Evidence-based Trade Policy Decision Making in Australia and the Development of Computable General Equilibrium Modeling

by

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Abstract

This paper explains why evidence-based trade policy decision making is heavily reliant on results generated by CGE models and why the development and application of these modeling has been particularly active in Australia.

The paper provides a short history of CGE modeling and describes the impetus to the field provided by two factors: (a) the failures of less theoretically formal approaches; and (b) the recognition of the ability of CGE modeling to handle policy-relevant detail.

The paper argues that CGE modeling flourished in Australia because Australia had the right issue, the right institutions and the right model.

JEL classifications: D68, A11, F14

1. Introduction

Trade policies have obvious direct effects. Industries that suffer reductions in tariff protection suffer loses 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 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.

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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 evidence-based trade policy decision making 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 modelling 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 evidence-based trade policy decision making.

Sections 2 and 3 give some necessary background. Section 2 defines CGE modeling. Section 3 provides a short history of CGE modeling. It describes the impetus to the field provided by two factors: (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 4 describes the development of CGE modeling in Australia. It argues that CGE modeling flourished there because Australia had the right issue, the right institutions and the right model.

Section 5 contains a brief trade-relevant application of CGE modeling. My aim is to give an impression of the power of CGE modeling: (a) to handle detail; (b) to identify and quantify indirect effects; and (c) to produce explainable plausible results. The application I have chosen is the effects on the U.S. of cuts in their tariffs and easing of their quota restrictions. The model is the 500 sector USAGE model with a 51 region extension. This model has been built along the lines of Australia's ORANI and MONASH models by researchers at Australia's Centre of Policy Studies in collaboration with the U.S. International Trade Commission. There are three reasons for choosing a U.S. application rather than an Australian application. First, the USAGE model is now the state of the art with respect to relevant detail for evidence-based trade policy decision making. Second, while CGE modeling in Australia is currently producing important results on a wide range of issues, trade is not one of them. This is because the protection debate has essentially been won in Australia with a political consensus in favor of low protection. Third, international readers of this paper will more readily understand results for California and New York than for Western Australia and Victoria.

Section 6 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.

2. What is a Computable General Equilibrium (CGE) model?[1]

The distinguishing characteristics of computable general equilibrium (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. They may also include optimizing specifications to describe the behavior of governments, trade unions, capital creators, importers and exporters.

(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.

An alternative name for CGE models is applied general equilibrium (AGE) models. This name emphasizes the idea that in CGE modeling the database and numerical results are intended to be more than merely illustrative. CGE models use data for actual countries or regions and produce numerical results relating to specific real-world situations.

3. A brief history

On my 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 (and applied). 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 modelling starts with Leontief's (1936, 1941) input-output models of the 1930s and includes the economy-wide mathematical programming 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.

[1] Sections 2 and 3 are drawn largely from Dixon and Parmenter (1996).

Following Johansen's contribution, there was a surprisingly long pause in the development of CGE modelling 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, i.e. 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 well before the Scarf algorithm was invented. 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 1960s were not an active period in CGE modeling, they were a key decade 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 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,

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

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 a important determinant of economic activity. In detailed CGE models, inputs of oil appear as variables in production functions. Then through cost minimising 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 modelling increased as applied economists recognised the power of optimising 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 Census and improved computer programs (e.g. the availability of programs such as GEMPACK, GAMS, HERCULES and CASGEN).[3] In our consulting work in Australia and the U.S., we 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 (1992)]. 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 *et al.,* 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

[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); Brooke, 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.

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, computable general equilibrium (CGE) models have been used in the analysis of an enormous variety of questions. These include:

the effects on

- macro variables, including measures of nation-wide or even global economic welfare;
- industry variables;
- regional variables;
- labor market variables;
- distributional variables; 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 affecting stocks of physical and human capital.

4. The Australian experience

The development and application of CGE modelling 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.

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. Because protection is about re-allocation of resources between industries via price signals, it is an ideal topic for CGE analysis.

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 economic modeling. 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 in a university.[7] This project failed. One interpretation is that the modelers 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 focused 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.

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

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).

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

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 the IMPACT Project to develop a facility for explaining complex results in terms of simple mechanisms.[8] 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 a course in China last month. 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.

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. 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 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

[8] 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.* (2006).

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.[9]

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, even in the 1960s. However, 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 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

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

[9] 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.

where

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

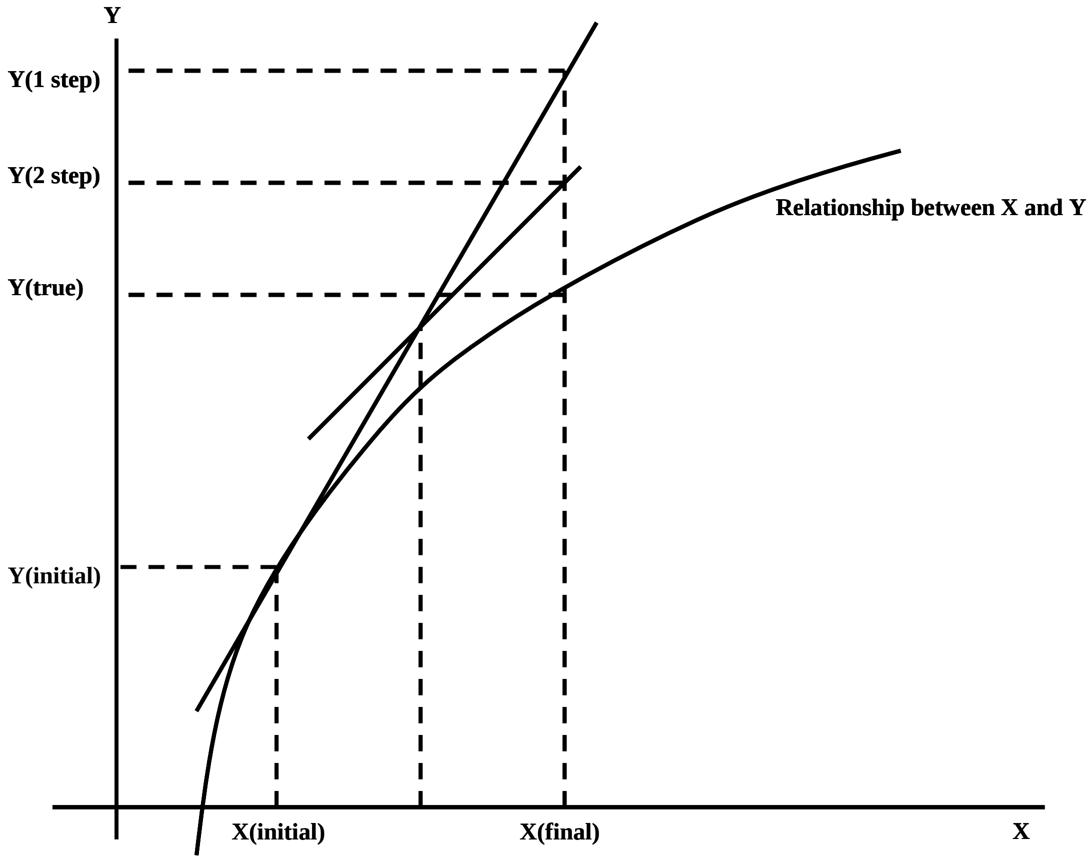
v_2 is the vector of percentage changes in the n-m exogenous variables;

A_1 is the m by m matrix formed from the m columns of A corresponding to 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 into the endogenous and exogenous categories should be flexible so that it can be varied from application to application.[10] In ORANI applications concerned with the short-run effects of a policy change, capital stocks by industry were included in the exogenous list whereas rates of return on capital were on the endogenous list. 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

Figure 1. The effects on Y of moving X from X(initial) to X(final) computed via 1- and 2-step Johansen procedures



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

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,[11] 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 now been extended to our dynamic models such as the MONASH model of Australia (Dixon and Rimmer, 2002), the USAGE model of the U.S. and the MC-HUGE model of China. In these dynamic models, we have 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. 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 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.

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

- 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 a tariff change, then tariff variables are moved away from their basecase forecast path. The effects of the tariff change on macro variables, exports by commodity and other endogenous variables are calculated by comparing their paths 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, ORANI and MONASH models became widely used in Australia and elsewhere for issues far beyond tariffs.

5. An application of a dynamic CGE model

This section contains a description of some CGE results on the effects on reducing protection in the United States. The underlying assumptions and detailed descriptions of the results can be found in Dixon *et al.* (2006). Here my objective is to give an impression of the power of CGE modelling: (a) to handle detail; (b) to identify and quantify indirect effects; and (c) to produce explainable, plausible results.

The results I am going to look at were generated by USAGE-ITC[12], a 500-industry model of the U.S. with an extension to the 50 States and the District of Columbia. They refer to the long-run effects of removing major U.S. import restraints[13], the restraints applying in 2002 on the 45 commodities listed in Table 1.

The U.S. restrains imports by the imposition of tariffs and country-specific quotas. In the USAGE-ITC simulation, quotas are treated as equivalent to export taxes that are imposed by foreigners on their quota-restrained exports to the U.S. and are removed when U.S. quotas are removed. As shown in Table 1, the USITC have calculated for the 500 USAGE-ITC commodities the tariff paid by importers and collected by the U.S.

[12] USAGE-ITC stands for U.S. Applied General Equilibrium-International Trade Commission. The model was developed for the U.S. International Trade Commission (USITC) to assist in its analytical work (see for example U.S. International Trade Commission 2004). The theoretical structure of USAGE-ITC is similar to that of the MONASH model of Australia (Dixon and Rimmer 2002).

[13] Earlier studies of this topic have used national CGE models identifying between 10 and 70 industries. See, for example, De Melo and Tarr (1990) and USITC (1999 and 2002).

government, and the quota-related increase in revenue received by foreign suppliers.[14] Column 3 of Table 1 expresses the USITC calculations as price wedges. The entry in column 3 for Sugar, for example, implies that U.S. tariffs and quotas applying to this commodity raise its landed-duty paid price by 119.32 per cent.

Macro effects

The most obvious macro effect of removing the tariff and quota price wedges on the 45 commodities listed in Table 1 is to stimulate imports. Thus we find a positive entry (0.732 per cent) in row 7 of Table 2.

The removal of the price wedges has a negative effect on capital stocks (row 2 of Table 2) mainly because the industries that are harmed have, on average, high capital intensities relative to those that benefit. For example, the capital share of primary-factor input in Sugar crops (an industry that suffers a sharp reduction in output from the removal of the quota on manufactured sugar, commodity 78 in Table 1) is over 80 per cent, whereas for the whole economy it is only 27 per cent. The result for investment (a reduction of 0.061 per cent, row 3, Table 2) reflects that for capital.

With aggregate employment fixed and a reduction in capital, we might anticipate a reduction in real GDP. However, the capital effect happens to be almost exactly offset by efficiency gains, leaving the ultimate effect on GDP at zero (row 5, Table 2).

Removal of the price wedges generates an increase in real consumption (public and private, C+G) of 0.070 per cent (row 6, Table 2). There are two sources of consumption gain. The first is the efficiency gain in GDP mentioned above. The second is the improvement in the terms of trade of 0.381 per cent (row 9, Table 2). The terms-of-trade increase arises because removal of quotas induces foreign suppliers to reduce their prices. A terms-of-trade improvement increases the purchasing power of real GDP by increasing the prices of commodities produced in the U.S. relative to the prices of commodities absorbed in the U.S.

Consistent with a terms-of-trade improvement, USAGE-ITC shows an increase in the price deflator for GDP relative to the CPI (compare rows 10 and 11, Table 2). The GDP deflator includes export price but not import prices. The opposite is true for the CPI.

Because C+G is 86.7 per cent of GDP and investment (I) is only 17.7 per cent, the contribution of the increase in C+G (0.867*0.070) to expenditure on real GDP far outweighs the contribution of the decrease in I (-0.177*0.061). Consequently, with zero change in real GDP, there must be an increase in real imports relative to real exports. As indicated earlier, the percentage increase in imports (M) is 0.732 per cent. This is about 0.2 percentage points greater than the percentage increase in exports (X, 0.533 per cent, row 8, Table 2). The 0.2 percentage point gap between imports and exports is implied by the results that we have already considered for GDP, C, G and I. The increase in exports of 0.533 per cent is facilitated in USAGE-ITC by a real devaluation (an improvement in U.S. competitiveness) of 0.373 per cent (row 1, Table 1).

[14] Details are in USITC (2004, chapters 2-4).

Table 1. Data for 2002 for the 45 commodities with the highest wedges and the effects of removing these wedges

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
								USAGE-ITC results Percentage changes		
	Tariff rate, T1	Export tax equivalent, T2	Price wedge, T3	Imports (c.i.f., $m), MCIF	Tariff collection C1[(a)]	Value of export tax, C2[(b)]	Value of wedge, C3[(c)]	Imports	Output	Armington elasticity
78 Sugar	1.02	117.11	119.32	1389	14	749	763	167.48	-27.9	5.00
55 Butter	19.46	33.94	60.00	248	48	63	111	162.31	-23.11	5.00
56 Cheese	11.42	25.65	40.00	806	92	165	257	116.34	-4.66	5.00
57 Dairy, dried etc.	4.48	29.21	35.00	658	29	149	178	124.94	-7.42	5.00
101 Tob StemRedry	6.66	15.64	23.34	669	45	90	135	53.23	-5.14	3.00
115 Apparel	10.88	9.93	21.89	66878	7276	6041	13317	10.92	-5.34	2.00
58 Icecream	10.37	8.73	20.01	8	1	1	1	92.42	0.02	5.00
117 Housefurnish	6.26	12.45	19.49	3067	192	340	532	8.31	-0.9	1.00
116 Curtains	8.95	6.03	15.52	260	23	15	38	20.58	-2.23	3.00
59 Fluid milk	13.65	0.00	13.65	23	3	0	3	49.69	-1.2	5.00
209 Luggage	13.20	0.00	13.20	3432	453	0	453	7.77	-9.6	3.10
102 Broadfabric	7.86	4.76	12.99	4609	362	209	572	32.07	-7.27	4.00
208 Leathrgloves	12.99	0.00	12.99	404	52	0	52	5.64	-3.16	1.40
114 Knit fabric mills	12.68	0.00	12.68	897	114	0	114	20.34	-7.33	2.80
15 OilBearCrops	1.79	9.96	11.93	180	3	16	20	48.74	-0.02	5.00
199 RubPlFootwr	11.78	0.00	11.78	5540	653	0	653	3.74	-1.29	1.30
207 Slippers	11.28	0.00	11.28	134	15	0	15	4.57	-0.74	1.00
210 WmnsHandbag	11.22	0.00	11.22	1576	177	0	177	6.2	-6.77	3.10
113 Hosierynec	9.38	0.81	10.27	444	42	4	45	8.2	-1.33	2.00
206 Shoes, not rubber	9.77	0.00	9.77	13929	1361	0	1361	2.96	-0.83	1.00
105 Threadmills	7.08	1.97	9.19	62	4	1	6	9.53	-2.55	2.40
98 Cigarettes	8.97	0.00	8.97	124	11	0	11	14.84	0.53	2.70
211 PerLeathrGds	8.66	0.00	8.66	798	69	0	69	7.98	-5.39	3.50
221 VitChinaTble	8.63	0.00	8.63	390	34	0	34	7.02	-6.76	2.40
217 CeramicTile	8.45	0.00	8.45	963	81	0	81	4.59	-6.31	2.50
112 Womenhosiery	6.55	0.52	7.10	641	42	3	45	7.46	-0.77	2.50
60 Cannedfish	3.59	2.58	6.26	1754	63	44	107	7.6	-7.13	5.00
383 CostumJewel	6.15	0.00	6.15	1344	83	0	83	6.49	-2.09	3.00
306 Ballbearings	5.82	0.00	5.82	1974	115	0	115	11.56	-3.72	4.00

…Table 1 continues

Table 1 continued

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
								USAGE-ITC results Percentage changes		
	Tariff rate, T1	Export tax equivalent, T2	Price wedge, T3	Imports (c.i.f., $m), MCIF	Tariff collection C1[(a)]	Value of export tax, C2[(b)]	Value of wedge, C3[(c)]	Imports	Output	Armington elasticity
373 Watches	5.43	0.00	5.43	3328	181	0	181	1.6	0.38	1.00
119 Canvasprods	5.38	0.00	5.38	339	18	0	18	7.02	-1.3	3.00
222 Earthenware	5.29	0.00	5.29	557	29	0	29	1.24	-2.91	2.40
104 YarnFinish	4.81	0.43	5.26	753	36	3	39	3.99	-5.18	2.50
388 Pens	4.94	0.00	4.94	1378	68	0	68	3.49	-1.82	3.00
120 Pleating	4.79	0.00	4.79	127	6	0	6	2.16	-1.59	1.40
213 Glass	4.65	0.00	4.65	3947	184	0	184	5.84	-1.31	2.60
269 Cutlery	4.65	0.00	4.65	851	40	0	40	8.61	-2.61	5.00
270 Handtools	4.32	0.00	4.32	1646	71	0	71	1.7	-0.24	1.00
66 Frozenfruit	4.21	0.00	4.21	1538	65	0	65	10.96	-1.63	5.00
103 Narrowfabric	4.18	0.01	4.19	525	22	0	22	1.96	-2.09	3.00
186 MmadeFibOth	3.47	0.00	3.47	1985	69	0	69	-3.5	-2.88	1.00
123 FabTextileProds	2.43	0.96	3.41	2022	49	19	68	0.74	0.21	1.00
109 CordageTwine	3.10	0.28	3.39	226	7	1	8	2.18	-0.83	2.00
111 Textilegoods	2.28	0.01	2.29	632	14	0	14	1.37	-0.39	1.80
107 Coatdfabric	2.22	0.05	2.27	434	10	0	10	1.77	-0.37	2.60
Averages or totals										
45 high-wedge coms.	9.23[(d)]	6.30[(e)]	16.12[(f)]	133489	12327	7913	20240			
Other commodities	0.58[(d)]	0.00[(e)]	0.58[(f)]	1326902	7712	0	7712			
All commodities	1.37[(d)]	0.54[(e)]	1.92[(f)]	1460390	20039	7913	27952			

(a) Calculated as C1 = (T1/100)*MCIF. Revenue collected by U.S. Government.

(b) Calculated as C2 = (T2/100)*[MCIF/(1+T2/100)]. Quota revenue collected by foreign suppliers.

(c) Calculated as C3 = C1 + C2 = (T3/100)*[MCIF/(1+T2/100)] where T3 = 100*[(1+T1/100)*(1+T2/100)-1].

(d) Average of T1’s using MCIF weights.

(e) Average of T2’s using MCIF/(1+T2/100) as weights.

(f) Average of T3’s using MCIF/(1+T2/100) as weights.

Table 2. Macro effects of removing major U.S. tariffs and quotas: USAGE-ITC results

Percentage changes		
1	Real exchange rate	-0.373
2	Capital stock	-0.062
3	Real investment	-0.061
4	Employment	0
5	Real GDP	0.000
6	Real private and public consumption	0.070
7	Imports, volume	0.732
8	Exports, volume	0.533
9	Terms of trade	0.381
10	Price deflator, consumption (cpi)	0.000
11	Price deflator, GDP	0.147

Effects of commodity outputs

A good starting point for understanding the USAGE-ITC results in column 9 of Table 1 for U.S. outputs of heavily protected commodities is the equation

$$x_d = z - \theta \times S_m \times (1 - S_{marg}) \times (p_d - p_m) \quad . \tag{3}$$

This is a stylized version of the demand by a typical agent in USAGE-ITC for the domestic variety of a commodity. In the equation,

x_d is the percentage change in the agent's demand for the domestic variety;

S_m is the share of the agent's expenditure on the commodity that is accounted for by the imported variety;

p_m and p_d are the percentage changes in the basic prices of the imported and domestically produced varieties (basic prices of imports are landed-duty-paid prices and those of domestic products are prices at the factory door or farm gate);

z is the percentage change in the agent's activity level (e.g. industry output);

θ is the agent's substitution elasticity (Armington elasticity[15]) between the imported and the domestically produced varieties; and

S_{marg} is the margin share in purchasers' prices, i.e. the combined share of wholesale, retail and transport costs.

To illustrate the use of equation (3) in explaining output results, I work through a straight-forward example: Luggage, commodity 209 in Table 1.

The principal users of Luggage are households. They have an import share (S_m) for this commodity of 0.80 and an Armington elasticity (θ) of 3.1. The price wedge on Luggage in 2002 was 13.20 per cent (column 3, Table 1). Thus the removal of the wedge has an impact effect on the landed-duty-paid price of Luggage of -11.66 per cent (= -13.2/1.132). Part of this is offset by nominal devaluation of 0.520 per cent (= -0.373 - 0.147, rows 1 and 11, Table 2)[16], leaving the final change in the landed-duty-paid price

[15] See Armington (1969).

[16] The movement in the nominal exchange rate is the movement in the real exchange rate minus the movement in the price deflator for GDP.

of imported Luggage at -11.14 per cent. From detailed USAGE-ITC results, not shown here, I find that the basic price of domestic Luggage falls by 1.02 per cent. This reflects reductions in the costs to the domestic Luggage industry of imported Broadwoven fabrics and Coated fabrics (commodities 102 and 107): both of these commodities are major inputs to Luggage and appear in Table 1 with significant wedges. Together the movements in the basic prices of imported and domestic Luggage imply a reduction in the relative basic price of the imported variety of 10.12 per cent (= 11.14 - 1.02). This shrinks to 5.96 per cent when we move to purchasers' prices for households. In common with other consumer goods, the sale of Luggage to households incurs considerable margins costs (about 41 per cent of purchasers' prices). With the value of $(1 - S_{marg}) \times (p_d - p_m)$ at 5.96 and with $S_m = 0.80$ and $\theta = 3.1$, the substitution term on the RHS of (3) gives a reduction in household demand for domestically produced Luggage of 14.8 per cent. Because Luggage becomes cheaper (the overall purchasers' price to consumers of domestic and imported luggage falls by 5.3 per cent), households buy more of it. The household elasticity of demand for Luggage in USAGE-ITC is about -0.73. Thus the reduction in the price of Luggage boosts demand by 3.9 per cent (= 0.73×5.3). In terms of equation (3), z = 3.9 where z is the percentage change in household demand for the Luggage import-domestic composite. Combining the activity effect with the substitution effect gives a reduction in household demand for domestic Luggage of 10.9 per cent (= 14.8 – 3.9). The reduction in total output of domestic Luggage (9.6 per cent, Table 1) is smaller than the reduction in household demand for domestic Luggage. This is mainly because there are significant exports of Luggage (about 17 per cent of total sales). Exports of Luggage are stimulated by the reductions in the costs of imported inputs and the real devaluation that accompanies the reductions in import restraints.

For Luggage and for most of the other commodities in Table 1, substitution effects are dominant in determining the reduction in domestic output. However, for some negatively affected commodities, activity effects are dominant. Consider for example Knit fabric mills (commodity 114, Table 1). Imports of this commodity are small, giving an S_m of about 0.10. While margins are quite small (S_{marg} =0.063 per cent) and the Armington elasticity is moderately high (2.8), the low import share limits the substitution effect on domestic demand for the domestic product to about -3 per cent. Most of the reduction of 7.33 per cent in domestic output of Knit fabric mills arises from activity contraction in industries that use Knit fabric mills as an intermediate input, particularly the Apparel producers. As can be seen from Table 1, the removal of import restraints reduces Apparel output by 5.34 per cent. For Knit fabric mills, this represents a contraction in the relevant activity level of about 4 per cent.

Despite suffering significant wedge reductions, some of the commodities in Table 1 show negligible output contraction (or even a small expansion, commodities 58, 98, 123 and 373). These commodities fall into two groups. The first group has very small import shares (S_m) in their domestic markets. Members of this group include Fluid milk and Icecream (commodities 59 and 58). The second group has significant exports. Output of these commodities benefits from real devaluation. Members of this group include Cigarettes, Tobacco stem redry and Fabricated textile products (commodities 98, 101 and 123).

Table 3. Exports shares of output in 2002, and the effects on output of removing major U.S. tariffs and quotas

USAGE-ITC Commodity	Export share (per cent)	USAGE-ITC results *Percentage changes* Output
90 Vegetable mills	54	4.66
79 Chocolate	19	3.41
99 Cigars	7	1.04
500 Export education	100	0.99
100 Tobacco snuff	39	0.91
479 Scrap	20	0.91
502 Water transport, international	0	0.87
344 Electron tubes	36	0.77
286 Oil & gas field machinery	82	0.66
499 Export tourism	100	0.66
295 Roll mill machinery	24	0.64
147 Public building furniture	22	0.63
81 Candy	2	0.63
202 Rubber & plastic hose	30	0.62
292 Machine tools, metal forming	53	0.61
416 Retail trade	0	0.58
87 Flavors & syrups	8	0.58
291 Machine tools, metal cutting	33	0.55
98 Cigarettes	18	0.53
358 Aircraft equipment	43	0.44
356 Aircraft	50	0.33

Table 3 shows that a common feature of the majority of the commodities for which USAGE-ITC projects a significant output increase[17] is a high share of exports in total sales (greater than 20 per cent). For example, the commodity with the largest positive output response to the removal of wedges is Vegetable mills (commodity 90) with an export share of 54 per cent. Output of high export-share commodities is stimulated by real devaluation. For Vegetable mills there is an additional factor: U.S. production costs of Vegetable mills are reduced by elimination of wedges on inputs of imported Oil bearing crops (commodity 15, Table 1), making U.S. Vegetable mills particularly competitive on international markets.

Not all of the commodities in Table 3 have high export shares. Seven have export shares less than 20 per cent. U.S. output of Chocolate, Candy and Flavors & syrups (commodities 79, 81 and 87) benefits from a sharp reduction in the price of sugar, one of the principal inputs to the production of these commodities. As can be seen from Table 1, sugar is the commodity with the highest wedge (119.32 per cent). Similarly, U.S. output of Cigars and Cigarettes (commodities 99 and 98) benefits from a reduction in the price of imported Tobacco stem redry. Water transport international (commodity 502) is the provision by U.S. companies of shipping services outside the U.S. These services are used mainly to facilitate flows of goods into and out of the U.S. They are modelled in USAGE-ITC as margins on imports and exports, not as direct exports. In the present simulation, output of Water transport international is stimulated by expansion in U.S. trade, both exports and imports. Retail trade (commodity 416) benefits in the simulation from a shift in consumer expenditure towards products that happen to carry high retail margins. These include Apparel and other textile products. Substitution

[17] Table 3 includes commodities with a simulated output increase of more than 0.5 per cent, and Aircraft and Aircraft equipment. The last two commodities play a role in our discussion of regional results.

towards these products is generated by reductions in their prices relative to those of other consumer goods.

Effects on employment by state

Table 4 shows percentage effects on employment by state calculated by applying a regional extension to the USAGE-ITC results generated in the wedge-removal simulation. The extension is tops-down, that is it generates state results from the national results without affecting the national results.[18] A tops-down approach is suitable for simulating the regional effects of a national policy change (such as the removal of tariffs and quotas).

The most striking feature of the results in Table 4 is the narrowness of their range. The worst affected states are Idaho and North Carolina which lose 0.498 and 0.477 per cent of their jobs, while the most favored state, Washington, obtains a 0.214 per cent increase in jobs.

Idaho and North Carolina are adversely affected because they have relatively high shares of their employment in the production of commodities for which national production shrinks when tariffs and quotas are removed. Idaho suffers from over-representation in its employment of sugar crops, sugar products and dairy products while North Carolina suffers from over-representation of textile production. However, even for Idaho and North Carolina the shares of these losing activities in state-wide employment is small. Idaho's employment share in sugar products, sugar crops and dairy-related activities is 0.91 per cent (compared with the national share of 0.18 per cent) while North Carolina's employment share in textile activities is 3.14 per cent (compared with the national share of 0.59 per cent). For Idaho, the contraction of sugar and dairy production imparts a direct loss of employment of 0.13 per cent while for North Carolina the contraction of textile employment imparts a direct loss of employment of 0.16 per cent. Even with high multipliers, about 3, these direct employment loses translate into total employment loses for the two states of less than half a per cent.

At the other end of Table 4, Washington is the most advantaged state. It benefits from over-representation in its economy of export-oriented commodities such as aircraft and aircraft equipment. However, as can be seen from Table 3, the removal of tariffs and quotas generates an output expansion for a typical export-oriented commodity of only about 0.6 per cent. Thus, even for states with an over-representation of export-oriented activity, the total employment gain can be no more than a small fraction of 1 per cent.

Summing up

The results in this section indicate that the removal of major tariffs and quotas would have only small long-run effects on the U.S. macroeconomy. The annual welfare gain, measured by the long-run percentage increase in private and public consumption is 0.07 per cent. That the projected effects are small should not be surprising. Table 1 indicates that the tariffs and quotas considered in this paper are equivalent to tariffs that generate revenue of $20.240 billion. This is only 0.2 per cent of GDP.

[18] The tops-down approach was pioneered in the context of input-output analysis by Leontief *et al.* (1965). It was introduced to CGE modelling by Dixon *et al.* (1978).

Table 4. State characteristics and effects on employment of removing major U.S. tariffs and quotas

State	USAGE-ITC results *Percentage change* Employment	State	USAGE-ITC results *Percentage change* Employment
12 Idaho	-0.498	32 New York	-0.004
33 North Carolina	-0.477	30 New Jersey	-0.002
34 North Dakota	-0.353	25 Missouri	0.004
40 South Carolina	-0.314	24 Mississippi	0.008
39 Rhode Island	-0.308	15 Iowa	0.009
23 Minnesota	-0.248	44 Utah	0.027
1 Alabama	-0.240	13 Illinois	0.034
49 Wisconsin	-0.219	51 Dist. of Columbia	0.045
50 Wyoming	-0.182	48 West Virginia	0.060
29 New Hampshire	-0.152	7 Connecticut	0.061
18 Louisiana	-0.125	43 Texas	0.062
42 Tennessee	-0.125	36 Oklahoma	0.063
41 South Dakota	-0.111	31 New Mexico	0.064
10 Georgia	-0.081	4 Arkansas	0.072
26 Montana	-0.065	11 Hawaii	0.072
8 Delaware	-0.063	35 Ohio	0.076
17 Kentucky	-0.047	20 Maryland	0.082
19 Maine	-0.047	9 Florida	0.091
45 Vermont	-0.045	5 California	0.102
21 Massachusetts	-0.045	22 Michigan	0.102
27 Nebraska	-0.028	37 Oregon	0.105
2 Alaska	-0.019	3 Arizona	0.107
6 Colorado	-0.016	16 Kansas	0.126
46 Virginia	-0.013	14 Indiana	0.127
38 Pennsylvania	-0.009	28 Nevada	0.144
		47 Washington	0.214
		All states	0.000

For most industries, output would change by between -1 and 1 per cent. However, there are a few industries for which output changes would be quite large. USAGE-ITC projects contractions in sugar and butter output of more than 20 per cent and contractions in the outputs of several textile industries of between 5 and 10 per cent. For export-oriented industries, USAGE-ITC projects small increases in output, exceeding 1 per cent for only three industries.

For the states, the regional extension projects employment changes of between -0.498 and 0.214 per cent. The narrowness in the range reflects two factors. First, the removal of major U.S. tariffs and quotas would have little impact on the outputs of most industries. Second, the few industries in which there would be a significant impact make up only minor parts of the state economies. This is true even for the states in which heavily protected industries such as dairy, sugar and textiles are concentrated.

6. Concluding remarks: getting established and future directions

Getting established

CGE modelling 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 modelling 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 required focus 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 analysing 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 analysing 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 modelling 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 modelling as a tool in a country's policy debate, to have an initial period of research that is the 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 modelling 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 the political debates have been used to locate the causes of differences between model results. On these occasions modelling has been improved and the standard of the public debate raised.[19]

Future direction

I think that the most important future direction for CGE modeling is validation. We must demonstrate that CGE models really work.

At their present stage of development, CGE models are vulnerable to the criticism that their behavioral specifications (e.g. utility maximization and cost minimization) are imposed without empirical validation. Only a minority of CGE modelers try conscientiously to estimate key parameters by econometric methods. The

[19] 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).

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. 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 judgements 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.

Rather than more times-series econometric work, I think that we now require tests in which we assess the ability of CGE models to "forecast" developments in a period such as 1998 to 2005 given data for the period up to 1998.

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 this sort of model is any good?" 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 United States for the periods 1992 to 1998 and 1998 to 2004. These reveal movements in industry technologies, household preferences and demand and 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 2004 to 2010.

With a sharp and urgent policy focus provided by Bob Koopman (Director, Office of Economics, USITC), we propose to test the benchmark-forecast method statistically by using it to produce "forecasts" for 1998 to 2004 taking as inputs results from the 1992 to 1998 historical simulation and macro forecasts that were available in

1998. Results from this 1998 to 2004 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 2004 and the actual macro outcomes;
- differences between the technology forecasts for 1998 to 2004 projected on the basis of the 1992 to 1998 historical simulation and the actual technology outcomes for the period revealed in the 1998 to 2004 historical simulation;
- differences between the preference forecasts for 1998 to 2004 projected on the basis of the 1992 to 1998 historical simulation and the actual preference outcomes for the period revealed in the 1998 to 2004 historical simulation;
- differences between forecasts of international conditions for 1998 to 2004 projected on the basis of the 1992 to 1998 historical simulation and the actual international conditions for the period revealed in the 1998 to 2004 historical simulation; and
- differences between forecasts of changes in trade and other policies for the period 1998 to 2004 and the actual changes for this period.

On the basis of the table we might conclude that USAGE provides reliable industry forecasts for a large 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 policy, is more difficult than investigation of issue (1).

A major assumption in simulations with USAGE (and most other CGE models) of changes in trade policies is that these changes do not affect industry technologies and consumer preferences. We plan to look at the performance through 1998 to 2004 of half a dozen industries for which there were major changes in trade policy. For each of these industries we will look closely at the forecasting errors associated with failure to correctly forecast shifts in import/domestic preferences and technologies. If these errors are large, this may indicate a necessity, in the context of USAGE, to link changes in import/domestic preferences and technologies 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 import/domestic preferences and technologies. In fact, this may be a method of improving our estimates of Armington elasticities. However, if in the end, the forecasting errors associated with import/domestic preferences and technologies remain large, then we will be forced to conclude that to predict the effects of trade policies, we will need to establish links between these policies, and technologies and preferences.

If, on the other hand, we find for our half-dozen target industries that forecasting errors associated with failure to correctly forecast shifts in import/domestic preferences and technologies are no greater than those for other industries, then we have some reassurance that USAGE simulations of the effects of trade policies are valid. We would have established that USAGE projections of the effects of changes in trade policies added to projections of the effects of plausible changes in import/domestic preferences and technologies generate accurate forecasts.

References

Adams, P.D. (2005), "Interpretation of results from CGE models such as GTAP", *Journal of Policy Modeling*, Vol. 27(8), pp.941-59.

Adelman, I. and S. Robinson (1978), *Income Distribution Policy in Developing Countries: A Case Study of Korea,* Oxford University Press, New York.

Armington, P.S. (1969), "The geographic pattern of trade and the effects of price changes", *IMF Staff Papers*, XVI, pp. 176-199.

Ballard, C.L., D. Fullerton, J.B. Shoven and J. Whalley (1985), *A General Equilibrium Model for Tax Policy Evaluation,* University of Chicago Press for the National Bureau of Economic Research, Chicago.

Bandara, J.S. (1991), "Computable General Equilibrium Models for Development Policy Analysis in LDCs", *Journal of Economic Surveys,* 5(1), pp. 3-69.

Bergman, L. (1990), "The Development of Computable General Equilibrium Modeling", pp. 3-32 in: L. Bergman, D.W. Jorgenson and E. Zalai, editors, *General Equilibrium Modeling and Economic Policy Analysis,* Basil Blackwell, Oxford.

Bergman, L., D.W. Jorgenson and E. Zalai, editors (1990), *General Equilibrium Modeling and Economic Policy Analysis,* Basil Blackwell, Oxford.

Bergman, L. and D.W. Jorgenson, editors (1990), *Journal of Policy Modelling*, 12(4), Winter, (selected papers from the IIASA meeting of 1989).

Bisschop, Johannes and Alexander Meeraus (1982), "On the Development of a General Algebraic Modeling system in a Strategic Planning Environment", *Mathematical Programming Study*, Vol. 20, pp 1-19.

Brooke, Anthony, David Kendrick and Alexander Meeraus (1988), *GAMS: A User's Guide* (Redwood City, California: Scientific Press).

Codsi, G. and K.R. Pearson (1988), "GEMPACK: General-purpose Software for Applied General Equilibrium and Other Economic Modellers", *Computer Science in Economics and Management,* Vol. 1, pp. 189-207.

De Melo J. and D. Tarr (1990), "Welfare costs of U.S. quotas in textiles, steel and autos", *Review of Economics and Statistics*, LXXII, pp. 489-97.

Dervis, K., J. de Melo and S. Robinson (1982), *General Equilibrium Models for Development Policy,* Cambridge University Press, Cambridge, U.K.

Devarajan, S. and S. Robinson, editors (1993), *Special Issue: Symposium on Applied General Equilibrium Modeling, Journal of Policy Modeling*, 15 (5 and 6), October-December.

Dixon, P.B., B.R. Parmenter, G.J. Ryland and J. Sutton (1977), *ORANI, A General Equilibrium Model of the Australian Economy: Current Specification and Illustrations of use for Policy Analysis,* Vol. 2 of the First Progress Report of the IMPACT Project, Australian Government Publishing Service, Canberra, pp. xii + 297.

Dixon P.B., B.R. Parmenter and J. Sutton (1978), "Spatial disaggregation of ORANI results: A preliminary analysis of the impact of protection at the state level", *Economic Analysis and Policy*, 8(1), pp. 35-86.

Dixon, P.B., A.A. Powell and B.R. Parmenter (1979), *Structural Adaptation in an Ailing Macroeconomy,* Melbourne University Press, Melbourne.

Dixon, P.B., B.R. Parmenter, J. Sutton and D.P. Vincent (1982), *ORANI: A Multisectoral Model of the Australian Economy*, North-Holland, Amsterdam.

Dixon, P.B., B.R. Parmenter and A.A. Powell (1984), "The Role of Miniatures in Computable General Equilibrium Modelling: Experience from ORANI", *Economic Modelling,* Vol.1(4), October, pp.421-428.

Dixon, P.B., B.R. Parmenter, A.A. Powell and P.J. Wilcoxen (1992), *Notes and Problems in Applied General Equilibrium Economics*, North-Holland, Amsterdam.

Dixon, P.B., M.T. Rimmer and M. Tsigas (2006), "Regionalizing results from a detailed CGE model: macro, industry and state effects in the U.S. of removing major tariffs and quotas", *Papers in Regional Science,* forthcoming.

Dixon, P.B. and B.R. Parmenter (1996), "Computable General Equilibrium Modelling for Policy Analysis and Forecasting", pp. 1-85 in H.M. Amman, D.A. Kendrick and J. Rust, editors, *Handbook of Computational Economics,* Vol. 1, Elsevier, Amsterdam.

Dixon, P.B. and M.T. Rimmer (2002), *Dynamic General Equilibrium Modelling for Forecasting and Policy,* North Holland Pub. Co., Amsterdam.

Don, H., Theo van de Klundert and Jarig van Sinderen, editors (1991), *Applied General Equilibrium Modelling,* Kluwer Academic Publishers, Dordrecht/Boston/London.

Drud, Arne, David Kendrick and Alexander Meeraus (1986), "HERCULES: A System for Development of Multi-sectoral Economy-wide Models", *World Bank Discussion Paper* No. DRD169 (April), pp. 12.

Frisch, R. (1959), "A Complete Scheme for Computing All Direct and Cross Elasticities in a Model with Many Sectors", *Econometrica,* Vol. 27, April, pp. 177-196.

Glezer, L. (1982), *Tariff Politics: Australian Policy-making 1960-1980*, Melbourne University Press.

Harris, R.G. with D. Cox (1983), *Trade, Industrial Policy and Canadian Manufacturing,* Ontario Economic Council, Ontario.

Harrison, W.J. and K.R. Pearson (1996), "Computing Solutions for Large General Equilibrium Models using GEMPACK", *Computational Economics*, Vol. 9, pp. 83-127.

Hertel, T.W., editor (1997), *Global Trade Analysis: Modeling and Applications,* Cambridge University Press, Cambridge, U.K.

Horridge, J.M., B.R. Parmenter and K.R. Pearson (1993), "ORANI-F: a General Equilibrium Model of the Australian Economy", *Economic and Financial Computing*, Vol. 3(2), pp. 71- 140.

Hudson, E.A. and D.W. Jorgenson (1974), "U.S. Energy Policy and Economic Growth, 1975-2000", *Bell Journal of Economics and Management Science*, Vol. 5, no. 2, Autumn, pp. 461-514.

Johansen, L. (1960), *A Multisectoral Study of Economic Growth*, North-Holland, Amsterdam (enlarged edition, 1974).

Jorgenson, D.W. (1984), "Econometric methods for Applied General Equilibrium Analysis", pp. 139-203 in H.E. Scarf and J.B. Shoven, editors, *Applied General Equilibrium Analysis,* Cambridge University Press, New York.

Jorgenson, D.W. and P.J. Wilcoxen (1994), "Energy, the Environment and Economic Growth", in A.V. Kneese and J.L. Sweeney, editors, *Handbook of Natural Resource and Energy Economics*, Vol. III, North-Holland, Amsterdam.

Keller, W.J. (1980), *Tax Incidence: A General Equilibrium Approach*, North-Holland, Amsterdam.

Kelley, A.C., W.G. Sanderson and J.G. Williamson, editors (1983), *Modelling Growing Economies in Equilibrium and Disequilibrium*, Proceedings of the IIASA Meeting of November 1980, Duke University Press, Durham.

Kmenta, J. and J.B. Ramsey, editors (1981), *Large-Scale Macro-econometric Models: Theory and Practice*, North-Holland, Amsterdam.

Leontief, W.W. (1936), "Quantitative Input-Output Relations in the Economic System of the United States", *The Review of Economics and Statistics*, 18(3), August, pp. 105-125.

Leontief, W.W. (1941), *The Structure of the American Economy 1919-1929,* Oxford University.

Leontief, W., A. Morgan, K. Polenske, D. Simpson and E. Tower (1965), "The economic impact – industrial and regional – of an arms cut", *Review of Economics and Statistics*, XLVII, pp. 217-241.

McKibbin, W.J. and J.D. Sachs (1991), *Global Linkages: Macroeconomic Independence and Cooperation in the World Economy,* The Brookings Institution, Washington, D.C.

Manne, A.S. (1963), "Key sectors of the Mexican economy 1960-1970", pp. 379-400 in A.S. Manne and H.M. Markowitz, editors, *Studies in process analysis,* New York, Wiley.

Meeraus, Alexander (1983), "An algebraic approach to modeling", *Journal of Economic Dynamics and Control*, Vol. 5, pp. 81-108.

Pearson, K.R. (1988), "Automating the Computation of Solutions of Large Economic Models", *Economic Modelling*, Vol. 7, pp. 385-395.

Pereira, A.M. and J.B. Shoven (1988), "Survey of Dynamic Computable General Equilibrium Models for Tax Policy Evaluation", *Journal of Policy Modeling,* Vol. 10, no. 3, pp. 401-36.

Piggott, J. and J. Whalley, editors (1985), *New Developments in Applied General Equilibrium Analysis*, Cambridge University Press, New York.

Piggott, J. and J. Whalley, editors (1991), *Special Issue on Applied General Equilibrium, Empirical Economics,* Vol. 16, no. 1.

Powell, A.A. (2000), "Probity before Pragmatism: Alf Rattigan, 1911-2000", *Economic Record*, Vol. 76(234), September, pp. 301-4.

Powell, A.A. and R.H. Snape (1993), "The Contribution of Applied General Equilibrium Analysis to Policy Reform in Australia", *Journal of Policy Modeling,* Vol. 15(4), pp. 393-414.

Rattigan, A. (1986), *Industry Assistance: the Inside Story*, Melbourne University Press.

Rattso, J. (1982), "Different macro closures of the original Johansen model and their impact on policy evaluation", *Journal of Policy Modelling*, Vol. 4(1), March, pp. 85-97.

Robinson, S. (1989), "Multi-sectoral Models" in H. Chenery and T.N. Srinivasan, editors, *Handbook of Development Economics*, Vol. 2, North Holland, Amsterdam.

Robinson, S. (1991), "Macroeconomics, financial variables and computable general equilibrium models", *World Development*, Vol. 19, no. 11, pp. 1509-25.

Rutherford, Tom (1985a), "MPS-GE Users Guide", Department of Operations Research, Stanford University, pp. 72.

Rutherford, Tom (1985b), "Operating Instructions for CASGEN", Department of Operations Research, Stanford University, pp. 9.

Sandee, J. (1960), *A long-term planning model for India*, New York, Asia Publishing House and Calcutta, Statistical Publishing Company.

Scarf, H.E. (1967a), "The approximation of fixed points of a continuous mapping", *SIAM Journal of Applied Mathematics,* Vol. 15(5), pp. 328-343.

Scarf, H.E. (1967b), "On the computation of equilibrium prices", in W. Fellner, editor, *Ten essays in honor of Irving Fisher,* New York, Wiley.

Scarf, H.E. (1973), *The computation of economic equilibria*, New Haven/London, Yale University Press, pp. x + 249.

Scarf, H.E. and J.B. Shoven, editors (1984), *Applied General Equilibrium Analysis,* Cambridge University Press, New York.

Shoven, J.B. and J. Whalley (1972), "A general equilibrium calculation of the effects of differential taxation of income from capital in the U.S.", *Journal of Public Economics*, Vol. 1, pp. 281-321.

Shoven, J.B. and J. Whalley (1973), "General equilibrium with taxes: A computational procedure and an existence proof", *Review of Economic Studies*, Vol. 40, pp. 475-489.

Shoven, J.B. and J. Whalley (1974), "On the computation of competitive equilibrium in international markets with tariffs", *Journal of International Economics*, Vol. 4, pp. 341-354.

Shoven, J.B. and J. Whalley (1984), "Applied General-Equilibrium Models of Taxation and International Trade: An Introduction and Survey", *Journal of Economic Literature*, Vol. 22, September, pp. 1007-51.

Shoven, J.B. and J. Whalley (1992), *Applying General Equilibrium,* Cambridge University Press, New York.

Srinivasan, T.N. and J. Whalley, editors (1986), *General Equilibrium Trade Policy Modeling,* MIT Press, Cambridge, Mass.

Tinbergen, J. (1967), *Economic policy: principles and design*, North-Holland Publishing Company, Amsterdam.

United States International Trade Commission (1999, 2002 & 2004), *The economic effects of significant U.S. import restraints: second, third and fourth updates*, Washington D.C.

Whalley, J. (1985), *Trade Liberalization among Major World Trading Areas,* MIT Press, Cambridge, Mass.