

**GENERAL EQUILIBRIUM MODELLING IN SOUTH AFRICA: AN
OVERVIEW AND APPRAISAL**

By

Riaan Rossouw, Hons. B.Com. (Economics)

Thesis submitted for the degree

Magister of Commerce

in the

School of Economics, Risk Management and International Trade

at

North West University (Potchefstroom Campus)

Promoter: Mr. W.F. Krugell

Potchefstroom

November 2004

ACKNOWLEDGEMENTS

One of the things you learn when you are involved in any project is that no one does it alone, and one of the sweeter things is to let those who have been there for you know how much you appreciate them.

I would like to express my gratitude to Waldo Krugell for his guidance, supervision, patience, and mentorship throughout the evolution of my thesis. Working under his supervision was a confidence-building experience. He gave freely of his time and provided the strategic and knowledgeable support I required to complete this thesis.

I would also like to thank:

Professor Wim Naudé for his time, effort, and constructive feedback on my work.

The School of Economics, Risk Management and International Trade at North West University (Potchefstroom Campus) for providing me with the necessary facilities and infrastructure.

My fiancé, Stephanié van der Westhuizen, who always supported me and often lent a helping hand when I truly needed it. She has been my inspiration and my guiding light.

All the institutions that generously supplied the information that I required.

My parents, Marilyn and Nick, for their support not only during the completion of my thesis but over the duration of my academic career.

Finally, I would like to thank the Lord for giving me the knowledge, ability and strength, without which I would not have been able to achieve anything.

INDEX

INDEX	iii
LIST OF TABLES	vii
LIST OF FIGURES	viii
ABSTRACT	ix
OPSOMMING	x

CHAPTER 1

INTRODUCTION AND PROBLEM STATEMENT

1.1 INTRODUCTION	1
1.2 PROBLEM STATEMENT	5
1.3 MOTIVATION OF THE STUDY	5
1.4 OBJECTIVES	6
1.5 METHODOLOGY	6
1.6 OUTLINE OF THE STUDY	6

CHAPTER 2

REVIEW OF CGE MODELLING

2.1 INTRODUCTION	8
2.2 COMPUTABLE GENERAL EQUILIBRIUM MODELS	10
2.2.1 Analytical	11
2.2.1.1 The basic components: agents, rules, signals and institutional structure	12
2.2.1.2 Closure of the model	14
2.2.1.3 Treatment of time	15
2.2.1.4 Level of spatial detail	17
2.2.2 Functional	17
2.2.3 Numerical	21

2.3	COMMENTS ON CGE LITERATURE	22
2.3.1	Criticism of the functional structure of the models	23
2.3.1.1	Neoclassical Theory	23
2.3.1.2	Choice of Functional Forms	23
2.3.1.3	Choice of Parameters	24
2.3.1.4	Static CGE Model	24
2.3.1.5	Results' Sensitivity	25
2.3.2	Criticism of the numerical structure of the models	26
2.3.2.1	Quality of Data	26
2.3.2.2	Model Calibration	27
2.4	CONCLUDING REMARKS	27

CHAPTER 3

CLASSIFICATION AND EVALUATION FRAMEWORK

3.1	INTRODUCTION	29
3.2	DEFINING CGE	30
3.2.1	Narrowing the definition	30
3.3	CATEGORISING CGE MODELS	31
3.3.1	Mathematical structure and methodology	31
3.3.2	Policy focus	33
3.3.3	Analytic, stylised, and applied models	34
3.3.4	Theoretical structures	36
3.4	A CLASSIFICATION OF CGE MODELS	38
3.4.1	Macro and Walrasian CGE models	39
3.4.1.1	Walrasian CGE models	40
3.4.1.2	Macro CGE models	41
3.4.2	A classification of macro CGE models by closures	41

3.4.2.1	Sen's base model	42
3.4.2.2	The neoclassical closure	43
3.4.2.3	The neo-Keynesian or forced savings closure	44
3.4.2.4	The Keynesian and Johansen closure	44
3.4.2.5	The Kaleckian or structuralist closure	45
3.4.2.6	The loanable funds closure	46
3.4.2.7	The Pigou or real balances closure	47
3.4.3	SAM-based versus econometric approach	48
3.5	SUMMARY	50

CHAPTER 4 CGE MODELLING IN SOUTH AFRICA

4.1	INTRODUCTION	52
4.2	CGE MODELS FOR SOUTH AFRICA	53
4.2.1	WALRASIAN CGE MODELS FOR SOUTH AFRICA	56
4.2.1.1	Fiscal policy model	56
4.2.1.2	Environmental model	58
4.2.1.3	Trade liberalisation model	59
4.2.2	MACRO CGE MODELS FOR SOUTH AFRICA	60
4.2.2.1	Macroeconomic Forecasting Models	60
4.2.2.2	Policy Models used in different sectors	68
4.2.2.3	The Macroeconomic impact of the HIV / AIDs pandemic	73
4.3	CLASSIFICATION OF CGE MODELLING	76
4.4	SUMMARY	80

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

5.1	INTRODUCTION	83
5.2	SUMMARY	84
5.3	RECOMMENDATIONS	86
5.4	THE WAY FORWARD	88
5.4.1	The way forward in general	88
5.4.2	The way forward in South Africa	89
	APPENDIX	91
	LIST OF REFERENCES	92

LIST OF TABLES

CHAPTER 4 CGE MODELLING IN SOUTH AFRICA

Table 4.1: Surveyed CGE models for South Africa	53
Table 4.2: Classification of CGE Models for South Africa	76

LIST OF FIGURES

CHAPTER 3

CLASSIFICATION AND EVALUATION FRAMEWORK

Figure 3.1: Classification of CGE Modelling	38
--	-----------

GENERAL EQUILIBRIUM MODELLING IN SOUTH AFRICA: AN OVERVIEW AND APPRAISAL

Abstract

Since the 1990s, there has been a considerable increase in the use of computable general equilibrium (CGE) models in South Africa to study a variety of policy issues, specifically, development plans, agricultural programmes, tax policy and international trade. This study asks: What is the state of computable general equilibrium modelling in South Africa after more than a decade of growth and development and what is the way forward?

Answering the above questions is both relevant and significant for two reasons. The first is that such an appraisal can help pave the way forward for general equilibrium modelling in general. The advantages of CGE models for policy analyses, compared to traditional macroeconomic models, are now widely acknowledged. General equilibrium models allow for consistent comparative analysis of policy scenarios and they incorporate microeconomic mechanisms and institutional features within a consistent macroeconomic framework, and avoid the representation of behaviour in reduced form. This allows analysis of structural change under a variety of assumptions.

The second reason pertains specifically to policy challenges facing South Africa and the modelling thereof. The CGE models of the 1990s were used to examine the issues of the day such as macro stability and the opening up of the economy. An appraisal of the models will indicate their usefulness in policy formulation then and now. Currently the challenges have shifted to the labour market, environmental questions and sub-national issues and a timely overview may help to indicate the way forward for CGE modellers.

BEREKENBARE ALGEMENE EWEWIGSMODELLERING IN SUID- AFRIKA: 'n OORSIG EN WAARDERING

Opsomming

Sedert die 1990s, was daar 'n aanmerklike toename in die gebruik van berekenbare algemene ewewigsmodelle in Suid-Afrika om 'n wye verskeidenheid beleidskwessies te bestudeer, meer spesifiek, ontwikkelingsplanne, landbouprogramme, belastingbeleid en internasionale handel. Hierdie studie vra die vrae: Wat is die toestand van berekenbare algemene ewewigsmodellering in Suid-Afrika na meer as 'n dekade van groei en ontwikkeling en wat is die weg vorentoe?

Om die bogenoemde vrae te beantwoord is beide toepaslik en beduidend vir twee redes. Die eerste rede is dat so 'n waardering die weg vir algemene ewewigsmodellering in die algemeen kan help uitlê. Die voordele van algemene ewewigsmodelle vir beleidsontleding, in vergelyking met tradisionele makro-ekonomiese modelle, word nou wydverspreid erken. Algemene ewewigsmodelle laat konstante vergelykende analise van beleidscenarios toe en hulle inkorporeer mikro-ekonomiese meganismes en institusionele kenmerke binne 'n konstante makro-ekonomiese raamwerk en vermy die verteenwoordiging van gedrag in vereenvoudigde vorm. Dit laat die analise van strukturele verandering onder 'n verskeidenheid veronderstellings toe.

Die tweede rede het spesifiek te doen met beleidsuitdagings wat Suid-Afrika in die gesig staar en die modellering daarvan. Die algemene ewewigsmodelle van die 1990s is gebruik om die knelpunte van die dag te bestudeer, soos makro-stabiliteit en die oopmaak van die ekonomie. 'n Waardering van die modelle sal die nuttigheid daarvan vir beleidsformulering aandui dan en nou. Huidiglik het die uitdagings geskuif na die arbeidsmark, omgewings- en sub-nasionale-kwessies, en 'n tydige oorsig kan help om die pad voorentoe vir algemene ewewigsmodelleerders aan te dui.

CHAPTER 1

INTRODUCTION AND PROBLEM STATEMENT

1.1 INTRODUCTION

"General equilibrium (GE) modelling refers to an analytical approach where the economy is regarded as a complete system of interdependent components (different markets, industries, households, etc.) and all decisions are taken according to fully optimising behaviour" (Rumler, 1999:3). Economic shocks, which might have an effect on any one of these components, may produce repercussions throughout the whole system. The effects of such shocks can be assessed by measuring the repercussions that are triggered by shocking the system in various ways (Bannock, Baxter and Davis, 1998:173).

The unique characteristics of GE modelling draw from the Walrasian general economic equilibrium theory in which the economy is considered as a set of agents, interacting in several markets for an equal number of commodities under a given set of initial endowments and income distribution within which each agent labels individually his supply or demand behaviour (Rumler, 1999). Optimising own utility, profit or cost objectives does this. A set of excess supply functions that fulfil the Walras law, i.e., the global identity of incomes and expenditures, are produced by these decisions. Arrow and Debreu (1954) and others have proved that, under some general conditions, there exists a set of prices that bring supply and demand into equilibrium.

CGE models are called "computable" in that they produce numerical results to GE models. "This means that the coefficients and parameters (elasticities) of the model are estimated by making use of real world data" (Rumler, 1999:3). CGE models determine changes, at the same time, in quantities of goods supplied and demanded, and their prices, in an aggregated multi-sectoral and multi-agent setup and are used for,

amongst others, comparative static analysis, to simulate the effects of shocks to the economy and produce numerical results.

The development of CGE models has had a long tradition in empirical economics (Rumler, 1999:3). The 1970s were marked by developments of theoretical propositions on the existence, uniqueness, optimality and stability of solutions to GE models, but the first CGE model credited to Johansen already dates back to 1960¹. Since then CGE models have been used as a powerful technique for quantitative analysis of a great variety of questions. Some of these include analysing the effects on industries, regions, the labour market, income and welfare.

Since Johansen, CGE models have evolved out of and have combined different modelling traditions. Johansen's Multisectoral Growth (MSG) model, which was built for Norway, was a combination of the dynamic input-output model with macroeconomic production and consumption functions, thus expanding the input-output model with relative price-driven substitution potential. This pioneering work sparked the development of many models both in Norway (see, for example, Longva, Lorentsen and Olsen, 1985), and elsewhere (see, for example, the ORANI model in Australia, Dixon *et al.*, 1982). CGE models are nowadays regularly and widely used to evaluate the effects of economic policy options and external shocks (Kehoe and Kehoe, 1994:2). This reputation stems from practical and theoretical needs in economics for numerical simulations, not least because of the fact that partial equilibrium analyses are unsuitable when policies and shocks have significant feedback effects (Bandara, 1991:5).

Of late dynamic CGE models have also been put forth, enabling researchers to address also multi-period (dynamic) problems by means of numerical GE analysis. Facilitated by the explicit representation of markets, CGE models have also been extended beyond the original Walrasian framework to model market imperfections and other economic

¹ Dixon and Parmenter (1996) consider the Johansen model with its 20 cost-minimising industries and one utility-maximising household sector the first true CGE model. The input-output models of Leontief and others in the 1930s can be regarded as vital forerunners of CGE models.

mechanisms that deviate from the original GE standard. As a result of this, some authors used the term "generalised equilibrium modelling" (Nesbitt, 1984) or "general equilibrium programming" (Zalai, 1982) to underline the flexibility of the CGE models.

In South Africa, Naudé and Brixen (1993a; 1993b) were the first to use the CGE approach to analyse policy questions. Their model was extended by the Industrial Development Corporation (IDC) into IDCGEM (see Joubert *et al.*, 1994; Horridge *et al.*, 1995,1996). The IDCGEM is the largest and most frequently used CGE model in South Africa (Burrows, 1995), and has been used, amongst other applications, to inform South Africa's GATT negotiations.

Since the early efforts of Naudé and Brixen, economy-wide policy analysis in South Africa has seen a considerable increase in the use of CGE models and have significantly contributed to the local policy making process. A dynamic one sector CGE model of the South African economy was developed by Gelb *et al.* (1992) and based on an aggregate social accounting matrix (SAM) for the year 1990. This model was used to evaluate the impact of a negative external shock to the economy, as well as a programme of government stimuli. Moreover, a rigid, albeit multisectoral, modelling template was developed by Naudé and Brixen (1993) at the World Bank to examine the impact of an increase in government expenditure, export demand, world price, and a lowering of import tariffs under various sets of closure rules. Tarp and Brixen (1996) applied the IMF financial programming model and the World Bank's revised minimum standard model to the South African economy and simulated exchange rate devaluations, external borrowing by the government, and higher international reserves. The modelling frameworks of these models were based on a single sector accounting framework that could, fundamentally, be represented in a SAM format.

Later, several large-scale multisectoral CGE models of the South African economy were developed by the IDC (Coetzee *et al.*, 1997), the World Bank/OECD (van der Mensbrugghe, 1995; Devarajan and van der Mensbrugghe, 2000), and the Development Bank of Southern Africa

(DBSA) (Gibson and van Seventer, 1996a), which were used in numerous applications including: investigations into trade liberalisation; green trade restrictions; currency devaluations; and government expenditure and restructuring (see for example Cameron *et al.*, 1994; Gibson and van Seventer, 1996b, 1997a, 1997b). Yet, the use of CGE models in South Africa have declined and the most recent applications of CGE analysis have been developed outside the country and mainly by the World Bank (see Arndt and Lewis, 2000, and Lewis, 2001). In the past two to three years there has also been increased local interest. At the bi-annual conference of the Economic Society of South Africa in 2003, nine papers on CGE modelling were presented. These renewed efforts are to a large extent being lead by academics from Pretoria University (see De Wet and Van Heerden, 2002; 2003; Kearney, 2002; 2003).

Thus, in the last 10 to 15 years, a number of practically useful CGE models have been developed to study a wide range of policy areas in which simpler, partial equilibrium tools would not be satisfactory. GE models have been used to study a variety of policy issues, including tax policies, development plans, agricultural programmes, international trade, energy and environmental policies and so on. A range of mathematical formulations and model solution techniques has been used in these modelling experiences. The practice of model building itself has become increasingly systematised, as reflected for instance, in the increasing use of standard computer packages such as GAMS (General Algebraic Modelling System) and GEMPACK (General Equilibrium Modelling Software).

CGE models have been used to inform policy in a number of countries and may play a significant role in future policy formulation in South Africa. In an attempt to improve the capacity to undertake economy-wide policy analysis using CGE models in South Africa, it is important to look back at what has been achieved over the past years to consolidate a base for future modelling efforts.

1.2 PROBLEM STATEMENT

Since the 1990s, there has been a considerable increase in the use of computable general equilibrium models in South Africa to study a variety of policy issues, specifically, development plans, agricultural programmes, tax policy and international trade. Now, one might ask: What is the state of computable general equilibrium modelling in South Africa after more than a decade of growth and development and what is the way forward?

1.3 MOTIVATION OF THE STUDY

Answering the above-mentioned questions is both relevant and significant for two reasons. The first is that such an appraisal can help pave the way forward for general equilibrium modelling in general. The advantages of CGE models for policy analyses, compared to traditional macro-economic models, are now widely acknowledged. General equilibrium models allow for consistent comparative analysis of policy scenarios by standardising their outcome around the concept of an equilibrium point fulfilling the same consistency criteria. In addition, the CGE models incorporate microeconomic mechanisms and institutional features within a consistent macroeconomic framework, and avoid the representation of behaviour in reduced form. This allows analysis of structural change under a variety of assumptions.

The second reason pertains specifically to policy challenges facing South Africa and the modelling thereof. The CGE models of the 1990s were used to examine the issues of the day such as macro stability and the opening up of the economy. An appraisal of the models will indicate their usefulness in policy formulation then and now. Currently the challenges have shifted to the labour market, environmental questions and sub-national issues and a timely overview may help to indicate the way forward for CGE modellers.

1.4 OBJECTIVES

- To provide an overview of CGE modelling, the structure of the models, shocks used and typical results from the literature.
- To use the overview to draw up a classification and evaluation framework for CGE models.
- To classify and evaluate the CGE models which have been used in the South African context. The focus will be specifically on the models derived from the IDCGEM framework since it is the most widely used model in South Africa.
- To appraise the CGE modelling efforts of the past fifteen years and indicate the way forward for CGE modelling in South Africa.

1.5 METHODOLOGY

The study will comprise of a literature study of CGE modelling in South Africa, analysing, classifying and appraising earlier work. To my knowledge, this thesis represents the first attempt to give an overview and appraisal of CGE modelling in the South African context.

1.6 OUTLINE OF THE STUDY

In chapter 1: Introduction, problem statement, and motivation.

In chapter 2: Review of CGE modelling.

In chapter 3: Classification and evaluation framework.

In chapter 4: CGE modelling in South Africa.

In chapter 5: Conclusion, recommendations, and the way forward.

The study is organised as follows: Chapter 2 gives a review of CGE modelling by looking at CGE models, their structure, shocks used and typical results from the literature. This will then be used to draw up a classification and evaluation framework for CGE models in chapter 3. In

Chapter 2, a framework of the types of information embodied in a CGE model, namely analytical, functional and numerical, is given, as well as comments on CGE literature.

Chapter 3 gives a definition and classification of CGE modelling, based on the historical development of empirical CGE analysis, the specification of different models and the determination of parameters, in order to draw up a classification and evaluation framework for CGE models.

In chapter 4 the classification and evaluation framework drawn up in chapter 3 is used to classify and evaluate the CGE models that have been used in the South African context. The focus is specifically on the models derived from the IDCGEM framework since it is the most widely used model in South Africa, but other methodologies are also briefly reviewed.

Chapter 5 concludes this study and reviews the main recommendations made. Further research possibilities are also presented.

CHAPTER 2

REVIEW OF CGE MODELLING

2.1 INTRODUCTION

Computable general equilibrium models have become workhorses for policy analysis since they are particularly suited for answering “what if” questions: What if productivity in agriculture increased, what if foreign demand for exports fall, what if emissions are taxed? Policymakers are typically interested in the direct and indirect effects of specific policy measures, but often these effects are studied only in partial setting. The CGE models have the advantage that the possible effects of specific policy measures can be examined without the excessive simplification and aggregation of partial equilibrium analysis.

CGE analysis is built on the idea that events in one sector of the economy will have flow-on impacts on the other economic sectors. Sequentially, the impacts on these other sectors may have noticeable feedback effects on the original sector, thus capturing the impacts of a policy change or specific event on all parts of the economy, by integrating feedback from all those, while recognising economy-wide constraints. CGE models enable the modeller to take into account general equilibrium effects and to study the interaction of different measures. Furthermore, a CGE modelling framework explains the complexity of micro-macro interrelationships with more accuracy (Clark, Dent and Watts, 2004).

While the art of CGE modelling used to be a field for a small group of specialists, the development of modern information technology (IT) and suitable software has made this particular tool of economic analysis accessible to a wide group of economists. In particular, GEMPACK and GAMS have provided the non-specialist with powerful tools both for programming and for obtaining numerical solutions to CGE models.

Furthermore, the organisation of national accounting data in the form of SAMs has made the construction of the empirical basis of CGE models a feasible task.

From this computational base, various models have been built and applied to address a variety of policy issues. Each model has its own advantages as well as limitations. During the last decade or so, there has been an increase of general equilibrium models developed for developing as well as developed countries (Iqbal and Siddiqui, 2001). The first serious attempt to use a large CGE model to study a real economy was that of Johansen (1960). For several years following, CGE models did not receive much attention. Then, Shoven and Whalley (1972), Whalley (1975, 1977), Shoven (1976), and Miller and Spencer (1977), produced among the earliest policy-oriented CGE studies. Subsequently, the number of CGE models of national economies exploded.

"Despite their popularity, CGE models are frequently criticised for resting on weak empirical foundations, particularly for estimates of behavioural parameters" (Shoven and Whalley, 1992; McKittrick, 1998). The problem is not confined to CGE models, but has been recognised for complex simulation models in general (Schmalensee *et al.*, 1998). Therefore it is necessary to also focus on the current shortcomings of CGE modelling to identify and one day eliminate these criticisms.

This chapter gives a review of CGE modelling by looking at CGE models, the structure of the models, shocks used and typical results from the literature. This will be used to draw up a classification and evaluation framework for CGE models in the next chapter. The plan of the chapter is as follows. Following the introduction, Section 2 gives a framework of the types of information embodied in a CGE model, namely analytical, functional and numerical. Comments on CGE literature are given in Section 3 and finally, in section 4 some concluding remarks are presented.

2.2 COMPUTABLE GENERAL EQUILIBRIUM MODELS

General equilibrium refers to the study of models where equilibrium is obtained in more than one market simultaneously. Theoretical general equilibrium models (developed by Walras (1874) and Edgeworth (1881) and formalised by Arrow and Debreu (1954)) occupy an illustrious place in economic theory. However, whereas the focus of general equilibrium theory has been to prove the existence and uniqueness of equilibrium, CGE models have the objective of turning these abstract models into a practical tool for policy analysis (Bandara, 1991; Decaluwé and Martens, 1988).

A CGE model works by simulating the interaction of various economic actors across markets. Optimising behaviour of individual actors is assumed and is incorporated into equations describing their behaviour, which essentially describe various first-order conditions for profit and utility maximisation. The CGE framework requires a complete specification of both the supply and demand sides of all markets, including all the nominal magnitudes in the circular flow. The models, which are structural in spirit, capture market mechanisms explicitly. Neoclassical general equilibrium theory provides the analytical underpinnings for this. The body of mainstream neoclassical theory, with its systematic accumulation of useful taxonomies and formal analytical results, provides a powerful framework of analysis.

Perhaps a way to better understand CGE models is to contrast it to the more familiar approach of partial equilibrium (PE) modelling. PE is a loosely defined term in the sense that it refers to an incomplete system where various *ceteris paribus* assumptions are (implicitly or explicitly) in place. PE models, which are driven by reduced-form elasticities, tend to lack a clear economic structure. Moreover, because they are incomplete systems, PE models cannot account for the interaction between the sector or sectors under consideration and the rest of the economy. In contrast to these disadvantages are simplicity and the fact that the reduced-form specification of PE models makes econometric estimation feasible. When a sector is sufficiently small for any interaction with the

rest of the economy to be ignored, PE models are suited to analysing shocks that are specific to the given sector. Where these conditions do not hold, GE methods are likely to provide a better understanding of the implications of policy changes.

Robinson (1989) states that in trying to understand CGE models, it is useful to establish a standard approach to describing the features of a general equilibrium model.

In this chapter the approach is to examine CGE models by looking at the three types of information that they embody: analytical, functional, and numerical. The analytical structure is the background theoretical material, which identifies the variables of interest and posits their causal relations. The functional structure of the model is the mathematical representation of the analytical material and consists of the algebraic equations, which make up the actual model. The numerical structure consists of the signs and magnitudes of the coefficients in the equations which form the functional structure. First, the analytical structure is considered.

2.2.1 Analytical

CGE models simulate the functioning of an economy by explicitly capturing the behaviour of the various agents (households, firms, government, rest of the world), the institutional framework (fiscal system and transfer mechanisms), and the market clearing processes (price and quantity). As a result, they can be considered "structural" as opposed to "reduced form" models.

"The structure of CGE models is Walrasian in spirit, stressing interaction among economic agents and the workings of market clearing processes. At the same time, these models can formally incorporate rigidities and distortions that are particularly strong in developing economies" (Robinson, 1989). The treatment of foreign trade, for example, can substantially differ from a standard neoclassical story through the

introduction of various foreign exchange rationing schemes or through quantitative import restrictions.

According to Ginsburgh and Robinson (1984), a general equilibrium model can be usefully described in terms of a number of components.

2.2.1.1 The basic components: agents, rules, signals and institutional structure¹

First, it is important to specify the economic actors or agents whose behaviour is to be analysed. A simple Walrasian model includes only producers and households. Most CGE models add other actors or additional institutions in the SAM framework, such as government and the 'rest of the world'. Second, behaviour rules must be specified for these actors. Thus, producers are typically assumed to maximise profits subject to technological constraints and households to maximise utility subject to income constraints. Third, agents decide according to signals they observe. In a Walrasian model prices are the only signals agents need to know. Fourth, one must specify the institutional structure of the economy, i.e. the "rules of the game" according to which agents interact. When the assumption is made that perfect competition implies that each agent is a price taker and that prices are flexible – markets exist and work perfectly.

A close connection exists between the specifications of the institutional structure and of the signals that agents observe and react to. For example, market equilibrium in a competitive model is defined as a set of prices and associated quantities such that excess demand on all markets is zero (Robinson, 1989:907). In a model with some fixed prices, agents will be subject to rationing and one must specify their behaviour in this situation. This might include the rationing rules and resulting spillover effects (Robinson, 1989).

¹ This discussion draws on Robinson (1989:907).

With the specification of the agents, their motivation, and the institutional constraints under which they interact, a general equilibrium model is still not completely determined. So-called "equilibrium conditions" also have to be defined. These are "system constraints" that must be satisfied, but that are not taken into account by any agent in making his decisions. Formally, equilibrium can be defined as "a set of signals such that the resulting decisions of all agents jointly satisfy the system constraints" (Ginsburgh and Waelbroeck, 1981). The signals represent the variables of the model that are in equilibrium. For example, market equilibrium in a competitive model is defined as a set of prices and associated quantities such that all excess demands are zero. In a market economy, prices are the equilibrating variables that vary to achieve market clearing.

A model's fundamental property lies in the definition of equilibrium conditions. The specification of variables in equilibrium and of system constraints that characterise equilibrium can be seen as a simplifying device that provides a way to describe the results of the working of an actual economy. For example, instead of specifying prices as variables that are in equilibrium to achieve market clearing, one could instead try to model price determination explicitly, specifying "disequilibrium" price adjustment rules to describe how prices change over time. Such a specification is theoretically very difficult to implement and completely unnecessary if one is willing to accept the market-clearing system constraints under flexible prices as a reasonable description of the final result of such a process within the time period described by the model (Robinson, 1989).

Times exist, however, when certain market-clearing assumptions are not reasonable. For example, in the CGE models of developed countries it is usually assumed that capital is mobile across sectors and is allocated in order to compare sectoral rental rates – an equilibrium condition that is consistent with an assumption of perfect capital markets. Such a specification obviates the need to describe exactly how the capital market functions – modellers are only interested in the result. The assumption of sectoral capital mobility in models of developing countries

is, however, rarely if ever reasonable. Instead, modellers have tended to assume that sectoral capital stocks are fixed within a period and, since sectoral rental rates are not equal across sectors, they have had to specify explicitly how the sectoral allocation of investment is determined from period to period (Bandara, 1991).

Once the basic components are set out, CGE models should also be described in terms of closure, treatment of time and level of spatial detail.

2.2.1.2 Closure of the model

CGE models usually have more variables than equations, which means that the user must specify the values of some variables. This set of user-specified exogenous variables is referred to as the model's closure (Naudé and Brixen, 1993).

Besides being used as a mathematical tool to help solve the model, the closure serves three fundamental purposes. First, the closure specifies some variables as exogenous to reflect various assumptions regarding the way economic agents behave, as well as any economy-wide constraints, for example, the government budget deficit, capital formation, wages, foreign currency prices, and so on. These constraints reflect the opportunity cost of scarce resources. The types of constraints applied in a simulation usually depend on whether the user is targeting the short run or long run² impacts of the item being studied. Secondly, the closure helps determine the run of the model. As a simple example, while above we have assumed endowments are constant and factor prices adjust to maintain labour market equilibrium, we could have taken a 'Keynesian' approach and fixed the nominal wage of some or all factors. In this case changes in the level of unemployment would become the mechanism by which equilibrium is maintained. Selecting different closures can have a significant impact on the model results, and the

² In CGE modelling, the "short run" is taken to represent a period of approximately one to two years, while the "long run" represents a period of approximately eight to ten years (Dixon and Parmenter, 1996).

selection of a particular closure often depends on the 'world view' that the modeller holds. Also, many models do not maintain the assumption of perfect competition in all markets. Other closures are possible and have been discussed at length elsewhere (see Dewatripont and Michel, 1987). Thirdly, a key part of closure is the setting or specification of the shocks the user wishes to apply to particular variables, and these shocks are derived from the topic of the study – for example, the question "What would be the effect on the economy of an X% tariff reduction on commodity Y?" would be implemented via a negative shock to the relevant tariff variable in the model (Dixon and Parmenter, 1996).

Thus it is clear that there are various types of CGE models and one way in which they can be distinguished further is according to their treatment of time.

2.2.1.3 Treatment of time

Some CGE models run static simulations from a projected future equilibrium. A comparative static (CS) model, for example, compares the economy at two distinct points in time, without modelling any explicit time periods or time path. Therefore the model is essentially timeless, comparing some hypothetical future scenario with its initial solution. Typically, the two states compared are the state of the economy with a given policy change and the state of the economy without the policy change. Consequently, this method of analysis does not provide any details of the adjustment path of the economy between the two points in time. A broad timeframe for these simulations, e.g. short run or long run, is specified by the closure (Ginsburgh and Keyzer, 1997). A time element can be introduced by solving the model sequentially, updating the capital stock to simulate investment and depreciation, the labour stock to simulate population growth, and productivity parameters to simulate advances in technology. Such models are known as recursive dynamic models.

These models perform year-to-year simulations with several types of inter-temporal links rather than calculating just a snapshot of the

economy before and after the policy implementation (Dixon and Parmenter, 1996). After the equilibrium solution is found for a given period, the between-period part of the model updates all the exogenous variables entering the static part of the model.

This operation is done using:

- (1) the equilibrium values of the foregone period, such as the amount of investment by sector that is added to existing capital to yield new capital stocks;
- (2) government policy decisions, such as a new level of tariffs or public investment;
- (3) simple exogenously specified trends, such as the growth of the population; and
- (4) pure exogenous variables, such as world prices.

The model can then find a solution for a new period of the basis on the new set of exogenous data. Therefore, these models are able to provide the user with information on the adjustment path resulting from any policy shock.

Truly dynamic models attempt to explicitly model intertemporal behaviour. This substantially increases the computational complexity.

For some policy simulations, understanding the adjustment path is considered as important to the user as the final outcome of the policy shock. In such cases, the results obtained from a recursive dynamic model are more informative and detailed than those obtained from a comparative static model. However, a recursive dynamic model is more complex than its comparative static counterpart, therefore more time and effort is usually required to design and interpret simulations from the recursive dynamic model.

A final analytical area in which CGE models can be distinguished is according to their level of spatial detail.

2.2.1.4 Level of spatial detail

A CGE model could, for example, be a national or multi-region model. The level of disaggregation generally depends on user preference and the availability of suitable input-output data.

Within the category of multi-region CGE models, a further distinction can be drawn as to how each region is modelled (Shoven and Whalley, 1984). One method is to use a 'tops-down' procedure that allocates the aggregate national results proportionally across regions according to known regional economic statistics, such as employment by industry. A major disadvantage of this approach is that it assumes that the cost and sales structures for a given industry, in each region, is the same as the national industry structure. On the other hand, providing the input-output data is available, each region can be modelled according to a 'bottoms-up' procedure. Under this procedure each region is modelled as a mini-economy with government budget and intra-region, inter-region and international trade flows separately specified. The major advantage of this procedure when using a multi-region model, as opposed to the 'tops-down' procedure, is that each region has separately specified supply constraints. Therefore, the 'bottoms-up' procedure, as opposed to the 'tops-down' procedure, is ideally suited to determining the impact of region-specific economic shocks (Shoven and Whalley, 1984).

CGE models are therefore basically simulation models, designed to investigate the impact of policies that work through the market system, such as taxes, tariffs or subsidy changes, or to analyse the impact of direct government intervention in the economy, such as the profile and composition of a public investment program, pricing policies or import restrictions. Next, the models are characterised in terms of functional structure.

2.2.2 Functional

CGE models are essentially numerical models based on general equilibrium theory, which are put into practice in the form of a computer

programme. From the perspective of the functional information embodied in a CGE model, its basic structure can be described as follows (see Gilbert and Wahl, 2000:3). Take a global economy consisting of M regions indexed by r . Let V^r be a vector (length F) of factor endowments in each region r , and P^r be a vector (length N) of prices in each region r . The GNP functions for each region can then be defined as $G^r(V^r, Y^r) = \max\{P^r \cdot V^r : P^r\}$, and similarly the expenditure functions as $E^r(P^r, U^r) = \min\{P^r \cdot D^r : U^r\}$, where U^r is aggregate utility in region r . The aggregate budget constraints are then:

$$S^r(P^r, V^r, U^r) = G^r(P^r, V^r) - E^r(P^r, U^r) = 0 \quad r = 1, \dots, M \quad (1)$$

From the first order conditions to the GNP maximisation problem one obtains sectoral supply functions by Hotelling's lemma, and Hicksian demand functions follow similarly from the derivative properties of the expenditure function, hence:

$$S_i^r(P^r, V^r, U^r) = D_i^r(P^r, U^r) - Y_i^r(P^r, V^r) = 0 \quad i = 1, \dots, N; r = 1, \dots, M \quad (2)$$

define Hicksian net exports. With trade there can be only one price vector, which is denoted P . International equilibrium then requires:

$$\sum_{r=1}^M S_i^r(P^r, V^r, U^r) = 0 \quad i = 1, \dots, N \quad (3)$$

By Walras' law these equilibrium conditions are not independent, and any one of them can be dropped. Hence, one element of P (say P_1) must be declared a numéraire price. The solution to the system of equations defined by (1) to (3) then yields a relative price vector, aggregate utility levels, and net exports. One can subsequently derive factor prices from the GNP function:

$$W_j^r = W_j^r(P, V^r) \quad j = 1, \dots, F; r = 1, \dots, M \quad (4)$$

Finally, since each sector is a price-taker in factor markets, from the first-order conditions of sectoral cost minimisation $C_i^r(W^r, Y_i^r) = \min\{W^r \cdot X^r : Y_i^r\}$ one obtains factor demands:

$$X_{ij}^r = X_{ij}^r(W, Y_i^r) \quad i = 1, \dots, N; j = 1, \dots, F; r = 1, \dots, M \quad (5)$$

In this simple model there are $M+MN+N+2MF+MFN-1$ variables, but we have only $M+MN+N+MF+MFN-1$ independent equations. In a neoclassical model the V^r are declared exogenous, enabling the system to be solved.

While the framework described here is very simple, the important features of CGE models discussed above are clearly illustrated. First, the utility maximisation conditions and the profit maximisation conditions underlying the expenditure function and the cost and GNP functions respectively, clearly shows that optimising behaviour is explicitly built into the model. Second, as reflected by the conditions underlying the GNP and expenditure functions, economy-wide constraints are enforced. Finally, it can be seen how such a closed system explicitly captures the relationships between sectors.

Within the above framework specific functional forms must be employed to define the substitution relationships of a CGE model (most commonly CES or Cobb-Douglas functions in value-added and Armington, Leontief in intermediate use, and Stone-Geary, Cobb-Douglas or CRESH in household demand – even though other functional forms exist and are used). After deciding on which functional forms will be implemented, the required free parameters (e.g., elasticities of substitution for CES production functions, income elasticities of demand and the Frisch parameter for Stone-Geary utility functions) are determined either by econometric estimation or literature searches. Through a process called calibration, the assumption is made that profit and utility maximising conditions will hold in the base year allowing the remaining parameters to be determined from the base data (Gilbert and Wahl, 2000).

The typical applied model retains the basic framework described by equations (1)-(5) despite adding some complexity. In CGE models of a single economy, prices are given exogenously, or are based on partial rest-of-the-world demand functions. Additional classic modifications comprise the final demands distinguished between households, government, trade and capital creation and the introduction of intermediate inputs in production. It is also common for most models to integrate imperfect substitution between foreign and domestic goods, and between alternative sources of imports (if multi-regional).³ Since these models are designed for policy analysis by counterfactual simulation, they will also incorporate a variety of distortions. Of the most common distortions will be in the form of taxes on various activities, and rigidities in various markets (Gilbert and Wahl, 2000).

Two methods are normally used for solving models once they have been constructed, of which the first method is a linear approximation, which has the advantage of computational simplicity. The second method includes the implementation of the model in levels form, and the use of non-linear solution methods, which has the advantages of producing accurate results for large-scale changes and reproducing the benchmark data, through which error checking is made automatic. Bandara (1991) noted that the institution with which the researcher is associated often reflects the choice of solution method. For example, the work of authors like Vincent, Mayer and Gupta are located within the theoretical structure and the solution technique of the ORANI model of the Australian economy. The research of this group can be labeled as the 'Johansen tradition' because these authors have followed the Johansen's linearised solution method. In any case, by breaking the simulation into smaller parts and solving sequentially, it is possible for the solution of a linearised model to approach to the solution of a non-linear model to an arbitrary degree of accuracy. Since many packages automate this

³ This latter assumption, known as the Armington (1969) specification, serves the dual purpose of dampening the trade and output responses to changes in relative prices, and allowing cross-hauling of products in the same category to be easily accommodated.

procedure, the differentiation of models on the basis of solution method has become less important.

Finally, it is possible to describe the models in terms of the numerical information that they contain.

2.2.3 Numerical

A CGE model is a mathematical representation of an economy. The previous sections have shown that at the core of the model is a set of equations describing the behaviour of various economic agents (for example, industries, households and governments) when faced with changes in key economic variables, for example, and most importantly, relative prices. This theoretical structure is usually derived from neoclassical microeconomics. Typically, households maximise utility subject to a budget constraint, and industries minimise costs subject to production functions. The core behavioural equations are supplemented with market clearing equations, which compare supply and demand in all commodity and factor markets. Such a model is calibrated from a numerical database, the central part of which is a set of input-output accounts showing, for a given year, the flows of commodities and primary factors between groups of economic agents (Dixon and Parmenter, 1996). Input-output or SAM accounts provide the underlying data framework for CGE models, with an income-expenditure account for each actor in the model. This data represents the state of the economy in question at one point in time – the base year. In order to obtain a solution to the model, the model's equations are solved simultaneously.

The procedure involved in choosing values for models' parameters is known as 'calibration' in the CGE literature (Mansur and Whalley, 1984). In general, for a given economy, an equilibrium situation is assumed that is known as 'benchmark' equilibrium. The values of the parameters of the models are chosen such that the model can replicate the benchmark data set. In general the benchmark data set is from national accounts (including input-output data) and government data sources. In practice the calibration procedure involves only a set of data for a

particular year. This is known as base year data. Some times a 'typical year' data base is used as an average over a number of years (Higgs, 1986). An important factor in models' calibration is that it completely depends on a single set of data as a benchmark data set.

To calibrate a CGE model two broad categories of data are required: firstly input-output and national accounts data and secondly various elasticity estimates. The SAM (containing mostly input-output data) provides a snapshot of the economy at a single point in time and each cell records the value of each transaction (i.e. the product of prices and quantities). When subject to change, from an exogenous shock or an endogenous change in demand or supply, how much of the change will be represented by a change in price and how much a change in quantities will depend on the structure of the model. Since in the SAM there is no automatic partition of the transactions value into price and quantity, one must be chosen. In practice one would start by normalising all (domestic) prices to unity in the base. How the cell then evolves is determined by the choice of values for key behavioural parameters.

The aforementioned thus portrays the way in which one can describe CGE models, while the next section analyses what has been written on CGE models in the literature.

2.3 COMMENTS ON CGE LITERATURE

Although CGE models have provided remarkable results regarding the possible effects of a variety of macroeconomic policies, it is not clear whether the quantitative predictions of CGE models are superior to those obtained with other methods. Despite the popularity of CGE models as an essential tool in applied economics, serious questions have been raised about the their empirical validity. Though CGE models have raised the complexity of the policy debate, the question still remains whether more credibility should be given to CGE insights or quantitative predictions (Bandara, 1991). Thus, there are a number of issues that have to be addressed before more confidence can be placed in the results of CGE models.

Criticism does not mean that other modelling approaches (e.g. Input-output, SAM models and macro econometric models) are not confronted with similar issues. Whalley (1985) and others viewed the criticisms aimed at CGE models as part of the larger debate concerning the contributions of empirical economics in general and for them, the insights that CGE models provide are sufficient to merit their use. However, given the continued demand for quantitative predictions by policy makers, along with the concerns raised in the literature, the most critical limitations of CGE models should be kept in mind. These are discussed below.

The critics of CGE models mainly focus their attention on the functional and numerical structure of the calibrated CGE model. Main comments on CGE framework are indicated in the following. This section draws on the work of Iqbal and Siddiqui (2001).

2.3.1 Criticism of the functional structure of the models

2.3.1.1 Neoclassical Theory

Most CGE models commonly use neoclassical specifications. As indicated by Hanson and Heckman (1996), neoclassical theory, although well known and understood, may not necessarily be an accurate reflection of the economy. Radical closure rules commonly adopted in neoclassical CGE models have been proved relatively inaccurate.

2.3.1.2 Choice of Functional Forms

Researchers use first order functional forms in most CGE models, specifically, constant elasticity of substitution (CES), which, by imposing a single non-negative substitution elasticity across all pairs of goods in the aggregator, embodies restrictive assumptions about the structure of the industries being modelled. Mansur and Whalley (1984) presented a comparison of a one consumer, two sector CGE model where one version is calibrated and the other is estimated but each uses CES-class

functional forms. They found that estimates of tax-induced welfare losses nevertheless diverged considerably for some periods. Mckitrick (1998) undertook a series of comparative simulations, which showed that the functional structure appeared to strongly influence the results from a policy simulation at both the industry-specific and macroeconomic levels, for large and small policy shocks. In this regard, McKitrick (1998) and Perroni and Rutherford (1995) suggested that a preferred alternative would be to use flexible functional forms. Examples of such forms are the translog or normalised quadratic forms, which have enough free parameters to provide a second order approximation to any underlying preference or technology aggregator function. These can therefore represent all the relevant own- and cross-price elasticities derived from an arbitrary utility or profit function, without imposing prior constraints.

2.3.1.3 Choice of Parameters

In the CGE model, parameters are determined in various ways. Some are determined on the basis of a survey of empirical literature, some are chosen arbitrarily, and the remainder are set at values which allow the model to replicate the data of a chosen benchmark year. Critics of this approach include, among others, Jorgensen (1984), Lau (1984), Jorgensen *et al.* (1992), Diewert and Lawrence (1994), and Mckitrick (1998), and their criticism is based on several grounds. First, modellers often use elasticities estimated from commodity and or industry classifications. These are often inconsistent with those maintained in the model, and/or archaic estimates from past literature studies or outright guesses when no published figures are available. These hamper the ability of the model to represent the real tastes of the economy under study and users of the simulation results find it almost impossible to appraise the evidence supporting the choice of most parameter values.

2.3.1.4 Static CGE Model

Most CGE models are basically static (a-temporal), meaning that the models used in most applications apply to a single period, which may range from a year to a lifetime. "Static CGE models can address

questions of what happens to an economy as it moves from one state of exogenous conditions to another, i.e. comparative static analysis" (Iqbal and Siddiqui, 2001). Comparative static analysis, by design, omits the time path of response. The introduction of dynamic behaviour in a CGE model is an attempt to incorporate the time dimension in policy analysis. Moreover, if CGE models are to be used for forecasting, they must include dynamic behaviour. The most invasive aspect of dynamic CGE models is dynamic household behaviour. Several concerns come to mind when dynamic behaviour is included. First calibrating to benchmark data for one year and then simulating a balanced growth path given existing exogenous conditions, has become common in the CGE literature. Therefore, the CGE model must not be calibrated to one year of data as pointed out by Pereira and Shoven (1988), but to a growth path. Some modellers have, through the "sequencing" of equilibrium conditions, established the time path, meaning that in each period, equilibrium is calculated given existing supplies of capital and labour. A new equilibrium is calculated when the supplies of capital and labour are updated. The sequence of the equilibrium conditions indicates the time path of the economy. However, where equilibrium is assumed to occur in each period, rather than being empirically established, expectations are typically assumed to be rational. Because structural features are often based more on convenience than on any prior knowledge about economies, it seems worthwhile to choose as short a time period as the data allow and to reserve the use of static models to single, short period applications (Iqbal and Siddiqui, 2001).

2.3.1.5 Results' Sensitivity

"CGE applications often do not examine the sensitivity of their results to alternative parameterizations. Where performed, sensitivity analysis is usually limited to simply judgmentally changing a few key elasticities" (Iqbal and Siddiqui, 2001). When using this procedure, there will always be uncertainty regarding the impotence of the elasticities selected. By changing each elasticity conditional upon the base values of the remaining elasticities, a more extensive sensitivity analysis can be performed. However, it is uncertain whether the particular combinations

of elasticity values are subjective toward some outcome, and how much the parameters should be changed to demonstrate the forcefulness of the results. Wigle (1991), and Partridge and Rickman (1998) indicated that the sensitivity analysis has been found to be overly optimistic about the forcefulness of CGE results. To make a worthwhile appraisal of the robustness of results, it is important that all possible combinations of feasible values of elasticities should be used, i.e. unconditional sensitivity analysis. For example, McGregor *et al.* (1995) employed the unconditional sensitivity approach. They assumed uniform distribution of thirty-nine elasticities, which require the modellers to specify the range of possible values of the elasticities. To assess the general reasonableness of the predictions of the CGE model, some comparison should be made, even though a direct comparison of CGE predictions to econometric estimates may be problematic (Iqbal and Siddiqui, 2001). Therefore, it is important that there should be sensitivity analysis and a verification of the model properties with current econometric evidence in the literature. This can be achieved by simulating the CGE model in a manner as consistent as possible with the framework within which the econometric estimates are obtained.

2.3.2 Criticism of the numerical structure of the models

2.3.2.1 Quality of Data

The quality of the data for an arbitrarily chosen benchmark year partially determines the quality of the model. The generalisations drawn from the model will be less valid, since there are always stochastic anomalies and extraordinary economic events associated with any one-year of a time series. "In addition, the data matrices often go through various scaling processes to force micro consistency, introducing untraceable biases into the rows and columns. These biases will directly influence the parameters of a calibrated model" (Iqbal and Siddiqui, 2001).

2.3.2.2 Model Calibration

The appropriateness of calibrating CGE models to a benchmark year data set has come under considerable scrutiny in the CGE modeling literature. Lau (1984), Hansen and Heckman (1996), and Partridge and Rickman (1998), noted that the reliance on one-year data makes the system under-identified and the normal structure of the economy may not be reflected by the benchmark year. "Some modellers have suggested that system-wide econometric estimation of a CGE model may avoid this inconsistency by incorporating cross-equation restrictions in the estimation process" (Iqbal and Siddiqui, 2001). But system-wide estimation has even more problems, especially at the regional level where price and quantity data are not readily available. Mansur and Whalley (1984) used averages of benchmark years as a remedy for calibrating to a single benchmark year. However, Lau (1984) and Hansen and Heckman (1996) pointed out that the statistical properties of this procedure are unknown.

2.4 CONCLUDING REMARKS

Despite of all criticisms and limitations that can be found in the CGE literature, CGE models are becoming more widely used in policy analysis. The advantages of CGE models for policy analyses, compared to traditional macro-economic models, are now widely acknowledged. Therefore, CGE models represent a significant advancement in economic analysis. However, it is not yet clear how accurate CGE models are quantitatively, particular in comparison to other types of models. Issues that need to be explored further are issues of functional form, elasticity specification, closure rules, sensitivity analysis, market structure, and dynamics. It should be examined whether CGE models better explain patterns in the data than other models why the findings of these models differ from those produced by other types of models. For CGE models to move beyond simply providing new insights to playing a more significant role in policymaking, much still remains to be done. To this end, CGE modellers might focus more on the dynamics or time-paths of relationships in an economy.

Since building, applying, evaluating, and maintaining a CGE model of an economy is such a large responsibility and time consuming, only fractions of individual careers have been devoted to the effort. Institutional effort and funding might be required, both for application and theory. Joint research programmes of modellers, econometricians, theoreticians, and computational economists might be necessary to sustain an effective large scale CGE model of an economy.

The choice of a suitable methodology for economic impact analysis must, for these reasons, be undertaken on a case-by-case basis and it is also important that the analysis be presented in a manner in which the assumptions that form the basis of the results are clear. An accurate appraisal should include sensitivity analysis providing information on how changes in the models' specification, reflecting alternate assumptions, would affect the results. If such documentation is included, it may be taken as a sign of a considered analysis.

In the next chapter a definition and classification of CGE modelling is given, based on the historical development of empirical CGE analysis, the specification of different models and the determination of parameters, in order to draw up a classification and evaluation framework for CGE models.

CHAPTER 3

CLASSIFICATION AND EVALUATION FRAMEWORK

3.1 INTRODUCTION

CGE models have become more and more popular to analyse the consequences of economic policy choices and the allocation of resources in countries worldwide. CGE models are auspicious because complex interdependencies are included in the analysis. The resulting final economic outcomes may differ adversely from the intention of the policymakers and the direct effects predicted by partial equilibrium models (Thissen, 1998:2). CGE models account for these interactions by modelling all links in the economy that represent a transaction of money or goods. This, however, means that modellers can only have an understanding of real economies when they can show that the detailed implications of their theories provide sufficiently accurate representations of the real world. Only then can their models be taken seriously for forecasting and policy analysis (Rust, 1997).

However, there is still much uncertainty regarding a definition of empirical CGE models. Different names like Transaction Value models, Computable General Equilibrium models, Applied General Equilibrium models and SAM-based General Equilibrium models have been used, without giving a proper classification of models. In this chapter a definition and classification of CGE modelling will be given (drawn from the work of Thissen (1998)), based on the historical development of empirical CGE analysis, the chosen model specification and the determination of parameters, in order to draw up a classification and evaluation framework for CGE models used in the South African context.

The remainder of this chapter is organised as follows. Section 2 gives a definition of CGE modelling. Different ways to classify models are

presented in section 3. A classification of CGE models is given in section 4, and the final section contains a brief summary of the chapter.

3.2 DEFINING CGE

"A CGE model may be defined as the fundamental macroeconomic general equilibrium links among incomes of various groups, the pattern of demand, the balance of payments and a multi-sector production structure" (Thissen, 1998:2).¹ The model integrates a set of behavioural equations, which describe the economic behaviour of the agents identified in the model and the technological and institutional constraints that they face. The agents identified by the model may be representative agents like a typical household with a given socioeconomic background. It is also possible that the behavioural equations describe the behaviour of larger entities like social groups. Because a set of prices and quantities exists, the model is in equilibrium, such that all excess demands for nominal as well as real quantities of commodities and services, are zero.

3.2.1 Narrowing the definition

Regrettably, this definition includes models that are generally not seen as CGE models and although many numerical multi-sector models are usually referred to as being 'CGE models', there exists no accord on a precise and excluding definition of a CGE model. Following Bergman's (1990) example, this definition problem might be overcome by narrowing the definition of CGE models by describing their common and distinct characteristics.

"CGE models are a combined representation of the economy and are based on the flow equilibrium in product and factor markets in both real and nominal values" (Thissen, 1998). In contrast to input-output analysis, both quantities and relative prices are endogenous, while

¹ This definition combines and narrows the definitions of Dixon, Parmenter, Powell and Wilcoxon (1992:70) and of Dervis, De Melo and Robinson (1982:132-133).

consumption is no longer exogenous but linked to income. The general equilibrium approach intends to model all links within the economy that represent a transaction of money or goods. The analysis is usually based on comparative numerical static analysis of changes in exogenous conditions. Therefore, the base equilibrium situation is compared with the new equilibrium after the exogenous shocks have taken place (Thissen, 1998).

Overall, the aim of CGE modelling is to build a model with a relatively translucent structure in order to clarify the mechanism with which policy measures or exogenous shocks affect the economy within a multi-sector framework (Thissen, 1998). It is often not the objective to forecast the exact outcome of policy measures as with, for example, a reduced form-forecasting model (Adelman and Robinson, 1978:6) given the existing limitations in parameter estimation and in the model structure, but to give only an indication of the direction and size of the effects. More often than not the model is built for one country, focusing on income distribution or resource allocation within the country, but also multi-country models regarding regional or global perspectives exist and are becoming more and more popular.

3.3 CATEGORISING CGE MODELS

The variety of models can be classified in a number of different ways. One approach is by mathematical structure (optimisation or simulation, static or dynamic, and linear or non-linear) or methodology (macroeconometric, computable general equilibrium). Another is according to policy focus. Models can also be classified by theoretical type or by the nature of the underlying theoretical structure. This section draws on the work of Robinson (1989).

3.3.1 Mathematical structure and methodology

Work on a new type of non-linear, multisectoral model, was developed in the early 1970s, which sought to replicate the mechanism of a market economy, solving for both market prices and quantities concurrently.

These models were aptly named CGE models and can be seen as a natural product of input-output and linear programming (LP) models, adding neoclassical substitutability in production and demand, in addition to an explicit system of market prices and a complete specification of the income flows in the economy (Adelman and Robinson, 1978).

Since then major improvements have been made in solution techniques that has permitted the implementation of CGE models. Four different approaches were pursued. "First, the solution of a CGE model can be formulated as a problem in finding a fixed point in a mapping of prices to prices through excess demand equations" (Robinson, 1989). Herbert Scarf pioneered this approach, and variations on his fixed-point algorithm have been used to solve a number of CGE models (Scarf and Hansen, 1973). As a second approach, a CGE model can be treated as just a collection of non-linear algebraic equations. They can then be attacked directly with numerical solution techniques. Adelman and Robinson (1978) and a number of others, have used this approach. "A third approach involves first linearising all the equations of the CGE model and then solving the linear approximation by simple matrix inversion" (Robinson, 1989). Johansen (1960) was the first to use this approach in an applied CGE model and, since then, the approach has also been used in a number of applications. A final approach involves constructing a non-linear programming model. This model's solution yields shadow prices that can be interpreted as market prices. Ginsburgh and Waelbroeck (1981) describe in detail the general approach of using programming techniques to solve CGE models.

Today, CGE models can be solved regularly and inexpensively. Applying a CGE model is significantly easier now than in the past. Many of the shortcomings of LP models have been overcome with the advanced development of non-linear programming methods, and it is now possible to integrate optimisation with a more complete specification of market systems, including endogenously determined prices (Robinson, 1989).

3.3.2 Policy focus

Another way of classifying models is according to the topic that they wish to address (Robinson, 1989). Issues addressed by the earlier input-output and LP models were largely concerned with questions of investment, international trade, and the implications of different development strategies in the medium to long run with the main focus on growth and structural change in production and foreign trade (Clark and Taylor, 1975). However, these models were not well suited to analyse mixed market economies. "Linear programming and input-output models do not capture market mechanisms through incentive instruments such as taxes and subsidies that affect the economy" (Robinson, 1989). The models provide a consistent economy-wide framework, but they do not provide a way to relate solution variables to actual policy decisions (Taylor, 1975).

Income distribution was of international concern in earlier years. This shift in policy interest generated further pressure to include prices and incomes directly in models. The focus on income distribution arose from a growing concern that rapid growth and structural change was not sufficient to reduce poverty and that large groups of poor people were not benefiting from growth (Adelman and Morris, 1973). The first CGE models for developing countries were built to answer two broad questions: (1) What were the distributional implications of different development strategies? (2) How could one design policy packages that would reduce the incidence of poverty and correct the worsening of the distribution that seemed inevitably to accompany industrialisation? Two of these models were the model of Korea by Adelman and Robinson (1978) and, later, the model of Brazil by Lysy and Taylor (1980).

Policy issues have thus played a significant role in the classification of the different types of models over the years and should therefore receive close attention.

3.3.3 Analytic, stylised, and applied models

Policy concerns have driven most of the work on empirical models. There is, however, in all policy analysis a tension between theoretical simplification and empirical realism. This tension should be kept in mind when judging empirical models. Models can be classified along a continuum running from analytic to applied (Robinson, 1989).

Firstly, analytic models are designed to explore the implications of various sets of theoretical hypotheses, with as few assumptions as possible about the magnitudes of parameters. "Therefore, analytic models are deliberately simplified to focus attention on important assumptions and causal mechanisms" (Robinson, 1989). In this process, the stylised facts are often exaggerated, which simplifies an analytic model and allows mathematical analysis of its properties (Adelman and Robinson, 1978).

Empirical realism is not the most relevant criterion when evaluating analytic models, which focus on the logical implications of different sets of assumptions. What makes an analytic model useful is that it isolates important effects while retaining a reasonable specification. "There is clearly a trade-off between empirical relevance (i.e. the range and complexity of issues that can be considered in a model) and analytic tractability" (Robinson, 1989). Analytic models are usually narrowly focused with a preference for a partial rather than a general equilibrium approach (Adelman and Robinson, 1978).

Numerous economic occurrences that can be isolated in particular analytic models work in opposing directions. Furthermore, the net effects in a real economy depend on the values of various parameters. When an analytical model is not sufficient, a solution might be to draw on empirical work and to build a stylised numerical model.

"Stylised numerical models have two main uses: (1) to analyse problems that are too difficult to solve analytically or that have ambiguous implications that depend on particular parameter values, and (2) to

illustrate the numerical order or magnitude of various effects whose analytic properties are well understood" (Robinson, 1989). Characteristically, stylised numerical models are more complex than analytic models. Stylised numerical models require wider applicability and no longer require simplicity. Yet, stylised numerical models tend to stay close to their underlying analytic models. Stylised models are still underdeveloped with regards to those models that seek to find a realistic way to identify the variety of important effects that might impose on a particular policy problem (Robinson, 1989:892). This would fall in the realm of applied models.

Applied models are different from stylised models. First, they extend further the range of stylised facts that are incorporated. Second, they try to capture important characteristics of a particular economy or situation (Robinson, 1989:892). For example, while a stylised model can represent various countries that are similar (e.g. oil-importing, semi-industrial countries), an applied model is built for a particular country. Applied models are more precise and restricted, because they include more institutional detail.

Applied models allow for increased institutional certainty. They also include a broader range of economic phenomena. "The trade-off is that the additional detail and size may obscure the major causal mechanisms that drive the model, without adding any empirically significant effects" (Robinson, 1989). Moving back and forth between analytic, stylised, and applied models is often advantageous, since different types of models permit different insights. Any particular problem can be better analysed by using more than one kind of model.

Overall, analytic models do not acquiesce specific policy recommendations, seeing that the stylised facts being considered are usually too stylised to be realistic enough for policy analysis. The policy conclusions drawn from analytic models tend to be quite common, such as: "free trade is good", "price distortions are bad and attempts to fix prices are terrible", "quantity restrictions on imports are worse than tariffs", or "do not ignore market mechanisms" (Robinson, 1989).

Furthermore, there are economists who delight in thinking up counterexamples. For similar reasons, a stylised numerical model can only rarely be used for policy analysis, since it is usually too simplified to provide good numerical estimates of the impact of various specific policies.

Despite the fact that the three types of models are different, the boundaries between them are often unclear. They represent different points along a range of models that differ in size, scope, and focus. "The differences are significant and much of the criticism of particular models often amounts to taking a stylised numerical model to task for not being an applied model, or vice versa" (Robinson, 1989).

The modeller should be able to trace any effect the model produces back to features of its theoretical structure or to particular parameter values. Therefore it is important that all models should be translucent. Applied models will be more difficult to interpret since their focus will be on the institutional details of a particular economy. What is important is whether the gain in institutional detail creates more realistic empirical results. In contrast, stylised models are often designed to reflect widespread features of a class of countries. Despite the ease of handling the models, what is important is whether country-specific effects are empirically important enough to offset the commonalities that models are designed to explore.

Applied models can also be simplified. Conducting tests time and again highlights important issues regarding the empirical importance of model specifications. Depending on the results found, a more stylised numerical model can be implemented, which still includes the mechanisms which were empirically important in the applied model.

3.3.4 Theoretical structures

Input-output models and their extensions into social accounting are powerful tools for applied general equilibrium analysis. CGE models, which were developed at a later stage, build on the input-output core,

which captures sectoral interdependence arising from the flow of intermediate goods among sectors, adding non-linear equations and endogenous prices. The majority of these models are structural, with unequivocal specification of supply and demand behaviour. The microeconomic spirit of the models is essentially reinforced by extensions to non-linear models integrating substitution possibilities and prices (Dervis, de Melo and Robinson, 1982:6).

Though most models for developing countries are Walrasian and neoclassical in spirit, the assumptions of neoclassical theory are quickly discarded when the problem of capturing the stylised facts characterising many economies arises. In authentic economies the assumptions of perfectly functioning markets with flexible prices, perfect competition and free mobility of products and factors are not sustainable. As an alternative, a variety of "structuralist" rigidities have been integrated into these models that seek to capture non-neoclassical behavioural relations, macro imbalances, and institutional rigidities distinctive of many countries. Methodological problems have risen from these deviations from the Walrasian structure, for example, Bell and Srinivasan (1984), Srinivasan (1982), and Shoven and Whalley (1984) have all commented on models that incorporate ad hoc features not fixed in traditional theory.

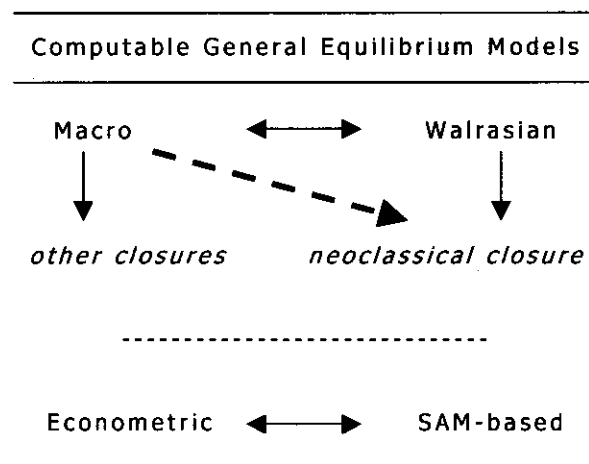
Valid empirical results will not be attained when a model with clean theoretical roots is used in a situation where its assumptions are not satisfied. Furthermore, these results will also not aid in policy analysis and may cause problems with interpretation, which may be seen as a challenge to theorists.

Now that the basis for classifying models has been laid, it is now possible and important to apply this classification framework to the various CGE models. This classification enables modellers to give an overview of the different analyses in CGE modelling. It also has the added advantage that the development of CGE analysis over time, where ideally new CGE models are improvements of older models, may be analysed.

3.4 A CLASSIFICATION OF CGE MODELS

In literature, CGE models are classified in three different ways. An introduction to these three classifications and how they are interconnected will be given in this section. An illustration of the classification system of CGE models is sketched in Figure 3.1. This classification system will be discussed, in detail, in the following three sub-sections.

Figure 3.1: Classification of CGE modelling



Source: Thissen, 1998:4

The historical development of CGE modelling and the intended purpose of the CGE models are principally used to classify CGE models. Multi-sector analysis and macro models were the forerunners for the first type of CGE models. These macro CGE models were regularly used for policy analysis in many developing countries. The ground-breaking work of Scarf (1967) on the numerical solution of a Walrasian system and the general equilibrium framework of Walras, created the benchmark for the second type of CGE models, namely Walrasian CGE models.

'Closure rules' have become a common classification method among most researchers working on macro CGE models. The main theoretical differences in the earlier macro models are used as a base for the

second classification (Thissen, 1998). The debate among economists which dominated economics in the 1960s and 1970s, where Walrasian models were considered as a specific subgroup of all CGE models, namely those with a neoclassical closure, are often used by these authors as a base for their choice of 'closure rules'.

The technique used to determine the parameters provides a base for a third classification of CGE models. "This classification distinguishes between models with parameters based on the calibration technique and models with parameters based on econometric estimation" (Thissen, 1998). Almost all CGE models are based on the calibration technique. The following sections draw on the work of Thissen (1998).

3.4.1 Macro and Walrasian CGE models

It is possible to make a distinction within CGE analyses based on the origins, purposes and theoretical background of the models (Robinson, 1989 and Willenbockel, 1994a). The general equilibrium framework of Walras is attempted to be made operational by one group and has its roots in applied welfare economics and, therefore, these models are the numerical complements of Walrasian general equilibrium models. Walrasian CGE models, which are extended from the basic competitive equilibrium as defined by Ginsburgh and Keyzer (1997), are based on the optimising behaviour of representative agents and have utility maximising consumers and profit maximising producers.² While on the other hand, macro CGE modelling is a logical extension of Leontief's input-output analysis and linear programming models often applied in development economics.

² The General Competitive Equilibrium is defined as: Every producer j , solves $\max_{y^j} \{p^* y^j \mid y^j \in Y^j\}$ where y^j are production plans, Y^j is the set of feasible production plans and p^* is the equilibrium price vector. Every consumer i , solves $\max_{x^i} \{u^i(x^i) \mid p^* x^i \leq h^* i\}$, where $u^i(x^i)$ is utility derived from the nonnegative consumption plan x^i and subject to the budget constraint for equilibrium income $h^* i$ which is equal to its receipt from selling endowments ω^i and shares θ^i in distributed profits: $h^* i = p^* \omega^i + \sum_j \theta^i_j p^* y^j$. All markets are in equilibrium: $\sum_i x^* i - \sum_j y^* j - \sum_i \omega^i \leq 0$, where $x^* i$ and $y^* j$ are respectively the equilibrium consumption and production plan. See also Ginsburgh and Keyzer (1997).

3.4.1.1 Walrasian CGE models

Harberger (1962) was the first to use Walrasian CGE modelling when he studied the occurrence of taxation within the framework of a numerical two-sector model. The work done by Shoven and Whalley (Scarf and Shoven, 1984; Shoven and Whalley, 1992), also by Hertel (1997) regarding the Global Trade Analysis Project (GTAP) as well as the work of Ginsburgh and Keyzer (1997) has further sophisticated this category of CGE models.

Walrasian CGE analysis has the objective to analyse the quantitative effects of exogenous changes on the optimal allocation of resources, on efficiency and on welfare (Thissen, 1998). Willenbockel (1994b) and Bergman (1990) were of the opinion that Walrasian CGE models do not intend to give a description of actual economies but to construct a 'mental organising framework' capable of analysing policy issues. Walrasian general equilibrium theory has been applied to a lesser extent in Walrasian CGE modelling over the last decade. Modifications are made to the Walrasian theoretical framework in order to make the model more pragmatic.³

These models can be compared to the neoclassical macro CGE models discussed below. Walrasian CGE models are commonly still based on optimising representative agents and markets are cleared by endogenous prices without quantity clearing markets, though it is not possible to make a firm division. If we look at, for example, a CGE model built by Taylor (1990a) where certain production sectors were not modelled by use of a production function, we can see that this type of model is not generally seen as belonging to Walrasian CGE models.

³ An example is the model of Feltenstein and Shah (1995) incorporating financial markets.

3.4.1.2 Macro CGE models

Macro CGE models, which are often used for policy analysis, developed from input-output analysis and the short run macro models and in these CGE models the input-output analysis is extended with endogenous quantities and prices while consumption is related to income, thereby closing the flow of money within the economy. Johansen's (1960) model is generally seen as the first model in this category of CGE modelling. The ORANI/MONASH models of Australia (Powell and Lawson, 1990; Vincent, 1990) and numerous models of developing countries (Decaluwé and Martens, 1988; Bandara, 1991) are used to further extend these macro CGE models.

As stated by Thissen (1998) "The objective within this field of research is to quantify short run income distribution consequences, sectoral growth and trade balance effects, rather than to explain resource allocation effects of exogenous shocks or policy alternatives". Opposite to Walrasian CGE models, macro CGE models may include ad hoc elements to describe the economy at hand, while the behaviour of economic agents may not be derived from optimising behaviour. The argument exists that these models trade off internal rigour for increases in empirical relevance resulting in models that are often impossible to solve analytically.

3.4.2 A classification of macro CGE models by closures

The closure mechanism is important due to the fact that choice of "closure" characterises the entire model or the modules within it. The type of closure is therefore important for two reasons. Firstly, to define the equations in a consistent manner, and secondly, to understand the workings of the model. Furthermore, the fact that the choice of macro-closure has a large affect on the policy simulation results obtained with a CGE model, has been discussed by Sen (1963) and by Taylor and Lysy (1979) (see, for instance, Taylor (1991), Decaluwé and Monette (1988), and Dervis, De Melo and Robinson (1982)). Because the short run macro CGE models often deviated from the Walrasian structure and the

neoclassical closure, the closure rule problem was renowned in this field. Because of the above-mentioned importance of the closure rule, existing macro CGE models are classified by their respective closure. The main closure that describes the fundamental equilibrating mechanisms on which the larger CGE models are based, is used as a basis for this classification. The following most important closures and associated 'schools' are discussed below:

- Sen's base model
- The neoclassical closure
- The neo-Keynesian or forced savings closure
- The Keynesian closure
- The Johansen closure
- The Kaleckian or structuralist closure
- The loanable funds closure
- The Pigou or real balances closure

The closure rule can be defined in two ways. Mathematically the model should consist of an equal number of equations and endogenous variables, meaning that the model builder needs to decide which variables are endogenous and which are exogenous. On the other hand, if the model is built in the Walrasian tradition and all decisions are based on optimising behaviour, the closure rule problem is the introduction of macroeconomic constraints that inflict upon the microeconomic behaviour of individual agents and which introduce the need for an additional endogenous variable that balances this constraint (see, for instance, Ginsburgh and Keyzer (1997:111-112)). Overall the personal theoretical preferences of the model builder and the empirically most probable adjustment processes, determine the closure rule.

3.4.2.1 Sen's base model

Sen (1963) introduced the problem of closure rules and demonstrated that the following short run macro model with an independent investment function (equation 5) where investment I is equal to some level I^* based on, for instance, 'animal spirits', good X_s produced by a

neoclassical production function f_p homogeneous of the first degree (equation 1) and production factors, labour L and capital K paid according to their marginal productivities with wage rate ω and total capital income κ (equations 2 and 3) is over-determined if the savings-investment balance (equation 6) with total savings S determined by the savings ratios s_ω and s_p out of, respectively, wage and capital income (equation 4) is added to the model:

$$X_s = f_p(L, K) \quad (1)$$

$$\omega = \frac{\partial X_s}{\partial L} \quad (2)$$

$$X_s = \kappa + \omega L \quad (3)$$

$$S = s_p \kappa + s_\omega \omega L \quad (4)$$

$$I = I^* \quad (5)$$

$$S = I \quad (6)$$

endogenous variables: X_s, I, S, ω, π

This single production sector model can effectively explain the closure rule problem. Because the production function is homogeneous of degree one, equation 3 may also be replaced by:

$$\kappa = \frac{\partial X_s}{\partial K} K \quad (3.3a)$$

Clearly, this model is over-determined since it consists of 6 equations and 5 endogenous variables and should be closed by either adding an endogenous variable or skipping an equation.

3.4.2.2 The neoclassical closure

The most common way to close the model is by means of the neoclassical closure. In the neoclassical model (equations 1, 2, 3, 4 and 6) equation

5 is dropped from the above system of equations. "According to Swan (1970) an assumption is made that a mechanism exists such that investment is brought into equilibrium with savings at a level that guarantees full employment in the economy, or that whatever is saved is invested" (Thissen, 1998:9). Though not modelled explicitly as in the standard Solow (1956) model, this mechanism is often assumed to be an interest rate. Walrasian CGE models commonly use the neoclassical closure, whereas it is used to a lesser extent in macro CGE models.

3.4.2.3 The neo-Keynesian or forced savings closure

Conversely, in the neo-Keynesian model (equations 1, 3, 4, 5 and 6) equation 2 is dropped. The forced savings models of Kaldor (1956) and Pasinetti (1962) are used as basis. The forced savings mechanism is created by fixing the nominal wage rate, while production is still determined by the supply of labour and capital. This is implicit in the model if equation 2 is skipped and may be made explicit by rewriting equation 4 as:

$$S = s_p K + s_w \left(\frac{W_n}{p} \right) L \quad (3.4a)$$

With W_n the exogenous nominal wage rate and p the endogenous price level that brings about the equality between investment and savings by a change in the income distribution. The well-known neo-Keynesian equation for profit income, which may be derived from this model, is:

$$K = \left(\frac{I^*}{(s_p - s_w)} \right) - \left(\frac{s_w}{(s_p - s_w)} \right) X$$

3.4.2.4 The Keynesian and Johansen closure

The closure associated by Sen with Keynes's (1936) General Theory is endogenising labour in the above system of equations. By introducing unemployment in this model (consisting of all the equations 1, 2, 3, 4, 5

and 6) it is assumed possible for investment to be different from its full-employment level, highlighting the role of the government who may intervene to bring about full-employment. This can be achieved in CGE models by endogenous government spending or taxes (the Johansen (1960) closure), and comes down to dropping equation 4 in the model described above. To model the government more explicitly in this model (equations 1, 2, 3, 5 and 6) it is possible to include equation 4 by rewriting it as:

$$S = s_p \kappa + s_w \omega L + G_s \quad (3.4b)$$

or as:

$$S = s_p (1-t) \kappa + s_w (1-t) \omega L \quad (3.4c)$$

With G_s equal to the endogenous government savings (the government expenditure minus government income) in equation 3.4b, or t equal to the endogenous tax rate in equation 3.4c.

3.4.2.5 The Kaleckian or structuralist closure

The work of Kalecki (1976) is used as a basis for the closure often used in structuralist models (Taylor, 1990b). In Kalecki's model (equations 3.1a, 3, 3.3b, 4, 5 and 6) the assumption is made that firms operate with excess capacity, therefore demanding labour as a function f_l of supply (equation 3.1a) and have market power on an oligopolistic market to set prices as a markup τ over costs (equation 3.3b).

$$L = f_l(X) \quad (3.1a)$$

$$\kappa = (1 + \tau) \omega L \quad (3.3b)$$

Since real wages are no longer assumed to be equal to the marginal productivity of labour, equation 3.2 is left out of the model. Wages are now determined by equation 3.3 such that total income is equal to total

value added while L is endogenous and unemployment exists. Also it can be shown in this model that profit income is equal to:

$$\kappa = \left(\frac{I^*}{(s_p - s_w)} - \frac{s_w}{(s_p - s_w)} \right) X$$

It is therefore not surprising that this model, at full capacity with an endogenous markup rate τ and exogenous production, gives comparable results to the neo-Keynesian model.⁴ Mixed results are often obtained in multi-sector models, especially if supply is fixed in certain sectors of the economy (often the agricultural sector).

3.4.2.6 The loanable funds closure

The fundamental topic in closure rules is the mechanism that brings investment and savings into equilibrium, or the implicit modelling of financial markets. A more open modelling of financial markets is needed to enlarge the available equilibrating mechanisms, or create mechanisms that are a mixture of several others. The loanable funds closure as explained in Taylor (1991), is the most suited closure in this case. The loanable funds closure is where savings are the supply of loanable funds and investment is the demand for loanable funds. Both supply and demand for loanable funds are balanced by an additional variable being the interest rate. Therefore, in the small model presented above this would imply a substitution of the equations 4 and 5 with the following two equations:

$$S = f_{sp}(i)\kappa + f_{sw}(i)\varpi L \quad (3.4d)$$

$$I = f_i(I^*, i) \quad (3.5a)$$

⁴ The occurrence of a change in the equilibrating mechanism of the model if full capacity is reached can be seen as a regime switch.

with i representing the endogenous interest rate, f_{sp} and f_{so} respectively the interest dependent savings functions of those earning wage and those earning profit income and f_i the investment function which depends on an exogenous level I^* and the interest rate. For the loanable funds model (equations 1, 2, 3, 4d 5a and 6) to be stable the interest elasticities with respect to savings and investment have to be opposite in sign.

The model can be compared to the Solow model if the elasticity of savings with respect to the interest rate is zero and the elasticity of investment with respect to the interest rate deviates from zero. In the reverse situation the model can be compared to the Johansen model. The main difference would be that the change in savings would be brought about by a change in the savings rate and not by a change in the tax rate (savings of wage and profit earners adjust, while in the Johansen model the savings of the government adjust).

3.4.2.7 The Pigou or real balances closure

Other equilibrating mechanisms, such as the Pigou or real balance effect, are introduced by the introduction of financial stocks in the model. Equation 4 may now be presented as:

$$S = f_{sp} \left(\frac{M}{p} \right) K + f_{so} \left(\frac{M}{p} \right) \omega L \quad (3.4e)$$

where M is an exogenous money supply, f_{sp} and f_{so} the savings functions and p the endogenous price level. So, if in this real balance model (equations 1, 2, 3, 4e, 5 and 6) excess demand exists, the prices will increase causing economic agents to reduce their consumption and increase their savings to make up for the loss in real balances.

"Extending the loanable funds approach by taking into account wealth effects, such as the Pigou effect, interest payments and interest clearing stock markets for financial assets, a fully developed Tobin's (1971) style

portfolio model is needed" (Thissen, 1998:13). By using a portfolio approach and fixing the nominal wage rate, 'empirical' models may combine several of the above mechanisms, which may result in a model where adjustments may cause a mixture of portfolio allocation, wealth effects and forced savings mechanisms to generate a new equilibrium after a policy shock. The adjustment mechanisms may be made more complicated by extending the model with the explicit modelling of expectations.

3.4.3 SAM-based versus econometric approach

Alternatively, the determination of the parameters of the model serves as a base for the classification of empirical economic models (see, for instance, Bergman, Jorgenson and Zalai (1990)). The parameters of CGE are generally determined by a calibration technique, which differs from the econometric methods used in large-scale macro econometric models.

The need for a simultaneous equations system estimation approach, which is infeasible for larger CGE models, serves as a reason for using a calibration technique in CGE modelling. This infeasibility is also caused by degrees of freedom problems and the scarcity of data and time (Lau, 1984; Mansur and Whalley, 1984). However, the calibration approach also affects the structure of the model. Since the number of parameters that can be determined by calibration is limited, the model builder can only use relatively simple structures, but this restriction can be circumvented by using parameters from other (econometric) research.⁵

Since parameters can be specified using only one observation, which requires little data, the ease of determining parameters can be seen as an important advantage of the calibration method. A further reason, with regards to developing countries, to use calibration instead of econometric estimation to determine the parameters of CGE models, might be because of the significant changes that occur in the economic

⁵ Normally the elasticities are obtained from secondary sources while the scale and share parameters are obtained from the SAM.

structure of developing countries. It is particularly difficult to link figures of the present situation with those of previous years if the directions of causality in the economy change. Sensible results might not be found if the estimation of parameters is done using figures for many years with all having equal weights (Taylor, 1990b). Thus, it may be preferable to use a calibration approach based on data for the period after the structural changes (Thissen, 1998).

The method of calibration has some further disadvantages beyond the limited reliability of parameters estimated using data for only one point in time. If calibration is used to determine the parameters, as in the case of econometric models where stochastic disturbances are introduced to capture the effect of variables omitted in the model, this stochastic disturbance term is assumed to be equal to zero, which implies that no factors other than those included in the model affected, or are expected to affect, the endogenous variables. An explanation may be in the focus of CGE models, which is not intended to give precise forecasts, but which attempt to clarify economic mechanisms with an indication of the qualitative effects.⁶

The absence of measures of reliability of the model and its parameters is a further problem associated with the calibration method. According to Lau (1984) forecasts may give some indication of the reliability. Harrison, Jones, Kimbell and Wigle (1993) also proposed that an indication of reliability can be given by the use of systematic sensitivity analysis. Because of the large amount of simulations that is required, this method is not widely used. A few less comprehensive sensitivity analysis studies, show that at the very least initial conditions significantly matter for CGE analysis (Wiese, 1995; Roberts, 1994), which make it seem likely that results from such an analysis will be more seriously affected by parameter errors if the period under investigation increases (Thissen, 1998). For long term CGE analysis, improvements are needed regarding the reliability of parameter estimates, such that the

⁶ For dynamic models it is obvious that some form of forecasting is needed to compare simulation results with the reference path.

dynamic behaviour of the model better describes the actual economic developments.

3.5 SUMMARY

It has been shown that there are a number of different ways to classify models, namely by mathematical structure or methodology: optimisation or simulation, static or dynamic, and linear or non-linear. Another way is according to policy focus, theoretical type or by the nature of the underlying theoretical structure.

It has also been shown that it is possible to classify the different CGE models in several groups based on their purposes, the historical development in CGE modelling, and the technique used to determine the model parameters. Walrasian CGE models are the numerical counterparts of the theoretical Walrasian general equilibrium models and as such often used for welfare analyses and the quantitative analysis of the optimal allocation of resources. The macro CGE models are generally used to clarify the economic mechanisms that operate in a specific country with its own economic structure. Besides the analysis of sectoral growth, these models often focus on the distribution of income and trade balance effects. It was shown that these models could be further divided into different groups based on the closure rule on which the model is based. Finally, a classification of CGE models was given based on the different approaches used to determine the model parameters.

It may be concluded that a Walrasian CGE model is suitable to analyse the effects of policy measures on the optimal allocation of resources, efficiency and welfare in an economy without too many rigidities. A macro CGE model with many structural equations is appropriate to clarify economic mechanisms or predict possible outcomes of economic policies given the present or an alternative economic structure in the short run. Moreover, the point estimates obtained from the 'normal' procedure of calibrating the model using a SAM for one 'base-year' are good enough for the analysis of impact effects of different policies, but they are inadequate for long run analysis. Improvement of the reliability of

parameter estimates, such that the dynamic behaviour of the model better describes the actual economic developments, is crucial for long term CGE analysis. An econometric approach is therefore more appropriate if long run analysis is the purpose of the model and there are no significant structural changes in the economy over the period the parameters are estimated.

In the next chapter this classification and evaluation framework will be used to classify and evaluate the CGE models that have been used in the South African context. The focus will be specifically on the models derived from the IDCGEM framework since it is the most widely used model in South Africa.

CHAPTER 4

CGE MODELLING IN SOUTH AFRICA

4.1 INTRODUCTION

There has been a considerable increase in the use of CGE models in South Africa to study a variety of policy issues, specifically, development plans, agricultural programmes, tax policy and international trade. Until recently, only a few survey articles on CGE modelling have been published. These surveys consider different subgroups of CGE models, such as those on CGE models used for policy analysis in developing countries (De Wet and Van Heerden, 2003; Naudé and Brixen, 1993). There exists no general survey article because there are too many different CGE models to cover the complete field of CGE analysis.

In this chapter the different models constructed for one specific country, South Africa, are used to give an overview of the different analyses in CGE modelling. Additionally this approach has the advantage that the development of CGE analysis over time, where ideally new CGE models are improvements of older models, may be analysed.

In South Africa, Naudé and Brixen (1993a; 1993b) were the first to use the CGE approach to analyse policy questions. Their model was extended by the Industrial Development Corporation (IDC) into IDCGEM (see Joubert *et al.*, 1994; Horridge *et al.*, 1995,1996). The IDCGEM is the largest and most frequently used CGE model in South Africa (Burrows, 1995), and has been used, amongst other applications, to inform South Africa's GATT negotiations.

South Africa's CGE research experience, treating a large variety of subjects and covering the different types of models as presented in the next section, may give lessons for comparable analysis for other countries. The existing CGE models for South Africa are presented in

sections 3 and 4. These sections give future modellers a guide to build on the older modelling experience. Comparing these different models in section 5 leads to certain important issues for future research on CGE modelling which are summarised in the concluding section.

4.2 CGE MODELS FOR SOUTH AFRICA

The surveyed CGE models, and some of their specific characteristics that are important for the present analysis, are summarised in Table 4.1. The CGE models are divided into Macro and Walrasian models.

Table 4.1 Surveyed CGE models for South Africa

Year	Model	Modellers/Authors	Publication
1993	Macroeconomic Forecasting Model (IDC CGE Model)	IDC with assistance from Impact Research Group of Monash University in Australia	IDC, Empirical Estimation of Elasticities in IDC's General Equilibrium Model (IDCGEM), Technical Series (TS2/1997), Industrial Development Corporation, Pretoria. JOULBERT, R. 1994. IDCGEM - A General Equilibrium Model of the South African Economy. Paper prepared for the EBM Research Conference, Johannesburg.
1993	Macroeconomic Forecasting Models (A Provisional CGE model for South Africa)	W.A. Naudé and P. Brixen	A Provisional CGE Model for South Africa. <i>South African Journal of Economic and Management Sciences</i> . 10: 22-33. On a Computable General Equilibrium Model for South Africa. <i>South African Journal of Economics</i> . 61(3): 153-165.
1994	Macroeconomic Forecasting Model (The National Institute for Economic Policy Model)	Peter Brain (NIEP Model – Original architects were S. Gelb, B. Gibson and L. Taylor, 1990)	Modelling the South African Economy – Real financial interaction. Working paper. Macroeconomic Research Group, University of Durban-Westville.
1995	Macroeconomic Forecasting Model (DBSA Model)	Development Bank of Southern Africa (DBSA) (built by B. Gibson and D. van Seventer)	The DBSA macro model, Development Bank of Southern Africa, Development Paper no 120, Halfway House.
1995	Macro, Sectoral Policy Models (Government Spending Programs)	J.M. Horridge, B.R. Parmenter, M. Cameron, R. Joubert, A. Suleman and D. de Jongh	The Macroeconomic, Industrial, Distributional and Regional Effects of Government Spending Programs in South Africa, General paper no. G-109, April.

1997	Macroeconomic Forecasting Model (Currency depreciation, trade liberalization and economic development)	W.A. Naudé, Z.R. Coetzee & K. Gwarada	Currency Depreciation, Trade Liberalisation and Economic Development. <i>South African Journal of Economics</i> . 65(2): 165-190.
2000	Macro, Sectoral Policy Models (Trade Policy Reform)	S. Devarajan and J. Lewis	Trade Reform in South Africa: Impacts on Households, Working paper: World Bank.
2000	Macro, Sectoral Policy Models (Poverty and income distribution)	N.M. Humphreys	A Poverty Focused CGE Model for South Africa, May.
2000	Macro, Macroeconomic impact of HIV / Aids (The World Bank CGE Model)	Arndt, C. and Lewis, J.D.	The macro implications of HIV/AIDS in South Africa: A preliminary assessment. <i>South African Journal of Economics</i> , 68 (5): 856-887.
2001	Macroeconomic Forecasting Model (intended to reduce the initial cost of undertaking CGE analysis in South Africa)	International Food Policy and Trade and Industrial Policy (CGE modelling framework developed by Löfgren)	Thurlow, J. 2003, A Dynamic Computable General Equilibrium (CGE) Model for South Africa: Extending the Static IFPRI Model, International Food Policy Research Institute Washington, D.C. Thurlow, J. (2003a) "Further Trade Liberalisation and Reform in South Africa: An Economy-Wide Assessment". TIPS Discussion Paper. Thurlow, J. 2003b, "The Impact of Regional Trade Agreements on the South African Economy". TIPS Discussion Paper. Davies, J., 2003. Microsimulation, CGE and Macro Modelling for Transition and Developing Countries. Paper presented as WIDER conference on Inequality, Poverty and Human Wellbeing, 30-31 May, Helsinki, Finland.
2001	Walrasian, Environmental Model (Revenue neutral tax on coal)	T.J. de Wet and J.H. Van Heerden	The dividends from a revenue neutral tax on coal in South Africa, <i>The South African Journal of Economic and Management Sciences</i> , 6: 3, Pretoria.
2001	Walrasian, Trade Liberalization Model (Agricultural exports of	S. McDonald and C. Punt	Some Welfare Implications of a Land Tax on the Western Cape, Paper prepared for the Biennial Conference of the Economic

	Western Cape)		Society of South Africa, Somerset West, South Africa, September 17-19.
2002	Walrasian, Fiscal Policy Model (VAT in RSA)	M. Kearney and J.H. Van Heerden	A Static, Stylised CGE model applied to evaluate the incidence of Value Added Tax in South Africa. Economic Society of South Africa: Bi-annual conference, Johannesburg.
2003	Walrasian, Fiscal Policy Model (Effects of a wage subsidy scheme)	K. Pauw and L. Edwards	Evaluating the General Equilibrium Effects of a Wage Subsidy Scheme for South Africa, Paper prepared for the Biennial Conference of the Economic Society of South Africa, Somerset West, South Africa, September 17-19.
2003	Macro, Sectoral Policy Models (Trade and Competition Policy)	M. van Schoor and L. Burrows	Trade and competition policy in a computable general equilibrium model (CGE) with imperfect competition and returns to scale, Biennial Conference of the Economic Society of South Africa, Lord Charles Hotel, Somerset West, South Africa.
2004	Walrasian, Environmental Model (Energy policy)	J. van Heerden, R. Gerlagh, J. Blignaut, S. Hess, R. Mabugu, M. Chitiga and T. de Wet	On Using a CGE Model to Simulate Energy Policy in South Africa, Ninth Annual Conference on Econometric Modelling for Africa, 30 June – 2 July.
2004	Macroeconomic Forecasting Models (Income inequality in South Africa)	W.A. Naudé and R. Coetzee	Globalisation and inequality in South Africa: Modelling the Labour Market Transmission, <i>Journal of Policy Modelling</i> , forthcoming.

Disclaimer¹

Along the lines of Robinson (1989) and Willenbockel (1994) we may make a distinction within CGE analyses based on their origins, objectives and theoretical background. The main division in CGE models made in the literature is between Walrasian CGE models and macro CGE models.

¹ A disclaimer is applicable here: Because CGE analyses are used for policymaking and private consultancies, information on CGE models is not freely available in the public sphere. Therefore, this section looks at the models and work available as academic papers and publications. But even in this area all the unpublished work is not always accessible, for example, Burrows (2003) (References for unpublished work in Appendix) that could not be included here.

4.2.1 Walrasian CGE models for South Africa

Recently a number of models for South Africa have been published which are Walrasian in character. These models are all based on the optimising behaviour of representative agents and have the objective to analyse the quantitative effects of exogenous changes on the optimal allocation of resources, on efficiency and on welfare.

Many of these include large-scale multisectoral CGE models of the South African economy developed by the Industrial Development Corporation (Coetzee *et al*, 1997), the World Bank/OECD (van der Mensbrugghe, 1995; Devarajan and van der Mensbrugghe, 2000), and the Development Bank of Southern Africa (DBSA, Gibson and van Seventer, 1996a). These models resulted in a number of applications such as investigations in trade liberalisation, green trade restrictions, currency devaluations, and government expenditure and restructuring (see for example Cameron 1994; Gibson and van Seventer, 1996b, 1997a, 1997b).

A distinction between these models can be made with respect to the following research subjects:

- Fiscal policy models.
- Environmental models.
- Trade liberalisation models.

4.2.1.1 Fiscal policy models

Value Added Tax (VAT) in South Africa: The model of Kearney and Van Heerden (2001), based on the SAM adapted from Devarajan *et al*. (1994) and Ginsburgh *et al*. (1997), is built within the Walrasian tradition. In the tradition of these models, it addresses the effects of fiscal policy, i.e. the incidence of Value Added Tax in South Africa. This closed economy model is highly stylised with no capital accumulation and fixed expenditure shares of the two distinguished income groups which each have a choice between two consumer goods. The model is a multisector model.

The results drawn from the model indicated that a percentage increase in VAT would not affect the lower income groups negatively if the higher government revenue flowed to the lower income group. Furthermore, most necessities used by the lower income groups are exempted from VAT. Therefore, any policy measures aimed at promoting growth, the redistribution of income, employment and the general increase in the standard of living can consider an increase in VAT. Government revenue increased with almost 2,5% through the increase in VAT.

Effects of a Wage Subsidy Scheme: Pauw and Edwards (2003) stated that unemployment amongst semi- and unskilled workers had reached severe proportions (over 50%) and threatened the political and economic stability of the South African economy. They used a CGE model of the South African economy to assess the economy-wide impact of a wage subsidy targeted at semi- and unskilled workers.

The model used was developed by the International Food Policy Research Institute (IFPRI) (see Löfgren *et al.*, 2001) and adapted for South Africa by Lewis (2001). The model is Walrasian and neoclassical in form, where the standard neoclassical model assumes full employment in all factor markets. This assumption is, however not valid for semi- and unskilled workers in South Africa. To model semi- and unskilled unemployment they assumed a fixed real wage and an unlimited supply of labour at this wage. All other sub-classes of labour (professional, skilled and informal workers) were considered mobile and fully employed at flexible wages.

The results from the model proved that under conditions of well-functioning labour markets (which is not completely the case in South Africa) a wage subsidy scheme could have positive effects on employment and various other economic aggregates. It was further found that increased consumption, investment, income, savings and employment could contribute towards higher output and GDP. They found that the method of financing as well as the scope of the subsidy could potentially have important indirect effects and should be considered carefully. However, wage subsidy schemes are only one of a possible

array of policy options to reduce unemployment. Therefore, it was found that careful evaluation of the alternatives is important prior to the implementation of a wage subsidy scheme.

4.2.1.2 Environmental models

Revenue Neutral Tax on Coal: Because the current tax system in South Africa is structured such that most of the tax burden falls on labour, the aim of De Wet and Van Heerden's model (2001) was to determine whether a fiscal reform that introduces a revenue neutral tax on the use of coal, could result in an increase in the overall welfare of South African citizens. The model used by De Wet and Van Heerden (2001) was an applied general equilibrium model of the South African version of the ORANI-G model. The model distinguished between 45 sectors of production in South Africa, which included the coal sector. 14 different households were distinguished along income groups, while capital, labour and land were included as primary factors of production. Distinction was also made between 4 different types of labour.

The results from the model indicated that an increase in the tax on coal would have positive, if marginal, environmental benefits for South Africa. Such a tax would, however, have negative consequences for the South African economy in the form of a lower level of employment, consumption and economic growth.

Energy Policy: Van Heerden, Gerlagh, Blignaut, Hess, Mabugu, Chitiga and De Wet (2004), analysed the question whether a developing country like South Africa stands to gain from taxing either energy consumption or greenhouse gas emissions. In addressing this question, they consolidated and applied the theoretical concept of a double dividend using energy consumption and greenhouse gas emissions data for South Africa and a SAM, all for 1998, through the application of a CGE model.

The UPGEM-model used, was formulated and solved using GEMPACK, a flexible system for solving CGE models and based on the ORANI-G-model of the Australian economy. The model was based on the official 1998

SAM of South Africa, published by StatsSA. This SAM consisted of 27 sectors, which was split into 39 sectors for the purpose of this paper, 12 household types and 4 ethnic groups.

Regarding the effect on the environment, the results were very positive: all the tax combinations gave a positive environmental effect. The decreases in emissions per unit of real government revenue collected when the four forms of environmental taxes were implemented, were in all cases more than the increases that could be expected with the tax breaks given. The tax breaks considered were a general decrease in the direct tax rates on labour and capital, and a general decrease in the indirect tax rate on final consumption. The implication of the study was that as long as an economic benefit from recycling taxes could be achieved, it would always be possible to reap a double dividend as well.

4.2.1.3 Trade liberalisation model

Agricultural Exports: McDonald and Punt (2001) used a CGE model to analyse the impact of increased agricultural export opportunities upon the economy of the Western Cape, with specific reference to grape and deciduous fruit production that had achieved appreciable productivity growth. The model was calibrated with a SAM for the Western Cape in 1993, in which agriculture (24 commodities and 9 agronomic activities/regions) and labour (11 skill classes and 4 racial classes) were extensively disaggregated.

The results from this model demonstrated that the economic benefits accruing from expanded export opportunities were not only influenced by capacity constraints but also by the patterns of interdependence within an economy. In the case of the Western Cape it was evident that the increases in exports of wine, table grapes and other deciduous fruits should have contributed positively to increases in employment and rural incomes, especially among farm-worker households. They should also have contributed to reductions in income inequalities. More importantly, the extent to which capacity constraints could be released would be an important determinant of the absolute magnitude of the benefits. This

suggested that trade opportunities accompanied by productivity growth were likely to be complementary in the search for growth and reduced inequality.

4.2.2 Macro CGE models for South Africa

Most of the earlier and also recent CGE models for South Africa are macro CGE models. These models primarily focus on the impact effect of different policies on the distribution of income, the trade balance and sectoral growth. Most of the models use closures that deviate from the neoclassical closure. Similar to Walrasian models, the closures of most macro CGE models for South Africa are determined by calibration.

The macro CGE models for South Africa may be divided into the following three main groups:

- Macroeconomic forecasting models.
- Policy models used in different sectors.
- Models studying the macroeconomic impact of HIV / AIDs.

4.2.2.1 Macroeconomic Forecasting Models

A Provisional CGE Model for South Africa: The very first CGE model for South Africa was built by Naudé and Brixen (1993). They used a multi-sector CGE model of which the equations were derived from solving the constrained optimisation problems of four types of households, the government, the external sector and 11 sectors of production. A SAM for 1988 was used as a database to calibrate the model's equations. The model consisted of a system of simultaneous non-linear equations and was based on the work of Drud *et al.* (1986), Drud and Kendrick (1990) and Dervis *et al.* (1982). The model consisted of a set of demand equations, a set of supply equations and linkage equations that ensured that total supply equaled total demand without necessarily matching individual suppliers with individual demands (Pyatt, 1988).

This model was one of the first CGE models suggested for South Africa, and was therefore regarded as provisional as far as the choice of factors, institutions, sectoral disaggregation and mathematical representation of the relationships between them were concerned. Economic policy simulations with the above model were performed through HERCULES. The results from each experiment were given by HERCULES in the form of a new SAM, which could be compared to the base 1988 SAM to obtain the effects of the economic policy.

Naudé and Brixen (1993) used the above model in comparative static fashion to simulate the impact of a 10 percent increase in real government consumption, a 10 percent increase in export demand, a 10 percent increase in the world price for exports and imports, and a 50 percent reduction in import tariffs. Each of the four experiments listed above were repeated under four sets of closure rules. The results from the experiments were consistent on a number of issues. First, the type of closure rule under which the experiments were performed was crucial for the results. Second, the special role played by the mining sector was distinguished. In many experiments the mining sector behaved differently from the other domestic sectors. Third, it was noticeable that the South African economy was particularly vulnerable to external shocks, no doubt due to the specific structure of the South African economy such as the dependence on foreign capital goods, coupled with the tendency for the government to expand expenditure when the gold price rises but not to cut back on programmes when the gold price falls. Fourth, other aspects of traditional structural adjustment programmes, such as liberalising trade, should be considered. Fifth, the saving-investment closure, whereby investment is saving driven, played an important role in the results that were obtained. Finally, although some of the simulated policies did have some effect in redressing the unequal distribution of income, these effects were marginal. It was found that the dominance of the government sector was part of the structural problem facing South Africa. The government should become a part of the solution, rather than remaining a part of the problem of economic restructuring. The emphasis should rather be on avoiding a "bloated bureaucracy syndrome" (Hugo and Stack, 1992:69) while increasing the

effectiveness of government expenditure through changing the composition of the budget expenditure.

The National Institute for Economic Policy Model: The NIEP model was developed by the Macroeconomic Research Group (MERG), which was established in the early 1990s. Their goal was to create an economic blueprint for the incoming African National Congress led government. S. Gelb, B. Gibson and L. Taylor, the original architects of the MERG model, developed a structuralist CGE model, which was then transformed into a structuralist-macroeconomic model with 1534 endogenous variables and 60 exogenous variables by Peter Brain of the National Institute of Economic and Industry Research in Australia. The model altered by Peter Brain was used intensively by MERG to formulate their quantitative policy recommendations. "Specifically, it simulated the requirements of the Reconstruction and Development Programme (RDP) in terms of employment generation, changing patterns of income distribution, balance of payments sustainability and the government deficit" (Jerome, 2004). The model was also used for further studies regarding infrastructure and the impacts of implementing a tariff reduction schedule.

The models' underlying theoretical framework was neo-Keynesian structuralist and emphasis was on aggregate demand. The results from the model indicated that, for the RDP to succeed given the rate of population growth, living standards of the top 20 per cent of households needed to remain constant or improve marginally over the next four to five years after which it could improve in line with the growth rate. Activities which will increase the stock of physical infrastructure, skill formation and physical capital formation, must be targeted by fiscal expansion and the reform of the tariff system must be gradual enough to encourage enterprises to adjust to international competition and enhance their export capabilities (Jerome, 2004). "Over the medium term, it will be necessary to adopt export oriented incentives for strategic industries in order to partly offset the anti export bias as a result of tariff reduction and rising imports" (Jerome, 2004).

The IDC's CGE model: The IDC model was developed in 1993 with the aid of the Impact Research Group of Monash University in Australia. The model was developed with the objective of assisting policymakers in quantifying the impacts of proposed economic policy measures. The model was used to evaluate the effects of increase in government spending under different financing methods; the implications of capital flows and trade policy on the industrial sector of the economy; the effects of an increase in government spending on provincial gross products; and the implication of the adoption of Uruguay Round trade liberalisation measures (Jerome, 2004).

The IDC model is a CGE model and a trial product of the Australian ORANI-F model. The theoretical foundation of the IDC model was provided by neoclassical Walrasian general equilibrium theory, with optimising behaviour for individual actors and firms in the economy. All industries have a constant elasticity of substitution technology, although input proportions and behavioural parameters may vary between industries (Jerome, 2004). The model is calibrated to a SAM, which is disaggregated into 103 single-product industries, 2 classes of commodities, 65 categories of labour and 24 households.

The results obtained from applying the model indicate that the income distribution effects of an increase in government spending financed by domestic borrowing and foreign capital inflows are relatively small. The results recommended the adoption of counter measures to offset the real exchange rate appreciation. The IDCGEM is the largest and most frequently used CGE model in South Africa (Burrows, 1995), and was used to inform South Africa's GATT negotiations. The results indicated that the implementation of the GATT would stimulate both final and intermediate goods, and that by reducing domestic costs relative to international price levels it would stimulate exports.

Currency depreciation, trade liberalisation and economic development: Coetzee, Gwarada, Naudé and Swanepoel (1997) used a CGE model, the IDCGEM of the Industrial Development Corporation (see also Joubert, 1994; Horridge *et al.*, 1995; 1996; Burrows, 1995), to

model two scenarios implied by trade liberalisation and the depreciation of the Rand. The first scenario took into consideration the abolition of surcharges, the phasing-out of GEIS (General Export Incentive Scheme), the current tariff reduction programme (TRP) and a 20 percent depreciation in the nominal effective exchange rate. The second scenario was the same as the first scenario except for the TRP. The TRP was accelerated by decreasing all tariffs by 5 percentage points (or less for tariffs lower than 5 per cent) starting in 1997.

IDCGEM is a multi-sectoral CGE model consisting of a system of simultaneous non-linear equations. It contains 103 single-product industries, 2 margins commodities, 65 categories of labour and 24 households. The input-output database was compiled by WEFA SA (now Global Insight Southern Africa) working from Van Seventer, Eckert and de Lange (1992). Data for the occupational and race disaggregation of employment and for the race and income level disaggregation of the household sector, was supplied. IDCGEM was applied in a so-called comparative-static way, assuming that the envisaged changes and shocks were applied to the economy "overnight". Furthermore, the results represented a "worse-case scenario" given a sudden, as apposed to a phased-in, implementation of the shocks.

The simulation results indicated that an accelerated tariff reform programme reduced the inflationary impact of depreciation on producers and households. The results from the study using theoretical as well as empirically-based arguments, was that, while a currency depreciation of the South African currency amidst trade liberalisation might be in conflict with development, accelerated tariff reduction suggested by the macroeconomic strategy might ease this conflict.

The Development Bank of Southern Africa (DBSA) Model: The DBSA model was built by Gibson and Van Seventer in 1995 and originated from Gelb, Gibson and Taylor's work on the MERG model. The model also updates and revises Gelb, Gibson, Taylor and Van Seventer (1993). This structuralist CGE model was used to examine the consistency and impact

of the new government's policies and to explain the effects of exogenous shocks on the economy.

The model is essentially a dynamic CGE model resting on a social accounting matrix and various real-financial interactions and incorporates conventional macro-economic relationships. The DBSA model is structuralist in that real-world departures from the Walrasian ideal of competitive markets are recognised and integrated through the incorporation of structural rigidities (Jerome, 2004). This is modelled by assuming that the economy is less responsive to changes in relative prices, at least in the short run (Gibson and Van Seventer, 1996a). A real and a financial SAM are used to calibrate the model and parameters are either based on fixed coefficients of the underlying SAMs, or are determined by assumption. The real SAM is based on the SAM for the year 1988 compiled by Van Seventer *et al.* (1992).

Economic activity is divided into nine sectors: one service sector and eight goods-producing sectors. These sectors are divided between price adjusting sectors (i.e., agriculture and mining), which are assumed to be operating at full capacity, and quantity clearing sectors. One set of uncalibrated coefficients are used in the investment functions of all of the sectors. These sectors are coefficients defined to capture the effects on specific sector's investment of changes in the real interest rate, inflation, capacity utilisation, profit rate and government investment (Jerome, 2004).

The model evaluates the impact of changes in the volume and structure of trade on macroeconomic variables; the effect of contractionary fiscal policy on the economy; and outlines the elements of a growth strategy for the medium term. It examines: the implications of an increase in government investment by raising the ratio of the Public Sector Borrowing Requirement (PSBR) to GDP by about 0,5 per cent; a proposal to fund low-income housing expenditure by reducing the level of government; the effects of a policy that emphasises export growth; the impact of a possible devaluation on income distribution, inflation,

growth and employment; and the macroeconomic consequences of different government expenditures scenarios.

The results obtained from the models' simulations indicate that the effect of export growth on macroeconomic variables depend on the way in which it is brought about. The core outcome of a devaluation of the exchange rate is to ease the balance of payments constraint through growth in non-traditional exports. As stated by Jerome (2004) "elements of a growth strategy should be the lowering of the marginal capital output ratio in various sectors through increased public sector spending and encouraging small and medium –sized enterprises". Under the assumption that the ratio of PSBR to GDP would decline, the implications of adopting a contractionary fiscal policy were examined. These policy implications were that an increase in private sector investment would not be sufficient to offset the PSBR decline completely resulting in moderate growth with increasing unemployment and a decline in public investment. In public expenditure, switching from the current to the capital account would result in a similar growth path, but with more inflation (Jerome, 2004).

International Food Policy and Trade and Industrial Policy Models:

The models' intention was to reduce the initial cost of undertaking CGE analysis in South Africa. Despite the model being essentially neoclassical, it is suitably adaptable to accommodate an extensive number of views on how the South African economy alters to exogenous shocks and the use of policy levers.

The model is recursive dynamic and is therefore an extension of the IFPRI model. The neoclassical-structuralist modelling tradition originally presented in Dervis *et al.* (1982), is used to create the model and is formulated as a set of simultaneous linear and non linear equations, which define the behaviour of economic agents, as well as the economic environment in which these agents operate. Market equilibrium conditions, macroeconomic balances, and dynamic updating equations are used to describe this environment (Jerome, 2004).

Using national accounts information and supply-use tables, a 1998 SAM for South Africa is compiled. The requirements of IFPRI's standard comparative static CGE model are used to make the SAM consistent. The economy-wide impact of a range of hypothetical policy levers, including: increased government spending; the elimination of tariff barriers; and an improvement in total factor productivity under three adjustment rules labelled loosely as neoclassical, Johansen and Keynesian, are simulated by using the above model. These adjustment options treat savings and investment differently. Under the neoclassical adjustment rule the economy is assumed to be savings-driven, while under the Johansen adjustment option the economy is assumed to be investment-driven and that savings-rates are scaled to ensure that the level of savings and investment is balanced. Finally, the Keynesian adjustment approach assumes that both the level of investment and the savings rates are fixed, where savings will still adjust to balance investment in that higher income will generate more savings given a fixed savings rate.

The results indicate that in determining the expected impacts of these policies, the assumptions made regarding the mechanisms of macroeconomic adjustment are important. To begin with, despite mixed results concerning changes in household income distribution, the effect of expansionary fiscal policy seems to be growth enhancing, while the Keynesian adjustment approach produces the most positive results. Furthermore, an elimination of import tariffs appears to have an increasing effect on the gross domestic product, with negative consequences for aggregate manufacturing and positive consequences for services. Lastly, an increase in total factor productivity enhances growth, while under neoclassical assumptions of the macroeconomic adjustment mechanisms the most positive results are derived (Jerome, 2004).

In the standard IFPRI model there is no explicit modelling of the financial market. The static model estimates the impact of a change in policy using comparative static analysis, and therefore there is no reflection of the path of adjustment over time, or of any dynamic feedbacks into the economy through changes in investment, technology

or productivity. In acknowledgment of this defect, the model has been upgraded by Turlock in 2001 into a recursive dynamic CGE model, where he based the behaviour of agents on adaptive expectations (Jerome, 2004).

The structure of the static model is similar with the exception that two SAMs are compiled for the years 1993 and 2000. A number of equations that allows the regional disaggregation of international trade; an upward sloping factor supply curve; and factor-specific productivity adjustments, have been included in the IFPRI model.

The model has already been used in a number of studies. A number of topics are covered, including health and health policy; social security and public finance; and labour market and trade policies. The model was used for a number of studies, including a study done by Ramprasad and Thurlow (2003) to reflect the impact of HIV-AIDS and the provision of anti-retroviral treatment on the South African economy. Davies (2003) also used the model to consider the effects of alternative labour market policies on future levels of employment and Thurlow (2003a and 2003b) used the model to review the impact that trade liberalisation, reform, and the adoption of regional trading agreements might have on the South African economy.

4.2.2.2 Policy models used in different sectors

Trade Policy Reform: A fairly standard static neoclassical CGE model was used by Deverajan and Lewis (2000) to assess the impact of trade reform on households. The 1992 SAM comprising 94 productive sectors was used to calibrate and determine the structure of the model. "The base SAM is aggregated into 34 sectors, 13 labour skill categories (further subdivided by ethnic group) and 24 households (4 ethnic groups, each subdivided into 6 income classes)" (Jerome, 2004). The current expenditures of the government are divided into five classifications, and investment is divided into its public and private components. Many sources of transfers are distinguished in both the SAM

and the model, for example transfers from government to households and across households.

Firstly, nested constant elasticity of substitution (CES) functions, and constant returns to scale, are used to model production. Secondly, household demand is modelled using the Extended Linear Expenditure. Thirdly, trade is modeled using the Armington assumption for import demand. Finally, a constant elasticity of transformation (CET) is used to model export supply. Consequently world import and export prices are given and terms of trade are fixed, since the small country assumption is assumed for all sectors. All markets, except for the labour market for unskilled black workers, are assumed to clear through prices, the reason for this being that in the labour market for unskilled black workers the real wage is assumed fixed and unemployment clears the labour market. Labour is assumed to be perfectly mobile across sectors for each labour skill type, and therefore there is a single nation-wide wage at which equilibrium can be found (Jerome, 2004).

The assumption is made that all households have the same utility function, although with different parameters. A modified version of the Stone-Geary linear expenditure system known as the extended linear expenditure system (ELES) is used in the model. "Consumer demand for any good (including demand for savings) has two components: a subsistence minimum and a fixed fraction of "supernumerary income", or disposable income less expenditures on all the subsistence minima" (Jerome, 2004). Simulations were done using four trade reforms, two diverse closure rules, two diverse assumptions on capital mobility and a complete removal of all tariffs.

The results obtained from the models' simulations indicate that black South Africans could benefit from trade liberalisation, even though it might be at the expense of wealthier white South Africans and that income distribution among blacks could worsen, while that within whites could improve. A shortcoming of the model might be the derivation of elasticities, which might have a large impact on the outcome of

simulations. They were not estimated econometrically, but were based on informed judgement.

Trade and Competition Policy: Van Schoor and Burrows (2003) tried to develop a reasonably complex CGE model that included the features of imperfect competition and returns to scale in production. The model was based on the standard IFPRI model (Lofgren *et al.*, 2001) and was developed as a general-purpose model for developing countries and the issues affecting them. The IFPRI model is comprehensive in features but flexible in implementation, and is based on widely accepted CGE practice. Thurlow and Van Seventer (2002) first implemented the model for South Africa and their 1998 SAM and other data (elasticities, parameters, etc.) were used by Van Schoor and Burrows for their model, since their data requirements were almost identical.

Van Schoor and Burrows (2003) presented a CGE with imperfect competition and returns to scale. Their results from their simulations showed that the inclusion of these features had important implications for trade, such that trade could have negative gains, although dependent on the particular closures chosen. Generally, the gains from trade were higher than in the same model without returns to scale and imperfect competition, at 1% or 1.1%, depending on the closures chosen, if measured by GDP change. They also found that welfare gains were much higher if firms were allowed to enter and exit sectors in response to changes in availability of economic profits. The applicability of their results was seriously hampered by the fact that most of the underlying data were not available, and consequently had to be practically made up.

Government Spending Programmes: Horridge, Parmenter, Cameron, Joubert, Suleman and De Jongh (1995) used a CGE model of the South African economy (IDC-GEM) to analyse the effects on the economy of increases in government spending such as were at the core of the government's Reconstruction and Development Programme. The analysis concentrated on the implications of alternative methods of finance for the programme.

The results of their simulations indicated that, with no restraints on government borrowing or foreign borrowing, an increase in government spending (at constant rates) expanded GDP and real consumption. It induced an appreciation of the real exchange rate, which restricted exports and promoted imports. Industries producing non-traded goods, especially for government demands, expanded relative to export and import-competing sectors. The results also showed that provinces which were dependant on export sectors, tended to lose shares in GDP, unless as in the case of the then Northern Transvaal they had relatively large shares of government industries. The income-distribution effects were also found to be small.

The result showed further that with a constraint on foreign borrowing, any increase in government spending not financed by taxation crowded out private investment. Private investment was relatively import-intensive implying that an appreciation of the real exchange rate would be required to preserve trade balance.

Poverty and Income Distribution: Compared to the rest of the world, South Africa has amongst the most skewed distribution of income and wealth, which could be attributed to several decades of apartheid. As shown by the World Bank (2000), about 13 percent of the population experience "first world" conditions, with access to education, low infant mortality rates, and minimal poverty while around 53 percent of the population, half of which have less than a primary school education, live in "third world" conditions, suffer from chronic malnutrition and maximal poverty. The greater number of South African households experience outright poverty and continuing vulnerability to being poor. Despite this bleak outlook, there are only a few models that explicitly model poverty situations. The notable exceptions are the CGE models by Naudé and Coetzee (2004) and Humphreys (2000).

The paper by Naudé and Coetzee (2004) draws on a CGE model to evaluate the extent and causes of income inequality in South Africa after 1994. They extend the CGE-modelling approach in South Africa by incorporating dynamics into the comparative static CGE model used by

the Industrial Development Corporation of South Africa. The 1995 SAM for South Africa developed by DRI-WEFA SA (Pty) Ltd. (now Global Insight Southern Africa) was used as database.

Naudé and Coetzee (2004) determined that the labour market is a broadcast instrument through which globalisation induces higher inequality through technological changes, higher unemployment and less wage income towards poorer/unskilled households. The labour market imperfections that they identified contributed to allocative inefficiency (the demand for high skilled labour outstripping the supply), dynamic inefficiency (the quality of the South African labour force may be declining in relative terms) and a deficiency of social justice and sense of equity. In an era of globalisation all of these failures or inefficiencies advocate the importance of labour market and human resource development policies as an answer towards the inequality, unemployment and low growth experienced by South Africa.

Naudé and Coetzee (2004) stated that "In South Africa, the elimination of racial discrimination and unionisation had reduced wage inequality, although the latter had through lowering wage employment indirectly contributed to higher household inequality". Furthermore, they found that wage setting ought to be made more flexible. The results suggest employment growth of up to 5.3% per annum on average may be realised under flexible nominal wage rates (constant or declining real wage rates) and that some of the adverse unemployment effects due to globalisation and technological upgrading could be avoided.

The results from the CGE model used by Naudé and Coetzee (2004) suggest that the welfare of African households will be affected unfavourably relative to that of other households by only between 1% and 3%. They also found that by raising African households' average annual expenditure by between 1% and 3% over the next three years it could assist in softening the inequitable impact of trade liberalisation in South Africa.

By using a CGE model of a small economy, Humphreys (2000) gave an appraisal of the impact of liberalisation on poverty in South. The goods in the model were aggregated into three types; primary goods including mining and agriculture; industrial goods and services, which made the model restrictive and it considered only three types of consumers: non poor, poor and very poor; three factors (capital, skilled and unskilled labour); and nine goods (non traded, import and export variety from each of the three sectors). Despite the fact that the model allows for unemployment, it is essentially Walrasian in character. The model uses a simplified version of the 1992 SAM with the addition of labour market and tariff rate data from other sources. Most of the parameters are borrowed from Devarajan and Van der Mensbrugghe (1999) and labour market information from Kingdon and Knight (1999).

The closure rule used in Humphreys' simulations was the classical closure rule in which a fixed savings rate was assumed for government and all consumers. Furthermore, to ensure that the investment-savings identity held, investment was adjusted. The circumstances assessed were gradual reduction in the tariff rate of each protected sector from 25% to 0% and a 5% increment. The results from the simulations indicated that government revenue fell obscurely from liberalisation, which resulted in a general fall in transfers from government to households and a reduction in government services. The growth of real income of non-poor and poor consumers, for whom these transfers constitute a small share of income, was only somewhat affected by the drop in government transfers. The very poor on the other hand, experienced a more extensive growth of real income as a result of a drop in tariffs (Jerome, 2004).

4.2.2.3 The Macroeconomic Impact of the HIV /AIDs Pandemic

The realisation that South Africa currently faces one of the highest HIV incidence rates in the world has fueled the growth in research interest on the economic impact of HIV/AIDS in South Africa. The message conveyed by these models, despite the diversity of the methodological approaches to modelling the economic impact of HIV/AIDS, remains the

same: HIV/AIDS will have major cost implication for South Africa in economic, social and human terms.

These models have been portrayed as highly aggregated and their impact largely manifests in terms of the demographic and labour market aspects of the HIV/AIDS epidemic. The formal sector is the main focus, and then by regarding the rest of the economy and labour force, deductions are made. Seeing as most Africans live and work in the informal sectors, in which market valuation of activities leaves much to be desired, the accuracy and believability of the results are severely affected. When demographic projections improve and when more precise assumptions can be drawn from micro-level research, the direct modelling approach might become more accurate (Ford *et al.*, 2002).

The World Bank CGE model: Arndt and Lewis (2000) used a supply-constrained CGE model to estimate the macroeconomic impact of HIV/AIDS on the economy of South Africa. Two scenarios, as stated by Jerome (2004), are created and compared: "a hypothetical "no-AIDS" scenario in which the economy continues to perform as it has over the last several years, and an "AIDS" scenario in which the key AIDS-related factors affect economic performance".

The World Bank CGE model is a Solow-type aggregated (one-sector, one-class) version of the standard neoclassical CGE model with profit-maximising producers, utility-maximising consumers and flexible prices that clear all markets except the market for unskilled labour, but lacks the distributional richness of a standard CGE model. The model is highly disaggregated with 94 productive sectors, 13 labour skill categories and 24 household types. "Institutional rigidities and imperfect markets are captured by the exogenous imposition of features such as immobile sectoral capital stocks, labor market segmentation, and a fixed exchange rate, which together limit a neoclassical interpretation of the models but permit their more realistic application to developing countries" (Jerome, 2004).

An aggregated version of a 1997 SAM estimated by WEFA, now Global Insight Southern Africa, was used to derive the basic data. This SAM has 45 productive sectors, and a household structure differentiated by deciles.

Fourteen productive sectors, including three service sectors of importance to analysis of HIV/AIDS, are contained by the model: medical and health services, social services, and government services. There are five primary factors of production (professional, skilled, and unskilled labor, informal labor, and physical capital), five household categories representing income distribution quintiles, seven different government functional spending categories, and three government investment categories. Sectoral production arises from a translog production function. This production function establishes how capital and labour inputs are combined together in generating value added. Output is then produced according to a fixed coefficients technology by combining the value added aggregate with intermediate (material) inputs. The assumption is made that producers maximise profits, which implies that each factor is demanded in order that marginal revenue product equals marginal cost. On the other hand, factors do not need to receive a uniform wage or "rental" (for capital) across sectors. The ratio of the sectoral return to a factor relative to the economy-wide average return for that factor is fixed by distorting the sectoral factor market.

The standard CGE assumption that domestic goods are imperfect substitutes for traded goods is maintained on the demand side of the model. Sectoral exports are combined using a constant elasticity of transformation (CET) function to form domestic output and the assumption is made that sectoral exports are different from output sold domestically. In both intermediate and final uses, as with exports, sectoral imports and domestically produced goods are imperfect substitutes.

Arndt and Lewis (2000) take a significantly pessimistic view by introducing a decline in total factor productivity (TFP) due to the HIV/AIDS virus, in addition to the loss of labour productivity resulting in

an increase of the negative macroeconomic impact. Total factor productivity, which is attributable to a combination of the two factor inputs (labour and capital) in production, refers to efficiency improvements (or declines). The authors justify the inclusion of this effect on the grounds that the epidemic will reduce the productivity of management and of capital (due to increased downtime linked to absenteeism), as well as lower morale amongst the workforce. While this seems conceivable, uncertainty remains why they couple the reduction of TFP growth to unskilled, in preference to skilled, labour, given that the activities of the latter are involved.

4.3 CLASSIFICATION OF CGE MODELLING

The surveyed CGE models are summarised in Table 4.2 in accordance with the classification framework illustrated in figure 3.1 in chapter 3. The CGE models are classified in three groups. The main classification of CGE models is based on both the historical development of CGE modelling and the intended purpose of the CGE models. The second classification is based on the main theoretical differences in the earlier macro models, namely, their closure, and the third classification of CGE models is based on the technique used to determine the parameters. This classification distinguishes between models with parameters based on the calibration technique and models with parameters based on econometric estimation (Thissen, 1998).

Table 4.2 Classification of CGE Models for South Africa

Macro	↔	Walrasian
1993, IDC CGE Model, IDC with assistance from Impact Research Group of Monash University in Australia, Macroeconomic Forecasting Model → Closure rule not available.		2001, Environmental Model, De Wet and Van Heerden, Revenue Neutral Tax on Coal → Short-run closure within the ORANI methodology – it is assumed that the supply of highly skilled and skilled labour is fixed.
1993, A Provisional CGE Model for South Africa, Naudé and Brixen, Macroeconomic Forecasting Model → Four closure rules used: (i) Fixed labour supply and flexible nominal wages together with a flexible exchange rate and fixed current account surplus. (ii) Fixed nominal wages with		2001, Trade Liberalization Model, McDonald and Punt, Agricultural Exports of Western Cape → The model closure rules impose the condition that land is agronomic region specific.

employment determined by labour demand with a flexible exchange rate and a fixed current account surplus. (iii) Fixed labour supply and flexible nominal wages with fixed exchange rate and flexible current account surplus. (iv) Fixed nominal wages and employment determined by labour demand with a fixed exchange rate and flexible current account surplus.

1994, The National Institute for Economic Policy Model, Peter Brain (NIEP Model – Original architects were Gelb, Gibson and Taylor, 1990), Macroeconomic Forecasting Model → Closure rule not available.

1995, DBSA Model, Development Bank of Southern Africa (DBSA) (built by Gibson and Van Seventer), Macroeconomic Forecasting Model → Closure rule not available.

1995, Sectoral Policy Model (IDCGEM model), Horridge, Parmenter, Cameron, Joubert, Suleman and De Jongh, Government Spending Programs → Closure rule not available.

1997, Macroeconomic Forecasting Model (IDCGEM), Naudé, Coetzee & Gwarada, Currency depreciation, trade liberalization and economic development → Not specified (IDCGEM was applied in a so-called comparative-static way, assuming that the envisaged changes and shocks were applied to the economy "overnight". Furthermore, the results represented a "worse-case scenario" given a sudden, as apposed to a phased-in, implementation of the shocks).

2000, Sectoral Policy Model, Deverajan and Lewis, Trade Policy Reform → Closure rule not available.

2000, Sectoral Policy Model, Humphreys, Poverty and Income Distribution → The classical closure rule is adopted in which a fixed savings rate is assumed for government and all consumers. Aggregate investment then adjusts to ensure that the investment-savings identity holds.

2000, The World Bank CGE Model, Arndt and Lewis, Macroeconomic Impact of HIV / Aids → Closure rule not

2002, Fiscal Policy Model, Kearney and Van Heerden, VAT in RSA → Closure rule not available.

2003, Fiscal Policy Model (Walrasian and neoclassical in its truest form) (IFPRI model), Pauw and Edwards, Effects of a wage subsidy scheme → Three closures were used for: The government balance (two alternative closures: One, government savings are assumed to be flexible; Two, a 'balanced budget' closure is modelled), the external balance (two possible closures: Either the exchange rate or foreign savings adjust to balance foreign flows), and the capital account balance (the savings-investment closure can be modeled in two ways: One, a Keynesian style model, with savings realized through changes in propensity to save. Two, a neoclassical savings-driven closure).

2004, Environmental Model, Van Heerden, Gerlagh, Bignaut, Hess, Mabugu, Chitiga and De Wet, Energy Policy → The closure rule reflects an economic environment in which the simulation results represent short-run time horizons. Differs from short-run closure model in that it differentiates between 11 different labour groups.

available.

2001, Macroeconomic Forecasting Model, International Food Policy and Trade and Industrial Policy (CGE modelling framework developed by Löfgren), intended to reduce the initial cost of undertaking CGE analysis in South Africa → Closure rule not available (three adjustment rules labelled loosely as neoclassical, Johansen and Keynesian, are used).

2003, Sectoral Policy Model, Van Schoor and Burrows, Trade and Competition Policy → Three closures are used: The savings-investment ("macro") closure, the neoclassical closure (IFPRI model employs a variant of this closure to fix investment not in absolute terms, but rather in terms of its ratio to GDP), and the Johansen closure, which relies on exogenous investment levels, and adjustment of savings to muster what is needed to cover investment.

2004, Macroeconomic Forecasting Model (IDC-DGEM, the IDC's Dynamic General Equilibrium Model), Naudé and Coetzee, Income inequality in South Africa → A short-term closure. The nominal scenario illustrates no deviation in the average nominal wage – i.e., a rigid nominal wage. It implies that through the average real wage and through changes in the real wage, total employment will be the adjustment mechanism in the labour market. Since nominal wages in the South African labour market tend to be sensitive in practice, this scenario can be viewed as a short-term closure.

Econometric



SAM-based

The following econometric models are not discussed in this study, but are only mentioned for reference:

1970, University of Pretoria Macroeconometric Model, de Wet and Dreyer, The model is linked to the United Nations through the Project LINK to long run global trends in world trade.

1991, The World Bank Macroeconometric Model, World Bank, The Macroeconomic Foundation, World Development Report.

2000, Reserve Bank Econometric Model, SARB, A model

1993, A Provisional CGE Model for South Africa, Naudé and Brixen, Macroeconomic Forecasting Model → 1988 South African SAM of Eckert *et al.* (1992) is used as a database.

1995, DBSA Model, Development Bank of Southern Africa (DBSA) (built by Gibson and Van Seventer) → The real SAM used is a flow matrix and is based on the 1988 SAM compiled by Van Seventer *et al.* (1992). The SAM was aggregated according to the categories of and updated to the year 1990 using data from the June 1992 issue of the SARB Quarterly Bulletin. Financial SAMs were prepared for 1989 and 1990, both as stock matrices.

comprising 400 equations was in use until the year 2000. This has been replaced by a far smaller model of 34 equations responsible for the main forecasts of the SARB inflation targeting, SARB Quarterly Bulletin.

1995, Sectoral Policy Model (IDCGEM model), Horridge, Parmenter, Cameron, Joubert, Suleman and De Jongh → Based on a SAM that was compiled by Claude van der Merwe of Economic Analysis Systems Pty Ltd, working from Van Seventer, Eckert and de Lange (1992).

1997, Macroeconomic Forecasting Model (IDCGEM), Naudé, Coetzee & Gwarada → Input-output database was compiled by WEFA SA working from Van Seventer, Eckert and de Lange (1992). Van der Merwe also supplied data for the occupational and race disaggregation of employment and for the race and income level disaggregation of the household section.

2000, Sectoral Policy Model, Devarajan and Lewis → Information on SAM not available.

2000, Sectoral Policy Model, Humphreys → It is based on a simplified version of the 1992 SAM with supplemented by labour market and tariff rate data from other sources. Most of the parameters are borrowed from Devarajan and Van de Mensbrugghe (1991) and labour market information from Kingdom and Knight (1999).

2000, The World Bank CGE Model, Arndt and Lewis, Macroeconomic Impact of HIV / Aids → The basic data is derived from an aggregated version of a 1997 SAM estimated by WEFA, a South African consulting firm.

2001, Environmental Model, De Wet and Van Heerden → a 2001 Social Accounting Matrix (SAM) of the South African economy by De Wet and Van Heerden (2001) as its primary source of data.

2002, Fiscal Policy Model, Kearney and Van Heerden → Information on SAM not available.

2003, Fiscal Policy Model (IFPRI model), Pauw and Edwards → Based on 1997 SAM for SA developed by WEFA, National Statistics data (SARB) from 1997 were used as control totals for the SAM.

2003, Trade Liberalization Model, McDonald and Punt → The SAM used is closely related to SAM structure

advocated by the System of National Accounts (UN, 1993), and is therefore distinctively different from the (implicit) SAMs used to calibrate the CGE models that have followed the lead of Dervis *et al.*, (1982). This SAM records exports as taking place from the commodity accounts, the make matrix includes secondary production and is not necessarily square, and prices are not expressed in terms of basic prices.

2003, IFPRI Model, Van Schoor and Burrows → Not based on Stats SA 1998 SAM, instead, based on their own compilation of data, including the 1998 supply-use tables published by Stats SA.

2001, Macroeconomic Forecasting Model, International Food Policy and Trade and Industrial Policy (CGE modelling framework developed by Löfgren) → Information on SAM not available.

2004, Environmental Model, Van Heerden, Gerlagh, Blignaut, Hess, Mabugu, Chitiga and De Wet → The model is based on the official 1998 SAM of South Africa, published by StatsSA.

2004, Macroeconomic Forecasting Model (IDC-DGEM, the IDC's Dynamic General Equilibrium Model), Naudé and Coetzee → The 1995 Social Accounting Matrix for South Africa prepared by DRI-WEFA SA (Pty) Ltd. (now Global Insight Southern Africa) was used as database.

4.4 SUMMARY

The first models are strongly influenced by the work of Naudé and Brixen (1993) and the structural approach to CGE modelling. Recent CGE models, though, are only partly built on the models of Naudé and Brixen (1993), although many of these models are related. It would be more efficient if the more recent models would use the experience of the previous decades of CGE modelling, though an explanation may be found in their difference in focus, extending only a small part of the model such that the model may answer the specific policy questions the model builder intends to address. However, the large scale restructuring of

many of the developing economies causes future research, next to improving parameter estimates, also to focus on adapting the earlier models for the changes in the economic structure. This has resulted in various models that are sophisticated with respect to small subsections, while staying highly stylised in other parts of the model.

To increase the policy relevance of the model it is of great importance that the models are also capable of addressing medium- to long-run policy simulations. Therefore, it is crucial that the reliability of parameter estimates increases.

This evaluation also makes clear the fact that CGE models are increasingly being used for forecasting and policy analysis in South Africa. The use of these models by policymakers, with the exception of the Reserve Bank, are however limited due to the supposed complexity of the analytical framework and the concentration of capacity within a small number of academic or related institutions (Thurlow and Seventer, 2002).

Problems are posed regarding the relevance and maintenance of most of the models due to their external orientation. Most of the modelling efforts, with the exception of the IFPRI/TIPS CGE model, have not been revised and updated periodically in line with new theoretical insight, findings and data.

Policymakers need to recognise that macroeconomic models play an important role in policy making, by providing the means to carry out policy simulations, explore alternative scenarios and to understand the past better by replaying history with alternative counterfactual assumptions (Murinde, 1993). Macroeconomic modelling teams should strive to be at the frontier of knowledge in modelling and theory. They should incorporate new insights notably in game theory, supply side modelling and the modelling of expectations and learning.

The next chapter concludes this study and reviews the main recommendations made. Further research possibilities are also presented.

CHAPTER 5

CONCLUSION AND RECOMENDATIONS

5.1 INTRODUCTION

Why is there a need for computable general equilibrium models? There are at least three reasons that can be given to answer this question: (a) to improve the understanding of economic processes; (b) to make predictions; and (c) to analyse the likely effects of economic policy and changes in such policy. For problems of types (a) and (b) many models have been devised, and are more or less effective under different conditions. For problems of type (c), the choices are more limited and the decision in any given case depends on the type of policy being investigated, the number of sectors affected, the relevant time period, and a few other factors.

CGE models have provided extraordinary insights into the working of economies and on the possible effects of macroeconomic policies, thus representing a significant advancement in economic analysis. However, it is not yet clear how accurate CGE models are quantitatively, particular in comparison to other types of models and despite many success stories in the field of CGE modelling, there is a need for something more.

In the first chapter it was asked: What is the state of computable general equilibrium modelling (CGEM) in South Africa after more than a decade of growth and development and what is the way forward? In trying to answer these questions, many issues have come to light. One is that, despite all the criticisms and limitations of CGE models, they are becoming more widely used by policymakers and academics in policy analysis and provide unique insights into the working of economies and on the possible effects of macroeconomic policies. Yet, a great deal remains to be done for CGE models to move beyond simply providing new insights to playing more of a role in policymaking.

Since building, applying, evaluating, and maintaining a CGE model of an economy is such a large responsibility and time consuming, only fractions of individual careers have been devoted to the effort. Institutional effort and funding might be required, both for application and theory. Joint research programmes of modellers, econometricians, theoreticians, and computational economists might be necessary to sustain an effective large scale CGE model of an economy.

The choice of a suitable methodology for economic impact analysis must, for these reasons, be undertaken on a case-by-case basis and it is also important that the analysis be presented in a manner in which the assumptions that form the basis of the results are clear. An accurate appraisal should include sensitivity analysis providing information on how changes in the models' specification, reflecting alternate assumptions, would affect the results. If such documentation is included, it may be taken as a sign of a considered analysis.

While this only partly answers the posed questions, it is now important to take a closer look at this study to properly formulate a more complete answer to these important questions. A summary of this study is given in the following section and the main recommendations made are reviewed in section 3. Certain important issues for future research on CGE modelling are summarised in the concluding section.

5.2 SUMMARY

Many policy issues have been addressed by CGEM: they have become standard tools to support economic policy analyses in developing countries (Bandara, 1991), they have proven themselves to be functional in describing economic interdependence and the price structure of an economy (Pyatt, 1988) and are functional for analysing issues such as income redistribution and economic restructuring (Devarajan *et al.*, 1991). CGE models have, however, only over the past fifteen years received attention from economists in South Africa. This is surprising in light of the fact that CGE models use a general equilibrium framework,

reflect the feedback and trickle down effects of an economic policy, use a consistent database and need data for only a single year (Naudé and Coetzee, 2004). Moreover, CGE models are explicitly based on theory and can thus evade accusations of "data mining" or "a theoretical time-series analysis" (Sims, 1980; Hendry, 1980; Darnell and Evans, 1990:113). CGE models enable one to perform counterfactual analysis, are deterministic, do not include error terms and provide a consistent and empirically rigorous framework for policy analysis and the repercussions of policy at the microeconomic level (Naudé and Coetzee, 2004).

Despite these advances in the field of CGEM, there are also limitations. One is the fundamentally static character of the analysis. This shortcoming can be avoided by allowing economic agents to pursue intertemporal optimisation. However, whilst this leads to many additional problems, the increased complexity, which an intertemporal framework entails, often means that modellers face a trade-off between the attention to behavioural detail and the degree of disaggregation which can be introduced, and thus may detract from one of the main benefits of CGE modelling. It is also not yet clear how accurate CGE models are quantitatively, particular in comparison to other types of models. Issues of functional form, elasticity specification, closure rules, sensitivity analysis, market structure, and dynamics need to be explored further. It should be examined whether CGE models better explain patterns in the data than other models and why modellers' findings differ from those produced by other types of models. Furthermore, issues of dynamics or time-paths of relationships in an economy, should receive more attention from CGE modellers (Iqbal and Siddiqui, 2001).

This makes one wonder: how do the results of CGE models differ from those of other models in South Africa? In other words, do CGE models add value? This might be a question for further and/or future research.

Questions still remain as to the dynamic stability of key parameters, many of which will have been deterministically calibrated given the base period dataset of CGE models. CGE analysis has inflexible data requirements, and this can be a potential source of difficulty. However,

it is believed that CGE models provide a detailed and consistent mode of analysis where partial equilibrium tools are insufficiently comprehensive.

The level of resources required to build a CGE model is little more than would be required for a careful SAM-based analysis. The decision about which tool to use is now less constrained by available computing technology. The modeller can concentrate on matching issues with the appropriate methodology, rather than be forced to pick a simpler methodology because available solution algorithms limit his or her ability to formulate more realistic models. Indeed, the gap between the formulation of new theory and its implementation in empirical models has shortened considerably in the past decade.

The science of economics advances through an interplay among new theory, statistical estimation, and empirical modelling. There is a healthy tension among these three strands that is evident in the work within CGE models. In the last decade, empirical implementation has pushed the limits of available theory and has moved significantly ahead of econometric estimation. In the last few years, there has been work to advance the theoretical underpinnings of CGE models, especially in the areas of trade and macroeconomics, and also to improve the statistical base for parameter estimation. No single strand has monopoly on "correct" analysis – it is through interplay among all three that progress is made.

Now that the policy issues addressed by CGEM have been presented and the limitations thereof brought to light, it is now possible to appraise the CGEM efforts of the past fifteen years and to indicate the way forward for CGEM in South Africa.

5.3 RECOMMENDATIONS

Many of the models that have been constructed for South Africa build on older models, although some models have started from scratch, either because of their ignorance of the older work, or because of the difference in focus of the model. A few Walrasian models exist, but most

of the models concentrate on either fiscal policy, the agricultural sector or trade liberalisation. It can be concluded that the model closure and the parameters are important for the obtained results. However, there is no agreement among modellers about which closure adequately describes the South African economy. This may be a consequence of the focus of the model and the time period under investigation.

The focus of the model also affects the type of country specific elements that are introduced. To address the South African economy many of the models discussed in chapter 4 incorporate structuralist features such as markup-pricing rules and excess capacity. The reforms implemented in recent years, and those to be expected in the near future will probably lead to less stringency in the South African economy and a more neoclassical modelling seems, therefore, appropriate (Jerome, 2004).

CGE models for South Africa have contributed to policymaking in a number of fields, such as development plans, agricultural programmes, tax policy and international trade. This is however still relatively limited, probably due to the period covered by the CGE analysis (usually short run), the unreliability of parameter estimates of the model and the analysed policy questions. Most of the CGE models for South Africa that have been discussed consider only short-term effects. A model that is capable of addressing medium to long-run analysis will certainly add to the policy relevance of these models.

With respect to the determination of parameters there is much room for improvement. The parameters of CGE models are in general, and also in the presented models for South Africa, derived from a calibration technique using only a SAM. The reliability of the resulting parameters is questionable because of possible exceptional circumstances in the base year of the SAM and the large consequences of errors in the data set, in terms of deviations of the calibrated parameters. The precise effect of deviations in the parameters from their 'actual' value due to the use of the calibration technique on the results of CGE analysis is difficult to assess. It is not clear which variations in simulation outcomes are reasonable and which are not. Furthermore, the exact formulation of the

model at hand, the value of other parameters not derived from the SAM and the size as well as the sort of policy measures will lead to different changes in the non-linear model outcomes.

The tremendous amount of work involved in systematically performing conditional or unconditional sensitivity analyses on large scale CGE models for errors in base year SAMs has prevented people from actually performing them (Harrison, Jones, Kimbell and Wigle, 1993). A few studies, which do a less comprehensive sensitivity analysis, show that at the very least initial conditions significantly matter for CGE analysis (Wiese, 1995 and Roberts, 1994). Furthermore, results obtained with CGE analysis might be more seriously affected by parameter errors if the period under investigation increases. Improvement of the reliability of parameter estimates, such that the dynamic behaviour of the model better describes the actual economic developments, is therefore crucial for long term CGE analysis.

5.4 THE WAY FORWARD

5.4.1 The way forward in general

General equilibrium modelling has come a long way since the early input-output models. A combination of advances in economic theory, numerical methods, and computer technology has made computing equilibrium quantities and prices for a multi-market economy a reality. Obviously, as soon as a general equilibrium simulation model can be solved, a multitude of new problems can be seen. The theoretical limitations of general equilibrium simulation models, which only capture flow equilibria across markets, become clear. Of the many directions in which new theoretical and applied work is needed, the following four areas are at the forefront: micro-macro interactions, dynamics, uncertainty, and optimisation (Robinson, 1989).

For micro-macro models to be at all realistic, they must involve micro-structuralist features. The analysis of links between micro markets and macro signals is an area of active research in macroeconomics, drawing

heavily on notions of uncertainty and expectations in a dynamic framework (Robinson, 1989). It is challenging to incorporate such theory into CGE models and research in this direction with analytic and stylised models might be worthwhile.

The common problem with dynamics lies in the fact that existing theory is inadequate to give the CGE modeller much guidance. There are numerous theoretical issues involved, including questions of micro-macro linkages and short-run versus long-run adjustment mechanisms. As stated by Robinson (1989:936) "Theorists tend to analyse dynamics in terms of intertemporal optimality and steady state, and criticising CGE models because they do not reflect what is acknowledged to be unrealistic theory dealing with long-run steady states and expectations is neither illuminating nor helpful. The challenge is as much to theorists as it is to CGE modellers".

Currently, there is some work being done to incorporate uncertainty in CGE models of which the results, so far, are suggestive and indicate that there are potential payoffs to further research (Robinson, 1989). One approach for optimisation that looks fruitful is to extend to CGE models the methods that have been used for sometime to explore questions of optimal policy choice in macro models. Optimisation models might be used to explore "second best" policy questions. For example, Dahl, Devarajan and Van Wijnbergen (1986) use a CGE model of Cameroon imbedded within an optimising framework. The results of their model indicate that the common rule of thumb that countries should seek to equalise tariffs across sectors, may often be incorrect.

Now that there is a universal idea of where CGEM is progressing, it is now possible to indicate the way forward for CGEM in South Africa.

5.4.2 The way forward in South Africa

During the last fifteen years many CGE models have been developed for use in policy analysis in South Africa. The development of these models has been slow and is hampered by the availability of data. The way

forward for CGEM in South Africa is thus of great importance for future modellers and for the CGE field of study. There are, therefore, a few issues that might need attention to ensure the success of CGEM in South Africa.

Improving parameter estimates might be crucial for all CGE models that intend to analyse the effect of policy measures for a longer time period than only one year. The explicit modelling of policy issues in CGE models is needed to perform policy analysis on nominal variables and to adequately describe the interaction between the different sectors of an economy. In the existing CGE models in South Africa, the unreliability of the parameters is a major shortcoming. Furthermore, it might be said that, although expectations are generally assumed to play an important role on the different markets, CGE models hardly pay any attention to this role of expectations. Thus, both the improvement of parameter estimates and the role of expectations in CGE models are important issues for future research in South Africa.

It can now be said that the pendulum has swung to its highest point in this respect, and is now commencing to return. So perhaps the intellectual danger of the future will be that modellers, instead of believing too little, will believe too much. Now is the time for laying a careful foundation. GE research, CGE modelling, and the like, are not ends in themselves, they are only means to an end. At the present stage of thought, the transition from the old to the new, from the lower to the higher, it is inevitable that there must be confusion and doubt, and the earnest thinker must be prepared to suspend judgement on many points; but at a later stage, when all negativity, error and lack of understanding, now so closely connected with CGE research in its various branches, will have been swept away, "truth" will emerge and lift this field into a purer and loftier conception of the modelling universe.

APPENDIX

NON-FREELY AVAILABLE WORK ON CGE IN SOUTH AFRICA

BURROWS, L. 1993. Moontlike gebruike van 'n berekenbare algemene ewewigsmodel vir Suid-Afrika. (Translated: *Possible uses of a CGE Model for South Africa*). EBM Research Conference, Bloemfontein, South Africa, November. (Unpublished).

BURROWS, L. 2003. Classifying empirical computable general equilibrium models: The case in South Africa. Biennial Conference of the Economic Society of South Africa, Lord Charles Hotel, Somerset West, South Africa. (Unpublished).

BURROWS, L. 2003. Is the jury still out on CGE modelling: An econometric critique. Eight Annual Conference on Econometric Modelling for Africa, University of Stellenbosch, Stellenbosch, South Africa. (Unpublished).

BURROWS, L. 2003. Trade and competition policy in a computable general equilibrium model (CGE) with imperfect competition and returns to scale. Biennial Conference of the Economic Society of South Africa, Lord Charles Hotel, Somerset West, South Africa. (Unpublished).

REFERENCES

- ADELMAN, I., AND MORRIS, C.T. 1973. Economic growth and social equity in developing countries. Stanford, CA: Stanford University Press.
- ADELMAN, I. AND ROBINSON, S. 1978. Income distribution policies in developing countries. Stanford, CA: Stanford University Press.
- ARMINGTON P.S. 1969. A Theory of Demand for Products distinguished by place of production. *IMF Staff Papers*, 16: 159-178.
- ARNDT, C. AND LEWIS, J.D. 2000. The macro implications of HIV/AIDS in South Africa: A preliminary assessment. *South African Journal of Economics*, 68(5): 856-887.
- ARROW, K.J. AND DEBREU, G. 1954. Existence of an Equilibrium for a Competitive Economy. *Econometrica*, 22: 265-290.
- BANDARA, J.S. 1991. Computable General Equilibrium Models for Development Policy Analysis in LDCs. *Journal of Economic Surveys*, 5(1): 3-69.
- BANNOCK, G., BAXTER, R.E. AND DAVIS, E. 1998. The Penguin Dictionary of Economics. Published by the Penguin Group, Sixth Edition.
- BELL, C.L.G. AND SRINIVASAN, T.N. 1984. On the uses and abuses of economy-wide models in development policy analysis. In SYRQUIN, M., TAYLOR, L. AND WESTPHAL, L.E. (eds), *Economic Structure and Performance*, New York: Academic.
- BERGMAN, L. 1990. The development of computable general equilibrium modeling. In BERGMAN, L., JORGENSEN, D.W. AND ZALAI, E. (eds), *General equilibrium modelling and economic policy Analysis*, Basil Blackwell, Oxford, pp. 3-30.

BERGMAN, L., JORGENSON, D.W. AND ZALAI, E. 1990. General equilibrium modeling and economic policy analysis. Basil Blackwell, Oxford.

BLITZER, C.R., CLARK, P.B. AND TAYLOR, L. 1975. Economy wide models and development planning. Oxford University Press for The World Bank, Oxford.

BRIXEN, P. AND TARP, F. 1996. The South African economy, macroeconomic prospects for the medium term. Routledge, London.

BURROWS, L. 1995. The Structure of a CGE Model for South Africa. Paper presented at the Biennial Conference of the Economic Society of South Africa, Johannesburg, 7 September 1995.

BURROWS, L. 2003. Classifying empirical computable general equilibrium models: The case in South Africa. Biennial Conference of the Economic Society of South Africa, Lord Charles Hotel, Somerset West, South Africa.

CAMERON, M., *et al.* 1994. Simulations with IDC-GEM: A CGE Model of the South African Economy. Paper presented at the 23 Annual Conference of the Economic Society of Australia, Gold Coast, Queensland, Australia.

CAMERON, C., DE JONGH, D., JOUBERT, R., SULEMAN, A., HORRIDGE, J.M. AND PARMENTER, B.R. 1994. IDC-GEM simulations for the workshop on economy-wide models of the South African economy. Development Bank of Southern Africa, 14-16 July, Halfway House.

COETZEE, Z.R., SWANEPOEL, J.J, GWARADA, K. & NAUDÉ, W.A. 1997. A Minimalist CGE Model for Analysing Trade Liberalisation in South Africa. *Journal of Studies in Economics & Econometrics*, 23(1): 1-12.

CLARK, M., DENT, S. AND WATTS, G. 2004. Influence of Travel Decision Parameters in a CGE Model Incorporating Tourism. Office of Economic and Statistical Research, Queensland, Australia. Working paper.

DARNELL, A.C. AND EVANS, J.L. 1990. The Limits of Econometrics. London: Edward Elgar.

DAHL, H., DEVARAJAN, S. AND VAN WIJNBERGEN, S. 1986. Revenue-neutral Tariff Reform: Theory and an Application to Cameroon. Country Policy Department, World Bank, Discussion Paper no. 1986-25.

DAVIES, J. 2003. Microsimulation, CGE and Macro Modelling for Transition and Developing Countries. Paper presented as WIDER conference on Inequality, Poverty and Human Wellbeing, Helsinki, Finland, 30-31 May.

DECALUWÉ, B. AND MARTENS, A. 1988. CGE modelling and Developing Economies: A Concise Empirical Survey of 73 Applications to 26 Countries. *Journal of Policy Modeling*, 10: 529–568.

DECALUWÉ, M. AND MONETTE, A. 1988. Macro closures in open economy CGE models: A numerical reappraisal. *International journal of development planning literature*, 3: 69–90.

DERVIS, K., de MELO, J. AND ROBINSON, S. 1982. General Equilibrium Models for Development Policy. Cambridge: Cambridge University Press.

DEVARAJAN, S., LEWIS, J.D. AND ROBINSON, S. 1991. From stylised to applied models: building multisector CGE models for policy analysis. Kennedy School for Government, Harvard University. (Unpublished).

DEVARAJAN S., LEWIS J.D. AND ROBINSON S. 1994. Getting the Model Right: The General Equilibrium Approach to Adjustment Policy. Draft Manuscript.

DEVARAJAN, S. AND VAN DER MENSBRUGGHE, D. 1999. Trade Reform in South Africa: Impacts on Households. World Bank, Working paper.

DEVARAJAN, S. AND J. LEWIS. 2000. Trade Reform in South Africa: Impacts on Households. World Bank, Working paper.

DEVELOPMENT BANK OF SOUTHERN AFRICA (DBSA). 1993. Employment Creation Strategies for South Africa. Mimeo, Halfway House: DBSA.

DEWATRIPONT, M. AND MICHEL, G. 1987. On Closure Rules, Homogeneity and Dynamics in Applied General Equilibrium Models. *Journal of Development Economics*, 26: 65-76.

DE WET, T.J., VAN HEERDEN, J.H. 2002. General Equilibrium Analysis of the Effects of a Consumption Tax of CO₂ Emissions. Proceedings: First annual conference of the Forum for Economics and Environment, Cape Town, 11 – 12 February.

DE WET, T.J. AND VAN HEERDEN, J.H. 2003. From Input-Output to Computable General Equilibrium (CGE) Modelling: Estimating the Effect on SMME Output Growth with Government Subsidies and other Policy Measures. ESSA.

DE WET, T.J., VAN HEERDEN, J.H. 2003. The dividends from a revenue neutral tax on coal in South Africa. *The South African Journal of Economic and Management Sciences*, 6: 3, Pretoria.

DIEWERT, W.E. AND LAWRENCE, D. 1994. The Marginal Costs of Taxation in New Zealand. Report Prepared for the New Zealand Business Round Table by Swan Consultants Pty Ltd., Canberra.

DIXON, P.B., PARMENTER, B.R., POWELL, A.A. AND WILCOXEN, P.J. 1992. Notes and problems in applied general equilibrium economics. Elsevier Science Publishers, North-Holland, Amsterdam.

DIXON, P. AND PARMENTER, B. 1996. Computable General Equilibrium Modelling for Policy Analysis and Forecasting. In AMMAN, H.M., KENDRICK, D.A. AND RUST, J. (eds), *Handbook of Computational Economics, Volume I*, Elsevier Science Publishers, North-Holland.

DIXON, P.B., AND PARAMENTER, B.R. 1996. Computable General Equilibrium Modelling. In AMMAN, H.M., KENDRICK, D.A. AND RUST, J. (eds), *Handbook of Computational Economics, Volume 1*, Elsevier Science Publishers, North-Holland, New York. pp.3-85.

DRUD, A., KENDRICK, A. AND MEERAUS, A. 1986. HERCULES: A System for Development of Multisectoral Economywide Models. World Bank Discussion Paper No. DRD 169 (April), pp. 12.

DRUD, A. AND KENDRICK, D. 1990. HURCULES: a system of large economy-wide models. Bagsvaerd: ARKI consulting.

EDGEWORTH, F.Y. 1881. Mathematical Psychics: An Essay on the Application of Mathematics to the Moral Sciences. London: Kegan Paul.

EDWARDS, L. AND PAW, K. 2003. Evaluating the General Equilibrium Effects of a Wage Subsidy Scheme for South Africa. Paper presented at the Biennial Conference of the Economic Society of South Africa, 17-19 Sept.: 7-10.

FELTENSTEIN, A. AND SHAH, A. 1995. General equilibrium effects of investment incentives in Mexico. *Journal of Development Economics*, 46: 253-269.

FORD, C., LEWIS, G. AND BATES, B. 2002. The macroeconomic impact of HIV/AIDS in South Africa. In KELLY, K., PARKER, W. & GELB, S. (eds), *HIV/AIDS, Economics and Governance in South Africa: Key Issues in Understanding Response*, Johannesburg: CADRE.

GELB, S., GIBSON, B., TAYLOR, L. & VAN SEVENTER, D.E.N. 1993. Modelling the South African Economy – Real-financial interaction.

Macroeconomic Research Group, University of Durban-Westville, Working paper.

GIBSON, B. AND VAN SEVENTER, D.E.N. 1996a. The DBSA macro model. Development Bank of Southern Africa, Halfway House, Development Paper no. 120.

GIBSON, B. AND VAN SEVENTER, D.E.N. 1996b. Trade, growth and distribution in the South African economy. *Development Southern Africa*, 13(5): 771-792.

GIBSON, B. AND VAN SEVENTER, D.E.N. 1997a. The macroeconomic impact of restructuring public expenditure by function in South Africa. *South African Journal of Economics*, 65(2): 191-225.

GIBSON, B. AND VAN SEVENTER, D.E.N. 1997b. Green trade restrictions, some macroeconomic and environmental consequences. In BETHLEHEM, L & GOLDBLATT, M. (Eds), *The bottom-line, industry and the environment in South Africa*, UCT press & IDRC.

GILBERT, J. AND WAHL, T. 2000. Applied General Equilibrium Assessments of Trade Liberalization in China. Paper Presented at the Workshop *China's Accession to the WTO: An Overview of Recent Analyses*, CPB Netherlands Bureau for Economic Policy Analysis Institute of Quantitative and Technical Economics of the Chinese Academy of Social Sciences, Beijing, October 19-20.

GINSBURGH, V. AND ROBINSON, S. 1984. Equilibrium and Prices in Multisector Models. In SYRQUIN, M., TAYLOR, L. AND WESTPHAL, L.E. (eds), *Economic Structure and Performance*.

GINSBURGH, V.A., AND WAELEBROECK, J.L. 1981. Activity analysis and general equilibrium modeling. Amsterdam: North-Holland.

GINSBURGH, V. AND KEYZER, M. 1997. The structure of applied general equilibrium models. MIT Press, Cambridge, Massachusetts.

- HANSEN, L. P., AND HECKMAN, J.J. 1996. The Empirical Foundations of Calibration. *Journal of Economic Perspectives*, 10: 87-104.
- HARBERGER, A. 1962. The incidence of the corporate income tax. *Journal of Political Economy*, 70: 215-240.
- HARRISON, G.W., JONES, R., KIMBELL, L.J. AND WIGLE, R. 1993. How robust is applied general equilibrium analysis. *Journal of Policy Modeling*, 15: 99-115.
- HENDRY, D.F. 1980. Econometrics – Alchemy of Science? *Economica*, 47: 387-406.
- HERTEL, T.W. 1997. Global trade analysis: modeling and applications. Cambridge University Press, New York and Melbourne.
- HIGGS, E. 1986. Domestic Service and Household Production. In John, J. (eds), *Unequal Opportunities: Women's Employment in England 1800-1918*, Oxford: Basil Blackwell.
- HORRIDGE, J.M., PARMENTER, B.R., CAMERON, M., JOUBERT, R., SULEMAN, A. AND DE JONGH, D. 1995. The Macroeconomic, Industrial, Distributional and Regional Effects of Government Spending Programs in South Africa. *Impact Project General Paper*, No. G-109, CoPS, Monash University.
- HORRIDGE, J.M., *et al.* 1996. IDC-DGEM: A CGE Model of the South African Economy for Forecasting and Dynamic Policy Analysis. Paper prepared for the International Symposium on Economic Modeling, Oslo, 3-4 July.
- HUDSON, E. AND JORGENSON, D. 1975. U.S. energy policy and economic growth 1975-2000. *Bell Journal of Economics and Management Science*, 5: 461-514.

HUGO, P. AND STACK, L. 1992. Whites in South African Public Service: Angst and the Future. In HUGO, P. (eds), *Redistribution and affirmative action*, Halfway House: Southern Publishers.

HUMPHREYS, N. MACARTAN. 2000. A Poverty Focussed CGE Model for South Africa.

[WEB:] <http://www.columbia.edu/~mh2245/papers1/CGE.PDF> [Date of access: 30 August 2004].

INDUSTRIAL DEVELOPMENT CORPORATION (IDC). 1997. Empirical Estimation of Elasticities in IDC's General Equilibrium Model (IDCGEM). Technical Series (TS2/1997), Industrial Development Corporation, Pretoria.

IQBAL, Z AND SIDDIQUI, R. 2001. Critical Review of Literature on Computable General Equilibrium Models. MIMAP technical paper series, No. 9.

JEROME, A. 2004. A Survey of Macroeconomic Models for Policy Analysis and Forecasting in South Africa. Paper prepared for Presentation at the Ninth Annual Econometrics Modeling for Africa, University of Cape Town June 30 – July 2.

JOHANSEN, L. 1960. A multisectoral study of economic growth. North Holland, Amsterdam.

JORGENSON, D.W. 1984. Econometric methods for applied general equilibrium analysis. In Scarf, H. and Shoven, J. (eds), *Applied general equilibrium analysis*, Cambridge University Press, Cambridge, pp. 139–203.

JORGENSEN, D. W., SLESNICK, D.T. AND WILCOXEN, P.J. 1992. Carbon Taxes and Economic Welfare. Harvard Institute of Economic Research Discussion Paper no. 1589.

JOULBERT, R. 1994. IDCGEM - A General Equilibrium Model of the South African Economy. Paper prepared for the EBM Research Conference, Johannesburg.

KALDOR, N. 1956. Alternative theories of distribution. *Review of economic studies*, 23: 94–100.

KALECKI, M. 1976. Essays on developing economies. The Harvester Press, Hassocks.

KEARNEY, M. 2002. Zero Rating Food: A Computable General Equilibrium Analysis For South Africa. AES.

KEARNEY, M. 2003. Restructuring VAT in South Africa: a Computable General Equilibrium Analysis. December.

KEHOE, P.J. AND KEHOE, T.J. 1994. A Primer on Static Applied General Equilibrium Models. *Federal Reserve Bank of Minneapolis Quarterly Review*, Spring.

KEYNES, J. 1936. The general theory of employment, interest and money. Macmillan, London.

KINGDON, G. AND KNIGHT, J. 1999. Unemployment and Wages in South Africa: A Spatial Approach. WPS 99-12, Centre for Study of African Economies, University of Oxford.

LAU, L.J. 1984. Comments on: Numerical specification of applied general equilibrium models: estimation, calibration, and data, by Ahsan Mansur and John Whalley. In Scarf, H. and Shoven, J. (eds), *Applied general equilibrium analysis*, Cambridge University Press, Cambridge, pp. 127–137. Lopezde.

LEWIS, J. 2001. Policies to promote growth in South Africa. Informal Discussion Papers on aspects of the South African Economy, The World Bank, Southern Africa Department, Discussion Paper 16.

LÖFGREN, H., HARRIS, R., ROBINSON, S., THOMAS, M. AND EL-SAID, M. 2001. A standard computable general equilibrium (CGE) model in GAMS. *Microcomputers in Policy Research*, 5. Washington DC: International Food Policy Research Institute.

LONGVA, S., LORENSTEN, L. AND OLSEN, O. 1985. The Multi-Sectoral Growth Model MSG-4: Formal Structure And Empirical Characteristics. Oslo, Central Bureau of Statistics, Discussion Paper, No. 8.

MANNE, A.S. 1985. Mathematical Programming Study 23 Economic Equilibrium: Model Formulation and Solution. Amsterdam: North-Holland.

MANSUR, A. AND WHALLEY, J. 1984. Numerical specification of applied general equilibrium models: estimation, calibration, and data. In Scarf, H. and Shoven, J. (eds), *Applied general equilibrium analysis*, Cambridge University Press, Cambridge, pp. 69–127.

MCDONALD, S. AND PUNT, C. 2001. Some Welfare Implications of a Land Tax on the Western Cape, Paper prepared for the Biennial Conference of the Economic Society of South Africa, Somerset West, South Africa, September 17-19.

MCGREGOR, P.G., SWALES, J.K. AND YIN, Y.P. 1995. Migration Equilibria in Regional Economies: A Multi-Period CGE Analysis of an Improvement in Local Amenities. In J.C.M. VAN DEN BERGH, J.C.M., NIKAMP, P. AND REITVELD, P. (eds), *Recent Advances in Spatial Equilibrium Modelling*, New York: Springer.

MCKITRICK, R.R. 1998. The Econometric Critique of Computable General Equilibrium Modelling: The Role of Functional Forms. *Economic Modelling*, 15: 543-573.

MILLER, M. AND J. SPENCER. 1977. The static economic effects of the UK joining the EEC: A general equilibrium approach. *Review of Economic Studies*, 44.

MURINDE, V. 1993. Macroeconomic Policy and Modelling for Developing Countries. Aldershot: Avebury.

NAUDÉ, W.A. 1993. Do Error Correction Models have a Contribution to make towards understanding Money Demand in South Africa? *Journal for Studies in Economics and Econometrics*, 16(3): 51-62.

NAUDÉ, W.A. AND BRIKEN, P. 1993a. A Provisional CGE Model for South Africa. *South African Journal of Economic and Management Sciences*, 10: 22-33.

NAUDÉ, W.A. AND BRIKEN, P. 1993b. On a Computable General Equilibrium Model for South Africa. *South African Journal of Economics*, 61(3): 153-165.

NAUDÉ, W.A., COETZEE, Z.R. AND GWARADA, K. 1997. Currency Depreciation, Trade Liberalisation and Economic Development. *South African Journal of Economics*, 65(2): 165-190.

NAUDÉ, W.A., COETZEE, Z.R., GWARADA, K. AND SWANEPOEL, J. 1997. A Minimalist CGE Model for Analysing Trade Liberalisation in South Africa. *Journal for Studies in Economics & Econometrics*, 21(1): 37-56.

NAUDÉ, W.A. AND COETZEE, R. 2004. Globalisation and inequality in South Africa: Modelling the Labour Market Transmission. *Journal of Policy Modelling*, forthcoming.

NESBITT, D. 1984. The economic foundation of generalised equilibrium modelling. *Operations Research*, 32 (6): 1240-1267, Nov.-Dec.

PARTRIDGE, M.D. AND RICKMAN, D.S. 1998. Regional Computable General Equilibrium Modelling: A Survey and Critical Appraisal. *International Regional Science Review*, 21(3): 205-248.

PASINETTI. 1962. Rate of profit and income distribution in relation to the rate of economic growth. *Review of economic studies*, 29: 267–279.

PEREIRA, A.M., AND SHOVEN, J.B. 1988. Survey of Dynamic Computational General Equilibrium Models for Tax Policy Evaluation. *Journal of Policy Modelling*, 10: 401-436.

PERRONI, C. AND RUTHERFORD, T.F. 1995. A Comparison of the Performance of Flexible Functional Forms for Use in Applied General Equilibrium Analysis. University of Colorado. Working Paper.

POWELL, A.A. AND LAWSON, T. 1990. A decade of applied general equilibrium modeling. In BERGMAN, D.J. AND ZALAI, E. AND L. (eds), *General equilibrium modeling and economic policy Analysis*. Basil Blackwell, Oxford, pp. 241–290.

PYATT, G. 1988. A SAM approach to modelling. *Journal of Policy Modelling*, 10(3): 327-352.

ROBERTS, B.M. 1994. Calibration procedure and the robustness of CGE models: simulations with a model for Poland. *Economics of Planning*, 27: 189–210.

ROBINSON, S. 1989. Multisectoral Models. In CHENERY AND SHINIVASAN (Eds), *Handbook of Development Economics*, Vol. II, Chapter 18, North Holland.

RUST, J. 1997. Dealing With the Complexity of Economic Calculations. Working Paper, Yale University.

RUMLER, F. 1999. Computable General Equilibrium Modelling: Numerical Simulations in a 2-Country Monetary General Equilibrium Model. Working Paper, No. 65, June.

SCARF, H. 1967. On the computation of equilibrium prices. In FELINER, W. (eds), *Ten economic studies in the tradition of Irving Fisher*. Wiley, New York.

SCARF, H.E. 1973. The computation of economic equilibria. Yale University Press, New Haven and London.

SCARF, H.E. AND SHOVEN, J. B. 1984. Applied general equilibrium analysis. Cambridge University Press, Cambridge.

SCHMALENSEE R., STOCKER T.M., AND JUDSON, R.A. 1998. World carbon dioxide emissions: 1950-2050. *The Review of Economics and Statistics*, 80(1): 15-27.

SEN, A. 1963. Neoclassical and neo-Keynesian theories of distribution. *Economic record*, 53-64.

SHOVEN, J.B. AND WHALLEY, J. 1972. A General Equilibrium Calculation of the Effects of Differential Taxation of Income from Capital in the US. *Journal of Public Economics*, 1: 281-321.

SHOVEN, J.B. 1976. The Incidence and Efficiency Effects of Taxes on Income from Capital. *Journal of Political Economy*, 84: 1261-1283.

SHOVEN, J.B. AND WHALLEY, J. 1984. Applied General Equilibrium models of Taxation and International: An Introduction and Survey. *Journal of Economic Literature*, 23: 1007-10051.

SHOVEN, J.B. AND WHALLEY, J. 1992. Applying general equilibrium, Cambridge University press, Cambridge.

SIMS, C. 1980. Macroeconomics and reality. *Econometrica*, 48: 1-48.

SOLOW, R. 1956. A contribution to the theory of economic growth. *Quarterly Journal of Economics*, 70: 65-94.

SWAN, T. 1970. Golden ages and production functions *In* SEN, A. (eds), *Growth economics*, Penguin Books, Harmondsworth, England, pp. 203–218.

TAYLOR, L. 1975. Theoretical Foundations and Technical Implications. *In* BLITZER, C.R., CLARK, P.B. AND TAYLOR, L. (eds), *Economy-wide models and development planning*, London: Oxford University Press.

TAYLOR, L. AND LYSY, F. 1979. Vanishing income distribution: Keynesian clues about model surprises in the short-run. *Journal of Development Economics*, 6: 11–29.

TAYLOR, L. 1990a. Socially relevant policy analysis: structuralist computable general equilibrium models for the developing world. MIT press, Cambridge (MA).

TAYLOR, L. 1990b. Structuralist CGE models. *In* Taylor, L. (eds), *Socially relevant policy analysis: structuralist computable general equilibrium models for the developing world*, MIT press, Cambridge, pp. 1–70.

TAYLOR, L. 1991. Short-run model closures and steady state growth, Income distribution, inflation, and growth_ Lectures on structuralist macroeconomic theory. MIT press, London, pp. 40–65.

THISSEN, M. 1998. A Classification of Empirical CGE Modelling. *SOM Research Report 99C01*, University of Groningen, Groningen, The Netherlands. December.

THURLOW, J. AND VAN SEVENTER, D.E.N. 2002. A Standard Computable General Equilibrium Model for South Africa. Trade and Macroeconomics Discussion Paper No. 100, International Food Policy Research Institute, Washington, D.C.

THURLOW, J. 2003a. Further Trade Liberalisation and Reform in South Africa: An Economy-Wide Assessment. TIPS Discussion Paper.

THURLOW, J. 2003b. The Impact of Regional Trade Agreements on the South African Economy. TIPS Discussion Paper.

THURLOW, J. 2003. A Dynamic Computable General Equilibrium (CGE) Model for South Africa: Extending the Static IFPRI Model. International Food Policy Research Institute Washington, D.C.

[WEB:]

<http://www.tips.org.za/research/item.asp?ID=707&WebType=Papers>

[Date of access: 22 March 2004].

TOBIN, J. 1971. A general equilibrium approach to monetary theory. *Essays in Economics*, Markham Publishing Company, Chicago, pp. 323–338.

VAN DER MENSBRUGGHE, D. 1995. Technical description of the World Bank CGE of the South African economy. OECD Development Centre, Paris. (Unpublished).

VAN HEERDEN, J.H., AND KEARNEY, M. 2002. A Static, Stylised CGE model applied to evaluate the incidence of Value Added Tax in South Africa. Economic Society of South Africa: Bi-annual conference, Johannesburg.

VAN HEERDEN, J., GERLAGH, R., BLIGNAUT, J., HESS, S., MABUGU, R., CHITIGA, M. AND DE WET, T. 2004. On Using a CGE Model to Simulate Energy Policy in South Africa, Ninth Annual Conference on Econometric Modelling for Africa, 30 June – 2 July.

VAN SEVENTER, D.E.N., ECKERT, J.B. AND ROUKENS DE LANGE, A. 1992. The Structure and Compilation of a Provisional Social Accounting Matrix for South Africa. Mimeo: Development Bank of Southern Africa.

VAN SCHOOR, M. AND BURROWS, L. 2003. Trade and competition policy in a computable general equilibrium model (CGE) with imperfect competition and returns to scale, Biennial Conference of the Economic

Society of South Africa, Lord Charles Hotel, Somerset West, South Africa, September 17.

VINCENT, D.P. 1990. Applied general equilibrium modelling in the Australian industries assistance commission: Perspectives of a policy analyst. In BERGMAN, D.J., AND ZALAI, L. AND E. (eds), *General equilibrium modelling and economic policy Analysis*, Basil Blackwell, Oxford, pp. 291–347.

WALRAS, L. 1874. Elements D'economie Politique Pure. Lausanne: L. Corbaz.

WIESE, A. 1995. On the construction of total accounts from the us national income and product accounts: How sensitive are applied general equilibrium results to initial conditions. *Journal of Policy Modeling*, 17: 139–162.

WIGLE, R.M. 1991. The Pagan-Shannon Approximation: Unconditional Systematic Sensitivity Analysis in Minutes. *Empirical Economics*, 16: 35–49.

WILLENBOCKEL, D. 1994a. Applied general equilibrium modelling - Imperfect competition and European integration. Wiley, Chichester U.K.

WILLENBOCKEL, D. 1994b. The computable general equilibrium approach under perfect competition, Applied General Equilibrium modelling - Imperfect competition and European Integration. Wiley, Chichester U.K., pp. 39–62.

WHALLEY, J. 1975. A General Equilibrium Assessment of the 1973 UK Tax Reforms. *Economica*, 42: 139–161.

WHALLEY, J. 1977. The United Kingdom Tax System, 1968–1970: Some Fixed Point Indications of its Economic Impact. *Econometrica*, 45: 1837–1858.

WHALLEY, J. 1985. Hidden Challenges in Recent Applied General Equilibrium Exercises. *In* PIGGOTT, J. AND WHALLEY, J. (eds), *New Developments in Applied General Equilibrium Analysis*, New York: Cambridge University Press.

WORLD BANK. 2000. The Macroeconomic Foundation, World Development Report, 2000. Oxford University Press.

ZALAI, E. 1982. Computable General Equilibrium Models: An Optimal Planning Perspective. *Mathematical Modelling*, 3.