# THE MSG2 AND G-CUBED MODELS OF THE AUSTRALIAN ECONOMY

**Warwick J. McKibbin**

*Australian National University*
*& The Brookings Institution*

Abstract: This paper gives an overview of the MSG2 and G-CUBED multi-country models. Both models include Australia and have been used for a number of important domestic and international policy questions of relevance to the Australian economy. In addition to introducing the models to non-modelers, the paper also summarizes the many studies that have been undertaken using the models. Although the focus of the paper is on studies of the Australian economy, the global coverage of both models and the vulnerability of the Australian economy to developments in the world economy, make many of the global studies relevant for the Australian economy. The Australian specific studies as well as many of the global studies are summarized.

Keywords: Mathematical models, Computer simulation, Dynamic modelling, Economics;

## 1. INTRODUCTION

This paper gives an overview of the McKibbin-Sachs Global (MSG2) model and the G-Cubed multi-country model. It draws on joint work with a number of co-authors but in particular on earlier research with Jeffrey Sachs of Harvard University and current research with Peter Wilcoxen of the University of Texas at Austin. The broad approach taken in both models is summarized and the strength of the two modelling approaches is illustrated by an overview of the insights discovered in the many studies that have been undertaken with the models.

The MSG2 model is outlined in section 2. The G-Cubed model is outlined in Section 3. A summary of the various studies using the models is presented in Section 4. Section 5 contains an overview of current plans for developments of the models. A comprehensive bibliography of the major studies undertaken using the models is presented in the References.

## 2. THE MSG2 MULTI-COUNTRY MODEL

The MSG2 model was developed by Warwick McKibbin and Jeffrey Sachs, in two distinct stages. The first model called MSG formed the basis of a number of papers by the authors in the mid 1980s. This model is also the version which participated in the Brookings model comparison project reported in Bryant et.al. (1988) and formed the basis of papers written before 1987. This earlier model was a modern Keynesian style macroeconomic model of the world economy with rational expectations in the foreign exchange market. The parameters were essentially reduced form parameters calibrated to the estimates of existing macroeconometric models.

The model was then completely reconstructed beginning in 1986, influenced by developments in modern intertemporal macroeconomic theory and modelling techniques used by computable general equilibrium (CGE) modelers which focus on individual optimization by economic agents. This newer model, called MSG2, is fully documented in McKibbin and Sachs (1991). A significantly extended version of this model, together with an extensive software package is available commercially as the McKibbin Software

Group model (MSG2 model). The commercial version is now used in-house by 45 users in 8 countries. Users include international organizations, government departments, academic economists and financial market analysts from a variety of countries including the United States, Japan and Australia. The model has also been used in a wide range of consulting exercises.

The MSG2 model builds on the approach in Lipton and Sachs (1983) and McKibbin (1986) who constructed models in which explicit intertemporal optimization by different agents in each economy forms the basis of structural behavioral equations. The main difference to static CGE models is the use of intertemporal budget constraints and intertemporal objective functions for agents. In contrast to static CGE models, time and dynamics are of fundamental importance in the MSG2 model. In addition, money is explicitly introduced into the model through a restriction that households require money to purchase goods. This assumption gives money an explicit role and gives the models its macroeconomic characteristics. In order to track the macro time series the behavior of agents is modified to allow for short run deviations from optimal behavior either due to myopia or restrictions on the ability of households and firms to borrow at the risk free bond rate on government debt. Deviations from intertemporal optimizing behavior take the form of rules of thumb which are consistent with an optimizing agent that does not update predictions based on new information about future events. These rules of thumb are chosen to generate the same steady state behavior as optimizing agents. Actual behavior is assumed to be a weighted average of the optimizing and rule of thumb assumption. For example, aggregate consumption is a weighted average of consumption based on wealth and consumption based on current disposable income. This is consistent with the econometric results in Campbell and Mankiw (1987) and Hayashi (1982b)). The final modification to the standard market clearing assumption in CGE models is the allowance for short run nominal wage rigidity in different countries. In the short run, dynamics are explicitly driven by asset accumulation and wage adjustment to a neoclassical steady state.

A summary of the main feature of the MSG2 model is contained in table 1.

The MSG2 model is based more firmly on micro-foundations than the standard macro-econometric model. It is actually described by the authors as a dynamic general equilibrium model of a multi-region world economy. A number of versions exist depending on the particular application of the model. Table 2 contains the countries currently modeled in versions of the MSG2 model.

The model is of moderate size (about four dozen behavioral equations per industrial region). It is distinctive relative to most other global models in that it solves for a full intertemporal equilibrium in which agents have rational expectations of future variables. Fiscal and monetary policies are examined in an intertemporal perfect-foresight environment, with considerable attention given to intertemporal optimization and intertemporal budget constraints.

Table 1: Main Features of the MSG2 Model

- both the demand and supply side of the major economies are explicitly modeled;
- demand equations are based on a combination of intertemporal optimizing behavior and liquidity constrained behavior;
- the supply side takes explicit account of imported intermediate goods especially the role of imported capital goods in investment in economies;
- major flows such as physical investment, fiscal deficits and current account imbalances cumulate into stocks of capital, government debt and net external debt which in turn change the composition and level of national wealth over time.
- Wealth adjustment determines stock equilibrium in the long run but also feeds back into short-run economic conditions through forward-looking share markets, bond markets and foreign exchange markets.
- Asset markets are linked globally through the high international mobility of capital.

Despite its foundation in dynamic optimization models, the MSG2 model has a mix of Keynesian and Classical properties by virtue of a maintained assumption of slow adjustment of nominal wages in the labor markets of many countries (although the institutional structure of wage determination differs across countries). In addition the short run role of liquidty constraints are important in investment and consumption decisions.

A complete equation listing for the latest versions of

the MSG2 model are presented in the User manuals, an example of which is Appendix A of McKibbin (1994).

Several important theoretical assumptions underlie the model structure. Each of the regions in the model produces a good which is an imperfect substitute in the production and spending decisions of the other regions.
Each industrialized region is assumed to produce one final good which is used for investment and consumption purposes in that region and in all of the other regions.

Table 2: Overview of the MSG2 Model

**Regions**

United States
Japan
Canada
Germany
United Kingdom
France
Italy
Austria
Australia
Mexico
Korea
High Income Asia
Low Income Asia
Rest of the EMS
Rest of the OECD
Oil exporting countries
Eastern European economies and the former Soviet Union.
Other non-oil developing countries

The LDC and OPEC regions each produce one good which is a primary input in the production processes of the industrial regions. Demands for the outputs of the LDC and OPEC regions are therefore derived demands for the production inputs.

Within each country the decisions of households, firms, and governments and their interaction in goods, factor and financial markets are modeled.

Firms hire factors of production (labour, capital, energy and other imported intermediate goods) so as to maximize the stock market value of the firm subject to a multi-factor production function and a cost of adjustment function for changing the physical capital stock (following Lucas (1967) and Treadway (1969)). Input and output prices are taken as given by the representative firm.

Households are assumed to consume a basket of goods in every period where the basket is made up of domestic goods (both public and private) and imported goods from each of the industrialized regions. They receive income to purchase the goods through providing labor services for production and receive a return from holding financial assets (bonds of all maturities, equity, and assets denominated in foreign currencies). The decision on how consumption expenditure is allocated between the various goods across time is based on a representative consumer who maximizes an intertemporal utility function which is an additively separable function of consumption of the private good and the public good, subject to the constraint that the present value of consumption equals the present value of income.

Governments provide a public consumption good as well providing public infrastructure. The infrastructure capital stock enters the private sector production function with increasing returns. The rate of return on the public capital is assumed to be equal to the return on private capital. Government spending is financed by a range of taxes both direct and indirect on households, firms as well as trade taxes. Governments also issue bonds or print money whenever outlays exceed revenue.

Financial markets are linked via arbitrage between the return to holding alternative domestic and foreign assets. A key feature of the MSG2 model is the explicit link between the real economy and financial instruments that reflect the return to the economic activities that underlie them. For example there is a direct relationship between the return on equities and the future value of the marginal product of capital in an economy. Arbitrage between the return on bonds and the return on equity therefore gives a direct relationship between nominal financial returns, the expected future marginal product of capital and expected changes in inflation. There are also explicit links between bond and equity markets across national boundaries. There are markets for equities, bonds of all maturities, foreign exchange and money.

Solving a model such as the MSG2 model which assumes rational expectations in different markets is not a straightforward exercise. Forward looking variables such as asset prices, consumption and investment decisions are conditioned on the entire future path of all variables in the model. This presents a two-point, boundary value problem; values for inherited variables (state variables) are known and the expected paths of exogenous variables are assumed to

be known. But for forward looking variables, assumptions can only be made about terminal conditions. The solution technique is set out in detail in McKibbin and Sachs (1991) Appendix C.

This section has given an overview of the MSG2 model. The properties and tracking performance of the model with a core set of countries are examined in detail in in McKibbin (1990a) and McKibbin and Sachs (1991). It is shown that a dynamic simulation of the model, imposing major identifiable shocks that occurred during the period, is able to replicate many of the features of the world economy during the 1980s.

## 3. THE G-CUBED MULTI-COUNTRY MODEL

The G-Cubed multi-country model was developed by McKibbin and Wilcoxen (1992). It combines the approach taken in the MSG2 model outlined above with the disaggregated, econometrically-estimated, intertemporal general equilibrium model of the U.S. economy by Jorgenson and Wilcoxen (1989). The Jorgenson-Wilcoxen model breaks the economy down into 35 separate industries, each of which is represented by an econometrically estimated cost function. The G-Cubed model has only 12 sectors but each sector is based on econometrically estimated cost functions.

G-Cubed has been constructed to contribute to the current policy debate on environmental policy and international trade with a focus on global warming policies, but it has many features that will make it useful for answering a range of issues in environmental regulation, microeconomic and macroeconomic policy questions. It is a world model with substantial regional disaggregation and sectoral detail. In addition, countries and regions are linked both temporally and intertemporally through trade and financial markets. Like MSG2, G-Cubed contains a strong foundation for analysis of both short run macroeconomic policy analysis as well as long run growth consideration of alternative macroeconomic policies. Intertemporal budget constraints on households, governments and nations (the latter through accumulations of foreign debt) are imposed. To accommodate these constraints, forward looking behavior is incorporated in consumption and investment decisions. Unlike MSG2, G-Cubed also contains substantial sectoral detail. This permits analysis of environmental policies which tend to have their largest effects on small segments of the economy. By integrating sectoral detail with the macroeconomic features of MSG2, G-Cubed can be used to consider the long run costs of alternative environmental regulations yet at the same time consider the macroeconomic implications of these policies over time. The response of monetary and fiscal authorities in different countries can have important effects in the short to medium run which, given the long lags in physical capital and other asset accumulation, can be a substantial period of time. Overall, the model is designed to provide a bridge between computable general equilibrium models and macroeconomic models by integrating the more desirable features of both approaches. Details on this integration and how G-cubed bridges the gap between CGE and traditional macro-econometric models can be found in McKibbin (1993b).

G-Cubed is still in the process of development but it is already a large model. In its current form it contains over 5,000 equations and 110 intertemporal costate variables. Nonetheless, it can be solved using software developed for a personal computer. In addition, an extensive set of software exists that will permit G-Cubed to be used for game theoretic analysis of how one or more countries might respond strategically to unilateral policies adopted by other nations. The key features of G-Cubed are summarized in Table 3.

Table 3: Summary of Main Features of G-CUBED

- Specification of the demand and supply sides of economies;
- Integration of real and financial markets of these economies;
- Intertemporal accounting of stocks and flows of real resources and financial assets;
- There is extensive econometric estimation of key elasticities of substitution from sectorally disaggregated data;
- Imposition of intertemporal budget constraints so that agents and countries cannot forever borrow or lend without undertaking the required resource transfers necessary to service outstanding liabilities;
- Short run behavior is a weighted average of neoclassical optimizing behavior and ad-hoc "liquidity constrained" behavior;
- The real side of the model is disaggregated to allow for production and trade of multiple goods and services within and across economies;
- Full short run and long run macroeconomic closure with macro dynamics at an annual frequency around a long run Solow/Swan neoclassical growth model.
- The model is solved for a full rational expectations equilibrium at an annual frequency with an horizon of more than a century.

The country and sectoral breakdown of the model are summarized in Table 4. As with MSG2 model there are now a number of version of G-Cubed with different country coverage. The range of countries modeled to date include the United States, Japan, Australia, the rest of the OECD, China, Oil Exporting developing countries (OPEC), Eastern Europe and states of the former Soviet Union (EFSU), and all other developing countries (LDCs) ) with twelve sectors in each region. There are five energy sectors (electric utilities, natural gas utilities, petroleum processing, coal extraction, and crude oil and gas extraction) and seven non-energy sectors (mining, agriculture, forestry and wood products, durable manufacturing, non-durable manufacturing , transportation and services). This disaggregation enables

Table 4: Overview of the G-Cubed Model

Regions

United States
Japan
Australia
China
Rest of the OECD
Oil Exporting Developing Countries
Eastern Europe and the former Soviet Union
Other Developing Countries

Sectors

Energy:
Electric Utilities
Gas Utilities
Petroleum Refining
Coal Mining
Crude Oil and Gas Extraction

Non-Energy:
Mining
Agriculture, Fishing and Hunting
Forestry/ Wood Products
Durable Manufacturing
Non-Durable Manufacturing
Transportation
Services

us to capture the sectoral differences in the impact of alternative environmental policies.

As with the MSG2 model, each economy or region in the model consists of several economic agents: households, the government, the financial sector and firms in the 12 production sectors listed above. The behavior of each type of agent is modeled.

Each of the twelve sectors in each country in the model is represented by a single firm in each sector which chooses it inputs and its level of investment in order to maximize its stock market value subject to a multiple-input production function and a vector of prices it takes to be exogenous. For each sector, output is produced with inputs of capital, labor, energy, materials and a sector-specific resource. The nature of the sector specific resource varies across sectors. For example in the coal industry it is reserves of coal, in agriculture and forestry/wood products it is land which is substitutable between these two sectors.

Energy and materials are aggregates of inputs of intermediate goods. These intermediate goods are, in turn, aggregates of imported and domestic commodities which are taken to be imperfect substitutes. Due to data limitations we assume that all agents in the economy have identical preferences over foreign and domestic varieties of each particular commodity. We represent these preferences by defining twelve composite commodities that are produced from imported and domestic goods.
For example, petroleum products purchased by agents in the model are a composite of imported and domestic petroleum. By constraining all agents in the model to have the same preferences over the origin of goods we require that, for example, the agricultural and service sectors have the identical preferences over domestic oil and oil imported from the middle east. This accords with the input-output data we use and allows a very convenient nesting of production, investment and consumption decisions.

The capital stock in each sector changes according to the rate of fixed capital formation and the rate of geometric depreciation. As in the MSG2 model it is assumed that the investment process is subject to rising marginal costs of installation, with total real investment expenditures in sector h equal to the value of direct purchases of investment plus the per unit costs of installation. These per unit costs, in turn, are assumed to be a linear function of the rate of investment. One advantage of using an adjustment cost approach is that the adjustment cost parameter can be varied for different sectors to capture the degree to which capital is sector specific.

The goal of each firm is to choose inputs of labor, energy, materials, resources and investment to maximize intertemporal net-of-tax profits. For analytical tractability, we assume that this problem is deterministic (in other words, the firm is assumed to believe its estimates of future variables with subjective certainty). Solving the optimization problem facing this representative firm, we find a set of demand functions for factors of production as well as an investment function similar to that for MSG2 where investment in each sector depends on Tobin's q for each sector. We can also use these factor demand equations together with the production function to rewrite the model in terms of cost functions. In this case the price of the output at each level of the tier structure will be a function of the price of variable inputs and the quantities of available fixed factors (such as capital). As with MSG2, it is assumed that investment in each sector is a weighted average of forward looking investment and investment out of current profits.

The price of labor is determined by assuming that labor is mobile between sectors in each region, but is immobile between regions. Thus, wages will be equal across sectors. The wage is assumed to adjust according to an overlapping contracts model where nominal wages are set based on current and expected inflation and on labor demand relative to labor supply. In the long run labor supply is given by the exogenous rate of population growth, but in the short run the hours worked can fluctuate depending on the demand for labor. For a given nominal wage, the demand for labor will determine short run unemployment in each industry. This will vary across industries depending on the composition of demand for each sectors good.

So far, the above discussion has described the demand for investment by each sector. It is assumed that the investment goods are supplied by a firm facing an optimization problem similar to those of the twelve industries described above (and not repeated here). Like other industries, the investment sector demands labor and capital services as well as intermediate inputs. The only difference is that it is assumed there is no sector-specific resource for the investment sector. The investment column in the input-output table for each country is used to parameterize the investment sector's production function. As with the derivation above, there is a shadow "q" associated with investment in the investment goods sector.

Household behavior is similar to that in the MSG2 model with some crucial innovations. Households consume a basket of composite goods and services in every period and also demand labor and capital services. Household capital services consist of the service flows of consumer durables plus residential housing. Households receive income by providing labor services to firms and the government, and from holding financial assets. In addition, they also receive transfers from the government.

The behavior of a representative household can be thought of as a sequence of decisions. Households first decide on aggregate consumption for each period. Aggregate consumption is chosen to maximize an intertemporal utility function in the same way as in the MSG2 model. Following the approach taken in the MSG2 model we assume that only a portion of consumption is determined by these intertemporal optimizing consumers. The other portion of consumption is determined by current income. Once this total consumption expenditure for a period is determined expenditure is allocated across goods and services based on preferences and relative prices. A nested constant elasticity of substitution utility function is used, so income elasticities will be unity and price elasticities can differ from unity. Total private consumption is allocated between capital, labor, a basket of energy goods and a basket of non-energy goods. Energy and materials are sub-aggregates of intermediate goods.

The solution for the consumption of capital services is a little more complex. Here we assume that consumers invest in household capital in order to generate a desired flow of capital services subject to the accumulation equation for capital and a cost of adjustment. Solving this problem yields results similar to those discussed for firms above. However, since no variable factors are used in producing capital services, the first order conditions for the problem give investment as a function of the shadow price of capital and an equation for the shadow price of capital itself. The demand for capital services arising in the household consumption problem determines the price of capital services given the supply of services. The stock of household capital at each point in time is determined by the initial stock of capital, the rate of depreciation and the rate of gross investment in the stock of capital. In the same way that investment by firms is determined, the investment by households depends on the Tobin's q associated with the stock of household capital.

It is assumed that the government in each country divides spending among final goods, services and labor according to the proportions in the base year input-output table for each country. The government budget constraint follows from that used in the MSG2 model.

Again the role of money and the linkage of financial markets follows the approach in the MSG2 model.

A key aspect of G-Cubed is its integration of data from input-output tables with conventional macroeconomic data. This is used to econometrically estimate many key relations in the model. The data used in G-Cubed comes from a number of sources. We estimate CES production and consumption relations using a time series of input- output data and other data for the United State economy from 1947 to 1987. Although endowments of factors of production are different across countries, the elasticities of substitution in production and consumption are assumed the same across countries. This is consistent with econometric results in Kim and Lau (1994).

Trade shares are based on the United Nations SITC (Standard Industry Trade Classification) data for 1987 with sectors aggregated from 4 digit levels to map as closely as possible to the SIC (Standard Industry Classification) used in the U.S. input/output data. This data now comes from the International Economic Database at the ANU. At this stage the elasticity of

substitution between imported and domestically produced goods are not estimated but are imposed to be unity. It is important to note that this is not the same as assuming that trade price elasticities are equal to unity.

The shares of optimizing versus backward looking behavior are taken from the MSG2 model.

G-Cubed is solved using the same software as the MSG2 model. The model has over 5000 equations in its current form with 111 jumping or forward looking variables and 148 state variables.

## 3. APPLICATIONS

### *3.1 Applications Of The MSG2 Model*

In the Australian context, the MSG2 model has been used to focus on a wide range of issues. McKibbin (1988) explored the impact on Australia of changes in fiscal and monetary policy in the United States and Japan. This paper also examined the impact on Australia of changes in Australian fiscal and monetary policies distinguishing between changes that are either temporary or permanent, anticipated or unanticipated. It showed that the expectations associated with each type of policy change can have very different effects on asset prices and therefore different effects on economic activity. That paper also showed that foreign fiscal and monetary shocks are more important for Australia through the effect on financial markets than through direct effects on trade flows caused by changes in demand. This suggests that the response of policy makers in Australia to changes in asset prices are likely to be just as important for the ultimate consequences for Australia, as the direct impact of foreign policies through changes in aggregate demand in the world economy.

McKibbin and Elliott (1989,1990) also focussed on the consequences of Australian fiscal policy especially with respect to the impacts on the balance of payments. It was shown that the impact of a fiscal expansion on worsening the balance of payments is large. This not only occurs because the increase in aggregate demand raises imports directly but because the fiscal expansion financed by issuing debt raises interest rates, causing an inflow of capital that appreciates the exchange rate. This appreciation then increase imports and lowers exports. The other side of this adjustment is the fall in total domestic saving relative to investment leads to an increase in the use of foreign savings.

McKibbin and Siegloff (1991) used explicit optimization algorithms to explore the impact of policy coordination in the world economy on the Australian economy. They also modeled the interaction of trade unions and the government as a dynamic game that is played simultaneously with the multilateral policy game. They found that global coordination of macroeconomic policies in response to a shock in the world economy is more beneficial to Australia than any policy responses that Australia can undertake alone. They also find that cooperation between the government and trade unions are important in determining the outcome.

The impact of NAFTA on Australia was examined in McKibbin (1994a). This paper showed that the impact of NAFTA on global capital flows into Mexico are the most important aspect of that trading arrangement for Australia. The traditional focus of analysts on questions of which countries sell which goods to NAFTA economies is shown to miss the more important general equilibrium point that in the short to medium run the dominant impact on Australia of NAFTA is through its effects on global capital markets. Because of Australia's external debt position the reallocation of global capital towards Mexico leads to a short run loss to Australia from higher world interest rates. In the long run the higher productivity growth in NAFTA economies leads to higher income for Australia. This paper also showed that the NAFTA shock, being both a demand shock as well as a supply shock (in the sense that their is a change in allocation of the physical capital stock in Australia) is an example where inflation targeting is a suboptimal policy relative to nominal income targeting in Australia.

Pearce, Vincent and McKibbin (1993) explored the impact that alternative deflation scenarios would have had on the Australian economy (in particular on Wool growers) during the period from 1987 through 1991. It was shown that the actual setting of monetary policy at the time, of a sharp rise in interest rates beginning in 1998, was the higher cost way to achieve a reduction in Australian inflation during this period. A better approach would have been to announce and pursue a target of nominal income growth consistent with gradually falling inflation.

Other international issues have been examined using the MSG2 model. The global impacts of regional trade arrangements using MSG2 have been examined in CBO (1993a), Ishii and McKibbin (1993b), Manchester and McKibbin (1995), McKibbin (1994c). In these papers the adjustment of private capital flows is shown to give results in the short to medium term that are different to the results of standard trade models. A clear example is given by the adjustment of the U.S. trade balance to NAFTA. In the MSG2

model, the inflow of capital into Mexico as a result of expected higher future productivity growth leads to a large change in the Mexican real exchange rate and this implies a deterioration in the Mexican trade balance reflecting the inflow of capital. This effect is shown to dominate (as it does in reality) the trade effects of labor intensity differentials between the United States and Mexico.

The impact of alternative global saving scenarios is explored in Armington(1991), Brennan (1994) McKibbin (1990d,1992d,1993a,1994b,1994e). Related to this issue the global implications of U.S. fiscal policy is examined in Bagnoli and McKibbin (1993), Ishii and McKibbin (1993a), McKibbin (1992b) and McKibbin and Bagnoli (1993). It is shown in all of these papers that changes in saving projections, whether through changes in the behavior of households of governments can permanently change the level of global real interest rates. These also imply important effects on real exchange rate fluctuations as well as important impacts on the level of per capita income. These papers also showed that in a world with high capital mobility, the savings decision of a particular country can have important implications for the level of per capita income in all countries.

The strategic aspects of fiscal and monetary interdependence between countries using game theoretical solutions to policy optimization problems can be find many of the papers listed in the bibliography. In particular important insights can be found in Ishii, McKibbin and Sachs (1986), McKibbin (1986), McKibbin and Sachs (1988a, 1988b, 1991), McKibbin and Sundberg (1993). These papers showed that the Nash equilibrium in a global policy game can be suboptimal relative to a coordinated policy response.

European issues such as the EC92 initiative, weaknesses of the European Monetary System, the Maastricht Agreement and German Unification are examined in CBO (1991), Giovannini and McKibbin (1992), McKibbin (1990, 1992c), McKibbin and Bok (1994b), McKibbin, Neck and Schafer (1993), and National Commission for Employment Policy (1993). As with many of the results from this model the adjustment in financial markets are important for the adjustment to the shocks examined. The EMS was shown to be particularly vulnerable to asymmetric real shocks such as German Unification and the fiscal adjustments required by the Maastricht Agreement. German Unification was also projected to be very costly because of the stickiness of German real wages and the low productivity of East German workers and the East German capital stock. The paper by McKibbin and Bok (1994a) also showed that a single currency in Europe would have probably handled the shock of German Unification with less output loss in Europe that occurred under the EMS. Monetary policy in Europe would have been less contractionary since policy would have been set by a European central Bank that presumably placed weight on output losses throughout Europe rather than only being concerned with inflationary pressure in Germany.

The Linkages between the industrial economies and developing countries are examined in a number of papers including Bryant and McKibbin (1995), McKibbin and Bok (1994a), McKibbin and Sundberg (1993, 1995). Sachs and McKibbin (1985). Key aspects of the results from these papers is that the coordination of policies in the industrial economies in the face of shocks have important benefits to developing countries through changes in interest rates, real exchange rates and trade flows. Also fiscal expansions in the industrial economies have negative effects on developing economies because the beneficial stimulus to demand in the industrial economies is more than offset by the negative effects of higher real interest rates in global capital markets.

The problem of regime choice for setting macroeconomic policies is examined in Henderson and McKibbin (1993,1994), McKibbin (1993b) and McKibbin and Sachs (1989c,1991). These papers show that nominal income targeting works well for many shocks. Inflation targeting works well for shocks to aggregate demand and financial shocks, however, inflation targeting performs poorly in the face of shocks to aggregate supply. In particular shocks to productivity and physical capital accumulation as handled badly, in terms of foregone output, by an inflation target..

A number of studies of the effects of the end of the Cold War have also been undertaken with the model. For example CBO(1993c), McKibbin (1994d,1995a), McKibbin and Thurman (1995). These paper found that the way in which the revenue gained from reduced defense budgets throughout the world is used is important for there to be any sense of an economic "peace dividend". In general, the reallocation of resources from defense to non defense industries will involve a period of unemployment of factors of production in the countries that are cutting military spending. This loss can be offset in the medium term by using the cuts in defense spending to credibly lower future fiscal deficits. In the long run, if the cutbacks are used to reduce fiscal deficits, income per capita is raised by defense cutbacks. In addition there are asymmetric effect of defense cutbacks across countries because of the different share of resources devoted to military spending in different economies. This suggest gains to sharing the costs and benefits of cuts in

military spending during the transition period of a decade or more.

Other topics explored using the model include measuring the costs of the Savings and Loan crisis in the United States (CBO(1993b), Manchester and McKibbin (1994)), the determination of equilibrium exchange rates (McKibbin (1990b), studies of the Canadian economy (McKibbin (1992a) and the Japanese economy (Tomita(1994)).

*3.2 Applications of the G-CUBED Model*

The G-Cubed model is relatively newer than the MSG2 model and is not yet available for other researchers to use independently although it is available for undertaking commissioned studies.

To date the main focus of model based studies has been on evaluating environmental policies, in particular the effects of carbon taxes.

Australian studies using the model for looking at carbon taxes include McKibbin (1994h), McKibbin and Pearce (1993, 1994a, 1994b) and McKibbin Pearce and Stoeckel (1994). These studies all highlight that a carbon tax in Australia leads to a significant reduction in real output with the greatest losses occurring in the short run. In addition any tax that aims at stabilizing carbon dioxide emissions at a constant absolute level would have to be continually increasing. The underlying baseline emissions of carbon dioxide rise into the indefinite future primarily due to population growth in Australia. These studies also show that a global tax on production of fossil fuels is preferable to a global tax on the use of these fuels primarily because Australia is a large coal exporter and with a tax on production the revenue from the tax is kept in Australia rather than being collected by the consuming country. These studies show that Australia will bear a disproportionate burden of an international agreement that targets emissions at 1990 levels because of the reliance of Australia on fossil fuels for energy generation, for export revenue and because Australia has the highest projected rates of population growth in the OECD.

The other main application of the model for Australia has been to examine the implication of change in trade policies. In particular McKibbin and Salvatore (1994) show that the impact of the recent GATT agreement has differential sectoral effects within Australia. In the short term, capital flows out of those sectors in Australia that have no tariff changes, into sectors that are likely to be increasing efficiency through tariff reductions. Thus factors of production, in particular capital, shift out of agriculture into manufacturing in Australia in the short run. In addition, capital flows out of Australia into economies that are expected to undertake significant liberalization because of anticipated increase in the return to capital in these economies. This has a depressing effect on all sectors in Australia. Over time as world agricultural markets are opened up, the gain to the agricultural sector begins to be realized but this takes a decade to emerge. Thus there is a distinct pattern in the timing of gains to the GATT agreement that a differentially felt across sectors and differentially felt across time in the same sector.

A further application of the model was in a recent EPAC study of the effects of differential sectoral productivity growth in Australia. It was shown that high productivity growth raises investment spending in anticipation of a rise in the return to capital. In addition, the projection of high productivity growth in manufacturing sectors that produce capital goods, lowered the cost of capital which further stimulates private investment in the economy. Strong investment from both sources has the effect of worsening the balance of payments. There is no real policy problem with this however, because the economy is easily able to finance the additional accumulation of debt and equity claims by foreigners through the higher future output that results from the productivity growth and the cumulation of physical capital. The rise in expected future productivity also leads to a rise in consumption and a short term fall in private saving because of expected higher future income levels. This further worsens the balance of payments in the short term.

The global applications of the G-Cubed model have been more varied. Carbon taxes are examined in McKibbin and Wilcoxen (1992a,1992b, 1993a, 1993b, 1993c, 1994). These studies show that the adjustment of capital flows are important for the impacts of carbon taxes. In addition the way in revenue is used is very important. The model has also been used to explore the sectoral impacts of changes in macroeconomic policy in McKibbin and Wilcoxen (1992a,1992b, 1993a,1994). It was found that monetary policy, although neutral in the long run, does have differential short run impacts on different sectors depending on the capital intensity of the sectors as well as the interest sensitivity of the demands for the output of each sector. Fiscal policy also differs from the standard macroeconomic model because the composition of government spending differs across sectors. In addition the sectors in the G-Cubed model are influenced differently by changes in asset prices, in particular changes in real exchange rates.

The Global implications of regional trade arrangements using G-Cubed have been explored by McKibbin (1994j) and McKibbin and Salvatore (1995). The trade implications of environmental policy are the focus of papers by McKibbin and Wilcoxen (1993b, 1995). These papers show that changes in environmental policy are unlikely to lead to major changes in trade flows through relocation of industry because the costs of environmental policy are generally small relative to the cost of relocating production facilities. This does not mean that environmental policies lead to small losses in economic output, but the policies are unlikely to be fully offset by substitution towards goods that are not subject to the same environmental regulation. In the context of U.S. policy for global warming the papers above have shown that the reduction in U.S. emissions also reduces global emission except for an offset of around 10 to 20 percent due to these substitution effects.

## 4. CONCLUSION AND FUTURE DEVELOPMENTS

The MSG2 and G-Cubed models have now been used to contribute to developments in modeling techniques as well as a wide range economic policy questions in a number of countries. Both models are currently being extended in a number of directions by researchers at other institutions as well as by the core modeling teams themselves. The MSG2 model is currently being modified to allow model consistent forecasts as well as the standard counter- factual policy simulations. In addition, the country coverage of the model is currently being extended to cover country models for individual economies in the Asia-Pacific region.

The G-Cubed model has recently spawned an Asia-Pacific G-Cubed model. This model outlined in McKibbin and Bok (1993) has six sectors in each country and coverage of the standard G-Cubed countries as well as Korea, Taiwan, Hong Kong, Singapore, Malaysia, Thailand, Philippines and Indonesia. It is particularly aimed at focussing on trade related issues in the Asia-Pacific region. Current work of the author with Alan Wong at ANU is developing this model further.

Acknowledgements

This project has received financial support from the U.S. Environmental Protection Agency through Cooperative Agreement CR818579-01-0 and from the National Science Foundation through grant SBR-9321010. The views expressed are those of the authors and should not be interpreted as reflecting the views of the trustees, officers or other staff of the Brookings Institution, the Environmental Protection Agency or the National Science Foundation.

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