CHAPTER 5: General equilibrium[1]

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A. Overview and learning objectives

While Chapter 4 looked at partial equilibrium models, this chapter focuses on the second family of simulation models, the so-called general equilibrium (GE) models. GE models will be preferred to partial equilibrium models when the scope of the experiment is large and when inter-market linkages (impact on factor rewards), budget constraints and real exchange rate effects are expected to be particularly important.

This chapter, however, fundamentally differs from the other chapters in this guide. We do not aim here at providing the tools and the techniques to actually run an economically meaningful GE model. We believe that the complexities of this technique cannot possibly be mastered in a single chapter of a guidebook. For this reason the chapter does not have a section with exercises.

The aim of this chapter is to provide the reader with an understanding of how GE models work, what they can and cannot do, and what is required to run a GE simulation. This knowledge is essential to choose the most appropriate methodology of analysis to address a question. Therefore, this chapter, although not a practical guide to GE analysis, is a necessary complement to the other chapters.

B. Analytical tools

Economic analysis may be partial equilibrium or general equilibrium in nature. A general equilibrium analysis explicitly accounts for all the links between the sectors of an economy – households, firms, governments and countries. It imposes a set of constraints on these sectors so that expenditures do not exceed income, and income, in turn, is determined by what the factors of production earn. These constraints establish a direct link between what the factors of production earn and what households can spend. A partial equilibrium model usually focuses only on one part or sector of the economy, assuming that the impact of that sector on the rest of the economy, and vice versa, is either non-existent or small. Partial equilibrium has many advantages, but when it comes to extensive policy changes, economy-wide repercussions are likely to be important. For example, changes in the tariff structure are often pervasive. In many cases, moving to a common external tariff implies a drastic reduction in protection, which would call for a real depreciation of the national currency to restore external balance. These scenarios could also imply substantial changes in factor markets, requiring adjustment in factor rewards. Clearly, if these effects operate at the country level, they apply with greater force when multilateral trade agreements are implemented. Because GE analysis takes into account the interaction across markets, it overcomes these shortcomings. In particular, by taking into account budget constraints, GE analysis gets rid of "free lunches". For example, in the case of a reduction in protection, a GE model will evaluate the extent of real depreciation necessary to maintain external balance. However, there are circumstances when the benefits of a general equilibrium model are offset by the high level of aggregation required to be able to use comparable and consistent data and by the difficulties in specifying parameters and functional forms in the model.

The purpose of the class of GE simulations in which we are interested is to determine the effects of a change in trade policy on the endogenous variables of the model – prices, production, consumption, exports, imports and welfare. The simulation represents what the economy would look like if the policy change or shock had occurred. The difference in the values of the endogenous variables in the baseline and the simulation represents the effect of the policy change. So the model should be able to foretell the effect on trade and production patterns if the trade policy was changed. Furthermore, based on the change in welfare, the policy-maker would be able to judge whether the country benefited from the change in policy or not.

It is important to keep in mind that GE policy experiments should only be seen as comparing second-best situations. The reason why is that parameter estimates computed in order to calibrate the model to SAM's data, for instance (see sections 3.2 and 3.3 below), do capture rigidities and market distortions that are likely to be present in most economic markets. However, by assuming that those rigidities and market distortions are invariant in the experiment under consideration, GE policy experiments would be able to generate clear-cut quantitative results contrary to theoretical and analytical models. In the latter, outcomes would depend on parameter values and could thus only be assessed in an ad hoc manner. This could be seen as a good argument to rely on GE assessments while investigating the impact of a specific policy reform.

During the development of the field, computing equilibrium was often a problem and one often referred to GE simulation analysis as "Computable General Equilibrium" (CGE) modelling. The name has survived although computational aspects are no longer an issue. This means that with increasing data availability, the avenues open to GE simulations are almost infinite. Hence this is only an introduction to the subject.

Having suggested the limitless options for GE simulations, we should point out the major criticism raised concerning this approach. As will become clear in the discussion on calibration, the approach here is to fit the chosen behavioural specification to the data, which means that the flow data (here reflected in the constructed SAM) represent equilibrium. In short, the model is never confronted with the data (even if, as mentioned above, one can experiment with different models, sometimes referred to as different "closure" rules). There is thus no formal hypothesis testing even though, with today's computing power, one could carry out a Monte Carlo analysis.

In addition, building a GE model for policy analysis is a time-consuming task. First, you must assemble the dataset. This is not that easy even if you can rely on simple functional forms. You also have to start with a balanced dataset, i.e. a balanced Social Accounting Matrix (SAM). Usually this requires some work and, when data come from different sources, you have to do the balancing yourself. Second, you must specify the model. Here the difficulty is that the slightest mistake results in a leakage (i.e. income is not equal to expenditure for one agent) and the model will not solve. Again, finding the source of the mistake can be quite time-consuming.

Overall, the good news about GE analysis is that it is rigorous and is an effective tool for testing the implications of alternative model specifications. The less-good news is that, if you wish to learn about GE modelling, there is no alternative to getting your hands "dirty" and building a model yourself. This is why we will proceed with a description of the full set of equations for a simple "toy" model.

1. The foundations of computable general equilibrium analysis

A GE analysis is able to account for all the linkages between the sectors of an economy. These could be inter-linkages between industries, both backward and forward, or they could be linkages between household expenditures and incomes. A GE model imposes income/expenditure and resource constraints, thus ensuring that households are keeping to their budget lines and that the total amount of primary factors employed in production does not exceed a country's factor endowments.

a. Linkages in the economy

The ceteris paribus assumption of partial equilibrium models can be restrictive, particularly if the analysis involves more than one market and if account is to be taken of income effects along with the substitutability and complementarity of products as well as shifts in the factors of production among sectors. A general equilibrium model captures the fact that markets are linked and that events that take place in one market have effects on other markets that need to be taken into account, since they can feed back into the original market.

These linkages work through a number of channels. One channel is the consumer. A reduction of the tariff on wheat, for example, will increase the quantity of wheat demanded by consumers and simultaneously reduce demand for products that are substitutes for wheat (such as rice), increasing demand for products that are complementary to it (such as butter). Changes in relative prices will also affect the composition of demand through their income effects. Another channel is producers. A fall in the tariff on wheat will reduce the returns from wheat farming, leading to a decrease in the quantity of wheat supplied by domestic producers. This will release factors of production – land, capital and labour – employed in the wheat sector to other sectors (such as rice) whose production may expand. Since the quantity of wheat demanded increases while the quantity supplied decreases, the change can only be accommodated by rising imports.

All these changes set up ripple effects throughout the rest of the economy. Resources released from the wheat sector are now available for use by other sectors in the economy. They will flow to sectors such as the rice sector and maybe to the export sector as well. There will therefore be changes in the patterns of production, consumption and trade that go well beyond the wheat sector, although the most significant change may still occur in that sector. For trade economists, the gains from reducing tariffs on wheat come from freeing up resources so that they can be employed in sectors where their contribution to the economy is greater. The only reason why the resources in question were employed in the wheat sector in the first place was because trade protection allowed producers there to pay more for the additional resources.

By way of contrast, a typical partial equilibrium analysis would only stop at the wheat market. It would capture the increase in the quantity of wheat demanded, the reduction in domestic production and the increase in wheat imports. But it would fail to capture what occurs in the markets for wheat complements and substitutes and would especially fail to capture the link between consumer income and expenditures on these other goods. A partial equilibrium analysis would not take into account how other sectors (e.g. exportables) might expand using the resources released from the wheat sector.

A general equilibrium approach is ideal for analyzing the effects of multilateral trade liberalization or regional integration in its broader sense. This is because multiple countries and markets are involved, and tariffs would be changing in all of those countries and markets.

b. Circular flow

Some of these economic linkages are captured by the circular flow picture of the economy's operation. There are two important institutions involved in the circular flow: households that are consumers as well as being the owners of factors of production such as land, labour and capital; and firms. Households sell the services of factors of production to firms, so there is a flow of these factor services from households to firms. In exchange, firms sell goods and other services to households. Hence there is a reverse flow of products and other services going from firms to households. Many GE models also explicitly represent the government, but the latter's role in the circular flow is often passive, i.e. collecting taxes and disbursing these revenues to firms and households as subsidies and lump-sum transfers subject to rules of budgetary balance specified by the analyst.

The circular flow could also be described in terms of payments and receipts instead of goods and services. Payments in the form of rent, wages, interest and profit are paid by firms to households, which receive the payments as income. There is thus a flow of payments from firms to households. Note that this means that firms do not retain profits (if any) and that these are redistributed to their rightful owners – households. Households in turn spend money on the goods and services produced by firms, which receive these as revenues; so there is a reverse flow of payments going from households to firms.

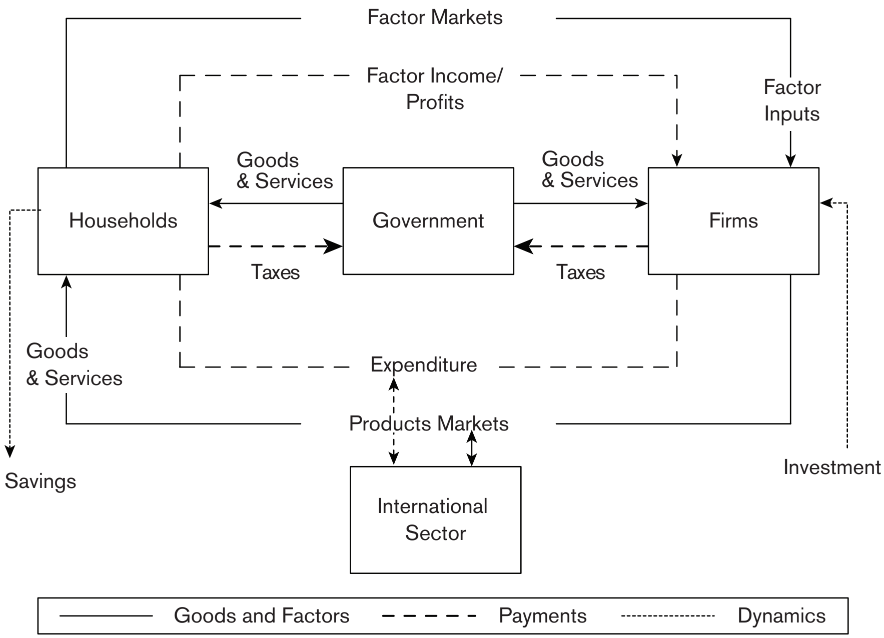
In a closed economic system, the value of these flows should be equivalent. This is reflected in accounting identities. Total expenditures on goods and services must equal the total income received by owners of the factors of production. If households save part of their income, this forgone consumption must be equal to investment, which allows an economy to increase its productive potential over time.

In dynamic models where the time path or sequence of equilibriums that the economy tracks is important, investment determines how fast the economy grows. In dynamic models, the distinction between stocks and flow has to be made. Savings by a household at any point in time is a flow. The household's wealth, however, is a stock and is formed out of the sum of all previous savings by the household. An analogous relationship holds between the economy's investments and its capital stock. Investments at any given time are a flow; capital stock is the accumulation of all past investments made by the economy. Hence, changes to the economy over time occur through the effect that these changes in flows have on stock variables.

Figure 5.1 describes the flow of goods and services/expenditures and receipts in an open economy with three sectors – households, firms and the international sector – plus government. Each economic transaction that involves an exchange of goods or services must be matched by a corresponding flow of expenditures and receipt of payment. For example, the transaction involving households purchasing goods produced by firms is depicted as both a flow of goods (plain line) and a flow of payments (dashed line). The flow of goods moves from firms to households; the flow of payments moves in the opposite direction from households to firms.

The link between the domestic economy and the international sector is captured in the four sets of arrows that lead to and out of the international sector. The international sector is a source of additional goods and services, i.e. imports, to the domestic economy. This is matched by a payment flow from domestic residents to foreigners. But some of the goods and services produced in the domestic economy also go to the international sector as exports. This flow outward of goods and services is matched by an inward flow of payments to domestic producers. If no capital flows are allowed between the domestic economy and the rest of the world, the value of exports must equal the value of imports.

Figure 5.1 The circular flow of commodities in an open economy



c. Optimizing behaviour in general equilibrium analysis

In general equilibrium analysis based on the Walrasian theory of general equilibrium, the underlying assumption is that of optimizing or "rational" behaviour by economic agents. This assumption is also maintained in partial equilibrium models but is more apparent and explicit in general equilibrium models. Thus households maximize utility subject to income constraints and firms maximize profits. This assumption is responsible for generating downward-sloping demand curves and upward-sloping supply curves. Optimizing behaviour by economic agents also lays the foundation for analyzing the welfare effects of different equilibriums and the policy measures that produce those outcomes.

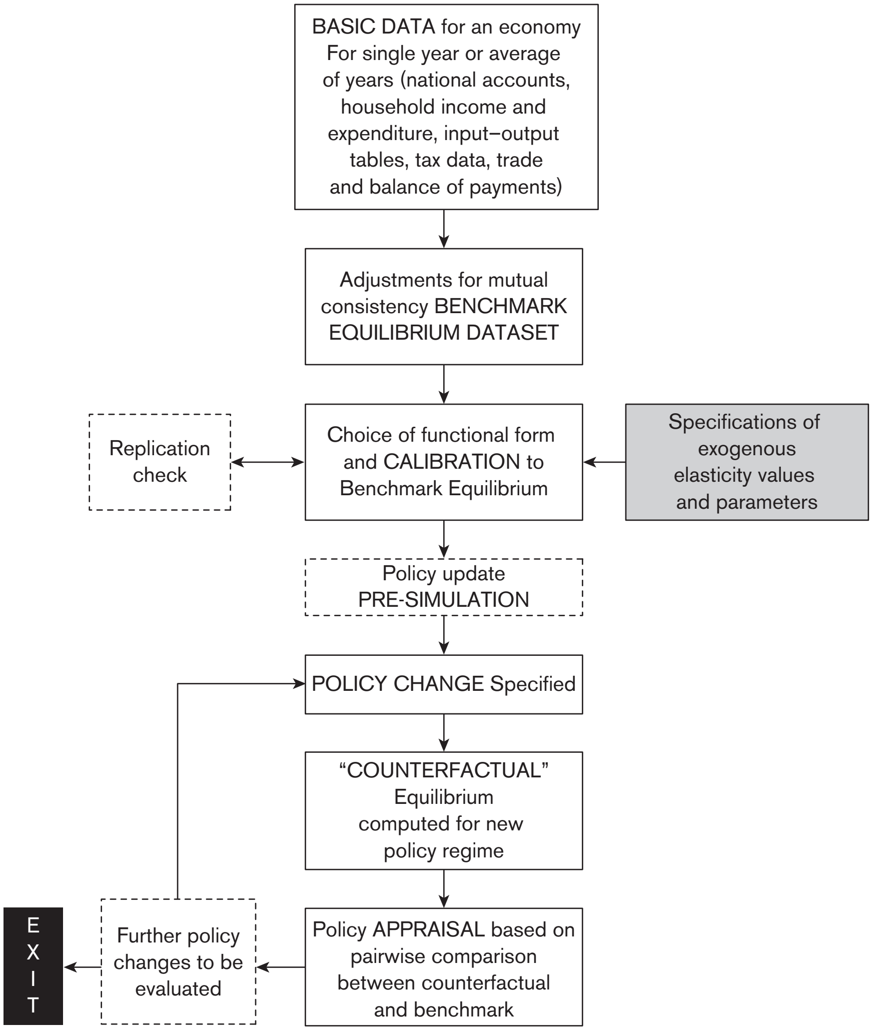
The indicator for assessing the efficiency of an economic system is consumer welfare. This is because the material resources of any economy are there to satisfy human needs. The role of firms or producers is to transform these resources as efficiently as possible into those goods and services that households desire. In other words, the role of firms and the role of the assumption of profit maximization are to ensure that society produces all that it is capable of producing (i.e. it is on its production possibility frontier and not within). As we explained in the circular flow subsection above, households are the ultimate owners of all factors of production and they receive all factor payments as income – wages, interest and rent as well as profits.

2. Implementation

Implementing some kinds of CGE analysis is not necessarily a very easy task if it has to be done from scratch. Shoven and Whalley (1984) noted that: "Modellers must know general-equilibrium theory so that their models have a sound theoretical basis; they need to be able to program (or at least to communicate with programmers); they must understand the policy issues on which they work; they have to know about data sources and all their associated problems; and they have to be conversant with relevant literature, especially that on elasticities." Although implementation is much more "user-friendly" today than it was two decades ago, the quality of an analysis still relies on the Shoven and Whalley competencies list.

Figure 5.2 contains the typical steps to follow in order to implement a CGE analysis of a particular policy reform.[2] The steps leading to defining the policy experiment to be assessed are presented in detail in the next three sub-sections, although not necessarily in the order appearing in the figure. The last steps dealing explicitly with the policy reform to be simulated and the analysis and

Figure 5.2 Steps towards a policy experiment with CGE models



appraisal of the relative results are the core of section 4. The case of the impact of the Uruguay Round is used to illustrate possible issues in such an exercise.

a. Applied general equilibrium models of trade

From a theoretical point of view, there are two major traditions in CGE modelling. The neoclassical tradition generally assumes full employment of labour and capital; sectoral adjustments are driven by relative prices. CGE models from the structuralist tradition generally assume quantity adjustments of output and cost-driven prices. We present some of the main differences of the two approaches in Box 1.1.

The neoclassical tradition, however, remains the dominant one. Tractability and high consistency with SAMs' accounting mechanisms justify such a situation to a large extent. In what follows, the core tradition is neoclassical. However, we also present various structuralist peripheral extensions and components.

i. Structure

Market structure

The large majority of CGE models assume that product and factor markets are perfectly competitive. This means that households and firms make their decisions regarding the purchase and sales of products and factors of production by taking the prices of these goods and factors as given, i.e. outside their control. Neither a single household nor firm is able to affect prices by its behaviour. Perfect competition also means that in equilibrium firms do not make economic profits.

In some recent CGE models monopolistic competition is allowed, usually in the manufacturing sector. The idea is that some products are differentiated into different models or types, as for example cars (sedan, coupé, SUV), and that consumers prefer this differentiation. Within the relevant range of output, production of each of these differentiated goods is subject to increasing returns to scale. Although existing firms have market power (their output decision affects price), entry by new firms, which is equivalent to introducing a new product, ensures that in equilibrium no economic profits are made.

Although the assumption of product differentiation and monopolistic competition makes a CGE model more complex, it allows the model to capture the very large role that intra-industry trade plays in the trade of developed countries. Older models of international trade, such as that of Heckscher-Ohlin that assume homogeneous products, would be unable to explain the importance of intra-industry trade. CGE models based on the hypotheses of constant return to scale and homogeneous goods explain intra-industry trade by assuming that goods differ by country of origin. This is known as the Armington assumption. The advantage of product differentiation models is that the degree of product differentiation is determined within the model rather than exogenously by the value of the Armington coefficients. In a CGE model with product differentiation, policy changes affect an economy also through the impact on the number of varieties available to consumers. Since consumers love variety, the larger the range of products available in the market, the greater their well-being.

Production and firm behaviour

The production side of a CGE model is represented by a set of goods (outputs), the inputs that are required to produce them and the technology of production. In most CGE models the production technology is divided into two levels – an intermediate and a final level. In the intermediate level, goods are used as inputs to produce a composite intermediate good; primary factors (land, labour and capital) are also used to produce a new item called value added. The final level involves using both the value added and the composite intermediate good to produce the (final) output. See Figure 5.2 for an example of this technology. The intermediate level is characterized by no substitution possibilities among the intermediate inputs and the primary factor of production. However, substitution is possible among primary factors and among intermediate goods. The final stage, which in essence creates the final product, also allows for substitutability between value added and the composite intermediate goods. This two-level structure affords a far better description of production in modern economies than the traditional production function involving just primary factors since most goods are made up of many finished components and parts sourced from other suppliers. The important parameters that describe this technology are the fixed coefficients of the intermediate input stage and the elasticities of substitution.

Control over the production sector of the economy is exercised by profit-maximizing firms. Using prices of goods and the factors of production as market signals, they make their decisions about how much of each good to produce. They purchase primary factors from households and intermediate goods from other firms and use these to produce the goods which, in turn, are sold back to households. Revenues received from sales of products are used to pay the owners of the primary factors of production in the form of rent, wages and interest and to pay suppliers of intermediate inputs. But because markets are perfectly competitive, economic profits are driven to zero.

Households

Households are the consumers as well as the owners of factors of production. As owners of land, labour and capital, they receive rent, wages and interest paid out by firms. This income is then spent on goods and services that households consume. Some of the income may be paid as taxes to government directly (e.g. income tax) or indirectly (e.g. tariffs on goods, sales tax, etc.) and some of it may be saved. Consumption yields utility to households.

The utility maximization problem is often posed in terms of a representative household. With the objective of maximizing utility, it must decide how much of its income to allocate to the goods and services that are available in the market. All of its endowments of land and capital are made available to firms (a full employment assumption) at the going market price for these factor services. Posing the optimization problem in this way, however, presumes that all households in the economy are identical and thus sidesteps interpersonal welfare comparisons (the issue of inter-country comparison of welfare is pursued in a later discussion below). However, issues involving the distribution of income can still be analyzed since changes in factor prices will reveal how distribution is affected, i.e. whether labour gains against property owners, etc. Moreover, where impacts on individual households are important, as in the case of the impact of a policy change on poverty, CGE analysis can be complemented by country-specific case studies to establish the potential effect on different household groups or different regions within a country (see Hertel and Winters, 2005).

Government

In CGE models, governments function to collect taxes and tariffs, disburse subsidies and purchase goods and services. These activities are not necessarily assumed to satisfy some optimization goal, unlike the case of consumers and firms. Even if some budgetary restrictions could be imposed to assess some fiscal transfer schemes for instance, the role of the government remains essentially passive. However, changes to these fiscal policy instruments provide the exogenous shocks that lead to adjustments to the rest of the economy which the CGE model seeks to capture. It is then possible to conduct a welfare analysis of these policy changes and to rank the available policy choices.

International trade

In a CGE model with international trade, the model will include links with other countries, which will also have their own sets of consumers, producers and governments. The introduction of a foreign sector requires treatment of one key issue – substitutability between imports and domestic products.

Almost all CGE models assume that the foreign and domestic products are not perfect substitutes so that products in international trade are differentiated by their country of origin (the Armington assumption). This means that wheat grown in the United States is different from wheat grown in Australia. Thus even with open trade between both countries, world prices for US wheat and Australian wheat need not be equalized and each country can simultaneously export its own wheat and import the wheat of its trade partner.

The differentiation by country of origin has implications for both consumer and firm choices. For example, in the case of the firm some of the intermediate goods that it purchases will be imported. The choice between domestic and imported intermediate inputs depends on the prices of the goods and the Armington elasticity, which is a measure of the substitutability between domestic and imported products. Furthermore, the imported product is also a composite good made up of imports coming from individual trade partners. For consumers, preferences are now defined for goods that are a composite of domestic and imported goods. Again, how much of domestic production or imports is purchased depends on the relative prices and the Armington elasticity.

On the export side, the country sells a differentiated product in the world market. One consequence of product differentiation by country of origin is the omnipresence of terms of trade changes. Terms of trade refers to the ratio of a country's export and import prices. Each country is the unique supplier of its differentiated product. This means the prices of its export goods depends on the amount demanded in the world market. A country can only export more if its export price were to fall, enticing foreigners to buy more of its goods. Thus, because of the Armington assumption changes in trade policy tend to produce significant terms of trade changes in CGE models. The possibility of terms of trade changes has important implications for gains from trade liberalization.

In CGE models with Armington's national product differentiation, trade expands purely at the intensive margin: each exporter increases the size of its exports but there is no change in the set of exporters nor in the set of destination countries. We know the importance of the extensive margin for international trade, which has been illustrated in previous chapters of this book. The extensive margin is a crucial force behind trade expansion following liberalization. Then the absence of the extensive margin in Armington-type CGE models results in the well-known "stuck on zero trade" problem.[3] The Armington specification has the effect of locking in pre-existing trade patterns and prevents the models from generating large changes in trade in sectors with little or no trade. Under this specification, if a country's imports from another country of a given product are zero initially, they will always be zero even after significant reductions in trade barriers. If imports are non-zero but small, they will remain small even if there are large changes in prices. This “stuck on zero trade” problem makes CGE models especially inappropriate for the least developed countries, which usually have limited trade with the rest of the world.[4]

ii. Equilibrium

Solving a CGE model involves searching for the set of prices that produces market equilibrium. In equilibrium, demand for goods equals their supply. The demand for factors of production equals the available endowments. Consumers have chosen the utility-maximizing basket of goods, given their incomes, while firms have chosen production levels that maximize their profits.

This means that equilibrium in the circular economic flow of Figure 5.1 results in the conservation of both product and value in the context of Walrasian general equilibrium. Conservation of product, which holds even when the economy is not in equilibrium, establishes that the quantity of a factor with which households are endowed or of a commodity that is produced by firms must be completely absorbed by the firms or households (respectively) in the rest of the economy. In other words conservation of product ensures that the flows of goods and factors must be absorbed by production and consumption activities in the economy. This is an expression of the principle of no free disposability and corresponds to the condition of market clearance. Conservation of value reflects budgetary balance, implying that for each activity in the economy the value of expenditures must be balanced by the value of incomes and that each unit of expenditure has to purchase some amount of some type of commodity. In other words, neither product nor value can appear out of nowhere. Nor can product or value disappear. Conservation of value is obtained with constant returns to scale in production and perfectly or monopolistically competitive markets. This implies that in equilibrium producers make zero profit. Lastly, the returns to households’ endowments of primary factors that are associated with the value of factor rentals to producers accrue to households as income that the households exhaust on goods purchases. When households’ factor endowments are fully employed so that no amount of any factor is left idle (e.g. there is no unemployment) and households spend their whole income on goods (some amount of which are for the purpose of saving), the principle of balanced-budget accounting known as income balance is satisfied.

The three conditions of market clearance, zero profit and income balance are sufficient to solve simultaneously for the set of prices and the allocation of goods and factors that support general equilibrium. The three conditions define Walrasian general equilibrium in terms of the allocation of goods and factors itself and not necessarily reaching this allocation through the process of exchange. This allocation is made up of the components of the circular flow corresponding to the solid lines in Figure 5.1. General equilibrium can therefore be modelled in terms of barter trade in goods and factors without the need to keep track of the compensating financial transfers explicitly. This explains why CGE models typically do not explicitly represent money as a good. However, the quantities of different goods need to be made comparable by expressing their values in some common unit of account. As a consequence, flows are expressed in terms of a numéraire good whose price is taken as fixed. This explains why CGE models only solve for relative prices.

Different settings of the exogenous variables such as tariff levels will produce different market equilibriums. For the policy-maker, it is important to be able to evaluate these different possible outcomes. A CGE model provides the policy-maker with the required measure in the form of consumer welfare. Each setting of the trade measure is associated with a particular equilibrium and a corresponding value for consumer welfare. The policy-maker should prefer that policy setting which produces equilibrium where the consumer's welfare is highest.

iii. Model closure

Differences in the process of adjustment of an economy to a policy shock will necessarily generate differences in the properties of the post-reform equilibrium. The way an economy adjusts to a policy shock will vary with the closure adopted by the CGE modeller, her choice being determined by her personal theoretical preferences and, in her view, the empirically most plausible adjustment processes.

For instance, different model closures are often used to represent various assumptions about the labour market, especially to allow for unemployment. If you assume that the labour market is perfectly flexible (neoclassical tradition) and that there is full employment, then you will adopt a closure that makes the wage rate endogenous with employment being exogenously determined by the labour endowment of the economy. In contrast, if you reckon that the labour market is characterized by involuntary unemployment, then the appropriate (structuralist tradition) closure rule would make employment endogenous and require that the wage rate be fixed exogenously, which could be at some level above the equilibrium level.

The choice of the "model closure", however, cannot be exclusively "ideological". It has to be determined also by the specific nature of the problem and by the variable the modeller intends to shock. Consider, for example, the case of a good produced in a small economy and on which the government levies an import tariff. In this case the domestic price of the good is set by the world market price plus the import tariff, while imports are determined by the model's equations of domestic demand and supply. Given the price, it is possible to calculate the quantity demanded and domestic supply, with imports being derived as the difference between demand and supply. In this set up, prices are exogenously fixed by the analyst while quantities are endogenously determined by the model. The modeller can simulate the impact of a tariff cut simply by solving the equations for the demand and supply for the new price (that is, the world price plus the new tariff rate).

Alternatively, it may be the case that the market for a certain product is protected by a quota and the modeller is interested in simulating the impact of changes in the volume of the quota on the economy. In this situation, given the world price and the quota, the market equilibrium condition "demand equal supply plus imports" (the latter given by the value of the quota) will determine the domestic price prevailing in the market. At that price the demand and supply will generate precisely the level of imports determined by the quota. In this set up, the quantity of imports is exogenous to the model, fixed by the specific country policy, while prices are endogenously determined by the model.

It is interesting to note that under certainty the economic impact of a tariff or a quota is equivalent. It is equivalent to setting a tariff at a level that yields a certain level of imports or setting a quota at the level that generates the same domestic price. It is for this reason that economists sometimes work with the tariff equivalent of a quota. In this case, the impact of changes in the quotas is simulated through variations in their tariff equivalents. The choice between working with quotas directly and working with their tariff equivalents is one of model closure. In the former case the quantity of imports is exogenous and the domestic price is endogenous. In the latter case, the opposite will be true.

Mathematically, the need for "model closure" springs from the requirement that the number of endogenous variables in a model should be equal to the number of independent equations so that the model can be solved. Hence if a model has n independent equations and m variables, where $m > n$, then one way of interpreting closure is that it involves choosing which n variables are to be made endogenous from among the m total variables. The remaining m–n variables will have to be kept exogenous. In other words, choosing a closure is equivalent to choosing the set of equilibrium conditions versus the set of identities. The numéraire has to be identified amongst the set of the prices of equilibrium components. However, and this is true in all circumstances, factor prices cannot be used as the numéraire. This is due to the fact that the supply–demand equalities in factor markets do not appear in the aggregate identity (total excess demand in value is zero) that leads to Walras' Law. The latter implies that one equilibrium condition becomes redundant when all others hold. One equilibrium condition can then be dropped and the underlying price becomes the numéraire. The numéraire can only be selected from the prices of composite goods, nominal saving or investment and foreign exchanges (in an open economy framework). For instance, in most neoclassical CGE models the numéraire is the price of nominal saving or investment. This means that the saving–investment equilibrium conditions have been dropped from the aggregate identity, setting total excess demand at zero and expressing all prices relative to the price of nominal savings or investment, i.e. the interest rate.

iv. Welfare

Various indicators of welfare have been used in the context of CGE models of trade. The measures most widely employed are Hicksian compensating and equivalent variations associated with the equilibrium comparison. The compensating variation (CV) takes the new equilibrium incomes and prices, calculating how much income must be taken away or added in order to maintain households at their pre-change utility level. The equivalent variation (EV) takes the old equilibrium incomes and prices and computes the change required to achieve utility levels reached in the new equilibrium. Welfare improvements correspond to a negative CV and a positive EV. In a single-country model context, economy-wide welfare benefits/costs of a policy reform are obtained by aggregating the CVs and EVs across individuals. In a multi-country context, overall welfare benefits/costs of a policy reform are measured by summing up the CVs or EVs across countries. It is common to adopt a sign convention so that a positive value for either measure indicates an increase in welfare. Then,

$$CV = \frac{\left(U^1 - U^0\right)}{U^1} I^1 \tag{5.1}$$

and

$$EV = \frac{\left(U^1 - U^0\right)}{U^0} I^0 \tag{5.2}$$

where U^1, U^0 and I^1, I^0 denote the new and old levels of utility and income respectively.

As a practical illustration of these measures, consider the following situation. A country is examining whether it should remove the tariff on an imported product or not. The compensating variation (5.1) of removing the tariff is the level of income that would have to be added or removed in order to retrieve the pre-tariff-drop level of welfare using the post-tariff-drop prices and incomes. The equivalent variation (5.2) of removing the tariff is the change in income, using current prices that would have the same impact on the welfare of households as the removal of the tariff. These variation measures have an appealing feature, since they are a monetary measure of the change in welfare, i.e. capable of being expressed in dollars and cents. Not only is a monetary measure more intuitively comprehensible, it also provides an important means of dealing with the problem of interpersonal comparisons of welfare in a multi-country model. It provides a standard transfer from the winners to the losers that will leave all countries at least as well off as before.

Suppose that a specific multilateral trade liberalization scenario has been simulated and the results indicate that one set of countries would see their level of welfare (as measured by the equivalent variation) increased compared to the baseline while another set of countries would see their level of welfare decline. By adding up these measures of equivalent variation, it is possible to assess the global welfare impact of this specific trade liberalization scenario. If this global total is positive, it is in principle possible for the winners to make transfers to the losers that would leave the latter as well off as before the trade liberalization and thus remove their objection to policy change and still have enough left over for the winners to experience net gains. Thus the liberalization policy is desirable from a global welfare perspective. If the global total is negative, however, there is no possible way of effecting transfers from the winners to the losers that will leave all countries at least as well off as before. Thus, the liberalization policy is undesirable from a global welfare perspective.

Note that this welfare evaluation has been conducted without having to weigh individual countries' well-being and making judgments about whether one country should count more than another. So long as the change in trade policy has the potential to increase global incomes enough so that winners can "bribe" losers to accept the change in policy, that change is desirable because in principle all can stand to gain.

v. Dynamics

CGE models can either be static or dynamic. In their static form, the impact of a policy reform (e.g. a tariff reduction) is established by comparing equilibrium properties before and after that reform. In other words, the comparison occurs after the adjustment process without considering the behaviour of the economy during that process. This is also what simulations based on dynamic models do eventually. The distinguishing feature of a dynamic CGE model, however, is that growth of output is possible and changes due to policy reforms can be tracked over a given period of time. Changes in economic indicators during the adjustment process can be retrieved. In addition, it becomes possible to compare the impact of various implementation schemes for the policy reform.

There are two types of dynamic CGE models: recursive/sequential and inter-temporal. Sequential/recursive dynamic CGE models are not truly dynamic and consist de facto of multiple static models linked to each other sequentially. The first model is solved for one period and then all variable values determined at the end of that period are used as initial values for the following one. This is like solving an initial value problem. Current economic conditions (e.g. the availability of capital) are dependent on past outcomes but are unaffected by forward-looking expectations and economic agents have myopic behaviour imposed on them by the modeller. Some of the variables in the model may evolve exogenously following a pre-determined baseline scenario. The latter is identified thanks to a macro econometric model adequately framed to undertake forecast. Changes in variables, whether they are endogenously (e.g. capital) or exogenously determined (e.g. population), will be reflected in the growth path of the modelled economy along its adjustment path towards the new equilibrium. That is, the impact of the policy reform is to be anticipated with respect to the baseline scenario outcomes in each period.

Unlike sequential dynamic CGE, inter-temporal ones are based on optimal growth theory, where the behaviour of economic agents is characterized by perfect foresight. In this type of dynamic CGE model, households choose a consumption plan (a sequence of consumption decisions) during the period under consideration that maximizes the discounted stream of their utilities. This means that in some periods households may consume more than they earn (dissave), while in other periods they may consume less than they earn (save). For their part, firms choose a production plan (a sequence of production decisions) that maximizes their discounted stream of profits. The availability of savings from households makes it possible for firms to turn these savings into new capital stock, thereby augmenting their productive capacity. Thus the growth rate in a dynamic CGE model is endogenously determined by the savings and investment behaviour of households and firms. The evolution of the economy would be driven by trade performance and its linkage to total factor productivity amongst other features considered by the modeller, the level of government investment on infrastructure and its assumed linkage to total factor productivity, as well as the investment in education through its impact on labour productivity. In the context of inter-temporal CGE models there is no need for an extensive baseline scenario. However, forward-looking behaviour could complicate the computational exercise tremendously since some variables in the current period could be affected by variables in the future. Constructing an inter-temporal CGE model is challenging in the sense that it is essential to keep it computationally tractable without compromising on the type or degree of economic detail modelled.

vi. Linking micro-simulation models

The distributive impact of trade reforms can only be partially assessed using standard macro/CGE models. These models lack the distributive detail found in micro-simulation. The latter refers to modelling of income and consumption of distinct individuals or households instead of resorting to representative household groups as traditional CGE models do. It is based on household surveys, essentially fiscal and labour surveys. Micro-simulation is thus essential in modelling the distributive effects of taxes and transfers. On the other hand it is constrained by the fact that it is often non-behavioural and by its inability to model prices, wages and macro variables.

The solution for qualifying distributional issues properly that is increasingly being advocated is to combine these different forms of modelling. The idea goes back to Orcutt (1957) but was not used for analysis of macro-poverty links until the late 1990s.

In case policy-makers are interested in the distributional impact of removing agricultural protection in developing countries, for instance, they need detailed information that goes beyond results that are obtained strictly from a standard CGE. Tariff removal leads to lower food prices, benefiting poor consumers. However, lower agricultural prices also reduce the wages of agricultural labourers, many of whom are also poor. The result is that some of the poor will benefit and others will lose. CGE is needed to capture the wage and price effects, and micro-simulation is needed to net out gains and losses for individual households, allowing accurate distributional analysis to be performed.

The combination of CGE/macro models and micro-simulation can be based on either their layering (the top-down approach), or on their integration. In the former approach CGE simulation results are passed on to a household model (macro and micro need not be reconciled but there is a possible lack of coherence). The top-down approach solves a traditional CGE with a limited number of household groups and then uses a micro-simulation model to generate household behaviour that reproduces the output of the CGE model. The specification of the micro-simulation model can be based on simple pro-rating, meaning that there is no behavioural response. In this context, only first order effects are captured. At the other extreme, micro-simulation models can be fully behavioural, with behavioural parameters econometrically estimated from a household survey. This means that the labour supply choices of each household are endogenized. With behavioural responses featured, second order effects of a policy reform would also be captured. With the integration approach, the household model is built directly into the CGE. In other words, the integration approach uses the individual households directly in the CGE instead of using representative households. This approach appears to be more promising than the top-down approach for several reasons. First, it comes closer to the vision of true general equilibrium. Second, and probably most interesting from a policy point of view, it has the potential for household heterogeneity to have impacts on sectoral and macro aggregates. Some modellers support the view that eventually this approach presents easily tractable technical difficulties. As standard CGE models, CGE/micro-simulation models can be either static or dynamic. Dynamics can be either in terms of ageing information or behavioural.

The main weakness of CGE models is that they are fundamentally non-testable. The way a CGE is built is first to specify an a priori causal structure ("story") and then calibrate it to a Social Accounting Matrix of a given country. The behavioural parameters are thereby specified in a largely ad hoc manner. Thus any story can be calibrated to any country. The traditional CGE models use a base year SAM to calibrate the share parameters of the model and mostly use unrelated studies or guesstimates for the remaining behavioural parameters; in the best case (e.g. Demery and Demery, 1991), some parameters are estimated from single equation regressions. Because CGE models also aim to represent medium-term equilibriums, the time series they produce (if any) are typically only interpreted in qualitative terms. There are two unfortunate results of this practice. First, models with very different behaviour can be calibrated to the same data, with no ready measure of which formulation best describes a given country (see e.g. the controversy in Sahn et al., 1996; de Maio et al., 1999; Sahn et al., 1999). Second, even if one has settled on a given causal structure, the behavioural parameters cannot be directly calibrated to data. The usual solution is to borrow parameter estimates from unrelated studies, ad hoc sensitivity tests and "reasonable range" guesstimates, none of which seem very satisfactory. A different way of addressing the uncertainty in free parameters is discussed by Harrison et al. (1993), who assume a priori probability distributions for all free parameters and proceed to do simultaneous sensitivity analysis on all of them, generating probability distributions for output variables. However, this approach seems to have two flaws that limit its use in applied models: first, the a priori probability distributions still have to be guesstimated, and second, doing a full unconstrained sensitivity analysis on all free parameters simultaneously is likely to produce a spread of end results so large as to be of no practical use.

Thus, until the CGE methodology is modified to allow for significance and quality-of-fit measures akin to those of econometrics, CGEs will remain little more than elaborate a priori stories, a medium for narrating the modeller's favourite theories in a consistent framework but with little reason to prefer one such story over another.

b. Data requirements

To operationalize fully a CGE model of international trade requires building the associated Social Accounting Matrix (SAM) and obtaining estimates of important behavioural parameters governing consumer demands, production technology and the substitutability of imports and domestic products. Those estimates are identified according to the adopted model specification. Some parameter values are likely to be chosen arbitrarily. The final step involves calibrating the model, i.e. calibrating the functional forms to the data in the SAM.

i. Social Accounting Matrix

The first step in operationalizing a CGE model is to organize the data on the structure of the entire economy in a way that takes into account the fundamental relationships between all agents in the economy across all sectors. The SAM is a tool that helps take into account all of these interactions in a systematic way and without error. If a SAM is not available (the usual case), the first step is to build one. This is what takes time. Even if you benefit from an available SAM, it will rarely be for the year you are interested in, or else the level of disaggregation across markets, sectors or households will not correspond to what is needed for the application. Because this is the most time-consuming task, we will devote more time to this aspect here. Choosing the functional form and calibrating is the easier part, at least when competitive behaviour is assumed.

The SAM builds on the circular flow conception of the economic system, where each expense must be matched by a corresponding receipt or income. As its title suggests, the relationships between sectors in a SAM are represented in the form of a table containing rows and columns. The rows correspond to the income or receipts while the columns correspond to the outlay or expenditures of a sector. Each sector of the economy will appear as a row (recipient of income) and as a column (as a source of expenditures). Algebraically, a SAM is thus represented as a square matrix with elements:

$$T = [t_{ij}] \tag{5.3}$$

where t_{ij} is the value of the transaction with income accruing to account (institution) i from expenditure by account j. Each row sum must equal the corresponding column sum, reflecting the fact that each institution exactly satisfies its constraint – its receipts must equal its expenditures. Algebraically:

$$\sum_{j} t_{kj} = \sum_{i} t_{ik} \quad \forall k \tag{5.4}$$

Thus the data is consistent if (5.4) is satisfied. When this is not the case, some reconciliation has to be made.[5] In case study 10, a consistent input–output table was available so all the authors had to do was to net out the public sector accounts.

A SAM is constructed using several basic sources of economic information: the economy's input–output table, the national accounts, government budgetary accounts, balance of payments and trade statistics. The input–output table provides information on the production sector of the economy, showing detailed inter-industry linkages and the contribution made by primary factors of production to each sector. Thus we know how much steel, rubber, plastics, etc. goes into the car industry. The macroeconomic accounts provide a breakdown of aggregate demand according to consumption, investment, government spending and the international sector (exports and imports). The trade account usually contains data on the destination and product composition of exports and imports. These have to be reconciled with the national accounts as well as with the input–output table. This integration means that the resulting SAM, for example, shows not only how much steel, rubber and plastics goes into the car industry but how much of each of those inputs are sourced domestically and how much sourced from abroad and from which trade partner. The government fiscal accounts provide information on public expenditures and revenues. Integrated with the other accounts in the SAM, it is possible to obtain information on government spending on domestically produced goods and imports and to determine how much revenue is generated from taxes applied to international trade (tariffs).

Table 5.1 outlines the schematic form of the SAM. Six accounts are distinguished. The first two accounts are the activities and commodities accounts. The activities account buys intermediate inputs (domestic and imported) and hires factor services to produce commodities generating value added in the process. The commodities account combines domestic supply and imports with intermediate flows aggregated in one cell.

The next two accounts are factor and household accounts. A distinction is made between the two to show the mapping from value added to household expenditure. Households receive net factor income transfers from the government account (tariff and quota rents when these apply).

The last two accounts are the government and ROW accounts. It is thus clear, as mentioned above, that the government's role is purely redistributive since government expenditures have been aggregated into household expenditures. The ROW account includes foreign exchange expenditures and transfers to foreigners as would be the case under voluntary export restraints (VERs), the MFA or any other quantitative restriction under which foreigners get the rents associated with the restriction.

In a CGE model of trade, the SAMs of different countries will need to be collected, standardized and then combined. This requires using SAMs from the same base year and converting all values into

Table 5.1 A Social Accounting Matrix for a standard trade model

Receipts \ Expenditures	*1. Activities*	*2. Commodities*	*3. Factors*	*4. Households*	*5. Government*	*6. Rest-of-the-world*	*7. Total*
1. Activities		Gross outputs					Total sales
2. Commodities	Intermediate demand			Consumption		Exports	Aggregate demand
3. Factors	Value added					Net factor income and other foreign exchange expenditure	Net factor income
4. Households			Net factor income		Government transfer	QR rents to domestic residents	Household income
5. Government						Tariffs	Government income
6. Rest-of-the-world		Imports					Foreign exchange expenditures
7. Total	Total costs	Aggregate supply	Factors expenditure	Household expenditure	Government expenditure	Foreign exchange receipts	

a single currency. When information is missing or data are inconsistent (like when expenditures exceed incomes, demand differs from supply or consumers' expenditure classifications do not match production classification), analysts need to "adjust" data. This could be a sizeable challenge for multi-regional trade models, given their large size. For example, the current version of GTAP (version 6) has 87 regions and 57 production sectors. A huge effort has to be mounted to collect, standardize and reconcile the data to produce a SAM for a CGE model of this size.

It is important to note that CGE models are built using value data. The general practice is to define quantity units as the amount that can be bought for one unit of currency (say one euro or one dollar) in the baseline dataset. This means that, in most cases, baseline prices will all be set to unity. In CGE models, therefore, only relative prices are important, not absolute prices.

ii. Behavioural parameters/elasticities

After all information about the expenditures and revenues and the interactions of all agents have been included in a SAM, the modeller needs to provide the value of the exogenous parameters (called behavioural parameters) that characterize the behaviour of producers and consumers.

These parameters measure the responsiveness of producers and consumers to relative price and income changes and therefore have an important bearing on the outcome of a CGE simulation. There are at least three (often more) types of behavioural parameters which are needed. First are the elasticities of substitution in value added that govern the substitutability of the primary factors of production. Second are the Armington elasticities that determine the substitutability of the domestic vs. the imported composite product. Third are the demand and income elasticities of the households or consumers.

One of the more important criticisms levelled against CGE models concerns the quality of the information used to derive these behavioural parameters. Hertel et al. (2004) have admitted that the history of estimating the substitution elasticities governing trade flows in CGE models has been "chequered" at best. In some cases, the CGE model builders do not statistically estimate these parameters themselves but take them, usually without much change, from other sources. For example, the substitution and Armington elasticities of the GTAP model are taken from the SALTER project (Jomini et al., 1991), while income elasticities were taken from FAO (1993) and Theil et al. (1989). In the Michigan model, the elasticities are taken from Deardorff and Stern (1990). Ideally, these parameter values should come with additional information (e.g. standard errors, functional form, etc.) which could provide some guidance about the reliability of these estimates. While databases may be regularly updated, the estimates of the parameters are not, so some of the behavioural parameters are based on estimates that are currently about 15 years old.

c. Calibration

The final stage for operationalizing a CGE model consists in calibrating all parameters remaining unknown. The estimation of such parameters could be done empirically. However, besides the fact that this would represent a considerable and tedious amount of work, most of the required time-series or even cross-sectional series data are rarely, if ever, available. In most CGE applications the adopted procedure to obtain a model's parameter estimates is to use information contained in the SAM itself, supplemented as needed by additional sources or whenever possible by econometric estimates. Thus, calibration involves choosing the values of a subset of the parameters in such a way that, together with the assembled SAM and the values of the behavioural parameters, the model is able to reproduce exactly the data of a reference year – the baseline. This means that there is only one observation for each parameter being estimated. In that context, model calibration is a mathematical procedure, not a statistical one. Usually the parameters that are calibrated are share or scale parameters. The SAM, for instance, includes data on factor payments by factor and sector. Together with data on the sectoral quantity of each sector (labour force, capital stock), factor returns can be computed. Using this procedure, the wage bill divided by the total number of workers in a sector will be the wage prevailing in that specific sector.

When linking micro and CGE models, outputs from the micro model can be used to calibrate the CGE model. These outputs thus provide a microeconomic basis for aggregate behaviour. This represents a powerful feedback relationship between the two linked models. This in turn enables us to assess and qualify the complex interdependence of various policy measures with respect to tariff, distributional, employment and other effects within the same econometric framework.

However, as underlined in Peichl (2009), generating these feedback effects through linking MS and CGE models is not a straightforward task.

The calibration procedure is the necessary final step before being able to compute the general equilibrium model at hand. If the model specification and the calibration exercise are correct, then the data of the SAM together with the characterizing equations of the model will be a solution to the model. Some consistency checks should be passed and could help in identifying possible errors. A CGE is deterministic, meaning that there are no residuals. Slack variables in some equilibrium condition could be used to identify possible leakages. If an equilibrium equation is not satisfied, it simply means that an error exists in the system of equations characterizing the model at work. Another consistency check would be related to the fact that most CGE models are homogeneous of degree zero in their entirety. It implies that multiplying all prices by any whole number should leave all real variables unaffected. This can be done with the numéraire price, and the result should be a doubling of all prices and nominal elements with no change in real values.

Once the consistency of the calibration of the model has been verified, policy experiments can be run. All simulations of the CGE model will be based on a comparison with the baseline.

C. Application

Policy simulations and their appraisal: assessing the impact of the Uruguay Round[6]

The Uruguay Round of trade negotiations provided one of the first opportunities for the use of CGE models to simulate the effects of multilateral trade negotiations. This section distils the lessons learned from that body of work. It provides an overview of the CGE models used at the close of the Uruguay Round by international organizations and the simulation results.

Estimates of the impact of the Uruguay Round were produced before, during and after the completion of the negotiations. Early studies conducted by the WTO estimated gains worth US$ 500 billion annually from the Uruguay Round. A study by the OECD estimated gains of US$ 200 billion from agricultural liberalization alone. But the preliminary estimates were significantly higher than estimates produced after the Uruguay Round was concluded. One of the most important explanations for this discrepancy was that the actual commitments contained in the final agreement implied a substantially lower degree of liberalization than assumed in the policy experiments conducted in those studies, especially relative to agriculture. Later studies, conducted at the end of the Uruguay Round on the basis of the actual agreement, revised these estimates downwards.

Table 5.2 presents some of these studies conducted after the completion of the Uruguay Round. A number of factors may be identified to explain differences in the simulation results. First of all, different studies covered different aspects of the Uruguay Round. For example, the Rural Urban North South (RUNS)-based models (Burniaux and van der Mensbrugghe, 1991), developed by the OECD and the World Bank, focused especially on the agricultural sector. Fifteen out of the 20 sectors modelled covered agricultural products, with three of the remaining five sectors consisting of important agricultural inputs (fertilizers, energy and equipment). Most of the industrial liberalization took place in a single aggregated sector, “other manufactures”, thus making it impossible to capture adequately the reallocation taking place across different manufacturing products. Due to the high level of aggregation of the manufacturing sector, possible gains deriving from phasing out textile quotas and other non-tariff barriers in industrial products could not be modelled. As a consequence, overall global gains were mainly driven by agricultural liberalization. In the study by Goldin and van der Mensbrugghe (1996), agricultural liberalization yielded 85 per cent of total gains. This is in striking contrast with those of other studies where the impact of manufacturing liberalization is better accounted for, with the contribution of agricultural liberalization to overall gains of the Round estimated to be less than 10 per cent (as in Francois et al., 1996). An attempt to quantify the impact of services liberalization is made in only two studies (Brown et al., 1996 and Nguyen et al., 1995).

The degree of regional aggregation in the models also affected the distribution of the gains. Important differences in the CGE estimates stemmed from whether sub-Saharan Africa was singled out or not. Agricultural reforms, and in particular the removal of subsidies, would lead to higher food prices, thus negatively affecting net food importing countries. In models with a high level of regional aggregation, this effect does not appear in the results, as losses are compensated for by the positive welfare gains of other countries in the region. Therefore, it would be misleading to claim that CGE simulations show that there are no losers from trade liberalization when the simulation entails a high level of regional aggregation. Yet overall, positive gains suggest that there is a margin for cross-country compensation, although in practice there is no reason to suppose that such compensation would occur.

A second factor that explains different CGE results is the different assumptions about market structure. Two approaches dominate. One approach assumes that products are differentiated both across firms and across countries. In this case, each firm has a certain degree of market power, so competition among firms is imperfect. Estimates of the degree of market power and scale economies are required in order to calibrate the model. Errors in the estimates of these parameters add to the degree of uncertainty in the results and affect their reliability. However, these models may provide a better approximation of reality than those based on perfect competition. An alternative approach is to assume that products within the same product category produced domestically are homogeneous, while products originating in different countries are imperfectly substitutable. This assumption is compatible with perfect competition; therefore, economies of scale do not need to be estimated. In contrast, this approach requires estimating the so-called Armington elasticities, i.e. trade substitution elasticities.

The third important element driving differences in results in the analysis of the impact of the Uruguay Round is the assumption about dynamics in the models. Some models hold capital stock fixed (static models) while others allow for capital accumulation in response to changes in investment. In general, models where capital stock changes with investment generate larger overall effects than those where capital is fixed. The reason is as follows: if trade liberalization results in higher savings, investments will increase. This, in turn, will add to capital and increase output. This process will take place over time. Therefore, the results portrayed in this case refer to a longer time

Table 5.2 CGE studies of the Uruguay Round

Publications	*Data/evaluation*	*Model structure*	*Sectors liberalized*	*Results*
Brown, Deardorff, Fox and Stern (1996)	Data and evaluation at 1990	▪ Michigan model ▪ 29 sectors (1 ag, 1 proc. food, 1 prim, 20 manuf., 6 services) ▪ 8 regions ▪ Perfect competition, CRS, Armington elasticities in ag, monopolistic competition and IRS in Manuf. ▪ Static	▪ Industrial tariff cut according to schedule. MFA not covered ▪ Agricultural tariffs including NTM-equivalents cut according to commitments ▪ Services: NTMs cut by 25 per cent	▪ GDP growth: US 0.9 per cent, EU 0.9 per cent, Japan 1.4 per cent, Australia and New Zealand 3.6 per cent, Mexico 2.8 per cent, Asian NICs 3.6 per cent, ROW 1 per cent
Francois, McDonald and Nordstrom (1996)	Data version 1992	▪ GTAP model ▪ 19 sectors ▪ 13 regions ▪ Model 1: CRS, perfect competition ▪ Model 2: IRS, monopolistic competition ▪ Saving-driven investment (i.e. dynamic model)	▪ Industrial Stariff cuts according to schedules, MFA quotas lifted ▪ Agricultural tariff cuts according to commitment, subsidies cut by 36 and 24 per cent in developed and developing countries respectively	▪ GDP growth: World 0.45 per cent (Model 1) and 0.9 per cent (Model 2), US 0.6 per cent, EU 0.5 per cent, Japan 0.4 per cent, Australia and New Zealand 0.9 per cent, Latin America 1.9 per cent, South-East Asia 1.8 per cent ▪ Decomposition of welfare effect: 10 agriculture, 50 textile and clothing, 40 other manufacturing ▪ Trade growth: increase by 6 per cent (Model 1), approximately 15 per cent (Model 2)
Goldin and van der Mensbrugghe (1996)	1985–93 data are used to validate the model. Projections are made for the period 1993–2002	▪ RUNS model ▪ 20 sectors (15 of which are agricultural sectors) ▪ 22 countries ▪ Perfect competition¨ ▪ Static	▪ Industrial tariffs cut according to schedules ▪ Agricultural reforms: tariffs including NTMs cut according to schedules. Subsidies cut by 36 per cent in OECD and 24 per cent in other countries	▪ GDP growth: US 0.1 per cent, EU 0.6 per cent, Japan 0.4 per cent, Australia and New Zealand 0.1 per cent, Mexico 0.5 per cent, Upper Income Asia 1.3 per cent ▪ Decomposition of welfare effect 85 per cent from agriculture

(Continued)

Table 5.2 (Continued)

Publications	*Data/evaluation*	*Model structure*	*Sectors liberalized*	*Results*
Hertel, Martin, Yanagishima and Dimaranan (1996)	1992 data, evaluated at 2005 Using data exogenous of regional growth of capital, population and technology, the world economy is estimated with and without the Uruguay Round policy change	▪ GTAP model ▪ 10 sectors ▪ 15 regions ▪ CRS, perfect competition, Armington trade elasticities	▪ Industrial and agricultural tariffs cut according to schedules. MFA quotas are lifted	▪ GDP growth: World 0.89 per cent, US and Canada 0.4 per cent, EU 0.7 per cent, Japan 1.04 per cent, Latin America NICs 3.8 per cent ▪ Trade growth: World 59 per cent, US and Canada 48 per cent, EU 42 per cent, Japan 22 per cent ▪ Decomposition of welfare effect: Agriculture 5 per cent, Industrial tariff 81 per cent, MFA 14 per cent
Harrison, Rutherford and Tarr (1995)	1992 data and evaluation	▪ GTAP model ▪ 22 sectors ▪ 24 regions ▪ Model 1: CRT, PC, Armington ▪ Model 2: IRT, monopolistic competition, intraregional, Armington-based trade ▪ Model 1 both static and dynamic	▪ Industrial and agricultural tariff cut according to schedule ▪ Export (domestic) subsidies cut by 36 (20) per cent and 24 (13) per cent in developed and developing countries respectively	▪ GDP growth: World 0.4 per cent (M1 static), 0.7 per cent (M1 dynamic), 0.42 per cent (M2 static); Model 1 regional results: US 0.4 per cent, EU 0.7 per cent, Japan 0.7 per cent, Lat. America 1.7 per cent, South-East Asia approx. 2.5 per cent ▪ Decomposition of welfare effect. Model 1 static: Agriculture 68 per cent, Industrial tariff 18 per cent, MFA 15 per cent; Model 1 dynamic: Agriculture 38 per cent, Industrial tariff 49 per cent, MFA 12 per cent; Model 2 static: Agriculture 61 per cent, Industrial tariff 23 per cent, MFA 17 per cent

horizon than in the case of static models. In static models, the adjustment process is not modelled and there is no clear indication of how long after the full implementation of a policy change it will take for the effects to be realized. It is commonly believed that the effects of a static model should be realized within five to ten years after full implementation of the policy change, as time is required for adjustments in employment to take place. When capital also needs to adjust, there is some convergence in thinking that the time required will be longer – within ten to 15 years.

Endnotes

1. This chapter reproduces and expands Piermartini and Teh (2006). We also refer the reader to Shoven and Whalley (1984), Wing (2004) and Robinson et al. (1999) for complementary readings.
2. See also Shoven and Whalley (1984) for a similar discursive approach.
3. See Kuiper and van Tongeren (2006) for a detailed discussion.
4. Zai (2008) addresses this problem by introducing the Melitz (2003) theoretical framework with firm heterogeneity and fixed exporting costs into a global CGE model.
5. For example, in the construction of SAMs for their archetype economies, Dervis et al. (1982) had to carry out reconciliation at two levels: (i) production accounts because the input–output tables were not consistent; (ii) the income and expenditure accounts. As described in their appendix A, altogether this involved ten steps. Reinert and Roland-Holst (1997) give an introduction to SAMs for CGE modelling.
6. For a detailed review and critical discussion of the assessment of the ongoing Doha Round we refer the reader to Piermartini and Teh (2006), section IV.B, and Bouët and Laborde Debucquet (2010).

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