Special Feature B

Macroeconomic Modelling at MAS

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1 Introduction

Most economists are familiar with the miniature macroeconomic models used at universities for academic purposes such as making a theoretical point, discussing macroeconomic theory or teaching. Fiscal and monetary authorities go further and use larger-scale macroeconomic models, because such models are needed for best practice forecasting and for realistically analysing the dynamic effects of alternative macroeconomic policies. The larger model at MAS is known as the Monetary Model of Singapore (MMS). Besides this flagship macroeconomic model, MAS also has a smaller Satellite Model of Singapore (SMS) to provide another perspective.

This Special Feature explains how MAS has developed MMS to meet its forecasting and policy analysis needs. This began in 1998 when MAS and I constructed MMS, which was launched in 2000. Since then, we have continued to work together to adapt MMS for economic shocks such as the GFC and the COVID-19 pandemic, to increase the capabilities of the model, especially for fiscal policy, to take into account advances in macroeconomic modelling, including in modelling household consumption, and to undertake routine model maintenance.

This Special Feature is structured as follows. Section 2 explains how the larger scale macroeconomic models used by national governments have evolved, distinguishing four styles of model. It also discusses the differing academic views about these styles, and how these have influenced the modelling choices made by central banks. Section 3 focuses on the style of model that was adopted in MMS, explaining the key features of this style and its use in other countries. Section 4 turns to the main features of MMS, and how they have evolved since 2000. Section 5 discusses the applications of MMS in forecasting and policy analysis at MAS. Section 6 concludes, highlighting how future work on the model can maintain its usefulness in such applications.

2 The Evolution of Macroeconomic Models

Blanchard (2018) distinguishes five different purposes for macroeconomic models. At universities, models are used to make a theoretical point, to discuss macroeconomic theory and as teaching devices. In government, models are used for forecasting and scenario/policy analysis.

Foundational models, such as the Mehra and Prescott model of the equity risk premium and the Mundell-Fleming model, make a theoretical point. Toy models, such as the Investment-Saving and Liquidity Preference-Money Supply (IS-LM) model, are used as pedagogical devices in undergraduate textbooks. Dynamic Stochastic General Equilibrium (DSGE) models provide a platform for discussions of macroeconomic theory (although in

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practice there are larger versions that are used more widely than this, as discussed below). These three purposes are associated with research and teaching at universities and usually involve the use of miniature models (Fukač and Pagan, 2011).

The remaining two purposes are associated with meeting the needs of national governments and require larger scale models. Policy models are used to model the dynamic effects of policy and other shocks. Forecasting models aim to give the best forecasts.

Fukač and Pagan (2011) discuss how these larger-scale macroeconomic models used by governments have evolved over four generations, from 1G to 4G. 1G models of the 1950s and 1960s focused mainly on modelling aggregate demand based on an IS-LM framework. 2G models of the 1970s and 1980s introduced a production function to model aggregate supply. 3G models of the 1990s had an economically interpretable steady state in which producers optimised profits, households and governments observed their intertemporal budget constraints, and some use was made of model-consistent expectations.

4G models were introduced in the 2000s and the biggest single change was to assume intertemporal optimisation by households. Dynamics were made part of economic optimisation problems rather than added more liberally at the estimation stage. They also made shocks part of the model. Finally, they used systems estimation instead of single equation estimation. These 4G models are more widely known as DSGE models. To some extent, the evolution of models from 1G to 4G has reflected an increased emphasis on economic theory.

The observation that macroeconomic models have evolved through four generations may leave the impression that 4G models, as the latest generation, are widely accepted as best practice. In reality, there is a spectrum of views about this.

At one end of the spectrum, Christiano, Eichenbaum and Trabandt (2018) (henceforth, CET) argue that DSGE models are best practice. CET prefer DSGE models on the theoretical grounds that “modern DSGE models are based on microeconomic foundations”. They argue that it is challenging to choose the best model using only traditional data, because “macroeconomic data are not sufficient for discriminating between many alternative models”, making different models “observationally equivalent”. CET conclude that “there is simply no credible alternative to policy analysis (based on DSGE models) in a world of competing economic forces operating on different parts of the economy”.

At the other end of the spectrum, Fair (2015) argues that his own modelling approach, which has both 2G and 3G characteristics, is more useful. His approach differs in three main ways from the DSGE approach. First, there is “much back-and-forth movement between empirical results and theory” rather than a given theory based on micro-foundations. Second, the rational expectations assumption is tested on a case-by-case basis rather than adopted universally. Third, single equation estimation is used so that testing can be conducted equation by equation and the model can be larger and more detailed. Fair argues that, by comparison, the methodology of DSGE model is “so ludicrous that essentially nothing useful has been learned from it, that it has led to a dark age of macro research”.

Blanchard (2018) expresses an intermediate view in arguing that “current DSGE models are flawed, but they contain the right foundations and must be improved rather than discarded”. He believes the main flaw is the assumption of intertemporal optimisation by households under rational expectations: “its implications, with respect to both the degree of foresight and the role of interest rates in twisting the path of consumption, are strongly at

odds with the empirical evidence". Given these flaws, he argues that DSGE models are useful as a platform for discussions of macroeconomic theory, but other types of models should be used for policy analysis or forecasting.

Blanchard's view, that different macroeconomic models should be used for different purposes, seems to be becoming more influential, with some central banks using multiple macroeconomic models.

The US Federal Reserve (2022) uses both the FRB/US model and the EDO model. The FRB/US model has been in use since 1996 and "is designed for detailed analysis of fiscal and monetary policies". It has a high level of detail and alternative assumptions can be made about how economic agents form expectations. It can be characterised as a 3G model. EDO is a DSGE model that has been in use since 2006. It "can be used for forecasting and policy analysis".

The Reserve Bank of Australia (RBA) uses both a DSGE model and the MARTIN model. The DSGE model (Rees, Smith and Hall, 2016) "is intended primarily for use in scenario analysis rather than as a forecasting tool". Ballantyne *et al.* (2020) explain that MARTIN is used "to help interpret recent economic developments, generate near and medium-term forecasts of key macroeconomic variables, and analyse the implications of risks and uncertainties facing the economy". Citing Blanchard (2018), they argue that DSGE models "have too many drawbacks to serve as the RBA's core macroeconomic model".

Thus, at the RBA, MARTIN is the core macroeconomic model, while the DSGE model provides another perspective. In a similar way, at MAS, MMS is the flagship macroeconomic model, while the SMS provides the DSGE perspective.

3 The Evolution of the Murphy Style of 3G Model

MMS has the general characteristics of 3G models that were listed earlier. There is detailed modelling of aggregate demand, which mainly drives economic activity in the short run. At the same time, in the medium to long run, economic activity is driven by profit maximisation in each industry subject to production function constraints. There is an economically interpretable steady state in which households and governments observe their intertemporal budget constraints. Finally, selective use is made of rational or model-consistent expectations.

In addition, MMS has some of the more specific characteristics of models that are associated with the 'Murphy' models. As described in Murphy (2020), from the 1980s to the 2010s, I developed a series of macro-econometric models of Australia, known as TARGET, AMPS, MM, MM2 and "an Australian macro-econometric model".

From MM2 onwards, these models incorporated industry detail, which was embedded in the core model in a fully integrated macroeconomic computable general equilibrium (macro-CGE) modelling approach. This differs from earlier macro-econometric models that either contained no industry detail or introduced it using a top-down, input-output approach, losing theoretical consistency with the core macro model.

In another distinctive feature of these models, in each industry, prices are sticky in domestic markets but flexible in export markets. This is consistent with the more limited pricing power that typically exists in export markets.

In another dichotomy, it is assumed that expectations are rational or model-consistent in financial markets, but backward-looking elsewhere. This is intended to recognise the obvious forward-looking behaviour of financial markets.

This Murphy style of macroeconomic model has also been adopted elsewhere. Besides working with MAS in Singapore, I have worked with The Treasury in New Zealand and the Ministry of Finance in Malaysia, among others, to construct macroeconomic models in that particular 3G style. More recently, I have worked as modelling adviser to the Australian Treasury, and their new EMMA model summarised in Bullen *et al.* (2021) follows a similar style, with the minor exception that the distinction between sticky and flexible prices is based on industries instead of markets.

The most recent model in the Australian series introduced a limited form of Ricardian equivalence (Murphy, 2020). Under full Ricardian equivalence, which is typically assumed in DSGE models, the private sector fully understands the government's intertemporal budget constraint. However, this unrealistically implies that temporary (lump sum) tax cuts fail to stimulate consumer spending, because households understand that the cuts will ultimately need to be financed by higher taxes in the future. In the interest of realism, in introducing Ricardian equivalence, the most recent model assumes that it only holds in the long run.

4 Developing MMS

The original version of MMS was constructed by MAS and myself from 1998 to 2000. It possessed all of the features of the Murphy style of 3G model described above, except it did not allow for the most recent innovation of long-run Ricardian equivalence.

Thus, when MMS was launched, MAS (2000) observed that "the MMS incorporates the latest advances and innovations in structural modelling such as well-defined long-run properties, rational expectations in financial markets, and detailed modelling of production in different sectors".

Just as importantly, the original design of MMS was adapted to capture distinctive features of the Singapore macroeconomy. The three most important examples of this adaption are the modelling of monetary policy, the choice of industry detail and the separate identification of foreign workers.

MMS recognises that the instrument of monetary policy in Singapore is the exchange rate, not a short-term interest rate. The ultra-open nature of the Singapore economy means that the exchange rate is a more important driver of fluctuations in inflation than interest rates, leading to Singapore's choice of the exchange rate as the monetary policy instrument.

MMS distinguishes five industry sectors, but the choice of sectors differs from that made in the Australian model because of the different structures of the two economies. Including some industry detail is indispensable in a macroeconomic model of Singapore, because the ultra-open nature of the economy is associated with a high level of industry specialisation. MMS distinguishes manufacturing, construction, finance & business services, housing services and other services. Manufacturing has long played a major role in Singapore's economy and trade, while finance & business services have become more important as Singapore emerged as a global financial centre. Construction and housing services are separately identified because of their linkages to investment.

Unlike the Australian model, MMS distinguishes foreign workers from the resident workforce. This is because workers on temporary work passes account for a much higher share of employment in Singapore than in Australia. Employment of foreign workers was distinguished by industry.

Five years after the launch of MMS, MAS took stock of its two decades of macroeconomic modelling activity in Enzler *et al.* (2005). The first flagship macroeconomic model, Singmod, became fully operational in 1990. It was a 2G model, so like 1G models it incorporated short-run Keynesian properties, but like other 2G models it also incorporated long-run neoclassical properties. MMS replaced Singmod as the flagship model, following its launch in February 2000. As a 3G model, MMS enforced the intertemporal budget constraints of households and governments, and introduced selective use of model consistent expectations. It also introduced an industry dimension to macro modelling at MAS.

In 2013, the modelling of employment of foreign workers in each industry was upgraded. Previously, employment of foreign workers in each industry was exogenous. This was changed so that the mix of local and foreign workers in each industry depended on their relative wages.

Maintaining good model documentation has always been a hallmark of macroeconomic modelling at MAS. In 2014, MAS published documentation on MMS (MAS, 2014b) and SMS (MAS, 2014c) and conducted a workshop to expose MMS to outside scrutiny (MAS, 2014a).

5 MMS Applications

Public authorities do not view national economic models like works of art, something to be admired. Rather, the true test of any such model in government is its usefulness in its intended applications. MAS (2000) was clear about the intended applications for MMS when it was launched.

"Macro models play an important role in policy-making. First, they are the principal tools for exchange rate policy analysis. Second, they are used to forecast key economic variables. These forecasts serve as inputs into our exchange rate policy reviews and medium-term planning scenarios. Finally, these models are used to analyse a wide range of policy issues."

-Dr Khor Hoe Ee, Senior Executive Director, MAS Economics Department, 2000

MMS has served all of these purposes. In fact, its purposes have expanded as follows.

In 2017, MMS's capability for exchange rate policy analysis was upgraded with the introduction of an optimal control facility. MAS (2017) explains how this facility can be used to construct an 'optimal' future path for the exchange rate, given an inflation target, an unemployment target based on the non-accelerating inflation rate of unemployment (NAIRU), and the aim to limit volatility in monetary policy. The model user can select relative weights for these three targets, and conduct sensitivity analysis of the 'optimal' exchange rate path to the choice of weights.

MAS (2019) unveiled enhancements to the fiscal block in MMS. These enhancements mean that MAS can now meaningfully distinguish the effects of a wider range of different types of changes to government spending and taxes. So, MMS is now an important tool not only for analysing monetary policy, but also fiscal policy. This was subsequently seen when MAS used MMS to support the Ministry of Finance in analysing the fiscal policy response to

COVID-19 (see Ministry of Finance, 2021). Likewise, Murphy (2022) used the Australian model for a similar purpose.

Finally, MMS has recently been further developed, following similar work with the Australian model, to use a new consumption equation that leads to Ricardian equivalence in the long run, but not the short run. Under Ricardian equivalence, households understand the government's intertemporal budget constraint, so they adjust private saving to perfectly offset the potential impact of changes in public saving on national saving.

Ricardian equivalence is not realistic as a short-run assumption because it implies that counter-cyclical tax policies are ineffective, whereas governments used such policies successfully to help stabilise economies following macroeconomic shocks such as the GFC and COVID-19 pandemic. Temporary tax cuts succeeded in increasing household consumption, thereby reducing national saving.

At the same time, households may have a general idea that government budgets need to be sustainable. The new consumption equation allows for this by assuming that, in the long run, households pursue a target for national wealth rather than for private wealth. This implies that, while changes in public saving are not fully offset by changes in private saving in the short run, they are in the long run.

Besides being plausible, this approach is also consistent with the empirical findings of Dissoua and Nafieb (2021). They find that budget deficits lead to current account deficits in the short run, but not the long run. The new MMS assumption that low public saving leads to low national saving in the short run, but not the long run, is consistent with this finding.

6 Conclusion

Macroeconomic models used at central banks need to be useful for forecasting and policy analysis. To that end, the general guiding principle in the design of the MMS style of macroeconomic model used at MAS and elsewhere is to incorporate economic theory to the extent that it is consistent with the historical data. Models based on economic theory, rather than more *ad-hoc* assumptions, are more likely to be structurally stable over time, and the scenarios they generate are more likely to be accepted because they are economically interpretable.

At the same time, macroeconomic models, with their focus on modelling business cycles, need to be consistent with historical data. Blanchard (2018) argues that the Euler equation used to model household consumption in DSGE models fails that test. While DSGE modellers have responded to this by making "ad hoc additions and repairs", Blanchard (2018) argues that this compromises the DSGE idea of having a sound theoretical model. For MMS, it may be best to wait and see if DSGE modellers can arrive at a consumption equation that is both theoretically rigorous and consistent with the historical data, and in the meantime to continue using the new MMS consumption equation incorporating long-run Ricardian equivalence.

In the immediate future, the challenge is to further develop MMS to structurally interpret the economic effects of the COVID-19 pandemic. One way of capturing the extent of COVID-19 restrictions is to use mobility indicators. Linkages could then be developed from the mobility indicators to household consumption and labour supply.

More generally, it will be important to follow the same approach of continuous model development. In the future, MMS will need to be adapted for new types of economic shocks and to take into account further advances in macroeconomic modelling, not to mention the perhaps less exciting but important task of routine model maintenance.

References

Ballantyne, A, Cusbert, T, Evans, R, Guttmann, R, Hambur, J, Hamilton, A, Kendall, E, McCririck, R, Nodari, G and Rees, D (2020), "MARTIN Has Its Place: A Macroeconometric Model of the Australian Economy", *Economic Record*, Vol. 96(314), pp. 225–251.

Blanchard, O (2018), "On the Future of Macroeconomic Models", *Oxford Review of Economic Policy*, Vol. 34, pp. 43–54.

Bullen, J, Conigrave, B, Elderfield, A, Karmel, C, Lucas, L, Ruberl, H, Murphy, C W, Stoney, N and Yao, H (2021), "The Treasury Macroeconometric Model of Australia: Modelling Approach", *Treasury Paper 2021-09*, September 3.

Christiano, L, Eichenbaum, M and Trabandt, M (2018), "On DSGE Models", *Journal of Economic Perspectives*, Vol. 32(3), pp. 113–140.

Dissou, Y and Nafie, Y (2021), "On the Link Between Current Account and Fiscal Imbalances in the Presence of Structural Breaks: Empirical Evidence from Egypt", *The Quarterly Review of Economics and Finance*, Vol. 79, pp. 15–27.

Enzler, J J, Murphy, C W, Ng, H T, Phang, S J and Robinson, E (2005), "Two Decades of Macromodelling at the MAS", *MAS Staff Paper No. 39*, July 1.

Fair, R (2015), "Reflections on Macroeconometric Modelling", *The B.E. journal of macroeconomics*, Vol. 15(1), pp. 445–466.

Fukač, M and Pagan, A (2011), "Structural Macroeconometric Modelling in a Policy Environment", pp. 215–245, in Ullah, A and Giles, D (eds), *Handbook of Empirical Economics and Finance*, Chapman and Hall/CRC, Boca Raton.

Monetary Authority of Singapore (2000), "MAS Launches New Macroeconometric Model to Forecast Economic Trends", Media Release, February 2, (URL: https://www.mas.gov.sg/news/media-releases/2000/mas-launches-new-macroeconometric-model-to-forecast-economic-trends--02-feb-2000).

Monetary Authority of Singapore (2014a), "MAS Macroeconomic Modelling Workshop 2014", *Macroeconomic Review*, Vol. XIII(2), pp. 76–85.

Monetary Authority of Singapore (2014b), "The Monetary Model of Singapore (MMS): A Technical Overview", (URL: https://www.mas.gov.sg/-/media/MAS/Monetary-Policy-and-Economics/Education-and-Research/Education/Macroeconometric-Models/The-Monetary-Model-of-Singapore-MMS-A-Technical-Overview.pdf).

Monetary Authority of Singapore (2014c), "The Satellite Model of Singapore (SMS): A Technical Overview", (URL: https://www.mas.gov.sg/-/media/MAS/Monetary-Policy-and-Economics/Education-and-Research/Education/Macroeconometric-Models/The-Satellite-Model-of-Singapore-SMS-A-Technical-Overview.pdf).

Monetary Authority of Singapore (2017), "Optimal Control in the Monetary Model of Singapore", *Macroeconomic Review*, Vol. XVI(1), MAS, pp. 78–84.

Monetary Authority of Singapore (2019), "Enhancements To The Fiscal Block Of The Monetary Model Of Singapore", *Macroeconomic Review*, Vol. XVIII(1), MAS, pp. 80–82.

Ministry of Finance, Singapore (2021), "An Interim Assessment of the Impact of Key COVID-19 Budget Measures", *Ministry of Finance Occasional Paper*, (URL: https://www.mof.gov.sg/docs/default-source/default-document-library/news-and-publications/featured-reports/interim-assessment-covid-19-budget-measures-(19-feb-2021).pdf?sfvrsn=314c26f_2).

Murphy, C W (2020), "Decisions in Designing an Australian Macroeconomic Model", *Economic Record*, Vol. 96(314), pp. 252–270.

Murphy, C W (2022), "Fiscal Policy in the COVID-19 era", *ANU Tax and Transfer Policy Institute Working Paper,* No. 4.

Powell, A A and Murphy, C W (1997), *Inside a Modern Macroeconometric Model: A Guide to the Murphy Model*, 2nd edition, Springer-Verlag.

Rees, D M, Smith, P and Hall, J (2016), "A Multi-sector Model of the Australian Economy", *Economic Record*, Vol. 92, pp. 373–408.

US Federal Reserve (2022), "Economic Research", (URL: https://www.federalreserve.gov/econres.htm).