries and new data definitions are just a few of the numerous events that can throw a forecast off its bearings.

1.2.3 In forecasting, judgement is needed. It is not simply a case of extrapolating historical patterns. Extraneous information about economic development needs to be taken into account, and shortcomings of the model need to be dealt with. The role played by judgement in these areas does not detract from the central role of the model.

Contingency Simulations and Policy Analysis

1.2.4 Policymakers need to be prepared for unforeseen circumstances. In a macroeconomic model, an external demand or supply shock can be simulated, and the deviation of important economic variables from the baseline predicted. By controlling important factors and addressing the simultaneity problem, the causation of these changes can also be identified. By reviewing the historical experience and injecting some creativity, several forecast scenarios coinciding with different assumptions of the risk factors can also be formed.

1.2.5 The use of models for policy simulations and evaluations of monetary rules are in some respects of greater importance than for forecasting. Different sectors of the economy react to policy changes in different ways. These models embody a certain view of the economy's structure and how it responds to these policy measures. The gigantic memory of a model allows us to keep track of the relationships among key variables in the economy. This in turn enables us to forecast the likely response of the economy to the policy prescription within a coherent and logically consistent framework.

1.3 DEVELOPMENTS IN MACROECONOMIC MODELLING

1.3.1 Econometric models of the 1950s and 1960s tend to be demand-oriented and often inconsistent with the main propositions of classical economic theory. By the mid 1960s, theorists had worked out how to construct models that are simultaneously consistent with short-term Keynesian demand, the classical long-run propositions, and neo-classical growth theory.[1] The first large-scale econometric model developed to be consistent with all three tenets was the Federal Reserve Board (FRB) model that became operational in 1969.[2] That model used an inflation-augmented Phillips Curve mechanism to determine wages and prices. The model was quite successful and remained in use, largely unchanged, through to the early 1990s.

1.3.2 There is much written in the literature suggesting that models incorporating Keynesian income-generating mechanisms failed in the 1970s and 80s. There exists an even more widespread belief that models containing Phillips Curves failed badly in that period. These claims are highly exaggerated. It is true that some simple forms of Phillips Curves performed badly, but inflation-augmented Phillips Curves with the property of a non-

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1 The core belief at the heart of Keynesian economics is that prices and wages do not adjust quickly enough to changes in supply or demand to clear all markets instantaneously. Thus, a prolonged underutilization of resources is possible.

2 Actually, it is not possible to make a working model completely consistent with neo-classical growth theory since that theory was developed on the obviously unrealistic assumptions of a closed economy and a single production and investment good. However, both the FRB model and Singmod were constructed so that they closely approximate the important results of the theory in long-run simulations.

accelerating inflation rate of unemployment (NAIRU) performed quite well throughout that whole period.[3,4]

1.3.3 It is also true that the US inflation that occurred in the period was not always well predicted even by models with a NAIRU. That was because the two oil shocks and the spectacular increases in oil prices that accompanied them were unanticipated. These, however, were event risks that even the best of economic models could not predict. If we were to assume prior knowledge of the huge increases in oil prices (introduced by identities into final goods prices) that accompanied them then, Phillips Curves with NAIRUs performed well. In fact, they also coped quite well during the period of disinflation in the early 1980s.[5]

1.3.4 Nevertheless, the weakest point of the older models was their treatment of expectations. Consider the example of a consumption function. In both the permanent income and life-cycle hypotheses, consumption should depend on expected future income. The most common solution to the problem of unobservable future income was to approximate expected future values by using a distributed lag on past values. This adaptive expectations approach might be a plausible description of the way real-world expectations are formed in some circumstances, but is quite implausible in some others (such as in asset markets). Nevertheless, it was virtually the only method then in use.

1.3.5 To critics from the rational expectations school, the defect appeared fatal. Their argument applied with particular force to the use of models for policy analysis. Equations estimated under one policy regime, they argued, would not continue to work if the policy regime changed because economic

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3 Whether a Phillips Curve exhibits a NAIRU depends on the values of the coefficients of price inflation in the equation. Prior to 1973, there was not enough variation in the US rate of inflation to confidently estimate these coefficients. Some models had non-NAIRU versions that underestimated wages in 1973-74. By early 1974, it was clear the NAIRU version was the correct one.

4 Actually, at least two more explanatory variables were needed. Increases in minimum wage laws and income security programs such as unemployment insurance shift the Phillips Curve upward. These variables were usually included in working Phillips Curves well before the period in question. Since Singapore has neither, consideration of them is moot for purposes of this paper.

5 For a comprehensive defense of the performance of Phillips Curves and of Keynesian economics against their rational expectations critics, see Gordon (1990) and Blinder (1987).

agents would take new policy regime into account in forming expectations (Lucas (1976)). Rational expectations theorists proposed substituting future values computed by the model in place of the lagged historical values.

1.3.6 Recent developments in economic modelling have seen a shift towards Computable General Equilibrium (CGE) models, which has emerged as a useful tool for the analysis of the effects of government policies. The CGE model is, in general, an economic system with a variety of agents, both consumers and producers, and is essentially derived from microeconomic optimisation theory, with considerable attention to individual behaviour. Alongside these efforts, some modellers have also worked on integrating the more traditional expenditure-based macro-approach with a CGE model on the production or supply side. These models also typically incorporate forward-looking expectations and are further elaborated in Section 3.

1.4 MACROMODELLING IN THE ECONOMIC POLICY DEPARTMENT (EPD)[6]

1.4.1 EPD has been engaged in macromodelling since at least 1986. Our efforts in this area were in part triggered by the increasing recognition of the need for a quantitative tool to assess the macroeconomic impact of policy options on the Singapore economy. This need was further reinforced following Singapore's emergence from the mid-1980s recession, together with the policy recommendations proposed by the Economic Committee formed in 1985 to study the short- and long-term problems, prospects for the economy, and the appropriate policy responses.

1.4.2 Economic modelling in EPD has tried to incorporate the generally accepted thinking in the literature, while at the same time ensuring that it is suited for our purposes of policy analysis and forecasting of the Singapore economy. In 1990, the first flagship macroeconomic model, Singmod, became operational. This model was in the spirit of the US FRB's MIT-Penn-Social Science Research Council (MPS) Model (Brayton and Mauskopf (1985)). Singmod is essentially a structural model incorporating both short-run Keynesian and long-run neoclassical properties, with the short-run dynamics captured using distributed lag structures. It was the Department's

6 Known as the Economics Department until 2002.

main tool for forecasting and policy experiments in the 1990s. The details of Singmod will be explained in Section 2.

1.4.3 Recently, there has been growing preference among modellers to make use of macro-CGE models. It has the ability to dynamically analyse policy effects at not only the economy level, but at industry levels as well. This has led to the development of the Monetary Model of Singapore (MMS) in the MAS. The MMS was officially launched in February 2000 and has been in use since. It also employs the error-correction technique, which captures both the short- and long-run dynamic adjustments of the Singapore economy. A detailed description of the MMS will be provided in Section 3.

1.4.4 EPD has a dedicated modelling unit comprising about three to four officers and a support staff to maintain the databases. Work on the models is closely integrated with the other research work within the department. The sectoral specialists are also engaged in forecasting and they produce, quite independently from the model staff, a forecast of GDP by sectors. The sectoral specialists also possess specific knowledge pertaining to the various sectors that might require adjustments of model equation residuals to take into account such specific factors in the model forecasts. The sectoral specialists also produce forecasts of many of the variables exogenous to the macroeconomic models such as foreign GDP, foreign prices, and various government expenditures, which the model staff then uses as inputs for the forecasting simulations.

1.4.5 Using both the exogenous variables and the special adjustments suggested by the non-model staff, an initial model forecast is produced. Both the model forecast and the sectoral forecast are presented at a staff meeting attended by senior department staff. The differences between the model and non-model forecasts are discussed and an attempt is made at reconciliation. The senior staff may decide to make a judgement call and direct the model staff to make further adjustments based on an assessment of the economic situation. This process sometimes goes through several iterations. The final forecast will incorporate the views of all the three groups.

1.4.6 Each time a forecast is done, the model is simulated to produce forecasts into the medium term. In comparison, the sectoral part of the forecast rarely extends beyond two years. This reflects the comparative advantages of the two types of forecasts. Over a short horizon, the special factors pertaining to the various sectors of the economy tend to have a very large effect on the forecast, so the non-model inputs tend to be quite important. Over a longer horizon, these special short-run factors become inconsequential, as the special circumstances that will arise in the future are largely unknown. The model, on the other hand, has its advantages in the longer term[7] as it contains a formal structure of how the economy works. This structure can tell us important things about the dynamic adjustments of economic variables to their steady-state values.

1.4.7 One reason the forecasts are run so far into the future is that policy initiatives, while aimed largely at short and intermediate term goals, have implications for the more distant future. A change in the rate of currency appreciation/depreciation, for example, has an effect on the rate of inflation many years into the future and these longer-term effects should be made clear.

1.4.8 A second reason for running the forecast simulations over a longer time horizon is to answer questions about longer-term trends in certain macroeeconomic variables such as government tax revenues or real GDP growth a decade or more into the future.

1.4.9 Indeed, models have proved to be indispensable in the two major areas of forecasting and policy analysis. Forecasting in EPD is done at least six times a year, in conjunction with the exchange rate policy reviews, and the release of the quarterly national accounts. MAS also co-chairs (with the Ministry of Trade & Industry) the Singapore government's Economic Monitoring Group or EMG. The EMG assesses the state of the Singapore economy and the risk factors facing it every quarter, with the view of recommending the official forecast for the Singapore economy. Forecasts of the key economic variables from MAS' econometric models are used as inputs into the EMG decision-making process.

1.4.10 In EPD, the most important policy analysis work involves the assessment of monetary/exchange rate policy. An initial forecast is made based on some 'baseline' assumption about the exchange rate policy path.

[7] Note that the model will not be able to predict whether the economy will be in recession or boom ten years into the future. However, it provides useful information about the average rate of growth that might be expected over the next five to ten years, the average ratio of fixed investment to GDP over that period, or the likely current account balance as a proportion of GDP.

This baseline forecast would incorporate all the assumptions on the exogenous variables and equation residuals as highlighted earlier. The model is then used to simulate the effects of alternative exchange rate paths under the baseline and alternative scenarios of the external environment, which help to identify the short- and medium- term trade-offs involved in the choice of a particular policy stance. Based on the simulation results, a few 'optimum' exchange rate policy paths that are consistent with MAS' monetary policy objective of achieving sustainable economic growth with low inflation over the medium term are identified.

1.4.11 The macroeconomic models have also been used to address economic issues that require a general equilibrium perspective of the economy. Some of these issues may not be related to monetary policy, but reflect general policy concerns. For example, the model has been used to analyse the effects of an increase in the goods and services tax and other budgetary measures on the economy. Others include simulating the impact of a global electronics slowdown and recession in the US on the Singapore economy. Questions of this nature can only be analysed satisfactorily with an economy-wide model, which better captures the transmission channels and relevant linkages.

1.4.12 In the rest of the paper, we provide the details of Singmod and MMS, the two main macroeconomic models that are used in EPD. These sections were principally written by our consultants Jared Enzler and Christopher Murphy, respectively. The paper concludes by articulating EPD's broad philosophy towards macroeconomic modelling.

2. INSPIRATION FOR SINGMOD

2.1 GROUNDWORK FOR SINGMOD

2.1.1 As explained earlier, macroeconomic modelling in MAS had its beginning in the late 1980s when EPD decided to commit resources to strengthening the quantitative and analytical capabilities of its research work. To this end, MAS requested for a technical representative from the International Monetary Fund (IMF), who proposed constructing a full-fledged macroeconomic model of Singapore for use in forecasting and policy analysis to complement EPD's existing forecasting capabilities.

2.1.2 A study was undertaken to examine the feasibility of constructing such a model. There were several considerations:

- First, for the model to be useful in cyclical analysis, it would need to be estimated on the basis of quarterly national accounts data. However, there were less than 12 years of such data when normally at least 15 years of observation points would be required.
- Second, there was no data on the income side of the national accounts at that time. It was not clear that a time series for some highly desirable concepts (such as disposable personal income for use in explaining consumption) could be satisfactorily approximated from the data available.
- Third, there appeared to be a higher degree of government intervention in the Singapore economy than in most economies that had been successfully modelled. Among the interventions were (i) target wage increases recommended by the National Wages Council that were widely believed to be the most important determinant of historical wage increases, (ii) mandatory Central Provident Fund contributions that many observers thought to be the most important determinant of the national savings rate, and (iii) the role of government-controlled businesses and statutory boards in various aspects of the economy.

2.1.3 However, preliminary investigation showed that some of the data problems could be circumvented, and initial econometric work suggested that the impact of government intervention was less extensive than anticipated.

For example, both wages and private savings were subject to market forces, while the housing market had been liberalised. Sensible equations could therefore be constructed largely from a priori considerations.

2.1.4 Having established that it was feasible to embark on creating such a model, the next task was to develop an economic/econometric modelling framework that would be appropriate for the Singapore economy.

2.2 MODELLING STRATEGY

Data vs. Theory in Equation Estimation

2.2.1 At the outset, there was a consensus that the model design should be heavily influenced by theoretical considerations. The modellers recognised the constraints of relying solely on regression techniques and that information from other sources had to be used to complete the model structure. This required the application of a priori knowledge of key economic relationships, which could be entered in the form of restrictions on the functional forms or permissible parameters of the estimated equations.

Restrictions

2.2.2 There were several different considerations that determined the restrictions applied to model design. First, economic theory may identify the major variables that would be important in explaining the key relationships in the economy.

2.2.3 Second, theoretical restrictions can provide guidance on establishing consistency among relationships in the model. For example, a given percentage increase in the exchange rate would result in an equal percentage reduction in all prices in the long run (money neutrality principle). Similarly, a given percentage increase in the rate of growth of the nominal exchange rate would lead to an equal percentage reduction in the rate of inflation.

2.2.4 Third, the neoclassical growth theory specifies a number of explicit relationships and constraints that should hold in the long run. Thus, the

Singapore economy would approach a balanced growth path with constant real interest rates, (nearly) constant capital/output ratios and current account balances as a proportion of GDP, if (i) population growth and the rate of technical change in Singapore were the same as for all foreign countries; and (ii) all foreign countries had constant real rates of interest.

2.2.5 Fourth, restrictions might also be suggested by information from other studies and it was EPD's strategy to incorporate liberally information from other sources wherever it was available and reasonable.

2.3 MODEL STRUCTURE

Consequences of being a Small - Open Economy

2.3.1 The small-open economy characteristics of the Singapore economy would have an impact on the policy framework, and in turn on the specification of the model:

- First, since the volumes of Singapore's imports and exports are small relative to the size of world markets, its export and import prices are largely determined abroad. Therefore, in Singmod, the import and export prices of goods incorporated long-run unit elasticities with respect to exchange rates and foreign prices.
- Second, since imports account for a very large part of the expenditures on consumption and capital equipment, foreign prices and the exchange rate have a correspondingly large direct impact on domestic prices. In Singmod, the import share of the consumption price equation was about one-half, while the price of imported building materials determined more than one-half of the construction deflator. Furthermore, the deflator for machinery and equipment investment was almost completely dependent on the foreign import prices of machinery and equipment.
- Third, since Singapore's capital markets are small relative to the size of world capital markets, its openness to capital flows causes domestic interest rates to be strongly influenced by foreign rates. Thus in Singmod, interest rates were determined by a modified interest rate parity condition

in which domestic factors played only a very minor role in determining domestic interest rates.

- Fourth, given that Singapore's exports and imports are very large relative to GDP, the exchange rate plays a primary role in equilibrating aggregate demand with potential supply. Moreover, two of the most interest-sensitive categories of expenditures (consumer durables and non-construction investment) consist almost entirely of imported items. Consequently, changes in the demand for them would have little effect on domestic production, further reducing the impact of interest rate changes.

Structural Overview

2.3.2 The equations in Singmod were divided into four blocks. The first (labour supply block) determined the trend domestic labour force and trend employment of foreign workers. The second block (the goods demand block) consisted of equations determining consumption, investment, exports and imports. These equations did not by themselves determine the level of aggregate demand since they depended on the real exchange rate and interest rates. The third (labour demand) block translated goods demand into the demand for workers. It contained equations for productivity, total employment, domestic and foreign employment, actual (as opposed to trend) domestic labour force and the unemployment rate. The fourth block of equations (the wage-price block) determined wages, prices, interest rates, and, given nominal exchange rates, the real exchange rate.[8]

2.3.3 Singmod contained linkages that tended to equilibrate aggregate demand and supply, even in the absence of the stabilisation efforts of policymakers. For any given level of the real exchange rate, the demand block solved for the level of aggregate goods demand. The labour demand block translated goods demand into employment and unemployment. If unemployment was below (above) the NAIRU, the rate of change of wages accelerated (decelerated). This gradually increased (reduced) the real exchange rate from what it otherwise would have been, and that in turn reduced (increased) aggregate demand and increased (reduced)

[8] The demarcations between these blocks were quite arbitrary. Placing the productivity, price and short-run employment equations outside the supply block helped to focus attention on the fact that the equilibrating mechanism operated only to equilibrate the long-run supply and demand for labour.

unemployment. Thus, there were always forces at work in Singmod which pushed economic activity towards the level that equated the actual unemployment rate with the NAIRU.

2.3.4 This equilibrating mechanism in Singmod worked rather slowly, implying that there was a role for macro policymakers to influence the exchange rate (and to pursue other macro policy initiatives) to smooth out fluctuations in economic activity.

Labour Supply Block

2.3.5 Neoclassical growth theory indicates, among other things, that over the longer term, production is limited by the size of the labour force and the level of technology. The size of the historical labour force was a matter of record, but some means had to be used to separate the cyclical and trend components in the historical data, and to project the resulting trend component into the future.[9] It was found convenient to break the labour force into its two constituent parts – population and participation rates – and to project the parts separately.

2.3.6 The first task was to project population by five-year age groups and by gender. The second task was to make projections for birth rates, death rates and immigration. The first two were done by extrapolating historical trends and using judgment, while projection on future immigration was based on inputs provided by other agencies.

2.3.7 The third task was to obtain projections of the trend labour force. To do so, we needed to project trend participation rates based on historical participation rates which were available by age and gender.

2.3.8 The fourth and final task was to project trend foreign labour. It was difficult to separate the policy-determined trend from the cyclical component

[9] The equations that determined domestic population (based on birth rates, death rates, etc.) and trend domestic participation rates did not actually appear in the model. These series were not dependent on anything else in the system and had to be calculated and forecasted only once each year as new data became available. The results entered into the model as exogenous inputs. These equations were, however, logically a part of the model and hence included in this description.

due to the periodic relaxation of foreign labour ruling. Nevertheless, a separation was done, again using considerable judgment. When added to the trend domestic labour supply series, the result was an estimate of future total trend labour force.

Goods Demand Block

2.3.9 The goods demand block followed the organisation of the expenditure side of the national accounts, in which GDP is disaggregated into consumption, investment, exports and imports.

Consumption

2.3.10 Consumption is divided into public and private components in the national accounts. Real public consumption was taken as exogenous in Singmod.

2.3.11 Modelling private consumption in Singapore presented serious challenges due to data deficiencies. The objective was to explain consumption on the basis of the life-cycle hypothesis which postulates that consumption is determined largely by private disposable income and private household wealth. Unfortunately, neither concept was available as a time series during model construction. To get around this, a time series for disposable income was estimated by using current dollar GDP and subtracting from it estimates of the relevant items (including, among other things, depreciation, taxes on an accrual basis, and the profits of statutory boards and government-linked corporations).

2.3.12 The resulting series depended upon many estimated derivative variables and as a result, was probably not a very good representation of actual disposable income. However, the alternative of explaining consumption directly on the basis of GDP had more significant problems. A significant part of the explanation for the extraordinarily high gross savings rate in Singapore was the high saving rate of the government, the statutory boards and the government-linked corporations. Moreover, it appeared that developments in public savings explained a substantial part of the movements in the national savings rate. All this had to be taken into account. Creating a disposable income series addressed these issues.

2.3.13 No attempt was made to create a household wealth time series for inclusion in Singmod. One large component, savings held in the Central Provident Fund (CPF) accounts, was used in the equation. Other components, such as household holdings of corporate equities, deposits, the market value of housing and household liabilities were not available, and their estimation would have been quite difficult. The lack of a proper wealth series was a major shortcoming of that equation.

2.3.14 Another data problem faced was that consumption expenditures in Singapore's national accounts were not disaggregated into durables, non-durables and services components. Data on the stock of durables as well as the services that flow from that stock were also not available. In reality, expenditures on consumer durables should be considered as investments by households, similar to the purchases of houses; therefore, expenditures on durables should ideally be modelled like expenditures on houses. Finally, real expenditures on automobiles were largely policy determined because the number of cars purchased was limited by the number of new Certificates of Entitlement (COE) issued. As a result, fluctuations in the demand for autos showed up mostly as changes in the price (including COE costs) of automobiles.

2.3.15 CPF contribution rates undoubtedly influence consumption and savings. In the calculation of disposable income, CPF contributions were not deducted. This is based on the assumption that consumption out of a given amount of disposable income would be negatively related to the CPF employer and employee contribution rates. The consumption equation had parameter estimates which indicated that consumption would be reduced at the margin by about one half of any increase in CPF contributions. The final equation took the general form:

$$C/Y = f(\Delta Y, \mathrm{W/Y}, DR, RCPF, OTHER) \quad (1)$$

where C is consumption, Y is disposable income, ΔY is the change in disposable income, W represents two out of several components of wealth, DR is the dependency ratio, $RCPF$ is the CPF contribution rate and $OTHER$

represents several explanatory variables designed to limit the effects of the data deficiencies.

2.3.16 With so many data deficiencies, this equation was probably the most intellectually unsatisfying of all the major behavioural equations in the system. While the equation fitted past data reasonably well, the deficiencies caused the specification of the equation to be inconsistent with consumption theory.

Fixed Investment

2.3.17 There are five different types of fixed investment in the national accounts and each of these is further divided into the public and private components. The public components of non-residential buildings, works, and transportation equipment were all treated as exogenous variables, as was private works. Private transportation equipment (which consists mostly of aircraft and ships) was taken to be exogenous as most of it was imported and purchases were very lumpy. All of the investment equations took on fairly similar specifications. For illustrative purposes, we consider the equation for machinery and equipment expenditure.

Machinery and Equipment

2.3.18 Public and private machinery and equipment expenditures were combined into one equation based on the assumption that public utilities plan capital equipment expenditures in a manner similar to that of private companies. The equation took the form of a “flexible accelerator”, with changes in output leading to desired changes in capacity, and capital intensity of production depending on factor prices. The equation incorporated putty-clay characteristics, implying that factor substitution could occur only in the design phase. Once equipment was installed, it had to be used with the amount of labour for which it was designed.

$$I_{M\&E} = \Delta C^{*} * V^{*} \qquad (2)$$

where $I_{M\&E}$ is investment in machinery and equipment, ΔC^{*} is the desired increase in capacity and V^{*} is the desired capital/output ratio for the new equipment. In estimation, the desired capacity increase was proxied by a distributed lag on past output increases, and the desired capital/output ratio, represented by a distributed lag on the inverse of the rental rate for capital equipment calculated in the manner developed by Jorgenson (1963) and Bischoff (1966).

2.3.19 Abstracting from tax considerations, the rental rate (R) was computed as:

$$R = (P_k/P_q) * (\delta + r) \tag{3}$$

where P_k is the price of capital equipment, P_q is the price of output, δ is the depreciation rate on equipment and r is a measure of the real interest rate. Obviously, if P_k/P_q remained constant together with r, the desired capital/output ratio would also stay unchanged. The real interest rate in Singmod was set up such that (see the wage-price block) it did not contain a trend component. However, the historical price of equipment relative to domestic output showed a downward trend, and thus the desired capital/output ratio for equipment exhibited a rising profile.

Inventory Investment

2.3.20 Inventory investment was modelled using a stock adjustment equation that responded to the final sales of several final expenditure components and the cost of capital which determined the desired inventory/sales ratio. The form of the equation was similar to the one used for both private non-residential and residential structures expenditures.

Exports and Imports

2.3.21 Exports and imports in the national accounts encompass both trade and services. Singmod contained equations which explained four categories of trade exports, five main categories of trade imports, and the full range of categories of service exports and imports from the balance of payments accounts. In general terms, the export equations were based on various weighted averages (by country) of foreign GDPs and weighted averages (again by country) of real exchange rates. The import equations depended upon various categories of final expenditures and (in some, but not all, cases) real exchange rates.

2.3.22 The most important of the export equations, and the one that accounted for the largest proportion of the variation of aggregate demand, was the equation for non-oil domestic exports. This equation is presented in more detail because of its importance and that it illustrates a number of concepts relevant to other demand equations. The structure, stripped of lag operators, can be summarized as:

$$\mathit{log(NODX)} = \alpha_0 + \alpha_1 * \mathit{log(GDP_f)} + \alpha_2 * \mathit{f(CAPACITY)} + \alpha_3 * \beta_1^{(time-1975)} + \alpha_4 * \mathit{OE_{us}/SE_{us}} + \alpha_5 * \mathit{log(REER)} + \alpha_6 * U_{diff} + \alpha_7 * U_{avg} \quad (4)$$

where *NODX* is real non-oil domestic exports, GDP_f is a logarithmic weighted average of the real GDPs of several foreign countries, *CAPACITY* is a measure of trend output of real non-construction domestic GDP, OE_{us}/SE_{us} is the ratio of new orders to shipments of electronics in the US (used to reflect world-wide conditions in the market for electronics products), *REER* is the real exchange rate (a logarithmic weighted average of the nominal exchange rates of Singapore's trading partners multiplied by the corresponding relative unit labour costs), U_{diff} is a weighted moving average of the change in the unemployment rate and U_{avg} is a moving average of a non-linear deviation of the unemployment rate from 2.0%.

2.3.23 The first and fifth terms represent the usual income and real exchange rate terms used in export equations. Holding all else constant, if α_1 were unity and foreign GDP were to grow at the same rate as domestic GDP, *NODX* would grow at the same rate as domestic GDP. Note further that if the real exchange rate were constant, an equation consisting of only these two terms would be consistent with balanced growth.

2.3.24 In fact, *NODX* growth during the historical estimation period had significantly exceeded that of both foreign and domestic GDP. This fact could not be accounted for by a falling real exchange rate, because the *REER* had on average been appreciating. It therefore became necessary to reconcile the equation with this observed "excess growth", while retaining consistency with the balanced growth path in the very long run.

2.3.25 The excess growth could be partly explained by the capacity of the tradable goods sector in the economy to expand the range of items it could export. This phenomenon was captured by the second term. The non-linear function of domestic capacity growth was constructed in such a way that extra growth coming from this source gradually declined. The presence of this term meant that the equation was not purely demand determined, but rather represented a reduced form of demand and supply factors.

2.3.26 Another reason for the excess growth could have been improved transportation and communications which facilitated increased trade. These forces were not easily measurable and so were captured in the model by the non-linear trend in the third term. The term was coded such that as 'time' progressed when the model was simulated, the power of the trend term asymptotically approached zero.[10]

2.3.27 The fourth term was a distributed lag on the ratio of electronics new orders to shipments in the US and served as a proxy for demand conditions in the world electronics market. This variable had no trend over the historical period. The final two terms represented cyclical domestic supply conditions. They suggested, respectively, that when the unemployment rate was falling, or when it was unusually low, orders for exports could be turned away. Like the domestic GDP_{trend} variable, they converted the equation into a reduced form of demand and supply factors.

Aggregate Demand

2.3.28 The various components of aggregate demand were combined using the usual GDP identity.

Labour Demand Block

2.3.29 This block translated the demand for goods into demand for labour, then proceeded to calculate the unemployment rate.

[10] The domestic capacity and the trend term could not be distinguished in the estimated equation. The coefficient on one of them was fixed a priori and the coefficient on the other was estimated. It seemed preferable to keep both terms as they represent different concepts.

2.3.30 The productivity equation was derived from an assumed Cobb-Douglas production function. A cyclical term was added to the equation to reflect the fact that as output changed, employers would vary the number of hours worked per employee and the number of employees only after a lag. A trend term was also added to capture technical progress.

Productivity Equation:

$$Log(Q/L)_t = \alpha_0 + \alpha_1 * log(K/L_{trend})_t + \Sigma\beta_\iota * dlog(Q_{t-1}) + \gamma * ED_t + log(TFP_t) \quad (5)$$

where Q represents output, L is employment, K is a measure of the capital stock, L_{trend} is trend employment, ED is the years of educational attainment of the workforce, and TFP is the estimate of total factor productivity. [11,12]

2.3.31 In the first round of estimation, the coefficients on the capital/labour ratio and the years of educational attainment were constrained using historical values and judgement while *log(TFP)* was replaced by a time trend term. The time trend and the residuals of this equation taken together represented a crude estimate of the log level of technology. This estimate of technology was smoothed and entered as an explanatory variable in a second round estimation with its coefficient restricted to unity. The resulting second round residuals were again smoothed and used as the technology variable for the third round. This process was continued until a smooth technical progress series was created and the equation residuals appeared random.[13] It is interesting to note that the resulting estimate of technical progress was indeed quite low in the years covered by the well-known study by Alwyn Young (1992).[14] However, the measured *TFP* growth rate increased sharply in the

11 The capital stock is a weighted average of the various capital stocks associated with the various investment series in the national accounts with the weights (held constant throughout the period) reflecting estimates of the marginal productivities of the various types of capital.

12 The educational attainment term is a quality-adjustment term for labour. The form is quite different from the quality adjustment of capital.

13 This methodology would result in a measure of total factor productivity rather than the labour-augmenting growth needed for consistency with a Solow growth model. However, with a Cobb-Douglas production function, the two rates of technical change are indistinguishable apart from a multiplicative constant.

14 This must almost necessarily be the case. The procedure used to estimate technology is very similar to that used to estimate *TFP* in growth-accounting studies. The main differences are the fixed rather than variable capital share and the use of changes in output to smooth cyclical variation in *TFP*.

early 1990s, before tapering off in the mid 1990s. In forecasting, the rate of *TFP* growth was projected by judgmental means.

2.3.32 Employment was estimated in the model by dividing the solution for output by productivity. A labour force equation related deviations of the actual labour force from the trend labour force (calculated in the labour supply block) to deviations of employment from the trend labour force. An identity then calculated the model's solution for the unemployment rate.

Wage-Price Block

2.3.33 Wages, prices, the real exchange rate and interest rates were determined in this block which generated forces that equilibrated aggregate demand towards a level that was consistent with the clearing of the labour market.

Wages

2.3.34 Singmod contained a standard short-run Phillips Curve:

$$w_t = \alpha_0 - \alpha_1 * U_t + \alpha_2 * p_{t-1} + \alpha_3 * lp_t \tag{6}$$

where lower case letters represent percentage changes of a variable. *w* refers to the growth rate of wages, *p* represents a measure of the consumer price index growth and *lp* growth in labour productivity. All three terms contain distributed lags (suppressed in the notation). The coefficients on the price terms summed to unity (the sum was forced in estimation, but was not significantly different from unity if estimated freely). The sum of the coefficients on the unemployment rate was strongly negative. This reflected the fact that there are no income security programs such as unemployment insurance or welfare in Singapore, and hence there is immense pressure on unemployed workers to find new jobs, even at lower wages than they received in previous jobs. This equation proved to be very robust. Moreover, the equation fitted the data quite well if the errors were averaged over four quarters.

Wage-Price Dynamics

2.3.35 To simplify the exposition, we initially assumed that the economy is closed and that the rate of productivity growth was zero. The short-run Phillips Curve becomes:

$$w_t = \alpha_0 - \alpha_1 * U_t + \alpha_2 * p_{t-1} \tag{7}$$

Note that the expression for inflation has been lagged one period for later convenience. In a working Phillips Curve there would be distributed lags on the right-hand terms but they are suppressed in this example since they are irrelevant to the understanding of the system. The α_i are all positive so the slope of the short-run Phillips Curve becomes $-\alpha_1$. For any given value of p_{t-1}, it represents the amount by which a 1 percentage point increase in the unemployment rate would decrease the rate of change of wages.

2.3.36 Suppose prices are determined as a constant (k) mark-up over unit labour costs (*ULC*).

Mark-up equation:

$$P_t = k * ULC_t \tag{8}$$

Since unit labour costs are simply wages divided by productivity, the mark-up can be written as:

$$P_t = k * W_t/LP_t \tag{9}$$

From this it follows (approximately) that the rate of change of prices equalled the rate of change of wages less productivity growth. Since the rate of productivity growth is assumed to be zero,

$$p_t = w_t \tag{10}$$

This expression for p_t was substituted into the right hand side of the short-run Phillips Curve. On rearranging, an expression for the evolution of wage increases over time was obtained:

Evolution of wage increases:

$$w_t = \alpha_2 * w_{t-1} + \alpha_0 - \alpha_1 * U_t \qquad (11)$$

For any constant value of U, this expression can be solved for the value of w at which w stops changing.

Long-run Phillips Curve:

$$w = \alpha_0/(1 - \alpha_2) - \alpha_1/(1 - \alpha_2) * U \qquad (12)$$

2.3.37 Equation (12) refers to the long-run Phillips Curve embedded in Singmod. It was used to solve for the rate of change of wages if the unemployment rate was held constant. Notice that if the price coefficient (α_2) in the short-term Phillips Curve was zero, the short- and long-term Phillips Curves would be identical. As α_2 increases toward unity, the slope increases until it becomes completely vertical at the *NAIRU*.

2.3.38 To compute the *NAIRU*, equation (11) was used, with α_2, the coefficient on inflation, set to one:

$$w_t - w_{t-1} = \alpha_0 - \alpha_1 * U_t \qquad (13)$$

The NAIRU represents the unemployment rate where wage increases are neither rising nor falling ($w_t - w_{t-1} = 0$). It follows that:

$$NAIRU = \alpha_0/\alpha_1 \qquad (14)$$

When unemployment falls (rises) below (above) the *NAIRU* in Singmod, the rate of wage increase (decrease) would accelerate. Since in Singmod the coefficient of prices in the wage equation was constrained to unity, this implies that the model contained a well-defined *NAIRU.*

2.3.39 Given the small and open nature of the Singapore economy, the proportion of final demand that is imported is quite large. Assuming that the price level that appears in the short-run Phillips Curve is a final goods price, such as the CPI, it will have both domestically produced (*PDOM*) and imported (*PM*) components.[15]

This can be represented as:

$$P_t = \beta^* PDOM_t + (1-\beta)^* PM_t \tag{15}$$

where β is the share ($0 < \beta < 1$) of domestic value added in the CPI. In rates of growth this (approximately) becomes:

$$p_t = \beta^* pdom_t + (1-\beta)^* pm_t \tag{16}$$

2.3.40 Only the domestic portion would be expected to follow the mark-up rule. If $pdom_t$ was replaced by w_t in this last expression and the result substituted into the short-run Phillips curve, and if the price coefficient (α_2) was set to one, the slope of the long-run Phillips curve would become $\alpha_1/(1-\beta)$. The long-run curve would no longer be vertical. Thus we see that a price coefficient of unity is not sufficient to lead to a *NAIRU* unless the import share is zero.

2.3.41 There is another circumstance, however, in which the *NAIRU* may appear even in the presence of a large import share in final goods prices. If the rate of change of import prices were the same as the rate of domestic prices, then final goods prices would rise at the same rate as domestic prices regardless of the size of the import share. In this case, w_t would be substituted for both $PDOM_t$ and PM_t and the *NAIRU* would be restored.

2.3.42 In the literature, the role of import prices tends to be frequently ignored as an expository convenience. Much of the literature regarding the existence of a *NAIRU* comes from the US, where the import share is small and where monetary policy largely concentrates on domestic considerations, leaving the nominal exchange rate to be determined by market forces. In the sufficiently long run, the rate of change of the nominal exchange rate can be expected to mirror the differential between domestic and foreign inflation rates, and with the import share being small, the short-run deviations from this

[15] *PDOM* is represented in Singmod by the CPI, excluding actual and imputed rents on housing and prices of cars. The excluded items were determined by a fairly different mechanism from other CPI prices.

differential are not too important. In a practical model of Singapore, however, the role of import prices cannot be ignored.

2.3.43 However, a mechanism akin to the equilibrating reference rate of NAIRU was built into Singmod. Indeed, an actual unemployment rate, over or under NAIRU – assuming the exchange rate was managed in order to keep increases in import prices in line with those of domestic prices – would not have been sustainable in the full systems of equations. Consider the following five equations, and make the assumption that foreign prices grow at the same rate as foreign wages.

(17) $w_t = \alpha_0 - \alpha_1 * U_t + p_{t-1}$ Short-run Phillips Curve with $\alpha_2 = 1$

(18) $p_t = \beta * pdom_t + (1-\beta) * pm_t$ Price equation in rate of change form

(19) $pdom_t = w_t$ Assumption of no domestic productivity growth

(20) $pm_t = pf_t - neer_t$ Import price equation in rate of change form

(21) $pf_t = wf_t$ Assumption of no foreign productivity growth

2.3.44 Substituting equation (21) into (20), the resulting (20) and (19) into (18) and the resulting (18) into (17) yields:

$$w_t = \beta * w_{t-1} + \alpha_0 - \alpha_1 * U_t + (1-\beta) * (wf_{t-1} - neer_{t-1}) \qquad (22)$$

Solving for the long-run value of w that results from a constant U, rearranging and noting that the resulting left hand side is the rate of change of the real exchange rate (*REER)* yields:

Long-run rate of growth of *REER*:

$$REER = w - wf + neer = (\alpha_0 - \alpha_1 * U)/(1-\beta) \qquad (23)$$

2.3.45 Since β takes a value between 0 and 1, the denominator of the right-hand side term in Singmod is always positive. If U_t was below (above) *NAIRU* (defined previously as $U = \alpha_0/\alpha_1$), the denominator would be positive (negative) and the *REER* would grow (fall) steadily. This gradually reduced (increased) exports and increased (reduced) imports, thereby lowering (raising) aggregate demand steadily. This process continued until the unemployment rate returned to the level consistent with *NAIRU*. Thus Singmod was constructed in such a way that in the long run, unemployment could not be persistently above or below the rate consistent with *NAIRU*.

2.3.46 The equilibrating effects of this mechanism operated quite slowly because the lags on the exchange rate in the export and import equations were fairly long. Consequently, they could not be relied upon to dampen short-term fluctuations in output and countercyclical exchange rate and fiscal policies were still needed to prevent long booms and recessions. Even wise macro policies combined with the equilibrating mechanism are insufficient to prevent significant fluctuations in economic activity.

Interest Rates

2.3.47 Interest rates were determined in Singmod by a modified interest parity condition in which the expected rate of change of the exchange rate was proxied by suitably restricted distributed lags on the differential between foreign and domestic inflation rates and past rates of change of the exchange rate and a measure of domestic economic activity.

$$\begin{aligned} i_{d,t} &= i_{f,t} - neer^e_t \\ &= i_{f,t} + \theta - \Sigma\alpha_i{*}neer_{t-i} + \Sigma\beta_i{*}(p_{d,t-i} - p_{f,t-i}) + \gamma{*}UTIL_t \qquad (24) \end{aligned}$$

where $\Sigma\alpha_i + \Sigma\beta_i = 1$, i_d is the domestic interest rate, i_f is the foreign interest rate, $neer^e$ is the expected exchange rate change, p_d is the rate of change of domestic prices, p_f is the rate of change of foreign prices, θ is a risk premium and *UTIL* is a measure of domestic capacity utilization. If movements in nominal exchange rates largely reflected inflation differentials in the longer run, the equation would, apart from the trendless risk premium and the trendless utilisation rate, on average, equate domestic and foreign real interest rates over long periods of time. Thus if foreign real interest rates remain relatively constant, on average, domestic real interest rates would be constant as well. This, in turn, implies relatively constant desired capital/output ratios in the domestic investment equations and allows the simulated economy to grow along a balanced growth path.

An Illustrative Simulation

2.3.48 To illustrate some of the system's dynamics and its tendency to return to a balanced growth path when disturbed, two simulations were conducted. In the first (baseline) simulation, the model was simulated over a 7-year period and the results recorded. The second (alternate) simulation was identical except that the equation for the demand for Real Non-Oil Exports (RNODX) was shifted upward in each quarter by an amount equal to 5 percent of its value in the baseline simulation. Such a simulation can be thought of as involving a positive external demand shock facing exporters in Singapore. Charts 1 through 6 report the differences between the two simulations.

2.3.49 Chart 1 shows the effect on real non-oil domestic exports (RNODX). In the first quarter, exports were indeed 5 percent higher, but in succeeding quarters, the effect was gradually reduced. By the end of the simulations, RNODX appeared to be levelling off at about 1.5 percentage points higher, but that is something of an illusion. The model contained cyclical mechanisms that tend to reverberate long after any initial disturbance. Because of the cyclical approach to the final resting point, exports had overshot at this point. The dot at the far right of the diagram provides an estimate of the final resting point. It is about 2 percentage points above the control solution.

Chart 1
Effect on Real Non-Oil Domestic Exports

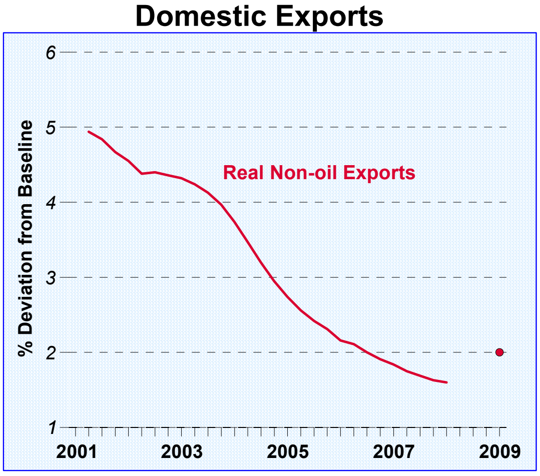


Chart 2
Effect on Real GDP

2.3.50 The cause of the eroding influence of the shock on RNODX should be familiar and can be seen in Chart 5. That chart indicates that by the end of the simulation, wages rose by about 2 percentage points and that the effect on wages was still increasing. With trend productivity little changed at that point, the real exchange rate also increased (appreciated) by almost 2 percentage points.[16]

2.3.51 Chart 2 shows the percentage effect on real GDP. Not surprisingly, the effect was initially much smaller (about 0.8 percentage point), as RNODX was only a portion of GDP and each dollar of RNODX induces 60 - 70 cents of real imports. The effect on GDP did not begin declining quickly, as did the effect on RNODX, but rather increased for several quarters and then fluctuated around its peak level until the end of the third year. The main reason for this can be seen in Chart 4, which reveals that the initial increase in GDP induced an increase in both equipment and construction spending. This is the standard accelerator effect on investment. Once GDP stopped rising, this accelerator effect wore out. At that point, the effect on both investment and total GDP declined sharply. The initial increase in GDP also led to higher incomes and higher consumer spending (not shown) which further increased GDP. The effect on consumption spending followed GDP downward. At the end of six years, the total effect on GDP started to turn negative. If the simulation horizon had been extended, the effect on GDP would have exhibited damped cycles converging toward zero.[17]

2.3.52 Chart 3 shows the effect on exports and imports of goods and services. The initial effect on exports was only about one half the size of the effect on NODX, reflecting the fact the RNODX is only about half of total exports. By the end of the simulation, the effect was very small. Like most of the other series, exports had overshot its final resting place, estimated to be around a positive 0.5 percentage point.

[16] The equation for non-oil exports uses a concept of the real exchange rate in which unit labour costs are computed using trend rather than current productivity.

[17] The increase in export demand cannot cause a permanent increase in output since there was no accompanying increase in potential supply. Whatever permanent increase in exports occurs must be offset either by an increase in imports or a reduction in some other component of final demand.

Chart 3
Effect on Imports and Exports

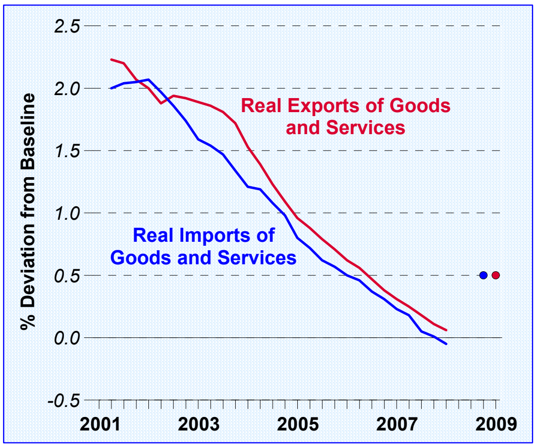
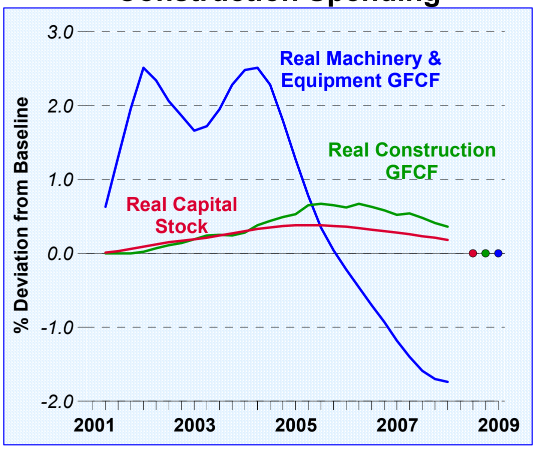


Chart 4
Effect on Equipment and Construction Spending



2.3.53 The effect on total imports was rather similar. This was not a coincidence. The equilibrating mechanism illustrated by this simulation was that a shift of aggregate demand set in motion forces that changed exports and imports by an amount sufficient to offset the original shift. Since the shift was in a category of exports, the exchange rate had to change by enough to reduce both RNODX and other exports, and to increase total imports, by an amount such that the relationship between total exports and total imports is unchanged. If the original disturbance had been to the demand for consumption or investment, imports would, in the long run, have been increased relative to exports.

2.3.54 Chart 4 shows the effect on equipment and construction spending. As previously noted, the equipment accelerator effect led to sharp cycles. The effect on construction spending was more spread out. The chart also shows the effect on the total capital stock because the capital stock is the primary determinant of trend productivity. In the long run, the increase in RNODX did not have any effect on these series.

2.3.55 Chart 5 shows the percentage effects on the wage rate, trend productivity, and the real exchange rate concept used in the RNODX equation. The effect on wages rose gradually, and as previously noted, reached about 2 percentage points by the end of the simulation. Had the simulation been continued, wages would have risen somewhat further before settling back to a gain of about 1.5 percentage points in the very long run. This overshooting in wages was the main cause of the overshooting in the other series. The chart also shows the increase in trend productivity (reflecting the increase in the total capital stock) and in the real exchange rate. The effect on trend productivity peaked at less that 0.4 percentage point and then headed back toward zero where it remained. As a result, the effect on the real exchange rate gradually approached the effect on wages, estimated to be about 1.5 percentage points in the very long run.

Chart 5
Effect on Wage, REER and Trend Productivity

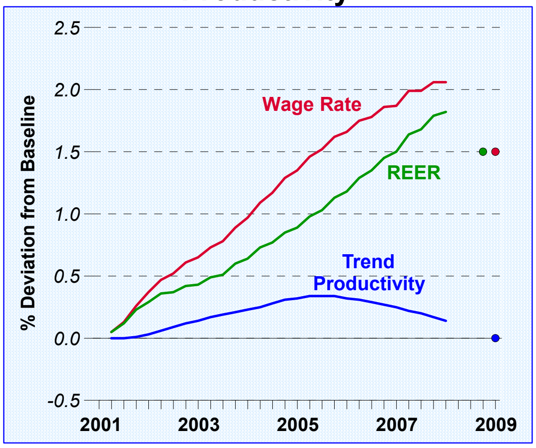
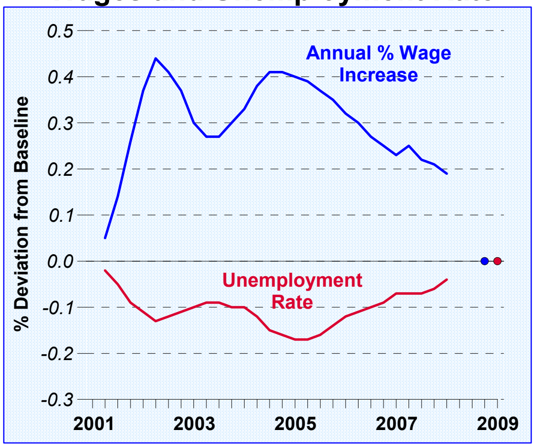


Chart 6
Effect on Rate of Change of Wages and Unemployment Rate



2.3.56 Finally, Chart 6 shows the effect on the unemployment rate and on the rate of change of wages. This chart is presented to show the cause of the wage overshooting. The unemployment rate initially declined, and that caused an increase in the rate of change of wages. By the end of the simulation, the effect on the unemployment rate had been nearly eliminated. If the simulation horizon had been extended, the effect on the unemployment rate would have turned slightly positive for a while, and then settled back to zero. The effect on wage increases would have ultimately gone to zero as well.

2.4 MODEL USAGE

2.4.1 Various equations estimated for Singmod were already in use at EPD for the preparation of staff forecasts from as early as December 1988. By early 1989, a full system could be simulated. Much of that year was spent on extending the model to include a very disaggregated import and export sector. By 1990, the expanded Singmod was in use for both forecasting and policy simulations, and Singmod began to play a key role in the Department's half-yearly review of the exchange rate policy. For the first time, policy papers were able to quantify the short- and medium- term trade-offs involved in the alternative paths for the exchange rate, while also highlighting the medium-term inflation impact of these various options.

2.4.2 Singmod had also evolved over the years. The system had gradually increased in size as needs for the explanation of new variables arose. For example, when the COE system for cars was introduced in 1990, the price of cars (including the cost of the COE) was forced up quite dramatically, thereby raising the CPI and the consumption deflator. To deal with this structural change, a demand equation for the stock of cars was developed, and then solved in the model for the car price.

2.4.3 A number of challenges arose over the years. One familiar episode is briefly discussed here because it provides some insight into the uses and limitations of models.

Housing Boom of the Mid 1990's

2.4.4 Since about 1993, expenditures for new housing began to outrun the predictions of the model's housing equation by ever-increasing amounts. Recall that the equation had been estimated on a very inadequate amount of data because of the effects of CPF liberalisation and the increased intake of foreign construction workers that occurred in the late 1970s and early 1980s. The income elasticity of demand for housing had been assumed to be something less than one based on studies from other countries. Nevertheless, it seemed impossible to construct any sensible housing expenditure equations that could fit the data from 1993 onward without allowing the long-run income elasticity of demand of housing to be considerably higher than unity.

2.4.5 To gain further insight into the situation, equations for housing prices were developed in 1995. This only compounded the problem, because housing prices were also increasing rapidly during that period and it similarly proved impossible to specify sensible price equations that not only could fit the data but also incorporate an income elasticity of housing demand of less than unity.

2.4.6 Model staff had the choice of retaining what seemed to be sensible explanations of housing prices and expenditures and regarding the excess demand as a price bubble, or of accepting an implausible income elasticity. Unfortunately, some combination of the two approaches was taken and the staff did not make as much of an issue of the price and expenditure overruns as they should have in hindsight.

2.4.7 This episode illustrates a more general point. At best, model equations can only show what economic agents would do if they act in accordance with fundamental economic forces. In the housing case, people apparently came to believe that housing prices would continue to rise even though the fundamentals were inconsistent with that belief. They purchased larger houses not to obtain more living space, but to become richer. The extra demand drove up housing prices, giving rise to expectations of still further increases. This is a bubble, and structural equations will not explain it.

2.4.8 After the collapse of housing prices in 1996-97, the housing expenditure and price equations were re-estimated with the data for the bubble period eliminated from the sample. This restored the income elasticities to plausible levels which fit both the pre- and post-bubble data reasonably well.

3. THE JOURNEY FORWARD WITH MMS

3.1 CONSTRUCTION OF MMS

3.1.1 The Monetary Model of Singapore (MMS) was constructed during 1998 and 1999 and launched at a conference in February 2000. MMS shares the emphasis in Singmod on long-run properties, while also taking model building at the MAS in some important new directions. MMS is similar in style to the MM2 model of Australia that was developed earlier, but takes into account differences in institutional structures, data availability and data properties between Singapore and Australia.

3.1.2 MMS and Singmod share some important long-run properties. This is based on the common view that while demand shocks may affect economic activity in the short run, in the long run, economic activity is supply driven. Specifically, as explained in the Section 2.3, in the long-run equilibrium of both models:

- the unemployment rate converges to a NAIRU (non-accelerating inflation rate of unemployment); and
- economic growth is steady and balanced.

3.1.3 At the same time, MMS takes model building at the MAS in some new directions as listed below:

1) While Singmod is primarily a macroeconomic model, MMS also has an industry dimension, allowing it to be used for a wider range of purposes. Specifically, as a macro-CGE model, MMS can be used for both forecasting and policy analysis at both the macro and industry levels. This is explained in Section 3.2.
2) MMS responds to the Lucas Critique of macroeconomic models by selectively incorporating rational expectations, as outlined in Section 3.3.
3) Like other recent models, MMS recognises the existence of the intertemporal budget constraints faced by the government and private sectors alike, as also outlined in Section 3.3.

These and other properties of MMS are demonstrated in Section 3.4 through the simulation of a change in the exchange rate.

3.1.4 MMS has proven to be a useful forecasting and policy tool. However, the model is continually reviewed to determine where improvements can be made to further enhance the usefulness of the model. For example, in 2002, the fiscal section of the model was further developed to make the model more useful for fiscal forecasting and policy analysis. This fiscal development work is outlined in Section 3.5. There is always more that can be done to improve a model, and the agenda for further developing MMS is outlined in Section 3.6.

3.2 EVOLUTION OF MACRO-CGE MODELS

3.2.1 While Singmod was essentially a macroeconomic model, MMS incorporates characteristics of both macromodels and CGE models. Developments in economic modelling over the last 20 years have seen a shift in macromodels towards CGE models, culminating in the creation of macro-CGE models. These new macro-CGE models have a number of advantages over pure macromodels, especially in the area of industry policy. The evolution of these macro-CGE models and their advantages are outlined below, as are the issues concerning the consistency of the model with Singapore data.

Convergence of Macro and CGE models

3.2.2 Originally, builders of macro and CGE models had different agendas and these two streams of structural and economy-wide modelling developed separately. Macromodellers were interested in macroeconomic forecasting and policy, and built models that focussed on dynamic adjustments of the economy at the aggregate level. CGE modellers were concerned with industry policy and focused on the industry structure of the economy in equilibrium.

3.2.3 CGE modellers became more interested in dynamics. This was because industry policymakers wanted more than long-run estimates of the gains from industry reform policies; they also wanted estimates of the time frame over which those gains would be realised and the short-term adjustment costs that would be involved.

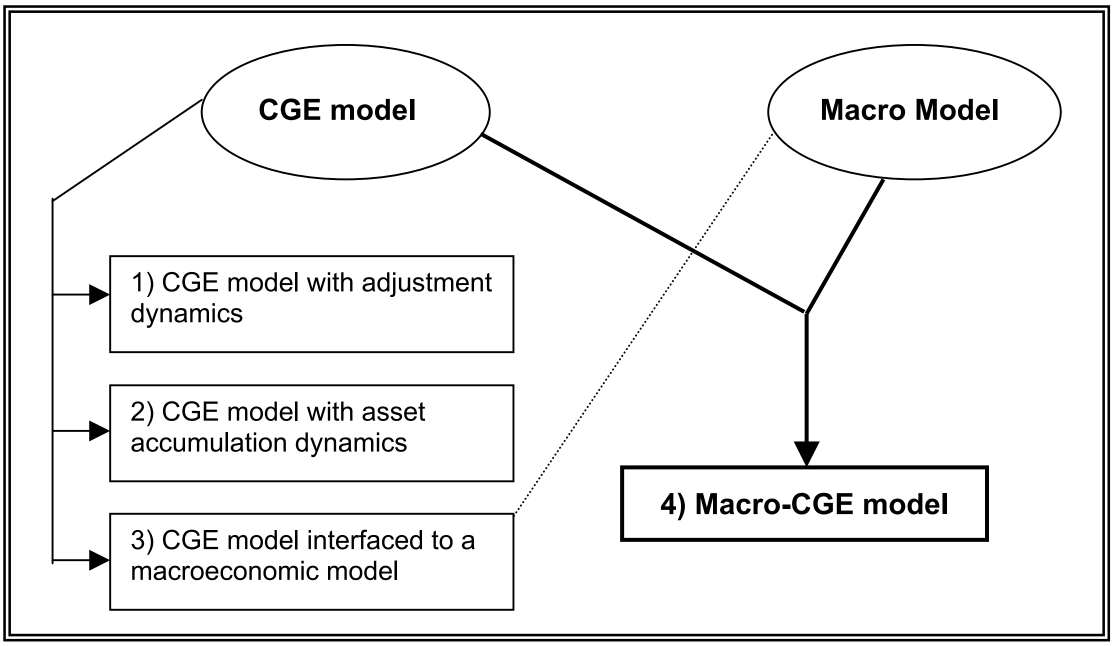
3.2.4 Dynamics were introduced into CGE models in three alternative ways, as illustrated in Figure 1:

1) endowing each sector of a CGE model with dynamics inspired by, but not fully integrated with, the style of macrodynamics in favour then;

2) introducing explicit asset accumulation (and the dynamics implied thereby) into a CGE model e.g. in Australia, the CGE model known as ORANI was developed into the ORANI-F model and its descendant, the Monash Model; or

3) interfacing a CGE model with a macromodel so that the latter provides the former with dynamics in a top-down fashion, e.g. again in Australia, the ORANI model was interfaced with alternative macromodels including the MM model.

Figure 1
Evolution of Macro-CGE Models



Developments 1) to 3) in CGE models brought macro and CGE models closer together and raised the prospect of their convergence.[18]

[18] For more discussion, please see Parsell, Powell and Wilcoxen (1989); Bourguignon, Branson and de Melo (1992); and Bourguignon, Branson and de Melo (1998).

3.2.5 At the same time, macromodellers became more interested in the long-run properties of their models, following criticism from both economic theorists and proponents of error correction models. Macromodellers began developing new models with an economically interpretable long-run equilibrium. They also more closely examined the long-run properties of their models.

3.2.6 This led to a new class of macromodels. In broad terms, the long-run equilibrium to which the new models converged included the one-sector equivalent of a CGE model solution. Profits were maximised subject to the constraint of the production technology, and markets cleared. Models of this type include the MM model of Australia that was released in 1989.

3.2.7 It was soon realised that a macro-CGE model could be developed from a new macromodel by replacing its one-sector production and trade specification with one featuring multi-sectoral production and trade. This led to the fourth approach (bold box in Figure 1) – designing a fully integrated model whose sectors exhibit short-run dynamics consistent with plausible macrodynamics, but which also exhibit long-run properties consistent with a typical CGE model solved in a long-run closure. Models of this type include the MM2 of Australia, the G-cubed model of the world, and now the MMS of Singapore. MMS distinguishes five industries in Singapore, which will be explained in Section 3.3.

Advantages of Macro-CGE Models

3.2.8 The advantages of macro-CGE models can be seen in MMS.

3.2.9 Like a macromodel, MMS provides macro forecasts and macro policy analysis. Indeed, as a macro-CGE model, MMS has greater functionality for macro forecasting compared to macromodels because it embodies the increasingly widespread practice of building up export and investment forecasts from the industry level.

3.2.10 As with a CGE model, MMS can be used for long-run industry policy analysis. That is, it provides long-run estimates of the effects at both the economy-wide and industry levels of changes to industry policy.

3.2.11 Thus, models like MMS have all of the economic content of both a new macromodel and a comparative static CGE model. But they also include the dynamic adjustment processes of individual industries, showing their transition from an initially perturbed state to a new equilibrium. This means that MMS has a wider functionality than the models in these two classes, making it an attractive tool for industry forecasting and industry policy analysis.

3.2.12 More generally, regardless of whether they are used for forecasting or policy analysis, the macro-CGE models promise a unified, coherent view of the economy, sweeping away unnecessary distinctions between economy-wide macromodels and economy-wide industry models.

Consistency with Singapore Data

3.2.13 As a macro-CGE model, there is a strong emphasis in MMS on consistency with economic theory. However, this is not at the expense of consistency with Singapore data. Consistency with economic theory is important so that MMS can be used meaningfully for policy simulation, while consistency with Singapore data is needed so that MMS serves as a useful forecasting tool.

3.2.14 The pursuit of data consistency needs to be tempered by recognising the limitations of the data. These limitations include the following:

- Most data are subject to measurement error.
- Sometimes data definitions do not match theoretical concepts.
- Singapore data are more volatile than data for larger countries.[19]
- Singapore has undergone structural changes e.g. the economy has become less regulated and the financial sector has become more important.

[19] Under simple assumptions, the coefficient of variation of a data series for a country is proportional to 1/√n where "n" is a measure of the size of the country.

However, these limitations do not mean that the data should be ignored. Rather, the data needs to be used critically, taking these limitations into account. This approach is similar to that adopted in the construction of Singmod.

3.2.15 MMS is made consistent with Singapore data in three related ways. First, equation dynamics are modelled using error correction models. This allows maximum flexibility for the equation dynamics of MMS to fit Singapore data. It also provides a clear distinction between the equilibrium and dynamics parts of equations.

3.2.16 Second, where feasible, equation parameters are econometrically estimated using Singapore data. Quarterly data are used, with the estimation period extending from the June quarter of 1984 to the most recent quarter of historical data.

3.2.17 Econometric estimation of parameters is important for reliable forecasting. It has been possible to estimate most of the parameters describing dynamic adjustment in the error correction models. Some of the parameters describing equilibrium responses are also freely estimated. In cases where this did not produce reasonable estimates, perhaps because of the data limitations listed above, it was important for plausible policy simulations that reasonable values were imposed.[20]

3.2.18 Third, a battery of diagnostic tests was conducted on the residuals of each regression equation. These tests investigate whether the error terms are well behaved in the sense of being serially independent, homoskedastic, and normally distributed. Other tests check for structural changes in the parameter estimates and misspecifications of the functional form.

3.3 STRUCTURE AND INNOVATIONS IN MMS

3.3.1 To develop MMS as a macro-CGE model, the supply functions or the production technology characteristics needed to be specified for each industry. This section begins by outlining these features.

[20] In some cases, reasonable parameter values can be obtained from estimates for similar countries such as Australia.

3.3.2 The section then explains how MMS takes model-building at the MAS in some other new directions, including:

- selectively incorporating rational expectations; and
- recognising the existence of intertemporal budget constraints.

3.3.3 Finally, this section describes how in the long-run of MMS, as in Singmod, economic activity is supply-driven because:

- the unemployment rate converges to a NAIRU; and
- economic growth is steady and balanced;

Supply Side, Industry Disaggregation and Production Structure

3.3.4 To develop the CGE dimension to MMS, the supply side of each industry needs to be specified. This involves:

- identifying industries;
- adopting production technologies; and
- invoking the assumption of profit maximisation.

3.3.5 MMS identifies five industries, linked together through an input-output table:

- manufacturing;
- construction;
- ownership of dwellings;
- other financial and business services; and
- other.

3.3.6 It is important to model manufacturing production because of its pivotal role in producing merchandise exports which in Singapore account for a very large part of the expenditure side of GDP (GDPe). A further benefit of this is that the model produces forecasts of manufacturing production, and these can be compared directly with independent forecasts of manufacturing production by the sectoral specialists, as a cross-check on the MMS forecasts.

3.3.7 The output of the volatile construction sector broadly equates with construction investment in GDPe (which in turn is disaggregated into dwelling and non-dwelling construction for both public and private). Modelling construction production means that the model takes into account that construction is relatively labour-intensive, allowing it to capture the big swings in construction employment that follow from the fluctuations in construction investment.

3.3.8 Modelling production by the ownership of dwellings sector involves establishing the link from the capital stock of dwellings to the supply of housing services. Interaction between the supply and demand of housing services in turn affects (actual and imputed) rents. Rents affect the actual rate of return on the capital stock of dwellings which, when compared with the required rate of return, affects the level of new investment in the stock of dwellings. Thus, modelling production by the ownership of dwellings sector is a necessary part of a coherent treatment of the housing market, which also involves modelling both dwelling investment and the demand for housing services.

3.3.9 “Other Financial and Business Services” is a large and (until the recent interruption) rapidly growing sector, accounting for over 20 per cent of GDP.

3.3.10 The remaining "other" category of production accounts for about 40 per cent of GDP.

3.3.11 Having identified the industries in MMS, the next step is to adopt production technologies for each industry. MMS has one production function for each of its industries or sectors, giving rise to five production functions in total. In each sector, the production function is used in deriving fully consistent equations for employment, investment, export supply, import demand and pricing.

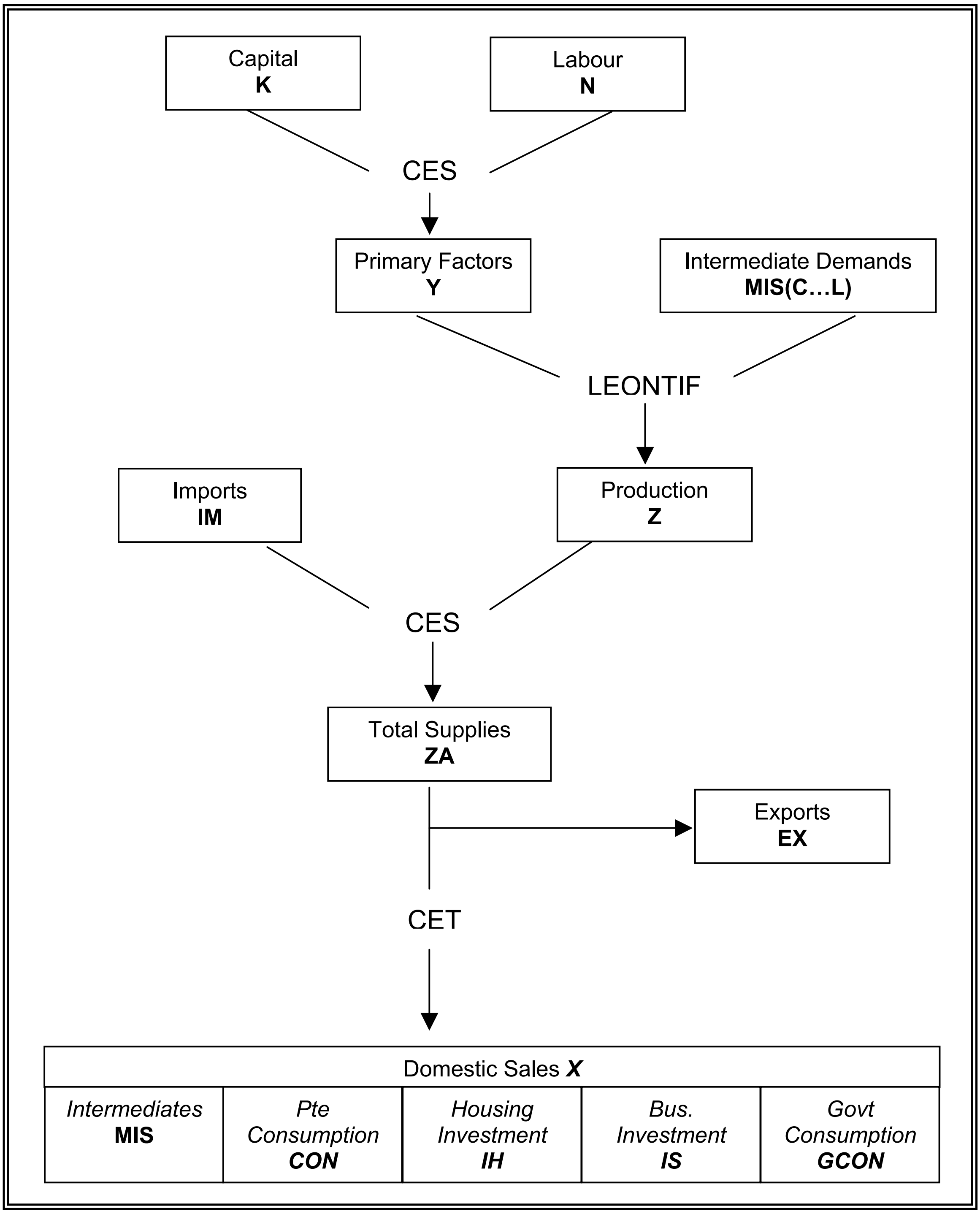
3.3.12 Figure 2 below outlines the production technology of a representative industry. Inputs include capital (K), labour (N), intermediates (MIS) and imports (IM), while outputs include domestic sales (X) and exports (EX).

3.3.13 The production technology allows both for substitution between inputs and transformation between outputs. On the inputs side, capital and labour are substitutes with Constant Elasticity of Substitution (CES) technology. On the outputs side, domestic sales and exports are transformed with Constant Elasticity of Transformation (CET) technology.

3.3.14 In MMS, imports are treated as an input that is used not only in production for the domestic market, but also in production for exports. This is because in Singapore, especially in manufacturing, it is not uncommon for imports to be re-exported after the addition of only a small amount of local value added.

3.3.15 Having adopted a production technology for each industry, the final step is to invoke the assumption of profit maximisation. In MMS, businesses in each industry attain a long-run position of profit maximisation subject to a production technology constraint through a hierarchical adjustment process.

Figure 2
Production Technology of a Representative Industry in MMS



3.3.16 In a Keynesian short run, in maximising profit, businesses are constrained by domestic demand and the capital stocks that they have in place. Through gradual adjustment of the price of domestic demand to its marginal cost of production, the domestic demand constraint is lifted, resulting in a classical medium run. Finally, in a Tobin-q formulation for business investment, capital stocks adjust slowly to equate the actual and required rates of return on capital, thereby lifting the constraint on capital. This yields a neoclassical long run of profit maximisation subject only to the production technology constraint.

Rational Expectations

3.3.17 MMS takes model building at the MAS in another new direction by selectively incorporating rational expectations. Economic agents in financial markets are assumed to have rational expectations, meaning that they base their expectations for the future on the predictions of MMS itself.

3.3.18 It is recognised that this is only an approximation to reality. Financial markets are well-known for bubbles and bouts of irrationality. Furthermore, in reality, economic agents are unlikely to base their expectations on any particular economic model.

3.3.19 Nevertheless, the assumption of rational expectations is a simple but powerful way of introducing forward-looking behaviour. It enables a model to capture the widely-recognised fact that financial markets respond virtually instantaneously to all kinds of new, relevant information. They attempt to efficiently process this information in revising daily their forecasts of the future that drive asset prices.

3.3.20 While the MMS assumes rational expectations in financial markets, it generally assumes expectations in other markets are backward looking. In these other markets, the stakes are not as high, so the costs of regularly making and acting on fully efficient forecasts are not justified.

3.3.21 To allow for forward-looking behaviour in financial markets, the MMS incorporates the Uncovered Interest Parity (UIP) condition. This sets the local 3-month interest rate equal to the foreign 3-month interest rate less the expected annualised rate of appreciation in the Singapore dollar in the coming quarter.

3.3.22 In part, this UIP equation introduces a positive relationship between the local 3-month interest rate and the strength of the spot exchange rate. However, we need two equations to determine these two variables. A second relationship, involving one or both of the local 3-month interest and the spot exchange rate, and reflecting the conduct of monetary policy, is needed to close off the financial sector.

3.3.23 Singapore's economy is so open that inflation depends more on the exchange rate than it does on the 3-month interest rate. For that reason, the MAS uses the exchange rate as the instrument of monetary policy. The outcome for the exchange rate from monetary policy is fed into the UIP equation to determine the 3-month interest rate.

3.3.24 The exchange rate equation itself is discussed in Section 3.4.

Intertemporal Budget Constraints

3.3.25 The final way in which MMS takes model-building at the MAS in a new direction is by incorporating the intertemporal budget constraints faced by the government and private sector alike. Specifically, in both cases, the present value of future expenditures cannot exceed the combined values of existing assets plus the present value of future receipts.

3.3.26 In modelling the government's intertemporal budget constraint, it is recognised that the Singapore government is a net creditor rather than a net debtor. Thus in the MMS, the government's intertemporal budget constraint could be enforced by requiring that public assets eventually achieve a target ratio to GDP. Instead, it is assumed that there is a target ratio of the budget surplus to GDP, as this better accords with the fiscal policy context in Singapore.[21] Failure to enforce the government's intertemporal budget constraint by one method or another would prevent the MMS from achieving a sustainable long-run equilibrium.

3.3.27 In MMS, the budget surplus achieves its target ratio through gradual, automatic adjustments of income tax rates. At the same time, the model user also has the ability to make discretionary changes in income tax rates.

3.3.28 The private sector's intertemporal budget constraint is taken into account in the private consumption function of MMS. The consumption

[21] It can be shown that a target ratio of the budget surplus to GDP, S, implies eventual stability in the ratio of public assets to GDP, A, where A=S/n and where n is the equilibrium growth rate of nominal GDP.

function includes a net private wealth term. To understand how this leads to a sustainable long run, suppose, for example, that the private sector embarks on a higher level of consumption spending (i.e. the consumption function shifts up). The implied reduction in private saving will lead to a higher current account deficit, causing foreign liabilities to rise relative to GDP. However, these increases in foreign liabilities erode net private wealth, causing private consumption to subside via the inclusion of the net private wealth term in the consumption function. This correction to private consumption halts the build-up in foreign liabilities, which then stabilise at a new and higher level relative to GDP. Without the wealth effect on consumption, foreign liabilities could explode.

Other Long-run Properties

3.3.29 MMS also shares some important long-run properties with Singmod. This is based on the common view that while demand shocks may affect economic activity in the short run, in the long run economic activity is supply driven.

3.3.30 In the long run, the unemployment rate converges to a NAIRU (non-accelerating inflation rate of unemployment). This ensures that while demand shocks may have a short-term effect on unemployment, they do not have a long-term effect. The NAIRU is estimated to be about 3 per cent.

3.3.31 Annual economic growth is steady and balanced in the long run. It equals about 3-5 per cent, comprising productivity growth of about 2-3 per cent, and labour force growth of about 1-2 per cent. However, growth rates for both productivity and the labour force can be varied as model inputs.

3.3.32 In the long run, the exchange rate appreciates at a steady rate, allowing Singapore, through the MAS, to choose its own inflation rate. Currently, the long-run rate of appreciation of the exchange rate is coded in such that the long-run domestic annual inflation rate equals about 2 per cent.

Equilibrating Mechanisms in MMS

3.3.33 MMS has two dominant and related features. First, it possesses a long-run equilibrium based on the same profit-maximising, market-clearing principles that are used in CGE models. Second, convergence to that long-run equilibrium is driven by the same equilibrating mechanisms that are traditionally found in macroeconometric models. This involves recognising the factors that lead to departures from long-run equilibrium, and then modelling how the resulting disequilibria are gradually eliminated.

3.3.34 In MMS, disequilibria can occur for several reasons. These reasons include stickiness in wages and prices, adjustment costs in varying capital stocks, and the ability of the government and the private sector to engage in unusually fast or slow asset accumulation for significant periods of time. These disequilibria and the methods by which they are eliminated, are now discussed in turn.

3.3.35 A positive demand shock will initially lead to increases in production and employment in MMS because prices and wages are sticky rather than perfectly flexible. However, the increase in production will raise marginal cost above price, leading to upward pressure on prices, which in turn will reduce demand. Similarly, the increase in employment will push the unemployment rate below the NAIRU, thereby putting upward pressure on wages, which will in turn reduce employment. Through these equilibrating mechanisms, price will once again equal marginal cost, and production and employment will be restored to their original levels. Thus, the model recognises that demand influences economic activity in the short term, but in the long term, economic activity is supply driven.

3.3.36 The capital stock moves to a new equilibrium level gradually rather than immediately in MMS. This recognises the costs involved in adjusting capital stocks, which are taken into account through the use of the Tobin-q theory of investment. A reduction in the cost of capital due, for example, to lower real foreign interest rates, reduces the required rate of return on capital relative to the actual rate of return. This lifts the Tobin-q ratio, leading to a period of higher investment. As the capital stock climbs, its marginal product gradually declines, until the actual rate of return is brought down in line with the lower required rate of return. This establishes a new equilibrium in which the lower cost of capital is matched by a lower marginal product of capital.

3.3.37 In MMS the government has a target ratio of its budget surplus to GDP, but it can depart from this target in the short term. For example, an increase in government spending will reduce the budget surplus, leading to slower accumulation of public financial assets. However, this lower budget surplus automatically leads to gradual upward adjustments in the rate of labour income tax. This occurs until equilibrium is restored. Specifically, the public surplus returns to its target ratio to GDP, which also implies that net public assets are restored to their original ratio to GDP.

3.3.38 The private sector's consumption is positively influenced by its net worth in MMS. An autonomous increase in private consumption will lead to an erosion of private net worth, causing consumption to revert back towards its original level. Through this equilibrating mechanism, the ratio of private consumption to private net worth is kept stable.

3.4 A SHOCK TO THE TRADE-WEIGHTED S$ – A SIMULATION USING MMS

3.4.1 MMS has a flexible exchange rate equation that accommodates a range of different approaches to setting the exchange rate. After explaining these approaches, this section simulates a change in the exchange rate in MMS as a way of illustrating some of the properties of the model.

Exchange Rate Closures

3.4.2 Since MMS is used for both forecasting and policy analysis, it needs to accommodate a range of approaches to setting the exchange rate. One approach, useful in forecasting situations, allows the exchange rate to be exogenous. Another approach, useful in policy experiments, allows the exchange rate to respond to the economy in different ways, including in a way consistent with the well-known Dornbusch Model. Under both approaches, monetary policy is influenced by changing a target exchange rate.

3.4.3 Under the exogenous exchange rate closure, changes in the target exchange rate are matched in the actual exchange rate, there being no variation in interest rates. This exact control over the actual exchange rate is useful in a forecasting situation.

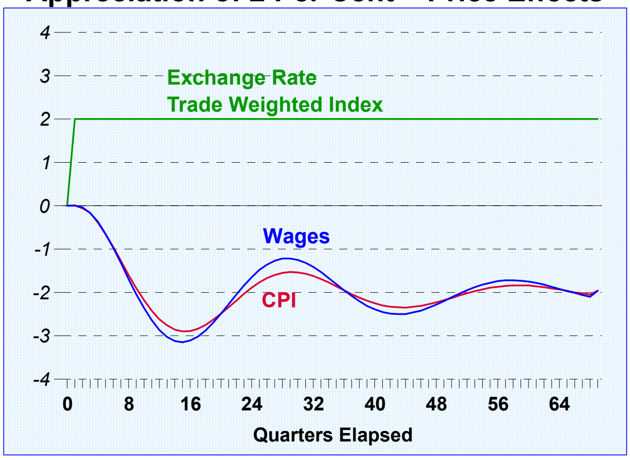
3.4.4 Under the Dornbusch closure, tightening monetary policy by lifting the target exchange rate is associated with a temporary lift in short-term interest rates. This is associated with an over-shooting jump in the actual exchange rate. However, the actual exchange rate eventually converges to its target, producing the same long-term results as under the exogenous exchange rate closure.

3.4.5 While the long-term results are identical, dynamic adjustment to changes in the target exchange rate is different between the two closures. Under the Dornbusch closure, overshooting of the exchange rate and higher interest rates means a more severe monetary tightening and a greater short-term loss in output. On the other hand, this also helps achieve quicker control over the price level, and overall convergence is also achieved more quickly.

Simulation of a Change in the Exchange Rate

3.4.6 Sections 3.2 and 3.3 outlined the properties of MMS. These properties are demonstrated here through the simulation of a change in the exchange rate. This is undertaken using the exogenous exchange rate closure described above, so changes in the target exchange rate are fully reflected in the actual exchange rate.

Chart 7
Appreciation of 2 Per Cent – Price Effects



3.4.7 This simulation is important because the exchange rate is the instrument of monetary policy used by the MAS. Thus, exchange rate simulations are really monetary policy simulations. Furthermore, because

Singapore is an ultra-open economy, exchange rate changes have very important effects.

3.4.8 The simulation involved raising the target (and therefore actual) trade-weighted index (TWI) exchange rate by 2 per cent above its baseline path indefinitely, as shown in Chart 7. This increase in the TWI represents a tightening of monetary policy.

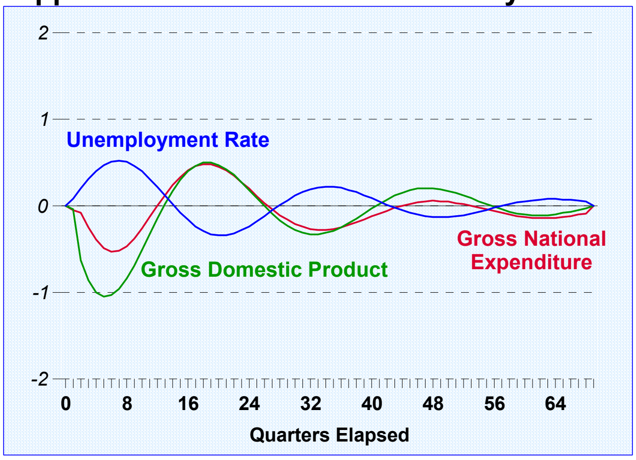
3.4.9 The increase in the TWI flows through to a similar 2 per cent reduction in prices for both imports and exports when expressed in Singapore dollars. Through a number of channels this gradually flows through to prices generally. Thus, Chart 7 shows that after seven quarters, both the CPI and wages are 2 per cent below their baseline paths.

3.4.10 Chart 8 shows that the tightening in exchange rate or monetary policy reduces domestic demand, with real GNE reaching a trough of 0.5 per cent below baseline after six quarters. The temporarily higher real exchange rate also significantly reduces real net exports. The fall in GNE combines with the fall in net exports so that after five quarters, real GDP (GDPP) reaches a trough of 1.1 per cent below baseline, as shown in Chart 8.

3.4.11 In a dampened response to the loss in GDP, the unemployment rate peaks at 0.4 percentage point above baseline after seven quarters. As in most countries, the dampened nature of this response is explained by pro-cyclical fluctuations in productivity and the discouraged worker effect on the labour force participation rate.

3.4.12 Domestic interest rates are unaffected. In the Uncovered Interest Parity equation described above, the local 3-month interest rate equals the foreign 3-month interest rate less the expected annualised rate of appreciation in the Singapore dollar in the coming quarter. This simulation does not include any change in foreign interest rates. It also does not include any change in the expected rate of appreciation in the Singapore dollar beyond the initial adjustment. Therefore domestic interest rates are unaffected.

Chart 8
Appreciation of 2 Per Cent – Activity Effects



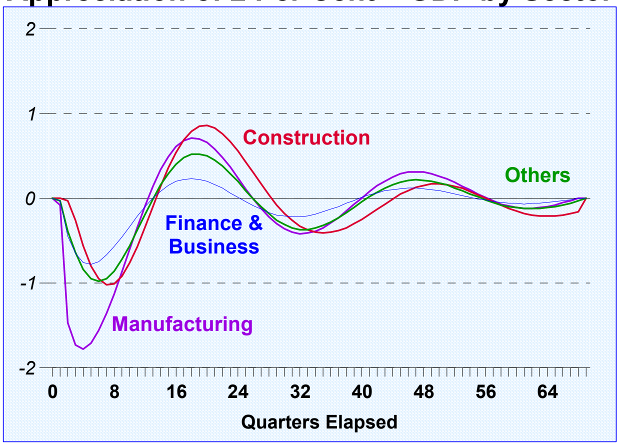
3.4.13 Charts 7 and 8 confirm the long-run neutrality of monetary policy in MMS. Appreciating the nominal exchange rate by 2 per cent ultimately reduces domestic prices by the same percentage, leaving the real exchange rate unchanged. Similarly, while economic activity is weaker in the short term, it is unaffected in the long term. It is in this sense that the exchange rate plays the role of a nominal anchor and monetary policy instrument in MMS. Thus, we have the standard long-run neutrality property that a given percentage rise in the nominal anchor (i.e., a given percentage appreciation of the exchange rate) ultimately leads to a matching percentage fall in all prices, and ultimately no effect on real variables.

3.4.14 MMS also provides details on five industry sectors and the simulation shows the effect of the exchange rate appreciation on each of these sectors. Chart 9 shows the effect on the output of four industry sectors. The fifth industry sector, ownership of dwellings, is not exposed to international trade and therefore is not greatly affected by this exchange rate shock.

3.4.15 The manufacturing sector is most affected. As mentioned above, the temporarily higher real exchange rate significantly reduces real net exports. As the manufacturing sector is the most export oriented sector, the subsequent effect on output is greater here than in the other sectors. The fall in net exports combined with the reduced domestic demand means that manufacturing output reaches a trough of 1.8 per cent below the baseline after four quarters.

3.4.16 In contrast, the effects on the other three sectors shown in Chart 9 are smaller and slower. The finance and business and other sectors are exposed to export markets but construction is not. Thus, the effect of lower net exports and domestic demand causes output to fall faster in the finance and business and other sectors. The reduced domestic demand means that construction output reaches a trough of 1.0 per cent below the baseline after six quarters.

Chart 9
Appreciation of 2 Per Cent – GDP by Sector



3.5 IMPROVED FISCAL SECTION

3.5.1 This section summarises the work that was undertaken in 2002 to improve the fiscal section of MMS. The fiscal section of the original MMS contained a medium level of disaggregation and, for internal consistency, relied to a large extent on model-based definitions of fiscal aggregates that were generally derived from the national accounts. This provided a workable framework for analysing fiscal policy in general terms.

3.5.2 However, it was found that for the model to be useful for fiscal forecasting, it needed to be developed in three ways:

- a mapping needed to be developed from the model-based definitions of fiscal aggregates to the official definitions of fiscal aggregates. In this way, the internal consistency of the model could be maintained by retaining the model-based fiscal aggregates, while the official aggregates would also be produced for fiscal forecasting;

- some further disaggregation of the fiscal aggregates was needed for greater forecasting detail and accuracy; and
- the model needed to take into account the delay between the accrual of personal and company tax liabilities and their payment.

3.5.3 Following the completion of these improvements to the fiscal section, MMS now provides the following detail of the budget balance in terms of official aggregates. (Table 1)

Table 1
The Government Budget Balance

Receipts	Outlays
Direct tax - personal & corporate income tax	Government operating expenditure
Direct tax - statutory boards' contribution	Government development expenditure
Direct tax - assets taxes	Special transfers
Indirect tax - GST	Net lending
Indirect tax - import duties	
Indirect tax - motor vehicles taxes	
Indirect tax - stamp duty	
Indirect tax - others	
Non-tax revenue - fees & charges	
Non-tax revenue - other	
Net investment income	
Net capital receipts	

3.6 MMS: THE FUTURE AGENDA

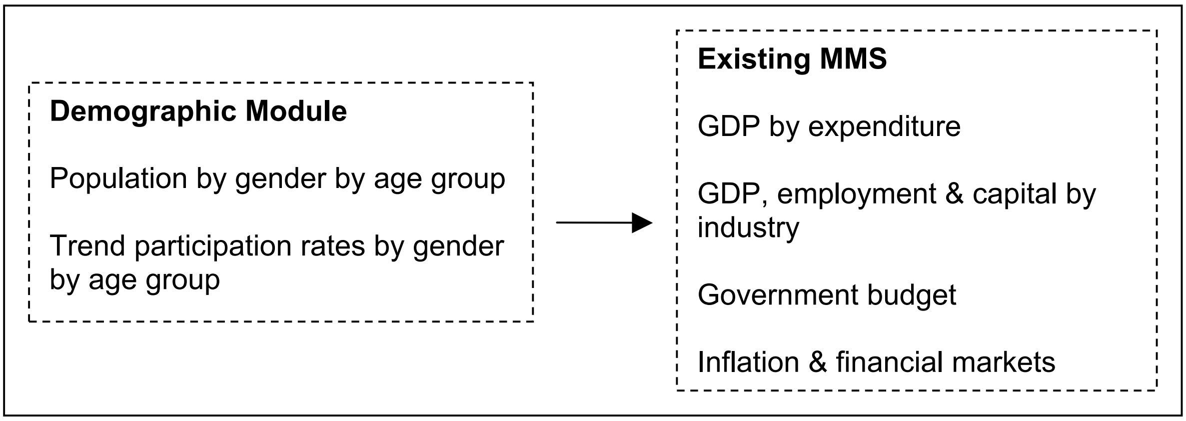
3.6.1 As outlined in Section 3.3, as a macro-CGE model, MMS is a modern economic model. Other modern features include its selective use of rational expectations and its incorporation of intertemporal budget constraints. However, as always, there is room for further development to enhance the richness of the model. As highlighted in the previous section, the fiscal section of the model was recently further developed to improve its usefulness in fiscal forecasting. Two examples of further possible development work are as follows:

- extending MMS to include a demographic module; and
- formalising the concept of uncertainty in forecasting.

Demographic Module

3.6.2 EPD is in the process of building a demographic extension to MMS, which will provide population forecasts by gender and age group, and its associated labour force projections. These forecasts will in turn feed into the existing macro-CGE model of the economy. (See Figure 3.) Using this extended MMS, the effects of alternative demographic scenarios on the economy and the government budget can be analysed. For example, effects of falling fertility and mortality rates, as well as the impact of foreign worker and migration policies, could be examined in more detail. These enhancements will be particularly useful for policy analysis in the context of Singapore's ageing population.

Figure 3:
Demographic Module in the Extended MMS



Formalising Uncertainty in Forecasting

3.6.3 Like most econometric models, MMS is estimated as a stochastic model, but simulated as a deterministic model. By definition, deterministic simulations make no allowance for uncertainty. Thus, like most forecasting models, MMS only provides point forecasts, rather than confidence interval forecasts.

3.6.4 Confidence interval forecasts are the appropriate way of highlighting the uncertainties in economic forecasts. This helps in knowing how much reliance to place on forecasts. It may also help in identifying areas where further work should be focused on, so as to try and improve the accuracy of forecasts.

3.6.5 Constructing meaningful confidence interval forecasts for MMS would require the development of a stochastic simulation facility. Ideally, this would factor in uncertainties in at least three areas:

- forecasts of exogenous variables;
- actual forecast errors; and
- parameter values.

3.6.6 While MMS is already proving to be a useful forecasting and policy tool, work in these areas should further enhance the usefulness of the model.

4. SUM-UP

4.1 EPD'S PHILOSOPHY TOWARDS MACROMODELLING

4.1.1 With the introduction of MMS and the complementary role played by Singmod and the other sectoral forecasting tools, quantitative work in EPD has become more rigorous and the models have come to play an integral part in macroeconomic policy analysis in the MAS. The structure and usage of the models have already been elaborated in the preceding sections. In addition, we had also described the transition from Singmod to MMS. This reflected an ongoing process of reviewing our modelling techniques to ensure they incorporate the latest developments in the field. Furthermore, the models are continuously updated with the latest set of data. They are also augmented as necessary to reflect the need of policymakers for more information on particular aspects of the structure of the economy. We shall now conclude the paper with a discussion of the qualities that we strive to build into models to ensure their continued relevance to policy-making.

4.1.2 One of the ultimate aims of EPD is to provide, through the use of macroeconomic models, sound and well thought out recommendations to policymakers. Thus, macroeconomic models must possess certain traits in order for them to be relevant and useful to policymakers. We highlight five main qualities.

4.1.3 First, macroeconomic models must be **responsive to structural changes in the economy**. If models are not updated, they will be of little or no value to the policymakers who must make hard decisions based on the policy implications of the models. Models today have in fact evolved to be quite different from those in the 1970s, which placed much emphasis on demand-driven outcomes for the economy. This was because governments believed in the power of discretionary monetary and fiscal policies to promote high growth and low inflation. However, the repeated failure of such macroeconomic models to identify critical turning points in the 1970s and 1980s caused many economists to question the assumptions behind the models. It then became clear that supply-side factors and the role of expectations also needed to be worked in. Thus, many models today incorporate these factors. In this respect, EPD has also placed emphasis on sectoral modelling, which focuses on the production structure of the various sectors of the economy. MMS has incorporated such sectoral detail by distinguishing five industries in Singapore, whereby profits are maximised subject to the constraint of the production technology in each sector. Such sectoral detail allows us to assess the impact of policy changes on both an economy-wide and individual sectoral level, and also enables us to analyse the dynamic adjustment processes of individual sectors to such policy changes. For example, a shift in exchange rate policy will have differing impacts on different sectors of the Singapore economy due to different import content ratios and exposures to international trade. Furthermore, rational expectations has been formally incorporated into financial markets in MMS, thus allowing the model to capture any adjustments in the economy due to changes in such expectations.

4.1.4 Second, a macroeconomic model must have a **good track record** in order to serve as a reliable guide to the policymaker. A model, no matter how theoretically and statistically robust it may be, is useless if it cannot provide a reasonably good approximation to economic developments. We are not referring to spot-on point forecasts or estimates but, at a minimum, a model must be able to provide policy-makers with a good feel for the directional effects of various policy options. In EPD, we keep systematic records of forecast errors and track the performance[22] of both macroeconomic models in order to identify areas that require improvement in terms of policy simulations and forecast accuracy. In addition, MMS incorporates error-correction estimation techniques in which the dynamic adjustments of the economic indicators through the first difference terms are able to capture the complexity and richness of the short-run relationships in the Singapore economy. Furthermore, the modellers in EPD obtain feedback from experienced colleagues in MAS on whether the policy simulations results from the models are reasonable and realistic.

4.1.5 Third, the workings of the model must be **transparent**. Ultimately, policy-makers will want to know the channels through which the effects of a policy flow through and how agents will react to that policy. In other words, policy-makers want to know the story behind each policy reaction. This will allow them to better assess the implications of the policy and hence respond appropriately. This requirement has, in some respects, probably placed greater emphasis on structural modelling in EPD. In policy analysis, we often want to analyse scenarios that differ from prevailing conditions, such as the

[22] For more details, please refer to MAS Macroeconomic Review, Chp 5, Vol 1, Issue 1, January 2002, " Special Feature on Forecasting in Periods of Uncertainty".

effects of a change in monetary policy or a particular tax rate. The medium- to long-term effects of such policy changes need to be explained within a sound and internally consistent framework in order for policy-makers to make informed decisions. Such conditional forecasts require structural models. Structural macro-CGE models like MMS are built on a foundation of fully-specified dynamic optimisation with fully-articulated preferences, technologies and rules of the game, as opposed to reduced-form decision rules of time-series models.

4.1.6 Fourth, macromodelling should adopt a **pluralistic** approach. It is rare for one model to be superior for all possible purposes: forecasting, policy making, conditional forecasts, testing hypotheses or investigating the effects of a previous policy change. EPD recognises that different models or modelling styles can be best suited for different purposes. As such, we do not rely on one flagship model, but rather we use different models as the purpose dictates. In EPD, we also rely on spreadsheet models for the different sectors of the economy. These are supplemented by non-structural time series models like ARIMA and unrestricted VAR models. These non-structural models have been able to extract any apparent regularity and relationships found in time-series data and thus are able to approximate the dynamics useful for short-term forecasting. The information provided by these various sources have helped us bound the range of plausible estimates and hence enabled us to arrive at probabilistic outcomes for our forecasts.

4.1.7 Finally, EPD believes in **pragmatism**, which is the practice of supplementing model output with sectoral analyses, survey data, market trends as well as value judgements. Although a model is a very useful tool for developing the forecasts, it does not replace the need for skilled economic judgements. Modellers need to be aware of the limitations of their models. The complexities of the economy cannot be fully captured by a macroeconometric model, no matter how comprehensive its specifications. In particular, macroeconomic models cannot quantify variables such as panic, greed or the herd psychology of investors. As a result, even the predictions of the most sophisticated model have been thrown off by unexpected developments in the environment. Thus, in order to improve our forecasting abilities, EPD incorporates additional economic information gathered from our involvement in the Economic Monitoring Group (EMG) and our close contact with other government agencies like IE Singapore, Economic Development Board and SPRING Singapore, who monitor more closely developments in the various industries including the manufacturing, commerce and retail sectors. EPD also maintains regular contact with private sector companies for their views on industry trends. Close contact and interaction with private sector forecasters and analysts have also been established through our quarterly 'MAS Survey of Professional Forecasters'. Hence, in EPD, the assumptions entering our models are continually re-assessed, and the output of the model adjusted where we have such additional sources of information to complement the raw forecast results.

4.1.8 To sum up, consider an analogy illustrating the usefulness of macroeconomic models given by former Minister for Health and Second Minister for Finance Mr Lim Hng Kiang [23], "For policymakers, models are like the maps and compass to the captain of a ship. The better the model, the more successful the policymaker is likely to be, in steering and guiding the economy safely through the treacherous waters to reach its destination. As the world economy grows in size and complexity, there is a need for more good models, not less." The relevance of macroeconomic models over the next few decades depends heavily on the merging of non-structural and structural approaches. This will have to be facilitated by advances in numerical and simulation techniques that will help macroeconomists to solve, estimate, simulate and forecast with more robust models.

4.1.9 Macroeconomic models will therefore continue to play an integral role in the economic analysis work of the Department. We are committed to continuously upgrading our suite of models to ensure that they reflect the latest technical developments in the discipline, and the ongoing structural changes in the economy.

[23] Speech by Mr Lim Hng Kiang, Minister for Health and Second Minister for Finance at the Conference Dinner of the Far Eastern Meeting of the Econometric Society, 2 July 1999.

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