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Trade Policy in Australia and the Development of Computable General Equilibrium Modeling

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Abstract

This paper discusses the early establishment in Australia of CGE modeling as a major policy tool. As background, it provides a short history of CGE modeling and describes the impetus to the field from: (a) the failure of less theoretically formal approaches; and (b) the recognition that this type of modeling can handle policy-relevant detail. The paper then argues that the CGE approach flourished in Australia because Australia had the right issue, the right institutions and the right model. The final section looks to the future of CGE modeling and the challenge of demonstrating that it really works.

- **JEL classification:** D68, A11, F14
- **Key words:** CGE modeling, Australian trade policy, tariffs

I. Introduction

Trade policies have obvious direct effects. Industries that suffer reductions in tariff protection suffer losses in output and employment. Evidence of these effects can be obtained from primary sources such as surveys of businesses in directly affected industries and analyses of time-series correlations between the growth of industries and their levels of trade protection.

However, trade policies have indirect effects as well as direct effects. When a country reduces tariffs or eases quota restrictions, there will be indirect effects on exports. We can expect the increase in imports associated with a movement towards

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free trade to be accompanied by real devaluation and a consequent stimulation of exports. Because indirect effects are diffuse, they are hard to see by simple examination of primary evidence. They need to be identified and quantified via economy-wide frameworks that embrace the relevant connections between, for example, tariffs, imports, the exchange rate and exports.

Since 1960, computable general equilibrium (CGE) modeling has gradually become the dominant economy-wide framework, largely replacing other approaches such as input-output modeling and economy-wide econometric modeling. Increasing recognition of the importance of indirect effects of changes in trade policies means that trade policy is now heavily reliant on results generated by CGE models.

CGE modeling has been prominent in the Australian economic debate since the 1970s. It has helped politicians and the public to understand the likely effects of changes in trade policies and policies in many other areas. By contributing to public understanding, CGE modeling has helped make it politically possible for governments to implement previously highly unpopular policies such as: cuts in protection; privatization of electricity supply, railways, and other former public utilities; and changes in labor-market regulations and regulations governing particular industries including stevedoring, sugar and coal mining.

The aim of this paper is to give some insights into how CGE modeling became established in Australia as the main tool of trade policy decision making. Section II gives some necessary background, defining CGE modeling and providing a short history. It describes the impetus to the field from: (a) the failure of less theoretically formal approaches, such as economy-wide econometric modeling, to shed light on the likely impact of the oil crises of the 1970s; and (b) the recognition of the ability of CGE modeling to handle policy-relevant detail. Section III describes the development of CGE modeling in Australia. It argues that this approach flourished there because Australia had the right issue, the right institutions and the right model. Section IV contains two sub-sections. The first picks up on earlier themes in the paper. It discusses how CGE modeling can become established in a country as a powerful policy tool. The second sub-section looks to the future of CGE modeling and the challenge of demonstrating that it really works.

II. Computable General Equilibrium (CGE) Modeling: Definition and History[1]

The defining characteristics of CGE models are as follows

(i) They include explicit specifications of the behavior of several economic actors (i.e. they are ***general)***. Typically they represent households as utility maximizers and firms as profit maximizers or cost minimizers. Through the use of such optimizing assumptions they emphasize the role of commodity and factor prices in influencing consumption and production decisions by households and firms.
(ii) They describe how demand and supply decisions made by different economic actors determine the prices of at least some commodities and factors. For each commodity and factor they include equations ensuring that prices adjust so that demands added across all actors do not exceed total supplies. That is, they employ market ***equilibrium*** assumptions.
(iii) They produce numerical results (i.e. they are ***computable)***. The coefficients and parameters in their equations are evaluated by reference to a numerical database. The central core of the database of a CGE model is usually a set of input-output accounts showing for a given year the flows of commodities and factors between industries, households, governments, importers and exporters. The input-output data are normally supplemented by numerical estimates of various elasticity parameters. These may include substitution elasticities between different inputs to production processes, estimates of price and income elasticities of demand by households for different commodities, and foreign elasticities of demand for exported products.

On this definition, the first CGE model was that of Johansen (1960). His model was *general* in that it contained 20 cost-minimizing industries and a utility-maximizing household sector. For these optimizing actors, prices played an important role in determining their consumption and production decisions. His model employed market *equilibrium* assumptions in the determination of prices. Finally, it was *computable*. It produced a numerical, multi-sectoral description of growth in Norway using Norwegian input-output data and estimates of household price and income elasticities derived using Frisch's (1959) additive utility method.

On a broader definition, CGE modeling starts with Leontief's (1936, 1941) input-output models of the 1930s and includes the economy-wide mathematical progra-

[1]This section is drawn largely from Dixon and Parmenter (1996).

mming models of Sandee (1960), Manne (1963) and others developed in the 1950s and 60s. I regard these contributions as vital forerunners of CGE models. On my definition, input-output and programming models are excluded from the CGE class because they have insufficient specification of the behavior of individual actors and the role of prices.

Following Johansen's contribution, there was a surprisingly long pause in the development of CGE modeling with no further significant progress until the 1970s. The 1960s were a period in which leading general-equilibrium economists developed and refined theoretical propositions on the existence, uniqueness, optimality and stability of solutions to general equilibrium models [see, for example, Arrow and Hahn (1971)]. Rather than being computable (numerical), their models were expressed in purely algebraic terms.

The most direct link between this theoretical work and CGE modeling was made by Scarf (1967a, 1967b and 1973). Drawing on the mathematics of the theoretical existence theorems, Scarf designed an algorithm for computing solutions to numerically specified general equilibrium models. This algorithm had finite convergence properties, that is for a wide class of general equilibrium models, the algorithm was certain to produce a solution in a finite number of steps.

Scarf stimulated interest in CGE modeling in North America. In the early 1970s, his students John Shoven and John Whalley became leading contributors to the field (see, for example, Shoven and Whalley, 1972, 1973, 1974). However, Scarf's work was inspirational rather than practical. Johansen had already solved a relatively large CGE model by a simple, computationally efficient method and Scarf's technique was never the most effective method for doing CGE computations. Even those CGE modelers who embraced the Scarf technique in the 1970s had by the 1980s largely abandoned it in favor of much older methods such as the Newton-Raphson and Euler algorithms.

While the decade of the 1960s was not an active period in CGE modeling, it was important in the development of large-scale, economy-wide econometric models (e.g. the Wharton, DRI, MPS, St Louis, Michigan and Brookings models).[2] Relative to CGE models, the economy-wide econometric models paid less attention to economic theory and more attention to time-series data. In CGE models, the specifications of demand and supply functions are completely consistent with underlying theories of optimizing behavior by economic actors. In economy-wide econometric models, the

[2]For a historical perspective on these models, see the papers in Kmenta and Ramsey (1981).

role of optimizing theories of the behavior of individual actors is usually restricted to that of suggesting variables to be tried in regression equations.

In the 1960s, the underlying philosophy of the econometric approach of "letting the data speak" seemed attractive to applied economists. This may be part of the explanation of the pause in the development of the CGE approach. In the 1970s there were two factors, apart from Scarf's bridge with the theoretical literature, which stimulated interest in the CGE approach.

First, there were shocks to the world economy leading to the most severe recession since the 1930s. These shocks included a sudden escalation in energy prices, a profound change in the international monetary system and rapid growth in real wage rates in many western countries. Without tight theoretical specifications, the econometric models could not provide useful simulations of the effects of shocks such as these which carried economies away from established trends. With their optimizing specifications, CGE models can offer insights into the likely effects of shocks for which there is no historical experience. For example, up to 1973, there was no modern experience of a sharp change in oil prices. Consequently, in regression equations based on pre-1973 time-series data, the price of oil has an insignificant or zero coefficient. This meant that models relying heavily on time-series analysis implied, misleadingly, that movements in oil prices would not be important determinants of economic activity. In detailed CGE models, inputs of oil appear as variables in production functions. Then through cost minimizing calculations, increases in the price of oil act on economic activity in CGE simulations in the same way as increases in the prices of other inputs. In the 1970s, interest in CGE modeling increased as applied economists recognized the power of optimizing assumptions in translating broad experience (e.g. experience of cost increases) into plausible predictions of the effects of particular shocks for which we may have no experience (e.g. the effects of an increase in oil prices).

The second factor driving the growth of CGE modeling has been its increasing ability to handle detail. The key ingredients have been improved data bases (e.g. the availability of unit records from Censuses) and improved computer programs (e.g. the availability of programs such as GEMPACK, GAMS, HERCULES and CASGEN).[3]

[3]Descriptions of general-purpose software for solving CGE models include Pearson (1988); Codsi and Pearson (1988); Bisschop and Meeraus (1982); Brooke, Kendrick and Meeraus (1988); Drud, Kendrick and Meeraus (1986); Meeraus (1983); and Rutherford (1985a and b). The existence of this software means that economists interested in building and applying CGE models no longer need either a high level of skill in programming or a sophisticated understanding of algorithms for solving systems of equations.

In consulting work in Australia and the U.S., my colleagues and I at the Centre of Policy Studies can now use CGE models to satisfy demands for analyses disaggregated into effects on 500 industries, 50 regions, 700 occupations, and several hundred family types. At this level of detail, no other technique has as much to offer as CGE modeling. As CGE modelers have learnt to handle more detail, CGE results have become of interest to public and private sector organizations concerned with, among other things: industries; regions; employment; education and training; income distribution; social welfare and the environment.

By the early 1990s, CGE modeling was an established field of applied economics. Several detailed surveys had appeared in leading journals and in books from prominent publishers [e.g. Shoven and Whalley (1984), Pereira and Shoven (1988), Robinson (1989, 1991), Bandara (1991) and Bergman (1990)]. There were regular international meetings of CGE modelers, often followed by the production of a conference volume [e.g. Kelley, Sanderson and Williamson (1983), Scarf and Shoven (1984), Piggott and Whalley (1985 and 1991), Srinivasan and Whalley (1986), Bergman, Jorgenson and Zalai (1990), Bergman and Jorgenson (1990), Don, van de Klundert and van Sinderen (1991) and Devarajan and Robinson (1993)]. Numerous monographs had been published giving detailed descriptions of the construction and application of CGE models [e.g. Johansen (1960), Dixon *et al.* (1977 and 1982), Adelman and Robinson (1978), Keller (1980), Harris with Cox (1983), Ballard *et al.* (1985), Whalley (1985), McKibbin and Sachs (1991), and Horridge *et al.* (1993)]. At least three CGE textbooks were available for graduate students and advanced undergraduates [Dervis *et al.* (1982), Shoven and Whalley (1992) and Dixon *et al.* (1992)] and graduate students all over the world were engaged in writing CGE theses.

In the last 10 years, the most significant development in CGE modeling has been the world-wide adoption of the Global Trade Analysis Project (GTAP). The project is the brainchild of Tom Hertel and his colleagues at Purdue University (Hertel, 1997). Using input-output data and other data contributed by hundreds of researchers throughout the world, they have constructed a world-wide model that covers trade between more than 50 countries (or regional groups of countries) and 60 products. The model reflects the theory of Australia's ORANI model and in most implementations it applies GEMPACK software developed in Australia by Ken Pearson and his co-workers at the Centre of Policy Studies (see, for example, Harrison and Pearson 1996). GTAP is now used extensively in the analysis of free trade agreements and has brought CGE modeling firmly into the focus of policy makers in dozens of countries.

Over the last 45 years, CGE models have been used in the analysis of an enormous variety of questions. These include:

the effects on

macro, welfare, industry, regional, labor-market, distributional and environmental variables

of changes in

taxes, public consumption and social security payments; tariffs and other interferences in international trade; environmental policies; technology; international commodity prices and interest rates; wage setting arrangements and union behavior; and known levels and exploitability of mineral deposits (the Dutch disease).

While most of these questions have been analyzed in single-country, single-period models, there are now numerous CGE models which are either multi-regional or multi-period (dynamic) or both. By going multi-regional, CGE modeling has thrown light on both intra-country and inter-country regional questions. In the first category are issues (important in federations) concerning the effects of tax and expenditure activities of provincial governments. In the second category are issues such as the effects of the formation of trading blocks and the effects of different approaches to reducing world output of greenhouse gases. By going dynamic, CGE modeling has the potential to broaden and deepen its answers to all the questions with which it has been confronted. It has also entered the forecasting arena. CGE models are now used to generate forecasts of the prospects of different industries, labor force groups and regions. These forecasts feed into investment decisions by private and public sector organizations.

III. The Australian Experience

The development and application of CGE modeling has been particularly active in Australia. Since the late 1970s, Australian policy makers have been calling for results from CGE models on almost every economic issue. CGE studies are regularly debated in the media and in the parliament. I am sometimes asked how Australia became such a leader in this field.[4]

I think the success of CGE modeling in Australia came about because Australia had the right issue, the right institutions and the right model.

[4]Powell and Snape (1993) contain a comprehensive survey of Australian CGE contributions up to about 1990.

A. The Issue

The issue was protection. This was perhaps the hottest economic issue in Australia from the time of the federation of the Australian colonies in 1901.[5] It nearly prevented federation because of squabbling between Victoria, a colony that favored protection, and New South Wales, a colony that favored free trade. Eventually, the Victorian protectionists won and the federated country of Australia adopted increasingly high tariffs. By the 1960s, Australian tariffs on many manufactured products were more than 50 per cent, and some manufactured products were protected from import competition by stringent quotas.

Given this background, it is not surprising that the development and application of the theory of international trade has been a major interest of Australian economists. Three prominent early Australian contributions are: Brigden *et al.* (1929), which attempted to quantify the costs of protection to the Australian economy and subsequently became widely known as a forerunner of the Stolper-Samuelson theorem; Corden (1957), which provided perhaps the first theoretically sound approach to the measurement of the costs of protection; and Corden (1966), which was a pioneering contribution to the measurement of effective rates of protection.

Because protection is about re-allocation of resources between industries via price signals, it is an ideal CGE topic. With a tradition of applied trade analysis already firmly in place, Australia was fertile ground for the early development of trade-oriented CGE modeling.

B. The Institutions

In 1921, the Australian government set up the Tariff Board (later the Industries Assistance Commission and now the Productivity Commission) to advise it on tariff and quota policy. Throughout most of its history, this institution followed a generally protectionist line. However, in the late 1960s the then Chairman of the Tariff Board, Alf Rattigan, recognized that there are losers from high tariffs.[6] He wanted a method for identifying the losers and quantifying their losses. He suspected that if the losers from protection were fully informed, then the political consensus in favor of protection would be challenged.

Rattigan was aware of the emerging field of economy-wide economic modeling.

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[5]For an authoritative discussion of the politics of Australian protection, see Glezer (1982).

[6]Rattigan tells his own story in Rattigan (1986). See also Powell (2000).

His initial approach to satisfying his need for quantification of the effects of protection was to support and encourage a well-financed modeling project set up in 1969 at Monash University.[7] The project was built around H. David Evans, an Australian who had just completed a path-breaking Ph.D. thesis at Harvard[8] in which he implemented a 36 sector economy-wide model of Australia and used it to analyze the effects of protection. The intention of the project was to expand the sectoral detail of Evans' Ph.D. model and to improve the specifications of the reactions of trade flows to price changes. However, the project failed to make significant progress. One interpretation is that Evans and his colleagues didn't have the right technique – they used a linear programming framework in which it is difficult to incorporate price-sensitive behavior. Another interpretation is that academics left completely to their own devices were not sufficiently motivated to produce a practical model for policy purposes.

Rattigan was not deterred. He appointed a new team of researchers in what became known as the IMPACT Project. The head of the project was Professor Alan Powell, Australia's leading econometrician and Australia's first professor of econometrics. This time, instead of leaving the researchers in the university, Rattigan moved them into the public service, thereby sharpening their focus on practical policy work. While keeping the academics in the public service, Rattigan (guided by Powell) allowed the research team maximum academic freedom. The research was completely open and the researchers were encouraged to present their work at conferences and to publish. Even when the project began to produce policy-sensitive results, a high degree of academic freedom and openness was maintained. This meant that the project not only benefited from academic criticism but was able to retain the services of ambitious talented academics.

A key aspect of the openness of the IMPACT Project was the provision of one- or two-week training courses to public servants, academics and business people. Starting in 1979, IMPACT used these courses to encourage other people to apply and develop its models. The courses and detailed supporting documentation were crucial in gaining acceptance of the models and exposing them to constructive criticism.

From an educational point of view, the training courses were probably as valuable for the instructors as they were for the students. They helped members of

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[7]The project is described in Powell and Snape (1993, p394).

[8]Published as Evans (1972).

the IMPACT Project to develop a facility for explaining complex results in terms of simple mechanisms.[9] These mechanisms were eventually transmitted to policy makers, allowing them to feel confident about the results and to convey them effectively in debate.

The tradition of providing training courses has continued to this day, with the Centre of Policy Studies (IMPACT's successor) conducting several courses a year, in Australia, the U.S., China and elsewhere. Following the lead of the IMPACT Project, the GTAP project has also adopted an active program of training. This has been an important part of the world-wide success of GTAP.

C. The Model

The main model developed at the IMPACT Project in the 1970s was ORANI. Initially ORANI was designed to satisfy Rattigan's requirement for a tool that could identify the losers from protection and quantify their losses.

Within a couple of years, ORANI satisfied this requirement.[10] ORANI showed how high tariffs caused high costs in Australia. High costs, or a high real exchange rate, limited Australia's ability to export. The model showed in a quantitative way that Australia's high tariffs were benefiting import-competing industries such as textiles, clothing, footwear and motor vehicles, and import-competing regions, particularly South Australia and Victoria. At the same time, ORANI identified the losers. It showed that high tariffs were penalizing exporting industries, such as wool, wheat, meat cattle and iron ore, and exporting regions, particularly Queensland and Western Australia. It also showed, contrary to popular belief, that high tariffs were not necessary for maintenance in Australia of high levels of employment.

Results from the ORANI model were helpful in shifting public opinion. Over the next 20 years it became politically possible to almost completely dismantle Australia's protection regime. Quotas are completely gone and tariffs on most manufactured commodities are less than 5 per cent. The highest tariffs are no more

[9] The mechanisms were often expressed via back-of-the-envelope models. Early IMPACT efforts at explaining results this way can be found in Dixon *et al.* (1977, 1982 and 1984). More recent efforts include Adams (2005), Dixon and Rimmer (2002, chapter 2) and Dixon *et al.* (2007).

[10] Rapid progress on the ORANI model was facilitated by a couple of factors. First, during my period at the IMF, 1972-4, I worked with Subhash Thakur on a model of South Korea. This effort was unsuccessful, but it provided a template for ORANI, incorporating some key ideas from IMF researchers, particularly from Armington (1969, 1970). Second, the ORANI team benefited from the Evans project: we inherited some databases and we learnt some lessons about what could go wrong with model design. For a detailed review of the Evans model, see Dixon and Butlin (1977).

than 15 per cent.

ORANI was designed to provide results that would be persuasive to practical policy makers rather than to academics. Practical policy makers want to see detail. They want to see results for industries that they can identify (e.g. motor vehicle parts), not for vague aggregates (e.g. manufacturing). They want to see results for regions, not just for the nation. Consequently, ORANI was designed from its outset to encompass considerable detail. The first version of ORANI had 113 industries. Within a few months the model was endowed with a facility for generating results for Australia's 8 states/territories. A year or so later this facility was extended to 56 sub-state regions. All of this work was taking place at a time when the largest general equilibrium models in other countries, models that were built for academic purposes, never contained more than about 30 sectors, and usually less than 10.

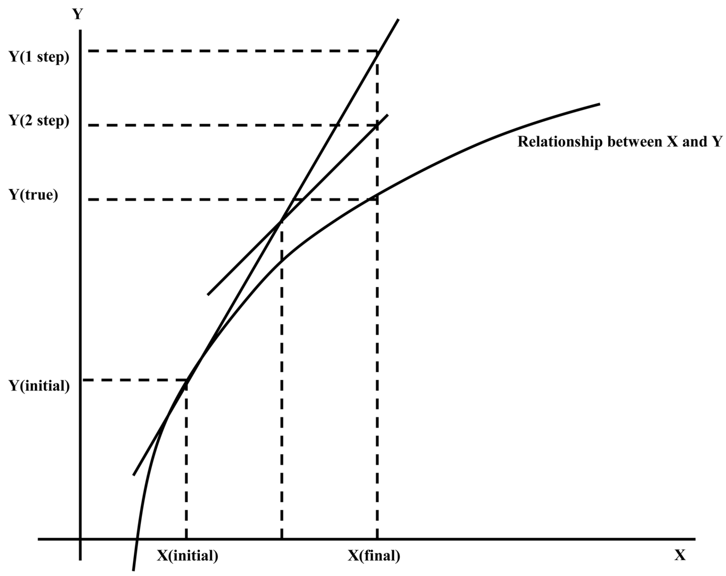
The imperative of providing results that were persuasive in policy circles meant that ORANI was equipped not only with industry and regional detail, but also with detail in other areas that were normally ignored by academics. For example, from its outset ORANI was equipped with detailed specifications of margins costs (e.g. road transport, rail transport, air transport, water transport, wholesale trade and retail trade) that separate producers of commodities from users of commodities. Recognition of margin costs is important in translating the effects of tariff changes into the implications for the prices paid by users. Attention to details such as this was important in providing results that could be believed by policy makers.

The creation of the detailed, policy-oriented ORANI model in the 1970s was facilitated by several technical innovations. I discuss two: the computational approach and closures.[11]

ORANI computations were carried out using an elaborated version of the method initially employed by Johansen (1960). In the Johansen method, all of the equations of a model are linearized, converting the model into a system of linear equations connecting changes or percentage changes in the variables. The Johansen method was computationally simple and could handle large systems of equations, even in the 1960s, but it suffered from linearization error. Perhaps for this reason, Johansen's work was largely ignored. However, it turned out in the initial applications of ORANI that linearization errors were not very important

[11]Other innovations included: allowance for multi-product industries and multi-industry products; the incorporation of Armington elasticities, with supporting econometric estimation; and the inclusion of detailed technical change variables.

Figure 1. The Effects on Y of Moving X from X(initial) to X(final) Computed via 1- and 2-step Johansen Procedures



and, in any case, could be eliminated by a relatively simple multi-step procedure. If we wished to calculate the effects of a 25 per cent tariff reduction, then we could start by calculating the effects of a 12.5 per cent reduction. Having decided where the economy would go to under the influence of a 12.5 per cent reduction, we could impose another 12.5 per cent reduction. If breaking the required shock (a 25 per cent reduction) into two parts was not sufficiently accurate, then we could use a computation with 4 steps. The procedure is illustrated in Figure 1. Note that Figure 1 implies that the errors in a 1-step procedure are approximately halved in a 2-step procedure. This idea was exploited to generate highly accurate solutions in a very small number of steps. By the mid 1980s, the ORANI computational method was embedded in the highly efficient and flexible GEMPACK code (Pearson, 1988), facilitating the adoption of ORANI-style models throughout the world.

A second technical innovation in ORANI was flexible closures. In its linearized representation, the model can be visualized as a matrix equation of the form:

$$A*v = 0, \tag{1}$$

where v is a vector of length n of percentage changes in the model's variables and A is a matrix of dimension m by n where $m<n$. To solve the model, we must select

a closure, that is we must select *n-m* variables to be exogenous (determined outside the model). Then via equation (1) we can compute the solution for the remaining *m* endogenous variables as

$$v_1 = -A_1^{-1} * A_2 * v_2 \tag{2}$$

where

v_1 is the vector of percentage changes in the *m* endogenous variables;

v_2 is the vector of percentage changes in the *n-m* exogenous variables;

A_1 is the *m* by *m* matrix formed from the *m* columns of A corresponding to the endogenous variables; and

A_2 is the *m* by (*n-m*) matrix formed from the *n-m* columns of A corresponding to the exogenous variables.

An early insight at the IMPACT Project was that the division of variables between v_1 and v_2 should be flexible so that it can be varied from application to application.[12] In ORANI applications concerned with the short-run effects of a policy change, capital stocks by industry were included in the exogenous list (v_2) whereas rates of return on capital were on the endogenous list (v_1). In applications concerned with the long-run effects of policy changes, the opposite configuration was adopted: rates of return were exogenous and capital stocks were endogenous. In short-run applications, real wage rates were exogenous and employment was endogenous. In long-run applications, employment was exogenous and real wage rates were endogenous. Some simulations were run with the trade balance endogenous and some were run with the trade balance exogenous. In one prominent application,[13] ORANI was used to answer the question: what would Australia need to do to increase employment by 5 per cent with no deterioration in the balance of trade? For this simulation, employment and the balance of trade were exogenous and policy instruments such as tax rates and government spending were endogenous.

The idea of flexible closures has been extended to subsequent dynamic models such as the MONASH model of Australia[14] and the USAGE model of the U.S.[15] In

[12]This idea is reminiscent of Tinbergen's (e.g. 1967) flexible treatment of instruments and targets. See also Rattso (1982).

[13]See Dixon *et al.* (1979).

[14]MONASH is a 113-industry, dynamic successor to ORANI (Dixon and Rimmer, 2002). It has been applied extensively in Australia since the early 1990s.

these dynamic models, there are four basic closures:

- the *historical* closure in which the exogenous variables are chosen so that historical observations on movements in consumption, investment, government spending, exports, imports, employment, capital stocks and many other variables can be introduced to the model as shocks. Computations with this closure produce detailed estimates of movements in technology and preference variables and also generate up-to-date input-output tables that incorporate available statistics for years since the last published input-output table. For example, historical simulations can be used to generate input-output tables for the U.S. for 2006 incorporating data for years beyond 2002, the year of the U.S.'s latest detailed input-output table.
- the *decomposition* closure in which technology and preference variables are exogenous so that they can be shocked with the movements estimated for them in an historical simulation. Computations with this closure can be used to identify the roles in the growth of industry outputs and other naturally endogenous variables of changes in technology, changes in preferences, and changes in other naturally exogenous variables. Decomposition simulations are valuable in policy work because they counteract exaggerated claims about the importance of policy changes in determining outcomes for industries. For example, representatives of Australia's motor vehicle industry may claim that cuts in tariffs explain their industry's rather poor growth performance over an historical period and that further cuts would be disastrous.[16] A decomposition simulation can show the role of tariff cuts in the past and allow it to be compared with the roles of changes in other relevant variables such as c.i.f. import prices, technologies and consumer tastes.
- the *forecast* closure which is used in simulations designed to produce a believable business-as-usual or basecase picture of the future evolution of the economy. The underlying philosophy of this closure is quite similar to that of the historical closure. In both closures, we exogenize variables for which we have

[15]USAGE is a 500-industry, dynamic model of the U.S. economy, based on MONASH. It was developed at the Centre of Policy Studies, Monash University, in collaboration with the U.S. International Trade Commission (Dixon and Rimmer, 2004). The Commission applies USAGE in analyses of trade issues (see for example U.S. International Trade Commission 2004, 2007). The model is being applied to energy and environmental issues by the U.S. Departments of Commerce and Agriculture.

[16]This type of argument can be found in submissions to Australian Government inquiries into the automotive industry. See, for example, Geelong Manufacturing Council and CARnet-Geelong Automotive Industry Network (2002, p. 7).

information, with no regard to causation. Rather than exogenizing variables for which we have historical observations, in the forecast closure we exogenize variables for which we have forecasts. This might include macro variables, exports by commodity and demographic variables for which forecasts are provided by official organizations. Technological and preference variables in forecast closures are largely exogenous and are given shocks that are informed by trends derived from historical simulations.

- the *policy* closure which is used in simulations designed to quantify the effects of changes in policies or other exogenous shocks to the economy. The underlying philosophy of this closure is quite similar to that of the decomposition closure. In both policy and decomposition closures, we are concerned with causation, with how tariff changes, for example, cause changes in the real exchange rate and thereby cause changes in employment and so on. Thus in policy closures, as in decomposition closures, naturally exogenous variables are exogenous and naturally endogenous variables are endogenous. In policy simulations, nearly all of the exogenous variables adopt the values that they had, either endogenously or exogenously, in the forecast simulation. The only exceptions are the policy variables of focus. For example, if we are interested in the effects of tariff changes, then tariff variables are moved away from their basecase forecast paths. The effects of the tariff changes on macro variables, commodity exports and other endogenous variables are calculated by comparing the paths of these endogenous variables in the policy simulation with their paths in the forecast simulation. Policy simulations conducted in MONASH-style models give policy effects as deviations away from realistic pictures of the economy of the future. By contrast, policy simulations conducted in comparative static models or models without realistic basecase forecasts generate policy results as deviations from the economy of the present or past. This can be misleading. The effects of policies imposed on economies with structures likely to be relevant in the future are often different from the effects of these policies imposed on economies with the structures of the present or past.

With their detail, simple and efficient computational method, open documentation and supporting training courses, the ORANI and MONASH models, together with derivative models, became widely used in Australia and elsewhere for issues far beyond tariffs.

IV. Concluding Remarks: Getting Established and Future Directions

A. Getting Established

CGE modeling has been well established as a policy tool in Australia since the late 1970s. It has been applied on behalf of government and business to many economic topics, extending well beyond trade-policy analysis. These include microeconomic reform, the environment and energy, major infrastructure projects, labor markets, training and fiscal policy.

While CGE modeling has proved broadly applicable, an initial narrow focus may be necessary in establishing it in a country's policy process. This focus should be provided by urgent demands from policy makers. In Australia, the focal issue was protection. My view is that researchers should not be set the vague task of building a general purpose model. They should be set the specific task of analyzing an important economy-wide issue. In this way, a policy-relevant model is likely to emerge as part of the solution of the specific problem. I found in Australia that once we had built the model that was relevant for analyzing protection, it quickly became apparent that the same model could be adapted for a much wider range of issues.

The alternative approach to establishing CGE modeling is to ask a group of researchers, perhaps located in a university, to build a general-purpose model in isolation from urgent policy matters. A problem with this approach is that researchers may then respond to the imperatives of academic publishing and academic promotion. These are technical novelty, adherence to current academic fashion, succinctness and ability to impress peers with erudite verbal and written exposition. None of these is necessarily an ingredient in the creation of a policy model. Such a model requires: application of relevant economic theory rather than novel or fashionable theory; detailed data work with meticulous and complete documentation rather than succinctness; and a willingness to elucidate, via simple back-of-the-envelope arguments, rather than a desire to impress, via erudition.

Practical policy models cannot be built without a major input from talented academics. Consequently, tension between academic work and practical work for the creation of policy models is a problem. The problem is exacerbated if it is necessary, for establishing CGE modeling as a tool in a country's policy debate, to have an initial period of research that is disciplined by a sharp and urgent policy focus and possibly conducted in the government bureaucracy. To have any hope of recruiting the right academics, bureaucracies must provide an open environment in which academics can participate in conferences, provide training and publish (possibly with a lag) even sensitive material.

The government bureaucracy need not necessarily be the only home of a country's practical policy-oriented CGE research. Once CGE modeling became an expected input to policy discussions in Australia, it was quickly added to the repertoire of Australian business consulting firms. Australia now has competing CGE models. Results from these models on a given issue often differ. In these circumstances there is a temptation by lazy commentators to dismiss all results by claiming that they cancel each other out. However, there have been some excellent examples in which back-of-the-envelope explanations in political debates have been used to locate the causes of differences between model results. On these occasions modeling has been improved and the standard of public debate raised.[17]

B. Future Direction: Validation

I think that the most important future direction for CGE modeling is statistical validation. There are two aspects to this problem. Can we demonstrate that CGE models generate: (a) useful forecasts and (b) useful projections of the effects of policy changes?

In the early days of CGE modeling, the main empirical focus was on the econometric estimation of elasticity parameters in the specifications of utility, production, import-demand and export-demand functions. Implicitly, it was thought that with statistically justified behavioral specifications for households, industries, importers and exporters we would have models that perform well on criteria (a) and (b).

The leading proponent of the application of econometrics to CGE modeling is Dale Jorgenson: see, for example, Hudson and Jorgenson (1974), Jorgenson (1984) and Jorgenson and Wilcoxen (1994). To support his many CGE applications to energy and environmental issues in the U.S., he has made econometric estimates of cost functions, indirect utility functions and trade parameters at a detailed level. The ORANI model of Australia (Dixon *et al.,* 1977 and 1982) also incorporated an immense amount of econometric work on trade and production elasticities.

[17]Perhaps the best example occurred in the motor vehicle tariff debate of 1997 when results from three models were debated in the Australian parliament. References can be found in Dixon and Rimmer (2002, p. 38).

However, I think it is fair to conclude that time-series econometric estimation has not delivered nearly as much to CGE modeling as was initially hoped and anticipated. In the vast majority of influential CGE analyses, settings of key parameters reflect judgments sometimes supplemented by sensitivity analyses. Parameters estimated by time-series econometrics have often proved unrealistic in a simulation context. For example, econometricians have estimated that export-demand elasticities are quite low, even less than one. But in a simulation context, low values can lead to implausible results suggesting that cost increases in export-oriented industries can improve welfare by generating increases in export revenue despite reductions in export quantities. Implications such as this have led many CGE modelers to abandon econometric estimates of parameters, even when such estimates are available. While valuable econometric activity continues,[18] I think that we now require tests which directly assess the ability of CGE models to forecast and to project policy effects.

Perhaps the most common reaction of practical policy makers/advisors when confronted with results from a detailed computable general equilibrium (CGE) model is: "how do I know these results are accurate?" This is a difficult question to answer. So far, the best answers that CGE modelers have been able to provide are in the form of back-of-the-envelope justifications. These are important and have appeal to some policy people. However, what is really needed is a statistical demonstration that CGE models can produce usefully accurate predictions of:

(1) changes in the industrial composition of economic activity under business-as-usual assumptions; and

(2) the effects on macro and industry variables of changes in trade and other policies.

In the context of (1), by "usefully accurate" I mean predictions that are better than those obtained by simple trends. In the context of (2), I mean predictions that are better than those obtained by surveys of opinions of industry experts. There is now an opportunity for serious work on issue (1).

Maureen Rimmer and I have conducted detailed historical simulations with the USAGE model of the U.S. for the periods 1992 to 1998 and 1998 to 2005.[19] These reveal movements in industry technologies, household preferences and demand and

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[18]See for example Hertel *et al.* (2007).

[19]The 1992 to 1998 simulation is described in Dixon and Rimmer (2004).

supply conditions for U.S. exports and imports. We have also devised a method for creating benchmark or business-as-usual forecasts. The method uses projections of results for industry technologies, household preferences and international demand and supply conditions revealed in historical simulations together with macro predictions from several U.S. government agencies. We have applied the method to generate benchmark forecasts for the period 2005 to 2011. We now propose to test the benchmark-forecast method statistically by using it to produce "forecasts" for 1998 to 2005 taking as inputs results from the 1992 to 1998 historical simulation and macro forecasts that were available in 1998.[20] Results from this 1998 to 2005 forecast for industry variables (e.g. employment by industry) will be compared with actual outcomes for the period.

We will create a table that attributes forecasting errors to different sources. For example, the table will show how much of the forecast error for employment in each industry is attributable to:

- differences between the macro forecasts available in 1998 for the period 1998 to 2005 and the actual macro outcomes;
- differences between the technology and preference forecasts for 1998 to 2005 projected on the basis of the 1992 to 1998 historical simulation and the actual technology and preference outcomes for the period revealed in the 1998 to 2005 historical simulation;
- differences between forecasts of international conditions for 1998 to 2005 projected on the basis of the 1992 to 1998 historical simulation and the actual international conditions for the period revealed in the 1998 to 2005 historical simulation; and
- differences between forecasts of changes in trade and other policies for the period 1998 to 2005 and the actual changes for this period.

On the basis of the table we might conclude that USAGE gives reliable industry forecasts for one group of industries provided the macro forecasts are accurate. For some other industries we might find that reliable forecasts can only be obtained if the forecasts of international conditions are accurate.

Investigation of issue (2), the accuracy of CGE models in predicting the effects of changes in trade (and other) policies, is more difficult than investigation of issue (1). The problem is that during any period in which an economy is adjusting to a change in trade policies, other factors will also be operating. This

[20]As with most of our research, this project is being undertaken with an urgent policy focus, provided by Bob Koopman (Director, Office of Economics, USITC).

point was not adequately addressed in the often-cited validation exercise by Kehoe (2005).[21] In that exercise, Kehoe assesses the performance of various models in predicting the effects of NAFTA. He notes, for example, that the model of Brown, Deardorff and Stern predicted that NAFTA would increase Mexican exports by 50.8%. Over the period 1988 to 1999, Mexican exports went up by 140.6 per cent. Kehoe then invites us to draw the conclusion that Brown *et al*. strongly underestimated the effects of NAFTA. However, what about all the other factors that affected Mexican trade volumes over these 10 years?

MONASH/USAGE decomposition simulations (described in Section III) allow isolation of the effects of these other factors, e.g. changes in technologies, changes in import-domestic preferences, changes in consumer preferences, changes in world commodity prices, changes in population, changes in required rates of return on capital and changes in transport costs.[22] However, a major assumption in existing applications of decomposition simulations is that changes in trade policies do not affect industry technologies and import/domestic preferences. In a validation exercise we will need to test this assumption.

We plan to look at the performance through 1998 to 2005 of half a dozen U.S. industries for which there were major changes in trade policy. For each of these industries we will look closely at the USAGE forecasting errors associated with failure to correctly forecast shifts in technologies and import/domestic preferences. If these errors are large, this may indicate a necessity, in the context of USAGE, to link changes in technologies and in import/domestic preferences with changes in trade policies. We can experiment with different values for key parameters, e.g. Armington elasticities, to try to reduce forecasting errors associated with technologies and import/domestic preferences. This may be a method of improving our estimates of Armington elasticities.[23] However, if in the end, the forecasting errors associated with technologies and import/domestic preferences remain large, then we will be forced to conclude that to predict the effects of trade policies, we will need to establish links from these policies to technologies and

[21]Kehoe *et al.* (1995) allows for other factors in a validation exercise concerning the short-run effects on consumer prices in Spain of a major change in indirect taxes. They recognized that during the adjustment period consumer prices were also affected by a drought-induced change in the price of agricultural products and a large change in the world price of oil.

[22]For an application of the decomposition method to an analysis of growth in Australia's trade see Dixon *et al.* (2000).

[23]Liu *et al.* (2004) apply an approach similar to this.

preferences.[24] More generally, this would be an example of a situation in which a validation exercise prompts research aimed at improving a model.[25] If, on the other hand, we find for our half-dozen target industries that forecasting errors associated with failure to correctly forecast shifts in technologies and import/domestic preferences are no greater than those for other industries, then we have some reassurance that USAGE simulations of the effects of trade policies are valid.

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[24]Links between technologies or productivity and trade policy have been suggested over the years by a long stream of authors including Leibenstein (1966, X-efficiency), Krueger (1974, rent seeking), Harris (1984, scale economies and imperfect competition) and Melitz (2003, reallocation of resources between firms within an industry). Also see Corden (1997, Chapter 7). Links between import/domestic preferences and trade policy have been hypothesized by several authors including Feenstra (1994, variety and the "price" motivating import demands) and Dixon and Rimmer (2002, variety and the nature of import restraints).

[25]Model improvement may be a major benefit of validation exercises. This is the case for example in Valenzuela *et al*. (2007) who were prompted to introduce real-world, import-price-smoothing mechanisms into their simulations of the effects of climatic variations on the world wheat market. This was a response to their initial results that showed too much price volatility in import destinations and too little volatility in export sources.

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