Forecasting the World Economy Using Dynamic Intertemporal General Equilibrium Multi-Country Models

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ABSTRACT

This paper gives an overview of the types of models available for analysing possible futures of the global economy. It then focuses on dynamic intertemporal general equilibrium models and describes how these models are used for both projections and scenario analysis. Some lessons from recent history both theoretical and practical are used to demonstrate the usefulness of the models.

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1. Introduction

Forecasting the world economy is a complex and daunting task. Indeed there are so many inter-related issues within and across countries that global forecasting and policy analysis would seem an almost impossible undertaking. Yet for many issues, and particularly in the recent years, having a global perspective is crucial. Recent developments in global economic models have created frameworks which are becoming increasingly indispensable for policy analysis and in thinking through a range of alternative global scenarios. Indeed it is in providing consistent scenarios and highlighting general equilibrium issues for input into a broader forecasting exercise, rather than as pure number generators, where the newer generation of global economic models have been most valuable in recent years.

In evaluating the usefulness of global forecasting using a modeling framework, it is important to consider these models relative to the practical alternatives rather than relative to an idealized world. There is never going to be an all encompassing model that represent the world economy completely and accurately. Models are just abstractions of reality - a simplification for understanding the myriad of important issues. One obvious alternative to an economic model would be to make predictions about the world economy without a coherent framework. To see why this is clearly dominated by economic models it is worth considering what a global economic model consists of. Economic models consist of two broad classes of equations. There are equations (called identities) that hold independently of assumptions about behavior and there are equations which reflect a combination of theoretical assumptions or empirical regularities about the behavior of economic actors in the world economy (households, firms and governments). At a minimum, a modeling approach to forecasting the world economy provides the consistency required by identities. For example forecasting that every country's trade balance will deteriorate over some future period violates a basic identity that the sum of all exports equals the sum of all imports. Basic relations such as these are imposed in a modeling framework but very often ignored in an adhoc global forecasting exercise. Very importantly, economic models based on transparent and well documented inter-relationships allow a way of thinking about many complex interdependencies in a coherent manner. In addition, economic models contain a body of theoretical and empirical capital that provide a context for evaluating current experience. Models should be one tool in a toolkit of alternative approaches to analyzing inherently uncertain futures. In their current form at least, these global economic models should be inputs into a forecasting exercise rather than the sole generators of numbers.

There are a number of alternative multi-country economic models available which are currently used by national and international organizations for undertaking projections of the future evolution of the world economy under a range of alternative assumptions. The goal of this paper is to lay out the alternative classes of approaches that are currently available putting these in their historical and methodological context. In particular, this paper focuses on a new class of models that have been developed over more than a decade. These models are called dynamic intertemporal general equilibrium models. As well as discussing the models used for global analysis, the paper also outlines a methodology for maximizing the returns to using models for projecting the future which is more closely related to scenario analysis than traditional econometric forecasting.

In section 2, the major streams of global models are outlined in their historical context. The dynamic intertemporal general equilibrium models that I have been involved with developing are introduced in section 3. These models are the MSG2 model, the G-Cubed model, the G-Cubed (Asia Pacific) model and the G-Cubed (Agriculture) Model. The way in which these models are used as part of forecasting exercises by a range of users are outlined in section 4. This section also gives a relatively technical explanation on how projections and scenarios are developed with the models in practical applications. Some lessons that have been learned from these models, in particular in the case of German Unification and the recent crisis in Asia as well as a theoretical insight on the volatility of asset prices are outlined in section 5. A summary and some thoughts about where models are heading is presented in section 6.

2. Alternative Global Models

Developments in global economic models have tended to follow the theoretical and empirical trends in national economic models and also the debates in economic theory, although the number of multi-country models has always been much smaller than the number of national models. In recent years the emergence of international databases, advances in computer technology and developments of numerical algorithms has accelerated the development and use of multi-country models.

Classifying models is a difficult exercise because models have so many dimensions. Most models can be traced to clear intellectual roots although recently new approaches to global models have started to synthesize across modeling schools.

There are two major streams of global models currently in wide use, although a number of other types of models exist. Within the major schools of modeling there are also a range of approaches. The major approaches are multi country computable general equilibrium (CGE) models[1] and macro-econometric models[2] . Within the macroeconometric approaches there are two broad streams. These are the older style macroeconometric models in the tradition of Lawrence Klein with a heavy reliance on econometric estimation (e.g. Project Link, Wharton model, DRI model) and the newer style models with greater reliance on economic theory (e.g. the International Monetary Fund MULTIMOD model and John Taylor's TAYLOR model at Stanford).

Recent developments of dynamic intertemporal general equilibrium models are an attempt to synthesize the key advantages of both major schools of modeling into a single framework (see McKibbin (1993) for an overview). Both the MSG2 and G-Cubed multi-country models, which are the focus of the current paper, are examples of this latter approach.

The distinction between the two broad approaches to global modeling outlined above is much the same as that between microeconomic and macroeconomic theory. However, as the distinction

1 These are also referred to as Applied General Equilibrium (AGE) models. Hereafter I will only use the term CGE models. See de Melo (1988), Robinson (1989) and Shoven and Whalley (1984) for an overview of CGE models. Examples of this approach in multi-country models are the GREEN model (Burniaux et al (1992)), Whalley (1985), Deardorff and Stern (1985) and the SALTER model (Jomini et al (1994)) and its derivatives such as GTAP (Hertel et al (1997)), and MEGABARE (ABARE/DFAT (1995)).
2 See Bryant et al (1988) for a summary of the major multi-country macro-econometric models and a list of references relating to each model

between microeconomic and macroeconomic theory has blurred, so has the distinction between CGE models, which have begun to incorporate dynamics, and the new generation of macro-econometric models which are more firmly based on optimization theory. In addition to the theoretical basis of the models there is also a significant range of techniques for parameterizing both schools of models. Parameters are either based on econometric estimates by the modelers or are "calibrated" by creating parameters that are based on "empirical evidence".

CGE models are derived from microeconomic optimization theory, with considerable attention to individual behavior whereas macro-econometric models are based on aggregate behavior with reliance placed heavily on correlations found in time series of aggregate data. There is by now a vast literature containing applications of computable general equilibrium models. The reader is referred to papers by Dervis et. al. (1982), de Melo (1988), Robinson (1989) and Shoven and Whalley (1984) for a detailed overview of CGE models.

The CGE modeling work descends directly from the work of Arrow and Debreu (1954). It transfers the well-known Walrasian general-equilibrium structure from an abstract representation of an economy into realistic models of actual economies that can be used to conduct policy evaluations by specifying production and demand functions and incorporating data reflective of the real world. Given the focus on individual optimization, the key parameters in these type of models are parameters such as expenditure shares and the elasticities of substitution of households and firms. These parameters are sometimes "calibrated" to a data set given an assumption about functional form of utility and production functions. Or they are estimated from extensive cross sectional data on households and firms. In addition to parameter calibration, it is often the case that the data behind the model is adjusted to be consistent with the equilibrium of the model.

The applied aspects of CGE modeling descend from the fixed coefficient work of Wassily Leontief [3]. By using input-output tables constructed for fixed coefficient models, introducing relative prices and empirical evidence on substitution in production and consumption, the CGE approach added a new dimension to this earlier modeling strategy. An early example of this type of work is Johansen (1960). During the last two decades, hundreds of such models have been built for single economies and an increasing number for the world economy. They have been applied to a number of policy issues, ranging from public finance and taxation, economic integration, GATT negotiations, and issues of North-South trade, to the evaluation of development strategies and energy and environment policies for almost all the major countries in the world. With the focus on micro-economic theory, CGE models are particularly well suited to analyzing questions in tax policy and international trade (see Shoven and Whalley (1984)). In addition they have played an important role in the literature on economic development (see the survey by de Melo et. al. (1982).

The advantage of CGE models is the transparency of the key mechanisms in many of the models. Also, considerable sectoral detail can be handled and even the results from the larger models can be understood from theoretical intuition. One problem with CGE models is interpreting the time horizon over which the results are relevant. This partly relates to how long it takes for markets to clear. The early static CGE models were used for comparative static analysis of the change between equilibria given a change in some policy. They were particularly useful for analyzing the long run effects of policies. Recent work has attempted to incorporate dynamics to allow for simple adjustment between equilibria in single economy model (e.g. Bourgignon et al (1989), Burniaux et.al. (1991), and Feltenstein (1986)) and more crudely in the multi-country (such as the approach in the MEGABARE model). However these extensions have usually had macroeconomic

[3] Input Output models are still used primarily in the United Nations system. The work of Duchin (1995) is an example

closures which are considered unsatisfactory by macro-economists. The absence of an aggregate price level or any role for money (or nominal exchange rate fluctuations) in particular is an important omission from most CGE models. These models are also problematic for short term forecasting because of the lack of a dynamic structure.

Other attempts to introduce dynamics through explicit intertemporal optimization of agents have lead to a class of models known as dynamic intertemporal general equilibrium models. Examples include Lipton and Sachs (1983), McKibbin (1986), Goulder and co-authors (1989,1990), Jorgenson and Wilcoxen (1990), McKibbin and Sachs (1991) and McKibbin and Wilcoxen (1992). This type of model will be discussed further below.

In contrast to the approach taken in CGE models, the standard approach in macro-econometric models developed during the 1960s and 1970s was for macroeconomic theory to be used as a guide as to the appropriate variables to use in regression equations (see Bodkin et al (1991)). These variables were then tested and either included or excluded based on various tests of statistical significance. Because of the focus on aggregate relationships, it was rare that these models imposed the types of constraints across equations to satisfy conditions from microeconomic optimization theory. In some cases, the conditions of homogeneity were not even imposed. With fewer theoretical constraints or seldom any imposition of steady state conditions to impose stability, the larger econometric models tended to be explosive over long periods and were only really useful for simulations over short time horizons. This was less of a problem when the models were used for short term forecasting but was a fundamental problem for medium term policy analysis.

These macro-econometric models broke down empirically in the 1970s, in part because they relied on data periods in which events such as supply shocks were relatively unimportant. While

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of a global Input Output model.

these models were criticized for their poor tracking performance in the face of shocks that were not in their estimation sample, the Lucas Critique dealt a theoretical blow by pointing out the role of expectations and the need to worry about theoretical structure and policy regimes 4. The modeling profession responded to this challenge by introducing rational expectations into a number of models. The multi-country models that incorporated the assumption of rational expectations such as the Liverpool, Taylor, MSG and Minimod (parent of Multimod) tended to be small models with relatively simple dynamics. This was partly due to the size constraints placed by the numerical techniques used to solve RE models. It was also because the long distributed lag structures in the traditional macroeconometric models made it virtually impossible to numerically solve these models including rational expectations. The main problem was that in many, if not all cases, these models were basically unstable. The instability which gradually appeared over a simulation horizon of a decade or less, manifested itself into the first year when attempting to introduce rational expectations. To give the saddle path stability that is required in rational expectations models required a tighter structure and more careful constraining of parameter estimates. Even today it is not a matter of size of models that prevents the use of rational expectations. The key problem is related to model stability. It is not that rational expectations was necessarily a desirable assumption to incorporate into these models. However, attempts to implement this assumption showed that the conventional style of macroeconometric model building produced models with medium term properties that were less transparent and less stable than more theoretically constrained models.

Global macro-econometric models that have been developed in the 1980s spanned the spectrum of macroeconomic and microeconomic theory with a variety of reliance on estimation

4 See Lucas (1973).

versus calibration techniques. Models such as Multimod[5], Liverpool model[6], the Taylor Model[7] and perhaps the new Federal Reserve Board model[8] and GEM are closer to the microeconomic theory part of this spectrum than the derivative models of the large scale models of the 1970s such as the DRI, EPA, INTERLINK, LINK, MCM or WHARTON models[9]. The MSG2 model in contrast, lies closer to the microeconomic theory end of the spectrum because it has explicit structural parameters and it is calibrated to a data set rather than estimated over a time series of data.

Each of the models has both strengths and weaknesses. For forecasting purposes the macroeconometric models have a distinct advantage because they tend to have a periodicity that is necessary for meaningful forecasts where CGE models are generally single period models. There has been attempts to solve CGE models with a period linked dynamic such as changing capital stocks etc (e.g. MEGABARE) but this is unsatisfactory for meaningful forecasting purposes. Using intertemporal general equilbrium models for forecasting presents a number of challenges which will be outlined below.

3. The MSG2 and G-Cubed Multi-Country Models

The MSG2 and G-Cubed suite of models are dynamic intertemporal general equilibrium models that attempt to bridge the gap between the traditional CGE models and macroeconometric models described above. In this section an overview of these models is presented. More details can be found at http:\\www.msgpl.com.au

5 See Masson et al (1988).
6 See Minford et al (1986).
7 See Taylor (1988) and (1995).
8 See Levin et al (1997)

A summary of the key features of these models is contained in Table 1 and the country country coverage in Table 2.

a. The MSG2 model

The MSG2 multi-country model was developed by Warwick McKibbin and Jeffrey Sachs, in two distinct stages. The first model called the MSG model formed the basis of a number of papers by the authors in the early and 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. As mentioned above this earlier model was a modern Keynesian style macroeconomic model of the world economy with the unique advance of including rational expectations in the foreign exchange market. The parameters of the model 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 by more than 60 users in 14 countries. Users include international organizations, government departments, academic economists and financial market analysts in a range of locations including the United States, Europe, Japan, and Australia.

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

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9 For an overview of these models see Bryant et al (1988).

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 the rule of thumb assumptions. 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 (1982)). The final modification to the standard market clearing assumption in CGE models is the allowance for short run nominal wage rigidity in different countries and therefore for significant periods of unemployment depending on the labor market institutions in each country. In the short run, dynamics are explicitly driven by asset accumulation and wage adjustment to a neoclassical steady state.

b. The G-Cubed Model

The G-Cubed multi-country model was developed by McKibbin and Wilcoxen (1992) and has been updated in McKibbin and Wilcoxen (1995). It is a dynamic intertemporal general equilibrium model combining the approach taken in the MSG2 model with the approach taken in the dis-aggregated, econometrically-estimated, intertemporal general equilibrium model of the U.S. economy by Jorgenson and Wilcoxen (1989).

The G-Cubed model was constructed with a grant from the United States Environmental Proection Agency, the US National Science Foundation and the Brookings Institution. It was 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 make it useful for answering a range of issues in environmental regulation, microeconomic and macroeconomic policy questions. Like the MSG2 model it is a world model with substantial regional disaggregation but unlike the MSG2 model it contains considerable sectoral detail. With its sectoral detail and clear macroeconomic structure, the G-Cubed model is designed to provide a bridge between computable general equilibrium (CGE) models that traditionally ignore the adjustment path between equilibria and macroeconomic models that ignore individual behavior and the sectoral composition of economies.

A range of researchers are currently involved in model development in Australia, the United States and Canada. The G-Cubed model is in the process of continual development but it is already a large model. In its current form it contains over 7,000 equations and 150 intertemporal costate variables. The key features of G-Cubed are summarized in Table 1. The country and sectoral breakdown of the model are summarized in Table 2 (column 2). The range of countries modeled to date include the United States, Japan, Canada, Australia, New Zealand, 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 dis-aggregation enables us to capture the sectoral differences in the impact of alternative environmental policies.

In summary, the G-Cubed model embodies a wide range of assumptions about individual behavior and empirical regularities in a general equilibrium framework. The complex interdependencies are then solved out using a computer. It is important to stress that the term "general equilibrium" is use here to signify that as many interactions are possible are captured, not that the economy is in a full market clearing equilibrium at each point in time. Although it is assumed that market forces eventually drive the world economy to a long run steady state equilibrium, unemployment does emerge for long periods due to different labor market institutions in different economies.

The G-Cubed (Asia Pacific) model draws on the theoretical approach of the G-Cubed model but focuses on a country and sectoral disaggregation of relevance for the Asia Pacific region[10]. It was originally developed to focus on trade liberalization and financial liberalization issues but has proven useful in analyzing the causes and consequences of the Asian crisis. The country coverage and sectoral detail is set out in Table 2 (column 3).

The G-Cubed (Agriculture) model was developed for the United State Department of Agriculture to analyze the impact of changes in global macroeconomic conditions on US agriculture. It is outlined in McKibbin and Wang (1998) and an application to the Asian crisis and its impact on US agriculture can be found in McKibbin, Coyle, and Wang (1998).

4. Using the Models for Projections and Scenario Analysis

In this section both the way in which these models are used as part of forecasting exercises and the way in which projections are actually implemented are outlined. Many of the issues of projecting the future of the world can be found in Bagnoli, McKibbin, Wilcoxen (1996).

10 See McKibbin and Bok (1993) and McKibbin (1996)

a. Using DIGE Models for Building Scenarios

There are a number of ways DIGE models can be used for forecasting. One of the problems with these models is that the models are an annual frequency which rules them out of short term forecasting exercises of duration less than a year. Although even in this case the asset price fluctuations are instantaneous and so a new piece of information fed into the model will generate asset price movements that could be interpreted as changes over a very short period. A more important problem is that the dynamic structure is not estimated econometrically and so for very short term forecasting exercises the models are unlikely to outperform data intensive approaches and in particular where these are focussed on a particular variable in a particular country (for example short term interest rates in the United States)[11]. Instead the power of the models is the ability to bring together a number of complex inter-relationships and produce a story of how the key adjustment mechanisms produce a particular outcome for a given input to the model. Part of this is based on theoretical relationships and part on empirical relationships. Both of which combine to give a quantitative estimate of the overall net effects of a given set of assumptions.

Many users of these models use the multipliers from the models to adjust their own detailed forecasting exercises. For example, the model generates results for a change in a range of financial and real variables for a change in US interest rates. These “deltas” are then utilized to change exogenous inputs in other short term forecasting models or to modify an existing set of forecasts compiled through a range of less rigorous procedures. It is this contribution in understanding the mechanisms that the DIGE models make a contribution to forecasting exercises. A clear example of this is discussed in the next section on the impact of the Asia crisis on the US and Australian economies. The models show that the effect of trade negatives and capital flow positives from lower real interest rates offset each other with much less impact than most Australian forecasters have predicted. Initially made in August 1997, these predictions are still robust at the time of writing this paper in September 1998. By now this effect has found its way into other forecasters projections. Rather than producing a precise set of overall forecasts these models have proven useful in getting the direction of the overall movements in bond rates over the past year.

b. Solving for a baseline projection in DIGE models

The previous section outlined how to use the models in a forecasting exercise. This section goes into some detail on the mechanics of how projections are generated using the global DIGE model. The current complete data available on a global basis of the type required for these models is up to the end of 1996. To maximize the use of this latest data ,the model is first solved from 1996 to 2070 to generate a model baseline based on a range of assumptions. These assumptions include assumptions about population growth by country (based on World Bank projections) and sectoral productivity growth by country by sector (based on a technology catch-up model) as well as assumptions about tariff rates, tax rates, and a range of other fiscal and monetary policy settings. Monetary policy is assumed to be targeting a stock of nominal money balances in each economy. Fiscal policy is defined as a set of fixed tax rates (apart from a lump sum tax on households that varies to satisfy the intertemporal budget constraint facing the government) and government spending constant relative to simulated GDP. The issue of projecting the future using a dynamic intertemporal general equilibrium model such as the G-Cubed model, is discussed in detail in Bagnoli et al (1996). This initial projection step is important for simulations because it builds in

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11 One way to overcome this is to produce a hybrid model that uses the DIGE model and econometric estimation of dynamics such as outlined in McKibbin, Pagan and Robertson (1998).

underlying structural change in the global economy which is endogenous to the exogenous assumption about differential productivity growth.

Given all of the exogenous assumptions and initial conditions including inherited dynamics, the full rational expectations solution of the model is found using a numerical technique outlined in Appendix C of McKibbin and Sachs (1991). Without additional intervention, this initial model solution will not generate the actual outcomes for the first year of simulation (in the current example 1996) because a range of forward looking variables such as human wealth, exchange rates, stock markets etc will be conditioned on the future path of the world economy and there is no reason these should be equal to the observed values for the initial year. The next step of baseline generation is then to calculate a vector of constants for all equations in the model, including arbitrage equations, such that the solution of the model in the base year (1996) is exactly equal to the observed data in that year. It is important to stress that in no way are we assuming that 1996 is a steady state solution of the model. It clearly cannot be. What we are imposing is that the 1996 database is on the stable manifold of the model in which all variables are moving on a stable path towards a steady state in the long distant future.

The wedges that are calculated as part of forcing the model to replicate a given year of data in asset arbitrage equations can be interpreted as risk premia in different asset classes. This has proven very useful in simulating the Asia crisis in which a jump in risk premia was an important part of the crisis.

Given all the adjustments and assumed future exogenous paths of technology, poulation growth and policy, the model is then solved again from 1997 inheriting the results from 1996 but adding any new information related to short term macroeconomic cyclical issues such as changes in fiscal or monetary stance or world oil prices. This new simulation from 1997 embodies both the longer term trends related to productivity and population projections as well as the short term cyclical positions in all countries.

Given this baseline which is a best guess projection we then use the model to generate a range of alternative possible scenarios to get an idea of the sensitivity of the underlying projections to key assumptions as well as to explore the impacts of changes in key drivers of the projections.

5. Some Lessons From Recent History

These models have proven to be very helpful for understanding shocks and how these affect underlying forecasts of the world economy. One example is research that was undertaken using the model in 1990 on the global impact of German Unification. A study using the MSG2 model was undertaken at the time and alternative scenarios explored. A paper in a recent special Issue of *Economic Modeling* has gone back and surveyed the major studies undertaken at the time and compared the predictions with the actual outcome to 1996 (see Gagnon, McKibbin and Masson (1996)). The major insight from the modeling research was that the Unification would be expensive despite political promises by the German government. In particular that the fiscal implications would be large and that this would worsen the German current account, strengthen the Deutschmark and put extreme pressure on other countries in he European Monetary System. It would also tend to raise world real interest rates. As it turned out each of the models gave similar results to the reality that transpired. Although the exact timing of the unemployment response and the assumed response of the Bundesbank was underestimated in the studies, the model based studies pinpointed the key issues from the shock and produced surprisingly accurate predictions of the outcome. These were very different to the public statements and indeed many of the financial market evaluations at the time.

A second example where the models have produced insights that have been valuable in formulating forecasts is the current crisis in Asia in which the G-Cubed (Asia Pacific) model was the first model to be used in 1997 to analyze the crisis that emerged in mid 1997. The impact on the economies of the region from a change in risk perceptions was modeled. It was found that the financial shock had large real consequences which were devastating for these economies. More helpful was the predicted effects of the spillovers to the rest of the world. These spillovers to the rest of the world are relatively small because the loss in export demand that accompanies the crisis in Asia is offset by a fall in long term interest rates as capital flows out of Asia into the non-Asian OECD economies. Thus strong domestic demand in economies such as the US induced by the general equilibrium effects of the reallocation of financial capital can more than offset the consequences of lower export growth on the US economy. The analysis also highlights the impacts on global trade balances reflecting the movements of global capital and pointed to both potential problems and lesson for policymakers over the coming years.

Although the crisis is still not resolved and new shocks are accumulating the impact of risk re-evaluation and the insights from the models over the year since the crisis were quite different from most forecasts.

A final example where these models have been useful is in the understanding of asset price movements in general equilibrium. A result from these models that puzzled myself and Peter Wilcoxen for a considerable period was why asset prices jumped twice in anticipation of a future shock and why asset prices and aggregate consumption and investment behavior generated by the models were more volatile than expected. The economic theory in all modern economics textbooks teaches us that as new information arrives about a future shock, asset prices will jump in anticipation of this news but once this information is embodied in the asset price, there will be no further jump when the shock actually hits. Yet in all the models outlined above, the anticipation of future shocks causes a jump in all asset prices both at the time the information set changes and then again when the shock occurs. The explanation is outlined in a theoretical paper (McKibbin and Wilcoxen (1998)). The key insight is that the key insights in all the theoretical literature are actually true in partial equilibrium, yet in general equilibrium if there is any stickiness anywhere is the economy, then the partial equilibrium results break down. For example, suppose there are adjustment costs in physical capital accumulation. A future event such as a rise in future taxes would cause households who want to smooth consumption, to increase their saving today to pay for the future tax. This saving would be put into physical capital and then future output from this investment would provide the real income to pay the real return on the saving undertaken. If capital is costly to adjust however, much of thus additional saving would not end up in investment but would be reflected in a sharp rise in the prices of fixed assets as holders of these assets realize a capital gain before any new physical capital can be put in place. The attempt by firms to smooth investment and households to smooth consumption in a global economy in which saving must equal investment is clearly not consistent. This general equilibrium inconsistency, causes asset prices to be more volatile than predicted by either the consumption or investment approach to asset price determination.

6. Conclusion

It is never going to be possible to build a model of the world economy that can do everything that users of these models will want. These models are abstractions of reality and should be used with that fact always at the forefront in the mind of the model user. Using these models as “black boxes" to generate numbers has very little payoff in my view. In an increasingly globalized world, it is important to understand the major linkages between economies both through flows of goods and services as well as through movements in international financial capital flows and the allocation of global real investment. The new dynamic intertemporal general equilibrium models described in this paper give several new insights into the evolution of the world economy, in particular the role of expectations and international capital flows has been a highlight of these models. For forecasting purposes, these models provide one tool in what should be a forecasters toolbox of alternative sources of information. In future years, integrating the short term forecasting models based on detailed econometric data exploration (for example following McKibbin, Pagan and Robertson(1998)) will likely increase further the usefulness of these models in the short term forecasting arena. However a great deal of research will be required to reach this stage in global models because of data problems as well as the required computer power.

There is inevitably going to be a tendency to make global economic models increasingly complex yet if the increased complexity sacrifices capacity to understand the economic basis of the modeling results, this would be a bad tradeoff in my view. It is better to have a variety of techniques for generating alternative futures that feed into an overall forecasting exercise. The role of global economic models in this approach is at the least to enforce consistency in adding up of global identities, but more importantly these model can (and have) added important general equilibrium insights that can dramatically alter partial equilibrium forecasts. There is so much uncertainty in predicting the future and new shocks are inevitable, that there will always be a role for anything that adds to our understanding of how to disentangle complex processes. Economic models, used properly and with full understanding of their limitations, will always be invaluable in this process.

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Table 1: Key Features of the Models

- ☻ Specification of the demand and supply sides of economies;
- ☻ Integration of real and financial markets of these economies with explicit arbitrage linkage real and financial rates of return;
- ☻ Intertemporal accounting of stocks and flows of real resources and financial assets;
- ☻ 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 based on expected future income streams and Keynesian current income;
- ☻ The real side of the model is dis-aggregated to allow for production of multiple goods and services within economies;
- ☻ International trade in goods, services and financial assets;
- ☻ Full short run and long run macroeconomic closure with macro dynamics at an annual frequency around a long run Solow/Swan/Ramsey neoclassical growth model.
- ☻ The model is solved for a full rational expectations equilibrium at an annual frequency from 1996 to 2070.

Table 2: Global Intertemporal General Equilibrium Models

MSG2	G-Cubed	G-Cubed (Asia Pacific)	G-Cubed (Agriculture)
Countries:			
United States	United States	United States	United States
Japan	Japan	Japan	Japan
Canada	Canada	Australia	Canada
Germany	New Zealand	New Zealand	Australia
United Kingdom	Australia	Korea	Canada
France	Rest of OECD	Rest of OECD	Mexico
Italy	China	China	Korea
Austria	EEFSU	India	EU12
Australia	OPEC	Thailand	Rest of OECD
Mexico	Rest of World	Malaysia	ASEAN
Korea		Singapore	Taiwan
High Income Asia		Indonesia	China/Hong Kong
Low Income Asia		Hong Kong	Rest of World
Rest of the EMS		Taiwan	
Rest of the OECD		Philippines	
OPEC		OPEC	
EEFSU		EEFSU	
Rest of World		Rest of World	
Sectors:			
Single sector	Electric Utilities	Energy	Food Grains
	Gas Utilities	Mining	Feed Grains
	Petroleum Refining	Agriculture	Nongrain crops
	Coal Mining	Durable Manufacturing	Livestock
	Crude Oil & Gas Extraction	Non-Durable Manufacturing	Processed Food
	Other Mining	Services	Forest and Fishery
	Agriculture, Fishing	Mining	Mining
	Forestry & wood products	Energy	Energy
	Durable Manufacturing	Textile and Clothing	Textile & clothing
	Non-Durable Manufacturing	Non-Durable manufacturing	Non-Durable manufacturing
	Transportation	Durable Manufacturing	Durable manufacturing
	Services	Services	Services