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THE CONCEPT OF COMPUTABLE GENERAL EQUILIBRIUM MODELS

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ABSTRACT

This paper contributes to the existing literature on the general concept on use of the Computable general equilibrium (CGE) models of importance in developing processes. Computable general equilibrium (CGE) models are used widely in policy analysis, especially in developed-country academic settings and also for the purpose of sharing these lessons with potential users in developing countries. The range of issues on which CGE models have had an influence is quite wide, and includes structural adjustment policies, international trade, public finance, agriculture, income distribution, and energy and environmental policy. This paper describes how to build multi sector computable general equilibrium models for policy analysis. The article presents the social accounting matrix (SAM) that provides the conceptual framework linking together different components of the model and furnishes much of the data as well.

KEYWORDS: Concept, Computable General Equilibrium, Models

1. Introduction and Definition of CGE Models

The current literature on Computable general equilibrium (CGE) modelling and economic analyses based on CGE models is vast. It has developed from three quite distinct origins, each one associated with the contributions of a particular author. The three authors are Leif Johansen, Herbert Scarf and Dale W. Jorgenson. CGE model has now a fairly long history of development since the Johansen's multi-sectoral growth (MSG) model of 1960 for Norway (descends from Leif Johansen) and the model developed by the Cambridge Growth Project in the UK. Both models were pragmatic in flavour, and were dynamic (traced variables through time) (Leif, 1960)

There is no precise definition of a CGE model, but whenever this particular label is used the model in question tends to have certain specific features. A very basic one is that it is a multi-sector model based on real world data of one or several national economies. However, Computable General

Equilibrium (CGE) modelling is an attempt to use general equilibrium theory as an operational tool in empirically oriented analyses of resource allocation and income distribution issues in market economies. Sometimes this class of numerical economic models is called Applied General Equilibrium (AGE) models (Scarf, 1967)

As theoretical models of specific classes of economic problems, for instance international trade theory can be seen as applications of general equilibrium theory the label "computable" seems more appropriate than the label "applied. In other words, CGE models are a class of economic model that use actual economic data to estimate how an economy might react to changes in policy, technology or other external factors. General equilibrium theory is a formalization of the simple but fundamental observation that markets in real world economies are mutually interdependent.

Theoretical general equilibrium analyses have provided important insights about factors and mechanisms that determine relative prices and the allocation of resources within and between market economies. As witnessed by, for instance, Debreu (1959) general equilibrium theory has reached a very high level of rigor and elegance. However, most contributions to general equilibrium theory have focused on the allocation of private goods and privately owned resources. The prime exception is Mäler (1973) who, inspired by Ayres and Kneese (1969), extended the general equilibrium framework to encompass externalities and environmental resources with public goods characteristics. Thus, CGE is the application of the General Equilibrium theorem to analyse empirically the impact of various economy-wide policies

The purpose of this paper is to contribute to and facilitate the use of CGE models, making them accessible to a wider group of economists and to show how Social accounting Matrixes and computable general equilibrium models can be used to highlight and address issues related to tax policy, environment problems, trade policy, income distribution etc. The first part of the paper presents the introduction and definition of CGE model. The remainder of this paper is organized as follows: section 2 describes the uses of CGE models. Section 3 provides an overview of the structure of a CGE model, followed by description of the categories of CGE models in section 4. Section 5 briefly describes the computers, software and stages in CGE modelling, while section 6 is the concept of the Standard Social Accounting Matrix (SAM) use in a CGE model. Section 7 is the concluding remarks.

2. What are CGE Models Used/Good For?

The CGE model is still believed as the most powerful tools in analysing an economy-wide policy impact, i.e. the policy that is heavily determined by market or sectoral interdependence (Arrow, 2005). The CGE theorem formalized the fact that the market is interdependence, i.e. the change in supply and demand in a market affects supply and demand in the other markets. Walrasian general equilibrium prevails when supply and demand are equalized across all of the interconnected markets in the economy. CGE models are simulations that combine the abstract general equilibrium structure formalized by Arrow and Debreu with realistic economic data to solve numerically for the levels of supply, demand and price that support equilibrium across a specified set of markets. CGE models are a standard tool of empirical analysis, and are widely used to analyse the aggregate welfare and distributional impacts of policies whose effects may be transmitted through multiple markets, or contain menus of different tax, subsidy, quota or transfer instruments.

CGE models are now widely used for the analysis of trade policy, environmental problems, agriculture, migration, labour markets, public finance, taxation, income distribution, structural adjustment, industrial policy, Income Distribution and so on. Most authors in the field would probably claim that a CGE model is an appropriate substitute for an analytical general equilibrium model whenever the size and complexity, in terms of the number of households and production sectors or pre-existing taxes and other distortions, make such a model mathematically intractable. They would probably also claim that a CGE model is useful whenever the magnitude, and thus not only the sign, of the impact of changes in exogenous conditions on key economic variables are to be estimated.

CGE models obviously rest upon strong assumptions about optimizing behaviour, competitive markets, and flexible relative prices. In addition, lack of data usually prohibits econometric estimation of key supply and demand parameters. In view of this the validity and usefulness for policy evaluation of the results generated by CGE models might be, and often is, seriously questioned. However, there is no general answer to the question about what CGE models are good for. The usefulness of a carefully designed and implemented CGE model depends on what it is intended for and what the alternatives are.

Today there are many CGE models of different countries. One of the most well-known CGE models is global: the GTAP model of world trade. CGE models are useful to model the economies of countries for which time series data are scarce or not relevant (perhaps because of disturbances such as regime changes). Here, strong, reasonable, assumptions embedded in the model must replace historical evidence. Thus, developing economies are often analysed using CGE models, such as those based on the IFPRI template model. CGE models are useful whenever we wish to estimate the effect of changes in one part of the economy upon the rest. For example, a tax on flour might affect bread prices, the CPI, and hence perhaps wages and employment. They have been used widely to analyse trade policy. More recently, CGE has been a popular way to estimate the economic effects of measures to reduce greenhouse gas emissions.

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CGE Are Desiderata for Policy Models

It has been about forty years since the first applied or computable general equilibrium model was developed for Norway by Lief Johansen. Active work with these models started up in the 1970s, with continuing advances in theory, data, and computing power. Economists must provide policy analysis that is relevant, transparent, and timely. Their methods and models must meet acceptable standards of validation and credibility in policy debates is greatly enhanced when a variety of different approaches and models are applied, and there is a consensus about the results. Robustness is more important than elegance.

CGE models have now become part of the standard toolkit of economists, and recent advances in software have made them accessible to anyone with undergraduate training in economics. They are widely used in academic research and in policy analysis, whenever it is necessary to consider the empirical implications of simultaneous equilibrium in a number of markets. In policy analysis, they are useful whenever policy changes affect a large share of economic activity or when it is important to consider changes in the sectoral structure of output, trade, demand, employment and/or prices.

The CGE models used in policy work vary widely in size, complexity, and domain of applicability. But all are designed to analyse the links between policy choices and economic outcomes. The policymaker is more concerned about getting consensus results from different analytical tools than with polishing and sharpening any one particular tool. Given the overriding need for relevance and timeliness in policy debates, it is hardly surprising that much of the work developing and using CGE models for policy analysis takes place in government agencies or research institutes.

To be useful for policy analysis, economic models should have a number of desirable features: (1) Policy relevance: The models should link values of policy variables to economic outcomes of interest to policy makers and useful in policy debates. (2) Transparency: The links between policy variables and outcomes should be easy to trace and explain. (3) Timeliness: Policy models must be based on relevant data, which implies that they must be implemented with recent data if they are to be used in on-going policy debates. (4) Validation and estimation: Estimated model parameters and model behaviour need to be validated for the domain of application of the model. That is, the model must be determined to achieve accurate results for the domain of potential policy choices under consideration in the policy debate. (5) Diversity of approaches: Validating results from policy models is greatly strengthened by analysis using a variety of models and at different levels of aggregation. Such diversity tests the robustness of the results and the importance of assumptions made in the various approaches. (6) Model Design: The first two criteria argue strongly for using structural models. Reduced-form models typically do not incorporate explicit links between policy variables and economic outcomes. Or, if they do, the reduced-form structure of such models makes it difficult, if not impossible, to identify the underlying structural relations, and hence difficult to trace out the links between policy variables and outcomes. Quite simply, reduced-form models tend to be black boxes whose results are difficult to explain.

Trade Policy: We turn now to the first of several areas where CGE models have been used to affect policy. It is perhaps fitting to start with trade policy. Most of the effects surrounding trade policy, such as those captured in the Stolper-Samuelson Theorem, are general equilibrium effects. Not surprisingly, therefore, CGE models have been used extensively to analyse, and in some cases influence, trade policy. The models themselves have been surveyed elsewhere. Rather than review the experience with all the models applied to analysis throughout the negotiations.

The specification of international trade relations is an important aspect of all open-economy CGE models, but seems particularly important in environmental CGE models. The primary reason for this is that international relocation of economic activity is a key potential response to unilateral environmental policy measures. It is beyond the scope of this paper to discuss specification issues in any detail, but a few words should be said about the treatment of international trade in CGE models of open economies. The most widely used approach is to adopt the “Armington assumption” (Armington, 1969), which implies that goods with the same statistical classification but different countries of origin are treated as non-perfect substitutes. The application of this idea in CGE models amounts to defining domestically consumed goods as CES-aggregates of domestically produced and imported goods with the same statistical classification. As a result the import of a given type of goods depends on the relation between the prices of imported and domestically produced goods of that type.

Another widely adopted approach to the “overspecialization” problem in CGE models is to retain the assumption about exogenously given terms of trade, while relative-price dependent export supply functions are added. These functions usually are derived from constant elasticity of transformation (CET) functions defining the output of a given sector as a revenue-maximizing aggregate of goods for the domestic market and goods for foreign markets.

Environmental Problems: Most environmental CGE models are designed to elucidate various aspects of climate change or, in some cases, acid rain policies. To a large extent climate change and acid rain problems are caused by emissions from the combustion of fossil fuels. In both cases the environmental damage depends on the accumulated stock rather than the current flow of pollutants. Moreover, the stocks of the pollutants in question accumulate slowly so there is a considerable time lag, particularly in the case of climate change, between the emission of pollutants and the resulting impact on the environment. These observations have several implications for the design of CGE models intended for policy analysis.

One obvious implication is that the model should have an elaborated treatment of the supply and demand for energy. In particular it should have an elaborated treatment of the possibilities to substitute other forms of energy, or other factors of production, for fossil fuels. It should also have an explicit treatment of the relation between the use of fossil fuels and the emission of various pollutants.

Another implication for CGE modelling is related to the fact that the benefits of environmental policy measures are "non-economic", i.e., that they come in the form of better environmental quality. Thus, a CGE model intended for cost-benefit analyses of environmental policies should have an "environmental module", i.e., a module in which the environmental benefits of reduced pollution are quantified and converted into a monetary measure of environmental benefits. The environmental module could also include "feed-back" mechanisms, i.e. a sub-model of the impact of environmental improvement (or deterioration) on factor productivity and household utility of environmental services.

It is obvious that environmental CGE modelling is quite a demanding task, and that the modeller is bound to encounter a number of intricate modelling issues. However, there are indeed major environmental problems with a much wider geographic and economic scope, and calling for measures with potentially quite significant effects on the allocation of resources in the entire national, or even global, economy. "Acid rain", which is related to emissions of sulphur and nitrogen oxides, is one example. The prime example, however, is "climate change", which is related to emissions of carbon dioxide and other so-called greenhouse gases. In both of these cases there is a strong link between the use of energy and the emissions of pollutants. Moreover, in both cases very significant emission reductions are considered to be necessary in order to protect the environment.

Not surprisingly CGE models are widely used for evaluation of policies related to climate change and acid rain issues. CGE models focused on climate change or acid rain problems basically deal with externalities and policies aimed at internalizing externalities. In the following I will treat each category as a separate type of environmental CGE model. Lacking a better terminology, the first category will be called "Externality CGE Models", while the second will be called "Resource Management CGE Models". It should immediately be pointed out, however, that in terms of numbers the "Externality CGE Models" completely dominate the field of environmental CGE modelling

Agriculture, Migration and Labour Markets: A number of CGE models were developed to analyse the impact on Mexico of agricultural reform combined with trade reform, and the impact of these reforms on rural- urban migration within Mexico and migration to the U.S.18 Complemented by sector and commodity studies, these CGE models were especially influential. All were applied models in which the authors included institutional details of the labour markets in the two countries, trade policies, agricultural policies, and adequate disaggregation of the agricultural sectors to capture the effects of policy changes in both countries. A number of robust conclusions emerged:

Taxation and Public Finance: Harberger's (1964) seminal paper on the distortionary effects of taxation, which used an extremely simple general-equilibrium model for their calculation, set the stage for CGE models. Entry into the domain of public finance, and since public finance is the quintessential concern of policymakers; it would be natural for CGE models to enter into the policy arena through this field. The use of CGE models in tax reform has followed a similar route. Simple, stylized models have given way to larger, complex models that capture a myriad of effects. A particular area of tax policy that has attracted several CGE applications has been energy and environmental taxation. Energy and environmental issues became hot, both literally and figuratively, in the mid-1980s,

Structural Adjustment: The oil price shocks of the 1970s caused severe disruptions in developing countries, requiring them to adjust their exchange rate and other macroeconomic policies in response. Many of these countries had distorted structural policies, such as trade restrictions, as well. The realization that the more distorted the structure, the worse the impact of the shock (Balassa,1983), led some countries, with support of the World Bank and International Monetary Fund, to undertake structural adjustment programs aimed at restoring macroeconomic balance while reducing distortions in economic structure. In many ways, CGE models were ideally suited for evaluating such programs. They were able to portray the macroeconomic adjustments, such as a depreciation of the real exchange rate, alongside some of the microeconomic policies, such as reduction of trade barriers, in a consistent framework. Furthermore, inasmuch as the economic structure was changing, standard macro-econometric models, where parameters such as the import demand elasticity were based on historical relationships, were clearly inappropriate. They also can provide some simple and easy-to-communicate lessons about adjustment policy, such as the formula for calculating the real exchange rate depreciation required to adjust to a terms of trade shock (Devarajan et al., 1993).

Income Distribution: The earliest CGE models of developing countries were designed to examine issues of income distribution. Partly due to the complexity of these models, and partly because distributional issues left centre stage in the policy arena during the debt-crisis and adjustment era of the 1980s, these models had little influence on policy. Nevertheless, the power of CGE models to illuminate distributional questions continues to make them the dominant tool. Beginning in the early 1990s, a series of CGE models examined the distributional consequences of adjustment policies (Sahn, 1996; Bourguignon, et al., 1991).

The most recent development in this arena is the introduction of country-owned poverty reduction strategies to underpin foreign aid and concessional lending from multilateral agencies. Since these strategies have to show the effects of all government policies including macroeconomic and structural policies) on poverty, various CGE models are currently being used to develop these poverty reduction strategies. There is also a growing literature on incorporating household survey data into an economy wide framework provided by a CGE model. These micro simulation models appear to have potential for analysing the links between macro policy choices and shocks, and the distribution of income at the household level.

Summary of Policy Models of CGE: Issues, Design, and Implementation

1) Growth and structural change
    a. Investment/education
    b. Role of trade
    c. Productivity growth
    d. Agriculture
    e. Industrialization
2) Long-run development strategies
3) Macro shocks and structural adjustment
4) Income distribution
    a. Long run: poverty and growth
    b. Short run: impact of macro adjustment
5) Fiscal policy
    a. Tax system design and/or reform
    b. Government expenditure policy
6) Globalization
    a. Trade policy reform: GATT/WTO
    b. Regional trade agreements
    c. Domestic policy reforms and trade system
        i. Impact of OECD agricultural policies

3. Structure of a CGE Model

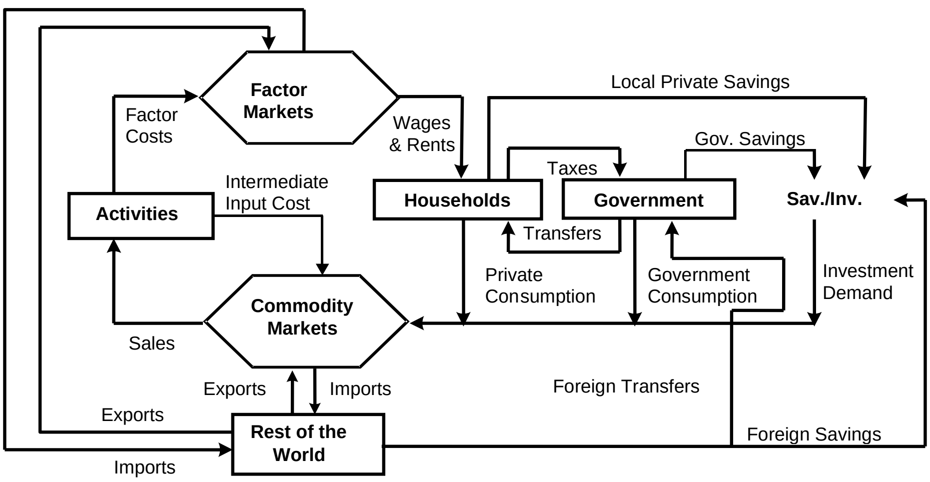
A CGE model consists of (a) equations describing model variables and (b) a database (usually very detailed) consistent with the model equations. The equations tend to be neo-classical in spirit, often assuming cost-minimizing behaviour by producers, average-cost pricing, and household demands based on optimizing behaviour. A CGE model database consists of, tables of transaction values, showing, for example, the value of coal used by the iron industry. Usually, the database is presented as an input or as a social accounting matrix. In either case, it covers the whole economy of a country (or even the whole world), and distinguishes a number of sectors, commodities, primary factors and perhaps types of households. A set of economic agents such as firms, households and government whose behaviour is to be analysed and a set of signals observed by these agents on which they make their economic decisions, such as market prices or government rationing quotas. Each agent has a set of endowments that can be used as production factors, such as labour and capital, and an economic account that records his revenues and expenditures; Behavioural rules for these agents that reflect their assumed motivation such as profit maximization for firms and utility maximization for consumers.

However, most CGE models conform only loosely to the theoretical equilibrium paradigm. For example, they may allow for non-market clearing, especially for labour (unemployment) or for commodities (inventories), imperfect competition (e.g., monopoly pricing), demands not influenced by price (e.g., government demands), a range of taxes and externalities, such as pollution.

In CGE models, elasticities are dimensionless parameters that capture behavioural response. For example, export demand elasticities specify by how much export volumes might fall if export prices went up. Other elasticities may belong to the Constant Elasticity of Substitution class. Amongst these are Armington elasticities, which show whether products of different countries are close substitutes, and elasticities measuring how easily inputs to production may be substituted for one another. Expenditure elasticities show how household demands respond to income changes.

In its mathematical form, the CGE model is a system of simultaneous, nonlinear equations. The model is square that is, the number of equations is equal to the number of variables. In this class of models, this is a necessary (but not a sufficient) condition for the existence of a unique solution. The equations in CGE model could be divided into blocks: prices, production and trade, institutions, and system constraints. New items (sets, parameters, and variables) are defined the first time that they appear in the equations.

Fig 1: Structure of Payment Flows in the Standard CGE model



4. Categories of CGE Models

In spite of these basic similarities there are also significant differences between individual CGE models, and a number of distinct categories of CGE models can be distinguished. While several classification alternatives can be envisaged the distinction between static and dynamic models seems to be appropriate for a broad classification of modelling approaches. However, there is a slight ambiguity with respect to the precise meaning of "dynamic" in this context. It is obvious that models in which forward looking behaviours on the part of households and firms is assumed and stock accumulation relations are explicitly included should be denoted "dynamic". But several static CGE models are used for multi-period analyses. Thus, solutions are obtained for each one of a number of consecutive years, and the solution for an individual year t is used to define the stock of capital and other relevant assets available in year t+1. As the model is static the agents are implicitly assumed have myopic expectations, i.e. to base resource allocation decisions entirely on current conditions.

In addition to the static-dynamic dimension it is useful to distinguish between single-country, multi-country and global models. Single-country models tend to be more detailed in terms of sectors and household types, and they are in general used for analyses of country-specific policy issues and proposals. Multi-country and global models, on the other hand, tend to have less sector detail and to be designed for analysis of proposed multi-lateral policies such as free-trade agreements. In the case of environmental CGE models the multi-country and global models in most cases are designed for analysis of trans-boundary pollution problems. Needless to say, the models within each one of these categories can differ in many ways. In particular they may differ with respect to the number of production sectors, the number of primary factors and the specification of international trade relations. On the issue of Comparative-Static and Dynamic CGE Models, many CGE models are comparative-static: they model the reactions of the economy at only one point in time. For policy analysis, results from such a model are often interpreted as showing the reaction of the economy in some future period to one or a few external shocks or policy changes. That is, the results show the difference (usually reported in percent change form) between two alternative future states (with and without the policy shock). The process of adjustment to the new equilibrium is not explicitly represented in such a model, although details of the closure (for example, whether capital stocks are allowed to adjust) lead modelers to distinguish between short-run and long-run equilibria.

By contrast, dynamic CGE models explicitly trace each variable through time -- often at annual intervals. These models are more realistic, but more challenging to construct and solve -- they require for instance that future changes are predicted for all exogenous variables, not just those affected by a possible policy change. The dynamic elements may arise from partial adjustment processes or from stock/flow accumulation relations: between capital stocks and investment, and between foreign debt and trade deficits.

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Recursive-dynamic CGE models are those which can be solved sequentially (one period at a time): they assume that behaviour depends only on current and past states of the economy. Alternatively, if agents' expectations depend on the future state of the economy, it becomes necessary to solve for all periods simultaneously, leading to full multi-period dynamic CGE models. Within the latter group dynamic stochastic general equilibrium models explicitly incorporate uncertainty about the future.

It useful to distinguish between stylized and applied CGE models. Stylized models can be described as putting numbers to theory, staying as close to the underlying analytic model as possible in order to isolate the empirical importance of a linkage that theory identifies as potentially important. Stylized models are not meant to be realistic since they are designed to focus on particular causal mechanisms that theory indicates are important, often ignoring other effects that might be important empirically. Applied models tend to be larger, seek to incorporate more descriptive detail of the economy being modelled, and encompass a wider spectrum of issues. Both stylized and applied models have been used in policy debates, but there are important differences in their uses. Stylized models tend to be narrowly-focused, but their simplicity can be a virtue in explaining results to policymakers. When pushed beyond their domain of applicability, however, they can be misused. While applied models, by design, incorporate more institutional and structural detail, their additional complexity may lead to problems in identifying the main causal mechanisms at work - the black box syndrome that critics argue is a common problem with simulation models. In short, to be useful for policy and avoid some of the pitfalls, modelers would do well to be guided by their own version of Occam.s Razor: Use the simplest model adequate to the task at hand.

5. Computers, Software and Stages in CGE Modelling

Early CGE models were often solved by a program custom-written for that particular model. Models were expensive to construct, and sometimes appeared as a 'black box' to outsiders. Today most CGE models are formulated and solved using one of the GEMPACK or GAMS software systems. General Equilibrium Modelling PACKage (GEMPACK), it is for general-purpose economic modelling software especially suitable for general and partial equilibrium models while, the Global Trade Analysis Project (GTAP) is based on GEMPACK. General Algebraic Modelling System (GAMS) is specifically designed for modelling optimization problems while, the Mathematical Programming System for General Equilibrium Analysis (MPSGE), which operates as a subsystem within GAMS. MPSGE is essentially a library of function which simplifies the modelling process and makes AGE modelling accessible to any economist who is interested in the application of these models. Use of such systems has lowered the cost of entry to CGE modelling; allowed model simulations to be independently replicated; and increased the transparency of the models

The General Algebraic Modelling System (GAMS) is a high-level modelling system for mathematical programming problems. It consists of a language compiler and a stable of integrated high-performance solvers. GAMS is tailored for complex, large-scale modelling applications, and allows you to build large maintainable models that can be adapted quickly to new situations. GAMS allows the user to concentrate on the modelling problem by making the setup simple. The system takes care of the time-consuming details of the specific machine and system software implementation (Lofgren et al. 2002)

Needless to say, the development of CGE modelling would not have been possible without the dramatic development of fast computers and suitable software. In the early days of CGE modelling lack of sufficient computer capacity put serious constraints on the size and specification of CGE models, and lack of user-friendly software made CGE modelling a field for specialists in numerical methods. Computer codes were model-specific and could not easily be used by other modellers. Moreover, sensitivity analyses to evaluate the uncertainty about parameter values were time-consuming.

A major change came with the introduction of GAMS (General Algebraic Modelling System, Brooke 1988), which allowed non-specialists in numerical methods to design and solve Walrasian models. More efficient computers made it possible to solve models with more sectors, and to take the first steps towards dynamic CGE modelling. It also made extensive sensitivity analysis feasible. As a result the use of CGE models expanded rapidly. The recent developments of GAMS/PATH (Ferris and Munson, 2000) have made it easy to solve dynamic models with a relatively large number of sectors at a low cost in terms of time and money.

The Stages of Modelling Involve:

i. Define Topic for Modelling
ii. Build Analytically Consistent Mathematical Model
iii. Collect Data
iv. Write A Code in Software
v. Benchmark Simulation, check for consistency
vi. Policy Experiment
vii. Policy Analysis

6. Social Accounting Matrices (SAM) and CGE

The starting point for the development of any CGE model is the construction of a micro-consistent benchmark dataset. Such a dataset must specify aggregate factor endowments, outputs by industry, factor usage by production activities, exports, imports, and the input–output structure of the economy. In addition, it may disaggregate by type of economic agent (households, firms, etc.) and detail the factor use, receipts and expenditures of public and external sectors of the economy. Since the pioneering work of Pyatt and Thorbecke (1976) the benchmark dataset needed for a CGE model has generally come to be specified in the form of a 'social accounting matrix' or SAM.

A social accounting matrix (SAM) is a comprehensive, economy wide data framework, typically representing the economy of a nation. It provides much of the data needed to implement a computable general equilibrium (CGE) model. More technically, a SAM is a square matrix in which each account is represented by a row and a column. Each cell shows the payment from the account of its column to the account of its row. Thus, the incomes of an account appear along its row and its expenditures along its column. The underlying principle of double-entry accounting requires that, for each account in the SAM, total revenue (row total) equals total expenditure (column total).

It is usually for a period of time (typically one year), accounts for the economy-wide circular flow of incomes and payments. It summarizes the structure of an economy, its internal and external links, and the roles of different actors and sectors. Its disaggregation is flexible and may depend on data availability and the purposes for which the SAM will be used. For example, if the SAM is to support analyses of poverty and inequality, it must include a detailed disaggregation of households and the factors, activities and commodities that are important in their income generation and consumption. The households may be classified on the basis of their income sources or other socioeconomic characteristics. A SAM brings disparate data (including input-output tables, household surveys, producer surveys, trade statistics, national accounts data, balance of payments statistics, and government budget information) into a unified framework.

The columns represent expenditures and the rows show receipts. These expenditures and receipts are made or received by factors, institutions, production activities, and the rest of the world (ROW). Institutions include households, companies, government and a combined capital account. The ijth entry in this table, which we will denote Tij indicates the receipt of account i originating from expenditure account j. Disaggregation within accounts to produce a more detailed SAM is possible, in which case some of the Tijs would become matrices. With such disaggregation note that T, becomes the economy's input–output table

In addition to providing a description of the structure of an economy, a SAM can be used for multiplier analysis. Calculations can be made to show how an exogenous change in expenditure, say from government or the ROW, would affect incomes in the various endogenous accounts if the structure of the SAM were unchanged in the process. In a closed economy with little excess capacity, or even in an open economy that is not a price-taker, such an exercise is of limited interest since we would expect general equilibrium price changes and a damping of multiplier effects due to factor scarcity. Still, in such a world the multiplier analysis can give some idea of the pressures created by exogenous shocks, and in a small open economy with excess capacity it might even provide reasonable predictions. In the case of a transition economy with a high level of unemployment, for example, it could plausibly be argued that SAM-based multiplier analysis might give a reasonable idea of the effects of trade or fiscal shocks. It is not hard to see how the SAM can be used for multiplier analysis. First, we must identify and segregate the exogenous accounts. Define a new SAM that excludes these exogenous accounts, and consolidate exogenous expenditure into the vector x. Normalise the SAM entries by the column expenditure totals to give a matrix of average expenditure propensities for the endogenous accounts, A. The vector of receipts or expenditures for the endogenous accounts, y, is then given by (Decaluwé et al. 1999).

The actual construction of a SAM is challenging. The raw materials take the form of the national accounts, input–output tables, household surveys, and a variety of other data. Concepts and definitions typically differ between these data sources.

Appendix below shows the basic SAM structure used in the CGE, an aggregated SAM with verbal explanations in the cells instead of numbers. With one exception, it has all of the features required for implementation with the standard CGE model. The exception is that in the standard SAM, taxes have to be paid to tax accounts, disaggregated by tax type, each of which forwards its revenues to the core government account. The tax types are divided into direct taxes (on domestic non-government institutions and factors), commodity sales taxes, import taxes, export taxes, activity taxes, and value-added taxes. Also note that, in the standard SAM, payments are not permitted in the blank cells of Appendix. Any original SAM that includes such payments should be re-structured before being implemented with the standard CGE model. In a real-world standard SAM, tax accounts are disaggregated, in addition it has multiple accounts for activities, commodities, factors, and domestic non-government institutions. In each category, the GAMS code can handle any desired disaggregation, including having just a single account. In any real-world application, the preferred disaggregation of the SAM and the CGE model depends on data availability and the purposes of the analysis. It is typically preferable to include relatively detailed treatment in areas of interest while keeping the database relatively aggregated in other areas. With regard to the structure of the standard SAM, a number of features are noteworthy.

Constructing the Prior

The initial task of building a SAM involves compiling data from various sources into a SAM framework. This information comes from national accounts, household budget and labour force surveys, foreign trade statistics, government budgets, balance of payments, and various other government publications. In other words, this information is drawn from a number of sources that may use (i) different disaggregation of sectors, production factors, and socio-economic household groups,

(ii) different years and/or base-year prices, and (iii) different data collection and compilation techniques. Consequently, the initial or prior SAM will inevitably include imbalances between row and column account totals. The development of a disaggregated microeconomic (Micro) SAM first requires the construction of an underlying macroeconomic (Macro) SAM that contains all economic control totals. The construction of a Macro SAM is centred on the national accounts and typically replicates the major national accounts values.

Account by account, this section first outlines the construction of the prior Macro SAM and explains how each Macro SAM entry is disaggregated to arrive at the prior Micro SAM. It should be noted that the prior Macro SAM is already balanced since it is drawn from consistent national accounting data. However, the prior Micro SAM is not balanced as it uses information from many data sources that are inevitably inconsistent.

7. Concluding Remarks

It has been about forty years since the first applied or computable general equilibrium model was developed for Norway by Lief Johansen. Active work with these models started up in the 1970s, with continuing advances in theory, data, and computing power. CGE models have now become part of the standard toolkit of economists, and recent advances in software have made them accessible to anyone with undergraduate and post graduate training in economics. They are widely used in academic research and in policy analysis, whenever it is necessary to consider the empirical implications of simultaneous equilibrium in a number of markets. In policy analysis, they are useful whenever policy changes affect a large share of economic activity or when it is important to consider changes in the sectoral structure of output, trade, demand, employment, and/or prices. The CGE models used in policy work vary widely in size, complexity, and domain of applicability, but all are designed to analyse the links between policy choices and economic outcomes. The questions driving the policy debate also must drive the models.

In the past thirty years, there has been a healthy and productive tension between policy applications of CGE models and developments in theory, econometrics, and data. Sometimes the models have been ahead of the theory, incorporating ad hoc specifications to capture what are considered to be empirically important effects, or to achieve realism in applied models. A good example is the work on structural adjustment models. In many cases, the response of the research community has been to advance the theory, develop new data sources, improve estimation methods, and develop new solvers to meet the needs of modellers. On the other side, theoretical developments in modelling household behaviours, dynamics, and the operation of markets are starting to show up in empirical models. With advances in software and computer capacity, the time gap between developing a new theory and implementing it in an empirical model is now quite short, so there is even more scope for productive collaboration between theorists, applied econometricians, and policy modellers. The numbers should get better, the policy debate will be better focused, and the result could be better policies.

CGE modeling has expanded very significantly, particularly during the 1990´s. Currently CGE modeling is both a field for specialized research, and an almost standard part of the toolbox of economists concerned with policy-oriented research. A major reason for the widespread use of CGE modeling probably is that a CGE model is an ideal bridge between economic theory and applied policy research. The "bridge" perspective, however, suggests that CGE modeling is a way of using rather than testing economic theory. Yet carefully designed and estimated CGE models have a lot to say about real world economies. CGE modelling has made significant progress in terms of the size and complexity of the models that can be solved. Yet complexity should never be an end in itself in CGE modeling. Much of the usefulness of a CGE model stems from its solid foundation in basic economic theory.

Finally, responsible economists, who want to be effective as economists, must provide policy analysis that is relevant, transparent, and timely. Their methods and models must meet acceptable standards of validation and also, credibility in policy debates is greatly enhanced when a variety of different approaches and models are applied, and there is a consensus about the results. Robustness is more important than elegance. The policymaker is more concerned about getting consensus results from different analytical tools than with polishing and sharpening any one particular tool. Given the overriding need for relevance and timeliness in policy debates, it is hardly surprising that much of the work developing and using CGE models for policy analysis takes place in government agencies or research institutes.

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Appendix: The Basic SAM Structure used in the CGE Model

		Expenditures								
		Activities	**Commodities**	**Factors**	**Households**	**Enterprises**	**Government**	**Savings - Investment**	**Rest of the World**	**Total**
Receipts	**Activities**		Marketed outputs		Home-consumed outputs					Activity income
	Commodities	Intermediate inputs	Transaction costs		Private consumption		Government consumption	Investment	Exports	Commodity Demand
	Factors	Value-added							Factor income from ROW	Factor income
	Households			Factor income to households	Inter-household transfers	Surplus to households	Transfers to households		Transfer to households from ROW	Household income
	Enterprises			Factor income to enterprises			Transfers to enterprises		Transfer to enterprise from ROW	Enterprise income
	Government	Producer taxes, value-added tax	Sales taxes, tariffs, export taxes	Factor income to government, factor taxes	Transfer to government direct	Surplus to government, direct enterprise taxes			Transfer to government from ROW	Government income
	Savings-Investment				Household savings	Enterprise savings	Government savings		Foreign savings	Savings
	Rest of the World		Imports	Factor income to ROW		Surplus to ROW	Government transfer to ROW			Foreign exchange outflow
	Total	Activity expenditures	Supply expenditures	Factor expenditures	Household expenditures	Enterprise expenditures	Government expenditures	Investment	Foreign exchange inflow	