

Policy Analysis in South Africa
with
Regional Applied General Equilibrium Models

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Abstract

The research question addressed in this study is first to illustrate the appropriateness and feasibility of a Regional Applied General Equilibrium (RAGE) model in the South African context for policy makers. Secondly the study provides proposals for the construction of a RAGE model to assist policy-makers to investigate spatial or regional (sub-national) impacts and policy-choices with a more sophisticated approach (other than a simplified top-down approach or partial equilibrium models) which would provide for more consistent results or implications as related to the spatial or regional implications of such impacts.

This study is an attempt to address this shortcoming by investigating and illustrating the need for such modelling ability. This is done by illustrating the value and potential of RAGE models by making use of a simplified “top-down” regional application. In particular, the shortcomings of such a ‘top-down’ approach are highlighted and the case made for a more sophisticated ‘bottoms up’ approach.

A literature review was conducted regarding the types of RAGE models that can be found, as well as on the various methodological approaches to regional or spatial Applied General Equilibrium (AGE) modelling. A simplified top-down model based on the AGE model used by South Africa’s Industrial Development Corporation (IDC) was constructed in order to conduct some illustrative applications. These illustrative applications highlighted some of the shortcomings of a top-down approach to regional AGE models based on an application of an electricity price and volume shock scenario.

Finally, this study presents proposals for future research regarding the development of RAGE models for the South African economy. These take account of the current work on Provincial Social Accounting Matrices (SAMs) lead by the Development Bank of Southern Africa. The feasibility of a hybrid regional AGE was illustrated and some future potential developments in this regard were stated.

JEL Classification: D58, I32, N70, N77, O20, O25, O29, O55, Q48

Keywords: Applied General Equilibrium Model, Computable General Equilibrium Model, Energy policy, Electricity, Economic Development, South Africa.

Summary

One of the legacies of the policies of the apartheid regime manifested in the South African economy today is the uneven economic development of South Africa's sub-national economies. In order to achieve greater geographical equity a specific focus on the geographic spread of economic activities and investment has been adopted by the government. There are various challenges emanating from the policies and strategies and ultimately the government needs to be able to improve the coherence of these strategies and ensure a more coordinated implementation, as well as some way of identifying sub-national (regional) trends and being able to evaluate the potential impact or implications of potential policy decisions, while also being in a position to monitor the effects of such policy implementations on the targeted regions.

Access to modelling tools with a regional or sub-national dimension enabling policy makers to analyse potential impacts of proposed strategies or test “what-if” scenarios would complement the policy makers’ arsenal of resources to apply to these questions. Through a chronology of Applied General Equilibrium (AGE) modelling developments based on Rossouw (2004), this study has focused on illustrating that AGE modelling tools addressing this spatial or regional dimension are limited in the South African context. Currently, it is the author’s opinion that there exists no such model of sufficient regional detail and sophistication in order to conduct really useful analysis of this nature.

This study contributes to an attempt to address this shortcoming by investigating and illustrating the need for such modelling ability, while also illustrating the value and potential of such analysis by making use of a simplified “top-down” regional application based on a version of the Industrial Development Corporation’s (by now dated) AGE model – IDCGEM.

A plethora of application opportunities for such a model currently exists and more will be uncovered once such a tool exists and is applied. Some examples were mentioned and a key topical example was used for the illustrative application of the IDCGEM – that of the current electricity shortage in South Africa. The subsequent issues of proposed price increases and lower supply availability related to this electricity shortage will have diverse impacts on the different provinces in South Africa. The illustrative example served to highlight some of the shortcomings of a top-down approach to regional AGE analysis.

One of the key issues or constraints to constructing such a regional AGE highlighted in the study is the existence and availability of suitably detailed inter-regional data sets to inform such a model. Through this research the author has also illustrated the feasibility to construct a more pragmatic (due to data constraints) hybrid (mix between pure top-down and bottom-up) model with the potential to be realised in the short to medium term based on the work (lead by the Development Bank of Southern Africa) currently being conducted to construct provincial social accounting matrices (SAMs) for South Africa for the base year 2006.

The recommendation from the study is that further work would need to be conducted in order to realise such a model. This would entail consolidating and extending the provincial and national SAMs into a coherent database suitable for use with a regional AGE model. In this case the Monash ORANI-style modelling would be proposed, as a lot of previous experience and knowledge with this specific approach have been gained in South Africa over the last 15 years. This approach has also been applied in various other countries for regional AGE models.

Once this model is operational and has been tested, relevant policy issues can be analysed to provide insight and assistance to policy makers with regards to sub-national/provincial implications of various policies.

Finally this study aimed to illustrate the need, viability and requirements in the South African context for a new, current regional AGE model. The actual development of such a regional AGE is left for future research.

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CHAPTER 1: INTRODUCTION

1.1. Purpose of this study

This study aims to illustrate the relevance, potential and need for an applied **Regional Applied¹ General Equilibrium (RAGE)** model for South Africa.

1.2. Hypothesis

The hypothesis underlying this study is that a RAGE model can be of use to better understand the economic challenges faced by South African policy makers on a sub-national (regional or local) level. These challenges include (as will be discussed in more detail below) growing spatial inequalities, spatial peculiarities and idiosyncrasies in resources endowments, and different sub-national impacts of national policies and international trends.

1.3. Background and problem statement

1.3.1. Background

Why is there a need for applied general equilibrium (AGE) 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

¹ In literature on the topic of general equilibrium models one finds references to both “Applied” and “Computable” general equilibrium models used interchangeably. The prior refers to the broader concept of the theoretical framework applied in practice, while the latter more specifically refers to the actual model applied on a computer with a specific piece of software such as GAMS (General Algebraic Modeling System) or GEMPACK (General Equilibrium Modelling PACKage).

(c) to analyse the likely effects of economic policy and changes in such policy.

For reasons (a) and (b) many models have been constructed, and are more or less effective under different conditions. For reason (c), the options are more limited and the choice in any given case will depend for example on the type of policy being investigated, the number of sectors affected, the relevant time period, and a few other factors.

In the context of the questions posed above, AGE models have provided unique insights into the mechanics of economies and on the possible impacts of various macroeconomic policies. AGE models represent a major enhancement in economic analysis. However, one still has to be cautious with the application of decisions based on a AGE model analysis, as it is not yet clear how accurate AGE models are quantitatively, particularly in comparison to other types of models and despite many success stories in the field of AGE modelling, there is a need for something more in terms of surety regarding the AGE relationship with reality (Iqbal and Siddiqui, 2001:22).

Despite their limitations AGE models are becoming more widely used. The advent of the micro-computer has allowed the application of AGE models by policymakers and academics in policy analysis to proliferate since the late 1970s (Bandara, 1991:10). These developments have provided unique insights into the working of economies and on the potential effects of various macroeconomic policies. Due to the fact that constructing, implementing, testing, and maintaining an AGE model for any economy is a major task and

resource intensive; only limited portions of individual careers have been devoted to this field of study and modelling. Institutional effort and funding is normally required, both for developing theory as well as enabling applications of such theory in applied models. Joint research programmes of modellers, econometricians, theoreticians, and computational economists might be necessary to sustain an effective large scale AGE model of an economy (McDonald & Punt, 2005:90).

Internationally various policy issues have been addressed by making use of AGE models over the last 35 years. In South Africa though, AGE models only started receiving attention from applied quantitative economists since the early 1990s. AGE models make use of a general equilibrium framework through which the feedback and trickle down effects of an economic policy question being studied is reflected, while using a consistent database and typically needing data for only a single year (Naudé and Coetzee, 2004:915). An additional advantage of AGE models is that they are explicitly grounded on micro- and macroeconomic theory and can therefore avoid accusations of potential “data mining” or “a theoretical time-series analysis” (Sims, 1980:15; Hendry, 1980:14; Darnell and Evans, 1990:113).

“Regional” and “spatial” applications of AGE models were a natural next level of development for AGE models. While the data requirements are more onerous than for national-level-only models, the benefit of being able to analyse implications of policy or other impacts on a more disaggregated level

within the economy outweighs the cost of compiling this additional information.

Leontief *et al.* (1965) developed a basic methodology to achieve a first level of “regional” disaggregation by dividing industries into *national* and *local* industries. *National* industries are defined as those industries that typically produce commodities or products that are readily traded between regions (e.g. agricultural, mineral and non-perishable manufactured goods and some services such as government services). *Local* industries in turn are defined as industries producing perishable goods and services that are not readily traded between regions.

By applying the above approach and through further refinements and further research, various approaches exist today to incorporate both multi-regional and spatial dimensions into AGE models. See e.g. Parmenter *et al.* (1985), Parmenter *et al.* (2000) and Adams *et al.* (2003).

1.3.2. Problem statement

One of the legacies of the policies of the apartheid regime manifested in the South African economy today is the uneven economic development of South Africa's sub-national or regional economies (Bond, 2005; Curtis, 1984; Morris and Robbins, 2004; Naudé and Krugell, 2003; 2006).

In order to achieve greater geographical equity a specific focus on the geographic spread of economic activities and investment has been adopted by the government, and more specifically the Department of Trade and Industry (thedti). A range of policies are already in place in this regard, such

as the Integrated Sustainable Rural Development Strategy (ISRDS), the Urban Renewal Strategy (URS), Industrial Development Zones (IDZs), Spatial Development Initiatives (SDIs), and the approach of Integrated Development Plans (IDPs) (Cameron, 2005:146). Furthermore, local government is viewed as a key catalyst for locally-led social and economic development by the Department of Provincial and Local Government (DPLG) and so-called Local Economic Development (LED) strategies and plans are required for all municipalities in South Africa (Bond, 2002).

There are various challenges emanating from these policies and strategies and ultimately the government needs to be able to improve the coherence of these strategies and ensure a more coordinated implementation. At the same time government also need some way of identifying sub-national (regional) trends and be able to evaluate the potential regional impact or implications of potential policy decisions, while also being in a position to monitor the effects of such policy implementations on the targeted regions. In this regard, policy recommendations and the implementation of resulting programs or projects have to be linked to areas of high poverty and unemployment and a more geo-technical approach to both data and analysis is required in order to satisfy these analysis and monitoring needs (Cameron, 2005:146).

The old statement that *"in order to go somewhere you need to know where you are first"* comes to mind in the context of this issue. Both national and local government has a need to be able to assess the demographic, economic and socio-economic status quo, as well as measure growth and development

on a sub-national level and more specifically on magisterial district, local metro and municipal levels. Indeed, governments on provincial and local level have a need for information on the spatial implications of their policies due to their constitutional obligations to promote economic development in their jurisdictions (Jansen van Rensburg and Naudé, 2007; Naudé, 2005).

Information and estimates are needed for activities such as:

- policy and strategy decisions;
- economic planning;
- market development; and
- for infrastructure planning, development and delivery

Therefore there exists a real need for more, timely as well as better quality sub-national (regional or provincial) and sub-provincial (spatial, municipal or magisterial) information to be collected, collated and made available in an easy to access manner to decision makers, than what is currently available from formal sources.

In addition to data and information, access to modelling tools with a regional or sub-national dimension that enables policy makers to analyse potential impacts of proposed strategies or test “what-if” scenarios would complement the policy makers’ arsenal of resources to apply to these questions. However, modelling tools addressing this spatial or regional dimension are limited in the South African context. Currently, to the author’s knowledge, there exists no such model of sufficient regional detail and sophistication in order to conduct useful analysis of this nature.

This study contributes to an attempt to address this shortcoming by investigating and illustrating the need for such modelling ability. The study also illustrates the value and potential of such analysis by making use of a simplified “top-down” regional application, while at the same time highlighting some of the shortcomings of a simplified top-down approach to regional AGE modelling in the South African context. The illustrative application is based on a version of the Industrial Development Corporation’s (IDC) (by now dated) applied general equilibrium (AGE) model – IDCGEM.

This study therefore aims to illustrate the need, viability and requirements in the South African context for such a new, current regional AGE model. The actual development of such a regional AGE is left for future research.

1.4. Research question

The research question to be addressed in this study is firstly to illustrate the appropriateness and feasibility of a regional AGE model in the South African context for South African policy makers.

In addition to the initial aim, the study also forwards some thoughts and ideas on how a regional AGE model can be constructed to assist South African policy makers to investigate spatial or regional (sub-national) impacts and policy choices with a more sophisticated approach (other than a simplified top-down approach) which would provide for more accurate and informative results or implications as related to the spatial or regional implications of such impacts.

1.5. Objectives

The objectives set for this study therefore are the following:

- a. To illustrate the appropriateness of RAGE model as a modelling framework for regional / spatial or sub-national policy analysis.
- b. To identify various ways and methodologies in which a RAGE model can be constructed in the South African context.
- c. To apply a simplified top-down RAGE model to illustrate its usefulness based on South African topical issues.

1.6. Methodology

An international literature review was conducted regarding the types of RAGE models that exist and are applied in practice internationally. The literature review also served to inform on the various methodological approaches to regional or spatial AGE modelling (e.g. top-down, versus bottom-up approaches). A simplified top-down model based on the existing IDCGEM model was applied in order to conduct some illustrative applications of a RAGE model for the South African context. This illustrative application highlighted some of the shortcomings of a top-down approach to regional AGE models based on an application of an electricity price and volume shock scenario.

1.7. Terminology

An **Applied General Equilibrium (AGE)** model can briefly be described as an economy-wide model that includes feedback between demand, income and production structure, and where all prices adjust until decisions made in production are consistent with decisions made in demand (Dervis *et al.*,

1985). These models are also referred to as Computable General Equilibrium (CGE) models, especially in the case where a practical computer-based model has been constructed.

“Regional” in this context refers to a sub-national regional dimension to the model. For the purpose of this research we prefer to use the term regional, however in the literature and types of models there is no consistency of application of “regional” in the context of intra-country versus inter-country applications of the term. In the context of this research we refer to inter-country applications as **“multi-country”**.

The term **“spatial”** in the context of this study is applied to refer to “micro” or “localised” applications, such as e.g. just a specific large city or metropolitan area.

Furthermore, in the context of this study in general **“regional”** refers to a provincial level dimension. However, this could also be expanded into lower levels of detail to for example magisterial, municipal or even large city level detail as for example in the case of Melbourne, Australia (see Horridge, 1999).

In the context of regional analysis in the specific case of South African political and legal geography it is important to understand the relationship or context between provincial, magisterial and municipal demarcations and concepts for South Africa. De Lange (2005) states that the South African government

consists of three distinct, but interrelated spheres of government, namely the national, provincial² and local spheres of government.

The building blocks of South Africa's local sphere of government consist of municipalities and differ significantly from magisterial districts. Magisterial districts are defined areas in which South African courts exercise jurisdiction, whereas municipal boundaries are the geographical areas, designated by the Municipal Demarcation Board, within which a democratically elected legislative and executive authority exercise the powers granted to such municipality in the Constitution of South Africa and subsequent laws.

1.8. Layout of the study

The rest of this study is presented as follows:

- In chapter 2 a brief overview of the nature of AGE models is given.
- Chapter 3 provides a historical overview of the development and use of AGE models in South Africa. From this chapter it is concluded that there is currently a lack of RAGE modelling in South Africa.
- Regional AGE models and their relevance for South African policy makers are illustrated in Chapter 4. In this chapter the focus is on understanding how RAGE models are constructed and used elsewhere

² The provincial sphere of government was established based on the pre-1994 nine provinces of the Republic, out of the areas of the former Republic of South Africa, and the Bantustans of Transkei, Bophuthatswana, Venda and Ciskei and the areas of the six self-governing territories. The geographical areas comprising each of the nine provinces is and still are defined by reference to specific magisterial districts created in terms of the Magistrates' Courts Act of 1944.

in the world, and to identify the generic components of a typical RAGE model.

- In chapter 5 a RAGE model is illustrated for South Africa. Here, a simplified “top-down” application is illustrated using the IDC’s AGE model, which is known as IDCGEM.
- Finally, chapter 6 contains a summary of the study and conclusions, with recommendations for future research.

CHAPTER 2: A THEORETICAL OVERVIEW OF AGE MODELS

2.1. Introduction

The previous chapter provided the background, problem statement, and motivation for the study as well as the methodology to be applied and delimitation of this specific study. It was stated that access to modelling tools with a regional or sub-national dimension enabling policy makers to analyse potential impacts of proposed strategies or test “what-if” scenarios would complement the policy makers’ arsenal of resources to apply to these questions. The main research question posed in the previous chapter to be addressed in this study is to illustrate the appropriateness and feasibility of a regional AGE model in the South African context for South African policy makers.

In order to put the discussion of the regional application of AGE models in context, this chapter provides a theoretical overview of the nature of AGE models. The chapter is structured as follows. In section 2.2 the motivation for the development of AGE models are set out. In section 2.3 an explanation of the concept of general equilibrium, is given. In section 2.4 the general application of AGE models is described, while in section 2.5 AGE models and their relationships with Input-Output (IO) analysis as well as Social Accounting Matrices (SAMs) are discussed. The AGE conceptual framework and concept of closures are discussed in sections 2.6 and 2.7 respectively, followed by an explanation of the interpretation of AGE percentage change results in section 2.8. Lastly, section 2.9 summarises.

2.2. The need for AGE models

The challenge the economic policy maker at all levels of government faces (as well as private business institutions operating for profit) is that limited resources must be allocated to areas that are most likely to achieve success in scenarios with the greatest probability of being realized. In order to assist and inform policy makers in this task economic models play an important role (Cameron, 2005:148).

“Economic theory does make unrealistic assumptions . . . But some abstraction from reality is necessary because of the incredible complexity of the economic world . . . Abstraction from unimportant details is necessary to understand the functioning of anything as complex as the economy.”

(Baumol and Blinder, 1997:9).

Economic models are mathematical representations of the economy that are designed to be simplifications of a complex reality. They combine those behavioural relationships believed to be responsible for the bulk of macroeconomic fluctuations, while omitting those deemed less important. This process of differentiation allows economists to make predictions that are reasonably accurate and that can be more easily understood and communicated to policymakers and other stakeholders (Coletti and Murchison, 2002:20).

Models can provide key perceptions for analysis of comprehensive packages of economic and non-economic policy instruments within a consistent

framework. Insights generated by modelling can help in evaluating various policy options. At the same time, however, policy options which seem technically and even economically feasible at the sectoral level may lose their attraction when the policy maker discovers their potential effects on the economy as a whole, or *vice versa* (Cameron, 2005:148).

Business risk, sector-specific institutional barriers and market imperfections can all frustrate the economic process. When they exist, they certainly will not disappear by themselves. Policies thus should aim to create a framework within which more economic opportunities become market possibilities. Such policies require knowledge (which models can help to provide) of the extent to which these obstacles endure and can be removed cost effectively (Coletti and Murchison, 2002:20).

In the longer term, technological evolution, as well as unforeseen changes in consumer behaviour and preferences complicates any economic impact assessment. Ignoring the long-term impact of short-term decisions cannot be cost effective except by accident. The dynamic challenge of sequential decision-making is to link short-term decisions and long-term goals with enough flexibility to cope with the uncertainties (Coletti and Murchison, 2002:21).

Finally, economic models help settle debates that cannot be settled by theory alone. Economic theory often suggests that potentially offsetting influences are at work in the economy. When combined with statistical methods, models

help economists quantify the relative importance of each factor, thereby providing an estimate of the net impact of these offsetting influences (Cameron, 2005:149).

2.3. General equilibrium

General equilibrium refers to a state in an economy where the needs of all participants in this economy are satisfied. This implies that there exists no excess demand for, or supply of, any goods or services traded in this economy (Arrow, 1974: 254).

The formalisation of the concept of general equilibrium is commonly attributed to Walras (1874) and his publication "*Elements of pure economics*". Walras observed that prices were formulated simultaneously in all markets in an economy. By using a mathematical system of simultaneous equations to describe the interaction between all participants involved in the economy, Walras attempted to prove the existence of a vector of prices that would allow the system to solve, but was unable to do so (Arrow and Debreu, 1954: 265). As a result of his endeavours, Walras developed what today is commonly referred to in Economics circles as Walras' law. This law states that if there are M markets in an economy, and $(M-1)$ of these are in equilibrium, it implies that the M -th market will also be in equilibrium (Weintraub, 1977:4).

The actual formal proof of the existence of such a price vector and state of equilibrium was only supplied in 1954 by Arrow and Debreu (Shoven and Whalley, 1992:12). Further developments of the theory of general equilibrium analysis focus on the existence and uniqueness of equilibrium. For more

detail see Arrow and Debreu (1954), Debreu (1959) and Hahn (1973). General equilibrium modelling evolved further based on the groundwork laid by Leontief (1936), linear programming models (LPs) and GAP-models and the path-breaking work of Johansen with his Multi-Sectoral Growth model in the 1960s (See Balderston, 1954; Dorfman, *et al.*, 1958; Chenery and Strout, 1966; and Bacha, 1990, for more information on these developments).

The dynamic nature of the economy and markets dictates that it is impossible to determine a condition where equilibrium will exist. However, an estimation for the equilibrium condition is attained by "freezing" the economy at a specific time and performing the calculations based on the values at that specific instance in time by using an applied general equilibrium model (AGE).

The AGE modelling approach is an empirical counterpart of the theoretical "general equilibrium analysis" mentioned above (Bandara, 1991:5). The aim of AGE modelling is to convert the abstract representation of an economy into realistic, solvable models of actual economies. In the AGE framework the main focus of analysis is quantitative and is based on the empirical data from a particular country being investigated. One of the major features of AGE modelling is its attempt to combine theory and policy in such a way that the analytic foundation of policy evaluation work is improved (Bandara, 1991:9).

2.4. General application of AGE models

Although the foundations for AGE models were already laid in the 1960s, applied general models have been only been constructed and implemented from the early 1970s (Bandara, 1991:10). There are three main factors contributing to why AGE models only came to be implemented effectively

since the 1970s. First, the relative importance of the sectoral dimension of economic growth was insignificant in the phase of stable conditions that most countries experienced during the 1960s; second, the development of suitable solution algorithms and affordable software and hardware facilities for the solving of large sets of simultaneous equations were limited up to the early 1970s; and finally, more attention was paid to linear programming models with emphasis on resource allocation (Bandara, 1991:10).

All applied general equilibrium models share three common features, the first being that they focus on the real side of the economy. Second, their supply and demand functions explicitly reflect the behaviour of profit maximising producers and utility maximising consumers. Third, both quantities and relative prices endogenous to these models, as well as the resource allocation patterns determined by them, have their roots in the Walrasian general equilibrium. (Weintraub, 1977:8) Despite these common features, all these models differ from each other with respect to detailed specifications and solution algorithms (Shoven and Whalley, 1992:71).

AGE modelling has been widely used by policy analysts in addressing contemporary policy issues in mixed economies since the 1970s in the areas of trade policy, income distribution, issues related to external shocks and structural adjustments, government fiscal policy related issues and choice of development strategies such as long-term growth and structural changes (Bandara, 1991:13). However, there is still considerable debate in the economic profession regarding the value and appropriateness of using AGE

models for policy analysis. The following points of advantages as well as criticism of AGE models are brought for and against the use of AGE models based on Bandara (1991:29-31) and Borges (1986:15-22), grouped by the author broadly into areas related to methodological, model application and policy application aspects:

2.4.1. Methodological advantages

- a) **Solid microeconomic foundations:** Probably the most important strength of the general equilibrium methodology is its solid microeconomic foundation. A typical AGE model specifies the behaviour of all the economic agents using widely-accepted principles of optimisation and choice, which are operational and remain the most frequently used basis for empirical work.
- b) **Standard methods allows for no ad hoc specification resulting in transparent model structures:** AGE models use standard methods to describe all the relationships among variables resulting in the fact that any ad hoc specification is precluded and making the structure of such models more transparent.
- c) **Embodied theory provides validity checks on results:** The embodied theory also provides a precise check on the validity of the results, since it is impossible (unless the model contains errors in specification) that a model will lead to results which are contrary to what the underlying theory predicts.
- d) **Coherent theoretical foundation results in internal consistency:** Related to the advantages of a coherent theoretical foundation is the

issue of internal consistency. AGE models by nature are internally consistent.

- e) **Makes possible the simulation of complex interrelationships:** AGE models allow the analyst to integrate into a single structure a whole series of effects which could not possibly be accounted for coherently in an informal manner therefore making possible the simulation of complex interrelationships while clarifying the role and impact of different factors.
- f) **Can handle large policy shocks:** The fact that AGE models are solved numerically and not analytically allows for AGE models to handle large policy shocks since it does not depend on the assumptions of small change.

2.4.2. Policy applications advantages

- g) **Provides framework for understanding and analyzing policy questions:** AGE models are capable of providing useful insight into important policy problems, by presenting an especially useful framework for understanding and managing structural change.
- h) **Provides quantitative significance of the mechanisms analyzed by theory as well as indirect effects of policy:** In policy debate and formulation, more is needed than the qualitative insights that pure theory can yield. Knowledge of the quantitative significance of the various mechanisms analyzed by theory is also required, including the indirect effects of policies which may escape intuition and thus the attention of theorists.

- i) **Allows for highly disaggregated models allowing structural impact analysis:** The flexibility of the solution algorithms has made possible the development of highly disaggregated models, which also contributes to their practical usefulness. It is well known that many policy actions or exogenous shocks will have an overall impact on the economy which is much smaller than their effect on the structure of the economy.
- j) **Provides the possibility of deriving better measures of the welfare gain or loss:** AGE models provide the possibility of deriving better measures of the welfare gain or loss associated with a new policy. Very often the impact of a policy decision is discussed in terms of very imperfect measures of welfare- such as income or gross national product. It is necessary to go beyond those rough estimates of the gains and losses associated with the change.
- k) **Provides a bridge between the theorist, the planner and the practical policy maker:** AGE models provide a bridge between the theorist, the planner and the practical policy maker. Policy makers will be able to recognize some of the real-world dilemmas they face in the questions addressed by the models, while theorists will recognize the fundamental theoretical structure and will be able to relate the functioning of AGE models to known theorems and analytical results.

2.4.3. Methodological disadvantages

- a) **Over reliance on unrealistic neo-classical assumptions:** AGE modelling over relies on unrealistic neo-classical assumptions such as

perfectly competitive markets and constant returns to scale; in practice the situation of persistent disequilibrium results in additional costs that may be incurred as the economy continues operating without all markets clearing.

- b) **Data and parameter requirements:** The data and parameter values used in the models are often criticized as being inadequate.

2.4.4. Policy applications disadvantages

- c) **Assumption of general equilibrium not relevant for all policy issues:** The general equilibrium assumption rules out the use of these models for many important policy decisions. In addition it is assumed that nothing happens until equilibrium is reached, precluding the analysis of the impact of certain policies on the path of change. The general equilibrium approach is therefore not very relevant to e.g. the discussion of macroeconomic issues related to stabilization policy.
- d) **AGE results are difficult to convey to policymakers in practice:** A major criticism with regard to practical limitations is that the calculated results from AGE models are difficult to explain to policy makers.

2.4.5. Model application disadvantages

- e) **Lack of empirical validation of the models:** One of the most frequently mentioned weakness is the lack of empirical validation of the models, in the sense that usually there is no measure of the degree to which the model fits the data or tracks the historical facts. The models cannot be used to replicate the evolution of the economy in the past as a means of checking their validity.

f) Does not deal with adjustment processes and associated costs:

The treatment of inter-temporal issues - saving and investment decisions - and of expectations. The general equilibrium approach is directed towards long-term questions. Its results should be interpreted in that context. Traditional general equilibrium models do not deal with adjustment processes and the costs associated with them, along the path between today's situation - or the "base case" equilibrium - and the new scenario – often called the "revise case".

g) The treatment of technological progress in the long term context:

Given that these models are designed to look at long term issues it is somewhat contradictory that their structure does not include a more careful treatment of technological change, the implications of which can be far reaching in the long run.

h) Unrealistic assumption of expenditures equalling revenues:

A standard assumption of the first generation of general equilibrium models that all economic agents are on their budget constraints, that is, expenditures equal revenues. Most important consequences of this approach are that the government runs a balanced budget and that there are no international current account imbalances. This however is not the case in more recent applications of AGE models.

i) Lack of explicit financial market treatment: Since all economic agents spend all their incomes in the purchase of goods and services, there is no scope for financial markets. Consequently, almost all of the existing models do not include money or monetary assets. Therefore, the models have been used to study resource allocation issues, but not

financial or monetary policy issues. In particular, it would be impossible to discuss problems related to inflation in the context of the existing models.

- j) **Simplistic treatment of foreign sector:** Most existing general equilibrium models have a very inadequate treatment of the foreign sector, and in particular of net trade flows. Again this criticism is not necessarily valid for certain modelling initiatives such as that of the Global Trade Analysis Project (GTAP) coordinated by the Centre for Global Trade Analysis, at the Department of Agricultural Economics at Purdue University.
- k) **Complexities of relevant closure selection:** When closing the model - that is, when specifying the last element of it - all degrees of freedom are lost and any behavioural relationships must be consistent with what has been specified for the rest of the model. Naturally, since the last element of the model has this "residual" nature, it must be a relatively unimportant component, given the application in question.

Despite the above mentioned criticisms AGE models are capable of providing useful insight into important policy problems, by presenting an especially useful framework for understanding and managing structural change. In policy debate and formulation, more is needed than the qualitative insights that pure theory can yield. Knowledge of the quantitative significance of the various mechanisms analyzed by theory is also required, including the indirect effects of policies which may escape intuition and thus the attention of theorists. AGE models provide a bridge between the theorist, the planner and the

practical policy maker. Policy makers will be able to recognize some of the real-world dilemmas they face in the questions addressed by the models, while theorists will recognize the fundamental theoretical structure and will be able to relate the functioning of AGE models to known theorems and analytical results.

Many quantitative methods are at the disposal of policy makers for assessing economic impacts of projects or events; however, the most commonly accepted is input-output analysis (Lundberg *et al.* 1995). The basic building blocks for AGE models from an information point of view are based on input-output tables, extended to social account matrices. These provide the basis for a AGE's information requirements. The relationship between these two elements and an AGE model is discussed in the next section.

2.5. Basic building blocks for AGE models

2.5.1. Input-output analysis

Input-output analysis is an analytical framework with the fundamental purpose to analyse the interdependence of industries in an economy (O'Connor and Henry, 1975:1). An input-output model in its most basic form consists of a system of linear equations, each one of which describes the distribution of an industry's product throughout the economy. While input-output analysis is a widely accepted and useful means of economic impact analysis, it is limited in that it does not reveal the personal income distribution effects across different household income segments (Holland and Wythe, 1993) and gives no consideration to industry occupation, skills and wages and the resulting

income effects. Therefore, using input-output models to assess economic impacts will not allow for a clear picture of which household income groups are benefiting / suffering and which are not, from the specified issue under review.

2.5.2. Social accounting matrices

A social accounting matrix (SAM) is a data system, including both social and economic data for an economy. The data sources for a SAM come from input-output tables, national income statistics, and household income and expenditure statistics (Cameron, 2003). Therefore, a SAM is broader than an input-output table and typical national accounts, showing more detail about all kinds of transactions within an economy. However, an input-output table records economic transactions irrespective of the social background of the transactors. A SAM, contrary to national accounts, “... *attempts to classify various institutions to their socio-economic backgrounds instead of their economic or functional activities*” (Chowdhury and Kirkpatrick, 1994:58).

A SAM is a way of logical arrangement of statistical information, concerning income flows in a country's economy within a particular time period (usually a year). It can provide a conceptual basis to analyse both distributional and growth issues within a single framework (Statistics South Africa, 1998a:7). For instance, a SAM shows the distribution of factor incomes of both domestic and foreign origin, over institutional classes and re-distribution of income over these classes. In addition, it shows the expenditure of these classes on consumption, investment and savings made by them.

King (1988) points out that a SAM has two main objectives:

- a) first, organising information about the economic and social structure of a country over a period of time; and
- b) second, providing statistical basis for the creation of a plausible model capable of presenting a static image of the economy along with simulating the effects of policy interventions in the economy or other economic impacts.

A SAM, coupled with a conceptual framework that contains the behavioural and technical relationships among variables within and among sets of accounts, can be used for the evaluation of the economy-wide effects of policy changes or other economic impacts rather than only for purely diagnostic purposes (Pyatt, 1988:349). The aforementioned conceptual framework is supplied in the form of an AGE model.

2.6. The AGE framework

The aim of AGE modelling is to convert the abstract representation of an economy into realistic, solvable models of actual economies. In the AGE framework the main focus of analysis is quantitative and is based on the empirical data from a particular country being investigated. One of the major features of AGE modelling is its attempt to combine theory and policy in such a way that the analytic foundations of policy evaluation work are improved. An AGE model can accordingly be described as an economy-wide model that includes feedback between demand, income and production structure, and where all prices adjust until decisions made in production are consistent with decisions made in demand (Dervis *et al.* 1985:132).

A typical AGE model has a theoretical structure that consists of equations describing, for some time period (Wing, 2004:5-8):

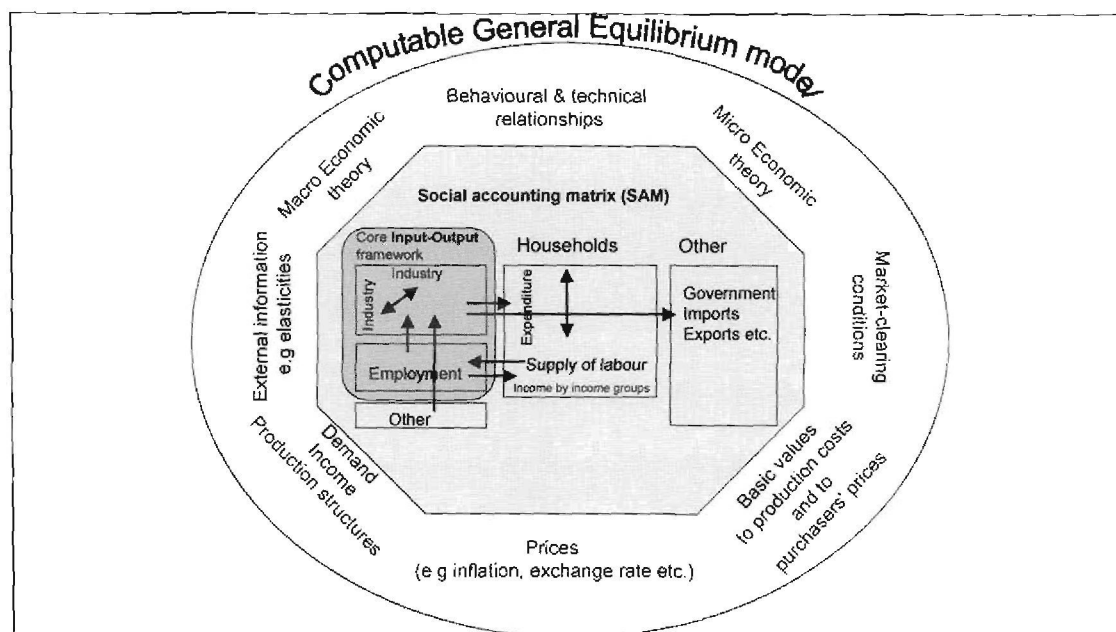
- producers' demands for produced inputs and primary factors;
- producers' supplies of commodities;
- demands for inputs to capital formation;
- household demands;
- export demands;
- government demands;
- the relationship of basic values to production costs and to purchasers' prices;
- market-clearing conditions for commodities and primary factors; and
- numerous macroeconomic variables and price indices.

Demand and supply equations for private-sector agents are derived from the solutions to the optimisation problems (cost minimisation and utility maximisation) which are assumed to underlie the behaviour of the agents in conventional neoclassical microeconomics. The agents are assumed to be price takers, with producers operating in competitive markets, which prevent the earning of pure profits (Bandara, 1991:12). In addition to this static core, the AGE model can include several accumulation relationships that link the values of stocks (capital by industry and net foreign debt) over time, relating them to initial conditions and to the values of the relevant accumulating flows (investment and depreciation by industry, and foreign borrowing).

The main equations of these models are derived from the constrained optimisation of neo-classical production and utility functions. Producers select inputs in order to minimise costs of a given output subject to non-increasing returns to scale industry production functions. At the same time consumers are assumed to select purchases in order to maximise utility functions subject to their budget constraints. Production factors are paid according to their marginal productivity. The government sector is included and imperfect competition can be introduced via price fixing, rationing and quantitative restrictions. At the equilibrium level these models' solutions provide a set of prices that ensures that all commodity and factor markets are cleared as well as making all individual agents' optimisations feasible and mutually consistent (Bandara, 1991:12).

The diagram in Figure 1 illustrates the simplified relationship between an IO table, SAM and AGE model:

Figure 1: Simplified relationship between and IO table, SAM and AGE Model



Source: Cameron, 2003.

One can therefore summarise the relationship and context between IO tables, SAMs and AGE models as follows (Cameron, 2003):

- a) Input-output (IO) analysis is an analytical framework with the fundamental purpose to analyse the interdependence of industries in an economy. An input-output table records economic transactions irrespective of the social background of the transactors.
- b) A social accounting matrix (SAM) comes from input-output tables, national income statistics, and household income and expenditure statistics. Therefore, a SAM is broader than an input-output table and typical national accounts, showing more detail about all kinds of transactions within an economy.
- c) An **applied general equilibrium (AGE)** model comes from a SAM, coupled with a conceptual framework that contains the behavioural and technical relationships among variables within and among sets of accounts. The aim of AGE modelling is to convert the abstract representation of an economy into realistic, solvable models of actual economies. In brief one can therefore state that an AGE model has the benefit that it can be used for a more detailed and realistic evaluation of the economy-wide effects of policy changes or other economic impacts than either an IO analysis or SAM.

2.7. Closure rules for AGE models

The concept of “closure rules” refers to the way in which the number of endogenous variables in a model is set equal to the number of equations of the model in order to ensure that there will be a mathematical solution to the system of equations (or model) (Robinson, 1991; Whalley and Yeung, 1984). Different closures for the same model will change the model’s quantitative

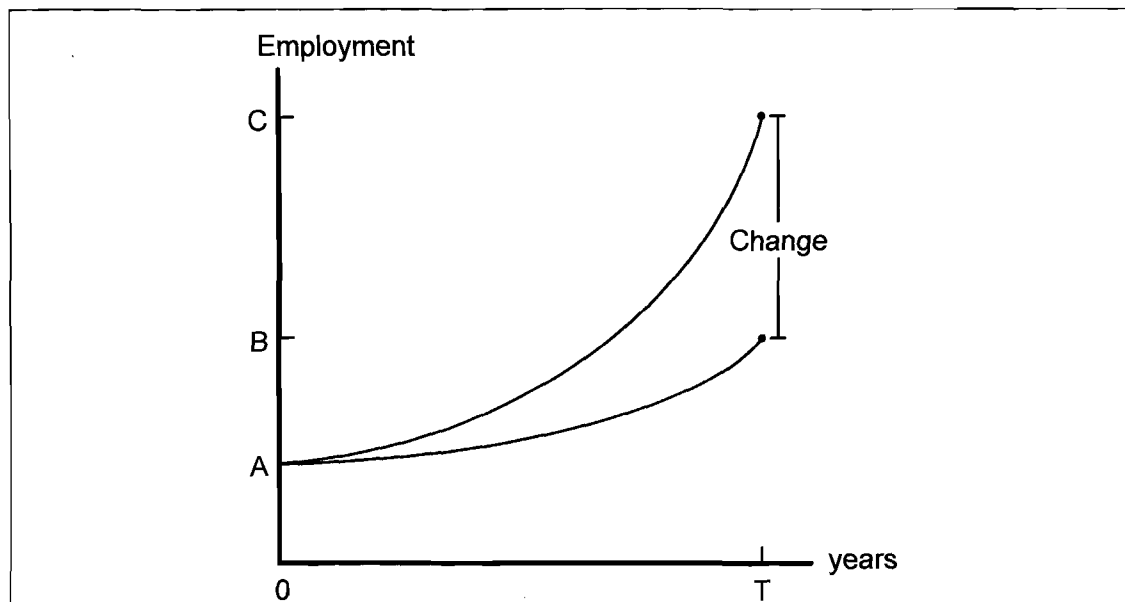
characteristics, and it is therefore important to apply the correct closure depending on the specific question being analysed (Bandara, 1991:17). According to Bandara (1991:17) closure rules are generally classified into four basic types, namely:

- a) The Keynesian closure – the assumption of full employment of production factors is relaxed with the implication that disequilibrium can occur in the labour market.
- b) The Kaldorian closure – the assumption that wages of production factors must equal their marginal productivity is relaxed.
- c) The Johansen closure – the assumption that household consumption is a function of only household income is relaxed and it is stated that full employment can be reached by shifting consumption.
- d) The Classical closure – the assumption that investment is a constant is relaxed and investment is viewed as endogenous.

2.8. Interpretation of AGE results

AGE models are used mainly for comparative static analyses. This form of analysis involves comparing equilibrium positions as opposed to examining the path which the market follows when moving from the old to the new equilibrium. Therefore, the change in a system from one position of equilibrium to another is investigated, without regard to the transitional process involved in the adjustment (Zamagni, 1987:98). Results of comparative-static AGEs all refer implicitly to the economy at some future time period. To enable the reader to understand how to interpret these results a brief example is in order.

Figure 2: Stylised representation of change reported in AGE model results



Source: Horridge *et al.* 1993 : 76

The example is illustrated by Figure 2, which graphs the values of for instance, employment, against time. The level of employment in the base period (period 0) is represented by **A** and **C** is the level which it would attain in **T** years time if some policy, for instance a tariff reform scheme, is implemented, all other things being equal. **B** represents the level which would be attained if the policy was not implemented. A comparative static AGE model would generate the percentage change in employment $((C-B)/B) \times 100$, illustrating how employment in period **T** would be influenced by the tariff policy in isolation. For these kind of simulations capital stocks are usually held at their pre-shock levels and econometric evidence suggests that a short-run equilibrium will be reached in about two years ($T=2$) (Horridge, *et al.*, 1993:73). Note that nothing is said about the path of change (the curved lines connecting **A** with levels **B** and **C**), only the change from **B** to **C**.

Further developments in the AGE field make the inclusion of dynamic elements, such as stock/flow accumulation relations between capital stocks and investment as well as between foreign debt and trade deficits, possible. The ORANI-F model (See Horridge, *et al.*, 1993 for a detailed description of the ORANI-F model) is an example of an AGE model with dynamic capability. ORANI-F is used for making medium-term forecasts for the Australian economy.

The main source of data for any AGE model is normally supplied in the form of a social accounting matrix (SAM) as explained in the previous section. Since a SAM represents the circular flow of income in a country, it is considered to be a natural candidate for a AGE to be based upon (Pyatt, 1988). According to Pyatt (1988) any model based on a SAM will also satisfy Walras' law. The relationship between SAMs and models can be described as asymmetric in the sense that for each model there exists a corresponding SAM, but for any given SAM a variety of possible models exist.

2.9. Summary

This chapter illustrated the need for AGE models as tools for policy makers in South Africa through the fact that economic models (and more specifically AGE models) can provide key insights for analysis of comprehensive packages of economic and non-economic policy instruments within a consistent framework and insights generated by this modelling can help in evaluating various policy options.

The concept of general equilibrium in the context of AGE models as well as Walras' law, a central building block of general equilibrium, was explained, as well as developments of the application of AGE models from the 1960's onwards. Common features as well as constraints of AGE models were discussed, after which the basic building blocks of information for AGE models, namely input-output tables and social accounting matrices, were discussed in brief.

The aim of AGE modelling, to convert the abstract representation of an economy into realistic, solvable models of actual economies with the main focus of analysis being quantitative based on empirical data was highlighted. The concept of closure rules was explained and the fact that it is important to apply the correct closure depending on the specific question being analysed was highlighted. Lastly a short explanation on the interpretation of percentage change results from a typical linearised solution approach was explained.

In South Africa, the potential benefits of using AGE modelling was realised in the early 1990s, following the availability of SAMs for the economy. The development and use of AGEs in South Africa is discussed in the next chapter.

CHAPTER 3: APPLIED GENERAL EQUILIBRIUM MODELLING IN SOUTH AFRICA

3.1. Introduction

In the previous section, an overview was given of the theoretical foundations of AGE modelling. Although the first SAM for South Africa was published in 1986 by the then Central Economic Advisory Services, the SAM was for 1978 and excluded useful household income and race dimensions (SEAD, 1986). In 1993 a provisional SAM was published by the Central Statistical Services (with base year 1988 for economic variables and 1991 Census for household variables) for the South African economy, and was used in descriptive manner to analyse questions relating to the interrelationships between growth, distribution of income and production in the economy (SSD, 1993). The first AGE models to make use of this SAM framework, however only dates from the early 1990s.

This chapter will discuss the development of AGE modelling in South Africa, and will show that despite a significant growth in the number of models and applications (both for policy as well as for private firm use) after 15 years of AGE modelling there is still a need to go beyond the country level to sub-national AGE models.

The chapter is structured as follows. Section 3.2 provides a chronology of applications of AGE models in South Africa since the early 1990's. Section 3.3 provides an overview of the focus of major applications of AGE models in South Africa over this period, illustrating the lack of sub-national detail and

applications for South Africa over this period. Section 3.4 summarises the chapter.

3.2. Major applications of AGE models in South Africa

The chronology presented in Table 1 is based on Rossouw (2004)³ in which they provide an overview of the developments in AGE modelling in South Africa since the 1990s, as well as the author's own experience⁴ and involvement in these events.

Rather than summarising the analysis of Rossouw (2004) here, this section will present a chronological timeline to represent the developments highlighted by Rossouw (2004), as well as to expand the list with some additional entries based on the authors' research as well as personal involvement in some of these efforts.

The chronology is non-exhaustive since the specific developments listed excluded works non-academic in nature. Over the period discussed in this chronology AGE models were applied in various impact studies of non-academic and non-public nature, some of which the author was part of personally. In addition, applications of multi-country model developments in which South African issues were analysed are also excluded. An example is

³ The author added some information as well as corrected some date references.

⁴ The author was part of the initial AGE modelling team at the Industrial Development Corporation of South Africa during the period 1994 – 1996. During this period the IDCGEM was applied to study a variety of topics, but the focus was mostly on international trade related topics.

the Global Trade Analysis Project (GTAP) coordinated by the Centre for Global Trade Analysis, at the Department of Agricultural Economics at Purdue University.

As mentioned by Rossouw (2004), the Industrial Development Corporation Computable General Equilibrium Model (IDCGEM), based on the Monash ORANI approach, dominated the AGE modelling scene during the 1990s. However, due to difficulties experienced by the IDC in retaining the capacity to utilise the model, its dominance of AGE modelling in South Africa started to diminish and the new millennium saw the emergence of new players in the field, both local and international, along with the appearance of a number of alternative modelling strategies.

One reason for a fresh wave of interest in AGE modelling in South Africa since 2000 was due to the World Bank's interest in the implications of HIV/Aids on the South African economy (Arndt and Lewis, 2000). The momentum was picked-up and sustained by researchers under the auspices of the International Food Policy Research Institute (IFPRI) (Thurlow *et al.* 2002 & 2003), but academic institution modellers have also been playing an active role in building new models to answer to new policy challenges (McDonald & Punt, 2005:88).

Table 1: Chronological developments of AGE modelling in SA 1993-2005

1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	
(1)→Potchefstroom University and the University of Copenhagen Naudé & Brixen Model = Provisional Multi-sector CGE Major focus = Government sector dominance in SA economy R - no regional aspects							(9)→Centre on Globalisation & Sustainable Development Humphreys Model = Small Open Economy 3-sector CGE Major focus = Trade Liberalisation & Poverty R - no regional aspects			(20)→University of Pretoria Van Heerden <i>et al.</i> Model = UPGEM - based on ORANI-G Major focus = Energy & Greenhouse Gas emissions R - no regional aspects					
(2)→Industrial Development Corporation (IDC) of South Africa Joubert <i>et al.</i> supported by Horridge <i>et al.</i> Model = 96-sector CGE based on ORANI-F Major focus = Free Trade - EUFTA and GATT R - no regional aspects							(10)→World Bank Arndt & Lewis Model = Solow-type standard Neo-classical CGE Major focus = Impact of HIV/Aids R - no regional aspects			(21)→Industrial Development Corporation (IDC) of South Africa Coetzee <i>et al.</i> supported by Naudé <i>et al.</i> Model = 103-sector CGE based on ORANI-F Major focus = Causes and extent of inequality in South Africa R - Top-down Provincial (9) share					
(3)→National Economic Policy unit (NIEP) Gelb <i>et al.</i> supported by Brain <i>et al.</i> ** Model = Multi-sector macroeconomic model / eclectic CGE Major focus = Reconstruction & Development Programme (RDP) R - no regional aspects							(11)→World Bank Devarajan & van der Mensbrugghe Model = Standard Neo-classical CGE Major focus = Removal of Trade Barriers impact on household R - no regional aspects			(22)→University of Pretoria Mabugu <i>et al.</i> Model = Intertemporal dynamic CGE Major focus = Draft - transitional changes of trade policy reform R - no regional aspects					
(4)→Industrial Development Corporation (IDC) of South Africa De Jongh, Cameron <i>et al.</i> supported by Horridge <i>et al.</i> Model = 103-sector CGE based on ORANI-F Major focus = Government Expenditure & Provincial Implications R - Top-down Provincial (9) share Major focus = Government Expenditure - Provincial GDP implications							(12)→University of Pretoria De Wet <i>et al.</i> Model = ORANI-G for SA Major focus = Fiscal reform with focus on Coal mining sector R - no regional aspects						(23)→University of North West Naude <i>et al.</i> Model = DTIGEM - based on ORANI-G Major focus = Transport sector productivity improvements R - no regional aspects		
(5)→Development Bank of Southern Africa van Seventer <i>et al.</i> supported by Gibson <i>et al.</i> Model = Structuralist CGE Major focus = Impact of new ANC government policies R - no regional aspects							(13)→University of Pretoria Kearny <i>et al.</i> Model = Stylized Walrasian Closed-economy model Major focus = Fiscal policy with focus on Value Added Tax R - no regional aspects								
(6)→Industrial Development Corporation (IDC) of South Africa Cameron <i>et al.</i> supported by Horridge <i>et al.</i> Model = 103-sector CGE based on ORANI-F Major focus = Government Expenditure & RDP implications R - Top-down Provincial (9) share							(14)→Dept of Agriculture - Elsenburg Western Cape Punt & McDonald Model = Neo-classical CGE Major focus = Exports & provincial Agriculture sectors R - Provincial (Western Cape) SAM & CGE								
				(7)→Industrial Development Corporation (IDC) of South Africa Coetzee <i>et al.</i> supported by Naudé <i>et al.</i> Model = 103-sector CGE based on ORANI-F Major focus = Accelerated Tariff Reduction Programme, Currency Depreciation R - Top-down Provincial (9) share						(17)→International Food Policy Research Institute (IFPRI) Thurlow <i>et al.</i> Model = Standard Neo-classical CGE Major focus = HIV/Aids & Trade Policy R - no regional aspects					
				(8)→Industrial Development Corporation (IDC) of South Africa Coetzee <i>et al.</i> supported by Naudé <i>et al.</i> Model = Dynamic 103-sector CGE based on ORANI-F Major focus = Sectoral Prospects - 1997 to 2001 projections R - Top-down Provincial (9) share						(18)→Dept of Agriculture, Western Cape Pauw and Edwards Model = Standard Neo-classical CGE Major focus = Adapting IFPRI - focus on semi & low skilled wages R - no regional aspects					
										(15)→International Food Policy Research Institute (IFPRI) Thurlow <i>et al.</i> Major focus = Standardising IFPRI for SA R - no regional aspects					
										(16)→International Food Policy Research Institute (IFPRI) Thurlow <i>et al.</i> Model = Dynamic Neo-classical CGE Major focus = Various Poverty & Trade Policy related R - no regional aspects					
										(19)→University of Stellenbosch Van Schoor and Burrows Model = Standard Neo-classical CGE based on IFPRI model Major focus = Adapting IFPRI - focus on imperfect competition & returns to scale R - no regional aspects					

Source: Author based on Rossouw (2004). * Author added additional developments to initial analysis of Rossouw. ** Author corrected date.
*** Author adjusted model classification of the NIEP model to an eclectic hybrid macro-econometric and AGE combination model

3.3. Focus of AGE models in South Africa

Rossouw (2004) observed that there has been a considerable increase in the use of AGE models in South Africa to investigate and inform a variety of policy issues since the early 1990s. For the South African context and the purpose of this study, the observation by Rossouw (2004) that at the end of the 1990s there has been a major shift both in the questions to which models have been addressed and in the types of models used is important for the context of this study.

A further observation by the author regarding the chronology of developments of AGE models in South Africa is that most of the applications were generally of comparative static nature, with some rudimentary dynamic models developing such as the recursive dynamic IFPRI model extension by Thurlow *et al.* (2002 - 16 in chronology) and the dynamic IDCGEM application by Coetzee *et al.* (1998 - 8 in chronology).

Some of the non-public application of AGE models during this time included studies on e.g. the implications of adopting best practice in the South African textile and clothing industries by the department of Economic Research and Development at the IDC during 1994. Another studied the effect of an increase in labour productivity on the South African economy during 1995. Yet another studied the effect of devaluation of the Rand on the South African economy, as well as the effect of exporting more coal on the South African economy. Another interesting study that was conducted in 1995 was around the topic of Petrol versus Diesel - the advantages of a price differential.

Although the IDCGEM contained a top-down regional dimension, the focus of analysis was never on the regional implications of these simulations, although in cases such as the impact of the implications on the South African economy of the General Agreement on Trade and Tariffs (GATT) conducted in 1995 the regional results on provincial level were also disseminated.

While the first AGE models in the South African policy environment were mainly used to understand issues of the day such as macroeconomic stability and the “then” liberalisation of the South African economy due to developments such as the European Free Trade Agreement concluded between South Africa and the European Union after 1994, later focus has shifted to a broader range of topics such as the labour market, environmental, welfare, health, fiscal and tax questions.

The relevance of the chronology presented here particularly relate to more recent and current sub-national issues in the sense that it illustrates that South Africa lacks any regional or sub-national focus in the development of AGE's to study South African sub-national economic issues (with the exception of the Western Cape model by Punt and McDonald, 2001 – 14 in chronology), while as articulated in the problem statement of this study, one of the major legacies of the policies of the apartheid regime manifested in the South African economy today is the uneven economic development of South Africa's sub-national economies.

In order to better understand alternative policy implications on sub-national (whether it is provincial, municipal or magisterial district detail) levels, South African policy analysts and makers will be greatly assisted if such a regional AGE (RAGE) model was available and accessible to analyse relevant issues in geographic or spatial context.

3.4. Summary

This chapter provided an overview of AGE applications in the South African context since the 1990s in section 3.2. In section 3.3 observations were made regarding the focus of analysis of the models developed during this period, as well as the lack of regional AGE abilities and the resulting lack of sub-national applications.

In the next chapter regional AGE modelling is discussed with a focus on specific relevance to South African policy makers.

CHAPTER 4: REGIONAL APPLIED GENERAL EQUILIBRIUM MODELLING

4.1. Introduction

It was concluded in the previous chapter that South Africa lacks any regional or sub-national focus in the development of AGE's to study South African sub-national economic issues. In this chapter South Africa's regional policy challenges are highlighted, with the aim of sensitising the reader to the fact that such policies exist and to highlight the need for proper tools to inform and assist decision making regarding such policies. Regional AGE approaches and models are discussed with reference to international RAGE applications to illustrate the relevance in other countries while at the same time questioning why South Africa doesn't use the same type of approaches.

This chapter is structured as follows. Section 4.2 highlights some of the regional development policies actively being pursued by the South African government. Different approaches to RAGE models are discussed in section 4.3, while examples of international applications of RAGE models are provided in section 4.4. The general relevance of RAGE model applications are discussed in section 4.5, while section 4.6 highlights specific relevance of RAGE model applications for the South African context. Finally a summary of the chapter is provided in section 4.7.

4.2. Regional development challenges in South Africa

The South African deputy president, Phumzile Mlambo-Ngcuka, stated on 6 February 2006 that more than 40 percent of the government and public enterprise investment expenditure in the near future will be focussed on

power generation, power distribution, rail transport, harbours and an oil pipeline. In addition, projects at a provincial and local municipal level will be funded through municipal and provincial infrastructure grant programmes. In this regard provinces were asked to propose special projects that would have a major impact on accelerating and sharing growth, contributing to the Accelerated and Shared Growth – South Africa (ASGISA) strategy for South Africa (South Africa, 2006).

As a result South Africa's Department of Trade and Industry (thedti) have adopted a specific focus on the geographic spread of economic activities and investment. As mentioned before as part of the problem statement of this study (section 1.3.2), a range of policies are already in place in this regard, such as the Integrated Sustainable Rural Development Strategy (ISRDS), the Urban Renewal Strategy (URS), Industrial Development Zones (IDZs), Spatial Development Initiatives (SDIs), and the approach of Integrated Development Plans (IDPs) (Cameron, 2005:146).

Regional or spatial development objectives are in themselves prominent goals to be attained by, for one, transport policy. In South Africa achievement of regional development should be considered as part of the strategy of government regarding transport development. This is due to the infrastructure investments associated with transport as well as the enabling role that transport plays in the economy, and should be regarded as a means of regional policy that could support less favoured or less developed regions if applied wisely.

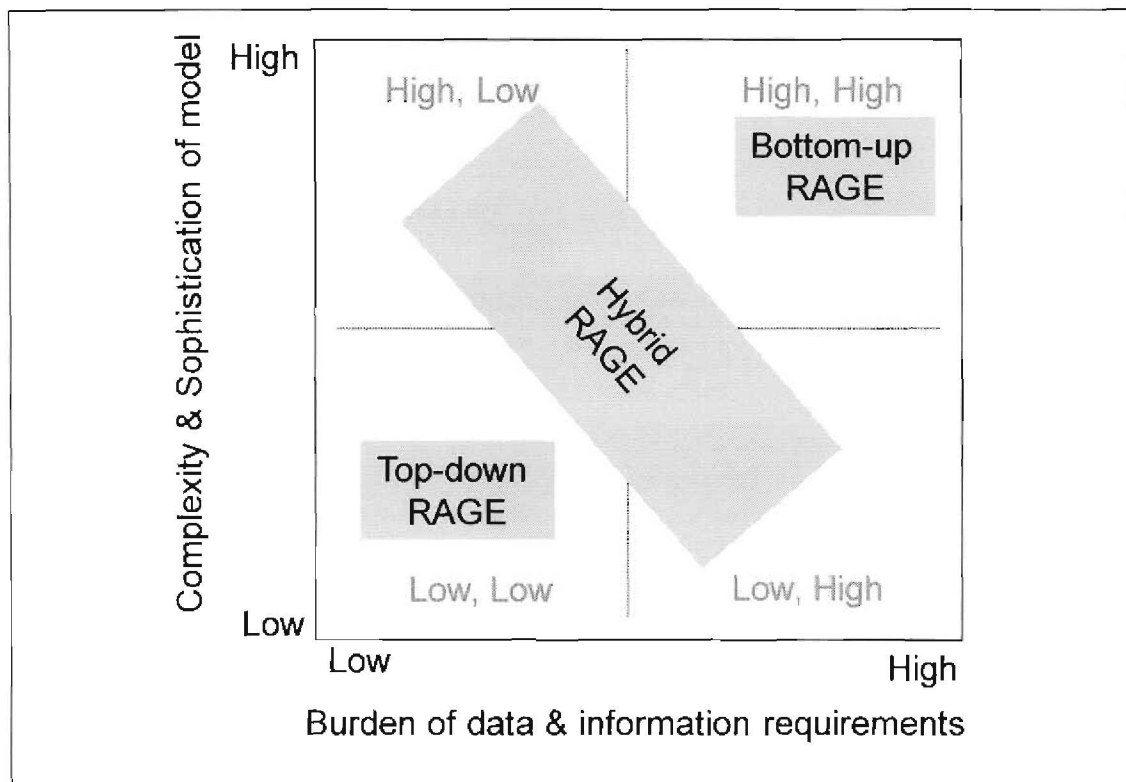
In the problem statement of this study it was also mentioned that there are various challenges emanating from these policies and strategies. One obvious technical challenge is that government needs to be able to evaluate the potential regional impact or implications of potential policy decisions. In this regard Iqbal and Siddiqui (2001:5-6) and Robinson (1991:1509) state that AGE models have become a “*standard tool*” for professionals and policy makers, as one of the advantages of AGE models is that this type of model do not excessively simplify or aggregate effects of policies being simulated. As regional AGE models add more detail and reflect more realistic sub-national interactions in the economy, we briefly investigate the types, areas of contribution and potential applications of RAGE modelling in order to illustrate the relevance of such tools (also for the South African case) as an aid to address this challenge.

4.3. Approaches to Regional AGE modelling

The field of RAGE modelling is still in a developmental stage and as such there is no approach or method accepted by all. One of the major reasons put forward as motivation for this diversity as well as late development or lack of RAGE's in many country's cases, is the extensive data requirement that AGE models have for regional applications (Parmenter *et al.* 1985:1).

At the two extremes found in the practical field of regional AGE modelling one finds the so-called “top-down” approach at the one extreme and the “bottom-up” approach at the other extreme. Figure 3 below illustrates the range of potential approaches in a stylized diagram.

Figure 3: Stylized range of regional AGE model approaches



Source: Author

The complexity and sophistication of the regional AGE modelling equations are presented on the vertical access, while the degree of burden of data requirements and detail is presented on the horizontal access. The top-down approach has relatively⁵ low complexity and sophistication, while at the same time having less onerous (low) data and information requirements, while the bottom-up approach has relatively high complexity and sophistication combined with more onerous (high) data and information requirements.

⁵ Please note the concept of relativity in this case refers to the bottom-up as comparator. AGE models in general has quite an onerous data requirement, hence the interpretation of "low" in this case must be emphasized to mean "relatively low" to normal AGE applications.

In practice, depending on factors such as the availability of information as well as the type of application, one finds hybrid applications that fall somewhere in the continuum between pure top-down and pure bottom-up approaches.

4.3.1. The top-down approach

Top-down models regionalise impacts of national level simulation results by applying top-down shares that excludes any explicit interaction between regional economic agents. Therefore equilibrium of the system is obtained at the national level and the impact is generally allocated down to regions based on a region's past economic base. These models are therefore not well suited to simulate the economy-wide implications of regional shocks (Parmenter *et al.* 1985:1)

4.3.2. The bottom-up approach

The fundamental difference between top-down models and bottom-up models are that in contrast to top-down models, bottom-up models contain equations and identities that simulates regional economic agents in order to achieve regional equilibriums, then aggregating impacts up to obtain the final aggregate national impact. Each region is therefore treated as a "small" economy on its own, interacting with the other region's economies via goods imports, exports and factor (employment, capital) movements. Inter-regional flow data is extremely important in the pure bottom-up case. In practice though, modellers have to make use of more "mechanically" estimated data than data from primary sources due to the scarcity of regional data as mentioned above.

4.3.3. The hybrid approach

Hybrid models make use of a combination of the above approaches for a mix of economic agents and factors. As an example, some factor markets may have national equilibriums (e.g. labour – or even sub-sets of labour and capital), while others may have local equilibriums, such as sub-sets of agriculture or certain types of services. Hybrid models attempt to strike a balance between data requirements (especially intra-regional flows) while still being able to provide some level of sophistication and realism to regional applications.

4.3.4. Summary of approaches

One can therefore define a top-down model as an interregional model based on the disaggregation of a national model, while a bottom-up model would be defined as a formal linking of individual self-contained regional models. A hybrid model would then be defined as a model containing elements of both top-down and bottom-up models.

4.4. Examples of regional AGE model applications

Although some of the earliest policy-oriented AGE work was conducted in the early 1970s, applications of regional AGE models are more recent according to Partridge and Rickman (1998) and Bröcker and Schneekloth (2005). This section is primarily based on the research conducted by Partridge and Rickman (1998), in which they present their findings of an investigation of what regional AGE models have contributed to the analysis and understanding of regional economics.

Partridge and Rickman (1998) focused only on models that are bottom-up in nature and as a result, the findings show a concentration of these types of applications mainly in the United States and Canadian geographies. This is to be expected, as most of the other parts of the world economies with the exclusion of Europe generally have a scarcity of detailed sub-national data. AGE models at a national level require data on aspects such as household consumption by product types, investment expenditures, industry output, industry technology and various types of elasticities, government expenditures, taxes, factor ownership and trade flows. These requirements just increase in near direct proportion to the number of dimensions in terms of regional disaggregation in the case of a bottom-up RAGE.

At a high level there are a further four factors that complicate the application of regional AGE models further over and above data availability. First, regional economies are more open than when modelling only the national level economy. This is due to the fact that regional economies can trade with both international markets as well as other regions within the country. Second, on the production factor side, labour also tend to be more mobile between regions, than it would be between countries and the modelling need to cater for this economic phenomena. Third, savings by residents within a region potentially have less impact on savings in such regions, as savings would probably be distributed based on more of a national level market structure. Fourth, and last, is the potential interaction between regional (provincial) level government expenditure, taxes and transfer policies and the regional (provincial) economy. Pure bottom-up models may attempt to capture these

four complicating factors while hybrid models may attempt to address only some of these factors subject to the application purpose and information availability.

Although it would therefore at first hand seem impossible to construct a sensible and reasonably disaggregated bottom-up regional AGE model, this section illustrates that it is possible and there are various models that have been constructed successfully for various countries in the world over the last number of years. In addition, there are various active efforts by international and country specific institutions such as the World Bank, Poverty and Economic Policy (PEP) Research Network, IFPRI and others to attempt to create more detailed data sets in order to conduct this type of analysis on a more widespread basis.

In the South African context there is at the time of writing of this thesis (2007/2008) a programme to actively compile a set of social accounting matrices for the nine provinces of South Africa. The stakeholders that are relevant to this project include the Development Bank of Southern Africa (DBSA), and a number of National Departments, including the Department of Provincial and Local Government (DPLG), Statistics South Africa (Stats SA), the South African Reserve Bank (SARB), and the National Treasury. Each province's Provincial government is a key stakeholder and role player in this

programme. At the time of compiling this study, indications⁶ from the DBSA were that 7 of the 9 province's SAMs were completed, and the remainder scheduled to be completed by the second half of 2008.

From the research by Partridge and Rickman (1998) combined with the author's research, the list in Table 2 below shows that there are more than 30 bottom-up applications of RAGE's that appear in the academic literature over the last 25 years (since 1983), while the author listed some top-down applications that are also in the academic literature. There are many more as this is not an exhaustive list. The table just serves to illustrate that this type of modelling is actively being used in various countries in the world, but more so in countries that have detailed sub-national data such as the United States and Canada.

Table 2: International example applications of RAGEs

Country / Area	Geography	Bottom-up	Top-down or hybrid
United States	Various States & Counties	18	na.
Canada	Regions within Canada	6	na.
European Union		1	na.
Germany	Baden-Wurtemberg	1	na.
Malaysia	Two regions	1	na.
Scotland	1 region	1	na.
Australia		2	2
China	29 regions	1	na.
South Africa	Western Cape, 9 Provinces	1	1
Total		32	3

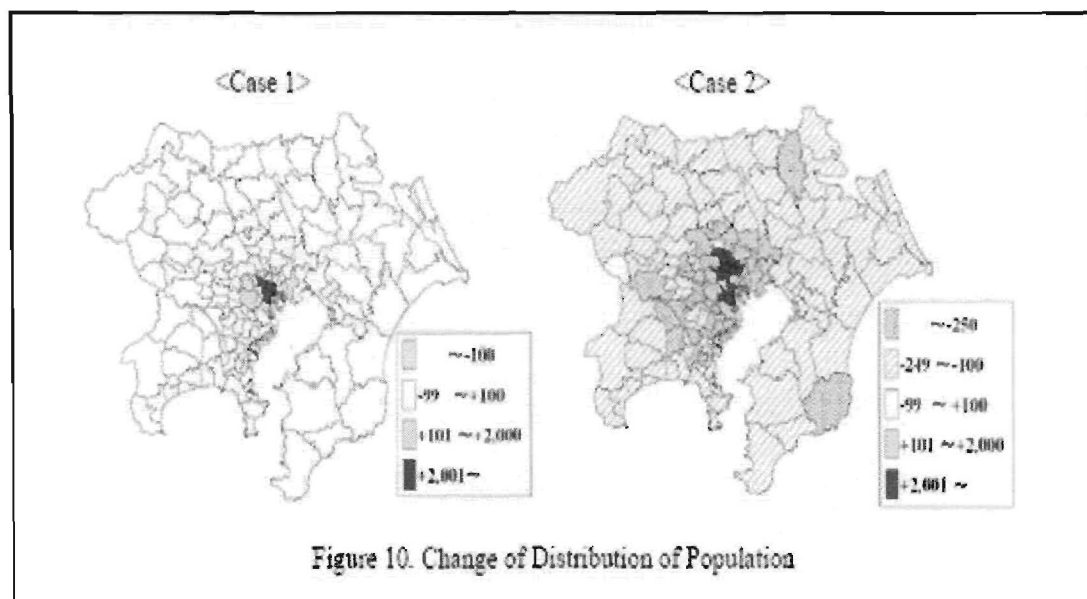
Source: Compiled from Partridge and Rickman (1998) and author research

⁶ Rousseau (2008) of the task team from the DBSA confirmed that Conningarth Economists, who has been contracted to compile these provincial SAMs, have completed all provinces with the exception of the Western Cape and Kwa-Zulul Natal.

Another type of model not included in the research by Partridge and Rickman (1998) are more focused on RAGE applications in the transport and logistics field. These models generally are limited to a specific geography within a country e.g. a large metropolitan or city area, or transport and logistics corridors only. For an example of metro or city applications refer to Sato and Hin (2005). They present a spatial AGE analysis of road pricing in the Tokyo metropolitan area.

Evident from the illustration in Figure 4 (of impacts in this case on distribution of population in Tokyo suburbs) is the localised “micro” spatial nature of this type of application of geographically detailed AGE models. Another example mentioned previously is that of the case of Melbourne, Australia (see Horridge, 1999).

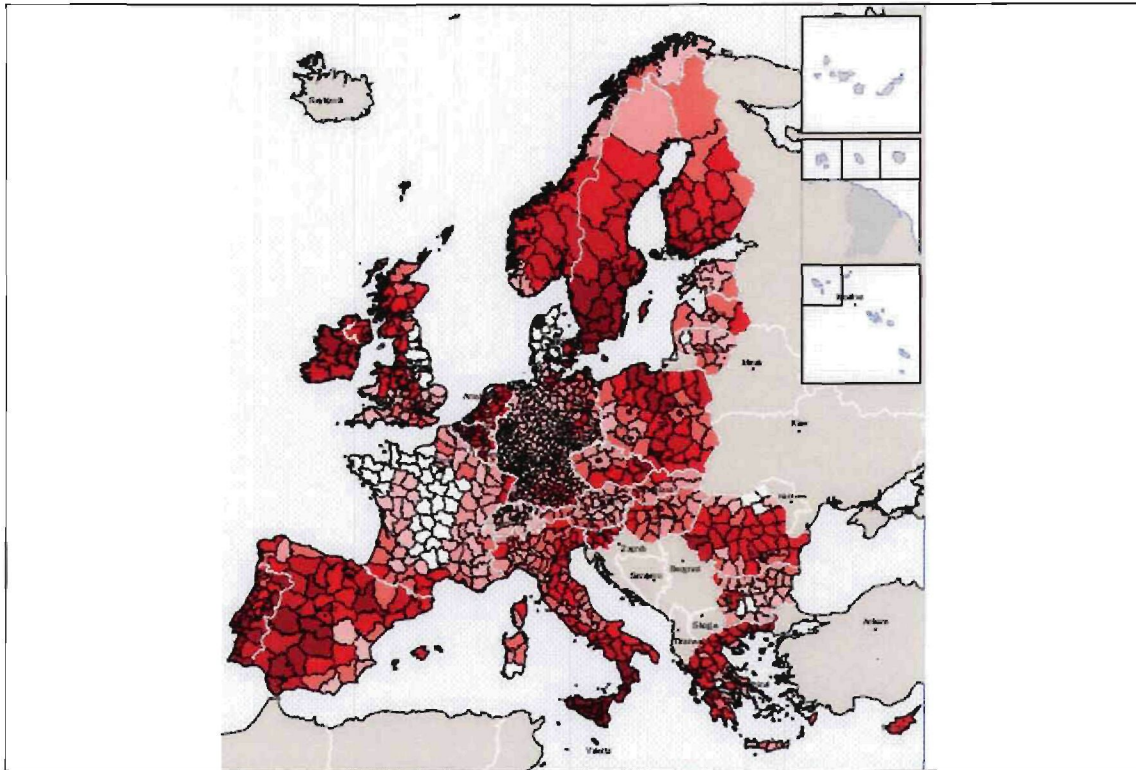
Figure 4: Example geographic representation of output from the spatial AGE model for Tokyo



Source: Sato and Hino, 2005:621

Yet another example not included in the research by Partridge and Rickman (1998) is that of Bröcker and Schneekloth (2005) with the CGEurope model.

Figure 5: Example geographic representation of output from the CGEurope model



Source: Bröcker and Schneekloth (2005)

The CGEurope model is a RAGE type model and is a comparative static non-monetary spatial computable equilibrium model with 1373 regions. Figure 5 is provided as an example of a geographic representation of the impact of a specific scenario. The purpose is simply to illustrate the feasibility of the application of such models, and the actual representation and results are of no consequence to this study and therefore does not include the variable and ranges plotted (which is percentage change in GDP of each of the regions due to the particular scenario modelled).

4.5. General relevance of RAGE model applications

Regional AGE models lend themselves to address a variety of policy and related issues. Due to the geographic disaggregation, RAGE models are well suited to analyse the geographic features of economic activity of consequence to the rate and dispersion or spread of economic development – so crucial to understand in the developing economy context such as South Africa's.

Gebetsroither *et al.* (2006) motivates the usefulness of AGE models for regional or spatial analysis based on the fact that these type of models:

- a) inherently accommodate simultaneous decision making by sector on both producer-producer and producer-customer output levels, structure and level of production input demands and distances;
- b) have inherent both fixed and variable transport costs varying between locations;
- c) inherently relate production cost dependency on output levels (variable returns to scale);
- d) impose budget constraints in the consumer, government and private sectors; and
- e) have an initial spatial or regional distribution of households (and thus regional or spatial distribution of both labour supply and household consumption potential), which is necessary to locate (in combination with explicit transport cost modelling) an initial efficient regional or spatial distribution of production. If transport costs are excluded from

these models of variable returns to scale certain agglomerations will occur, but their regional location would then be ambiguous.

The possibility to include transportation as well as production costs in the determination of regional economic activity location therefore is a fundamental advantage of RAGE models. This allows for more “spatially focused” understanding of regional effects, especially if such a model contains sufficient regional detail that for example metropolitan and municipal level activity is modelled as in the example of the CGEurope model mentioned previously.

RAGE models are also useful and have been applied to help understand implications of various areas in the economic policy analysis environment such as for example (Partridge and Rickman, 1998:220-226):

- Regional effects of national tariff and trade liberalization policies
- Regional effects of agricultural, environmental and natural resources policies
- Regional effects of regional fiscal and tax policies
- Regional effects of transportation policies
- Regional effects of national policies that are implemented differently across regions e.g. public investment allocations and transport infrastructure developments.

Regional AGE models also lend themselves to economic impact analysis type applications such as for example:

- the quantification of the possible impacts on a regional and national economy of a new infrastructural project such as a new rail line in respect of both the construction and operational phases of such a project;
- the quantification of the potential employment creation impacts of for example development projects initiated by the regional (provincial in South Africa's case) government, other developmental agencies (such as the DBSA in South Africa's case) or even the private sector, and
- the forecasting of probable future growth implications for regional (provincial) economies, identifying the economic sectors from which such potential growth impetus could come.

4.6. South African specific relevance of RAGE model applications

RAGE models are well suited to geographically disaggregate the impact of national level economy-wide policies such as for example regional tax incidence or a topical issue such as the mining royalty bill considered by the Department of Mineral Energy (due to the localised nature of mining activities with strong inter-regional and international links). More specific examples where RAGE models could be applied to understand in the potential national and inter-regional implications of infrastructural policies and interventions in the South African context include developments such as for example the Gautrain rapid rail link development, the Soccer 2010 developments, the Durban-Johannesburg pipeline development and various other transport and logistics related government infrastructure investment initiatives.

More recent high-profile developments in the Electricity sector in South Africa would also be well served by having such RAGE models available to analyse for example the regional economic impacts of electricity shortages or load shedding. One of the reasons for this is that black-outs or load shedding are localised and regional in nature, however, the industries and economic activity influenced by such events have regional, national and international links. Policymakers in governmental departments such as for example the South African Department of Minerals and Energy (DME), Department of Public Enterprise (DPE), National Treasury and Department of Transport, to name but a few, could benefit in having the ability to analyse the implications of such events with a RAGE model.

Another potential institution that would benefit from having a RAGE model available is the Development Bank of Southern Africa (DBSA). Mouton (2004) indicated that since the transformation of local government in 2000, South Africa has seen an increased interest in information pertaining to infrastructure investments with specific focus on infrastructure backlogs. The DBSA and its clients are keenly interested in eradicating these backlogs. By applying a RAGE approach the implications of such regional investments on economic and more specifically household welfare (and subsequent feedback to the rest of the economy) could be studied and applied as a potential aid to prioritise scarce resources and to sequence efforts that will have the largest spin-offs into the rest of the South African economy first.

4.7. Summary

In this chapter high-level regional development challenges from a policy point of view were highlighted, with the aim of illustrating the appropriateness and need for a RAGE model to assist in analysis and decision making regarding such policy implications on a sub-national level in South Africa. The top-down, bottom-up and hybrid approaches to RAGE modelling were described as well as an indication of examples of international applications of such models for policy analysis.

This chapter further illustrated that internationally there has been various developments not only in national level regional applications, but also in the isolated micro-spatial area of AGE models e.g. the transport and logistics sectors. However, the focus of this study is on the need and potential for a model that will allow studying of the whole national economy in regional terms (for example all provinces, or all municipalities), as opposed to focused “localised” spatial type applications such as metropolitan specific examples mentioned in this section. The relevance of RAGE models were illustrated as well as specific examples of relevant South African potential areas of application of RAGE models were identified in brief.

In the next chapter the IDCGEM is described briefly and then applied to a relevant scenario on the electricity sector with the focus on illustrating the regional impacts and potential shortcomings of a simplistic top-down model.

CHAPTER 5: ILLUSTRATION OF A TOP-DOWN RAGE MODEL FOR SOUTH AFRICA

5.1. Introduction

So far, this study has considered the theoretical basis of AGE models, discussed the need and motivation for such models in South Africa, and outlined the development of these models in South Africa. The lack of an AGE model to focus on regional (sub-national) level policy impacts in South Africa was noted, and some of the approaches elsewhere in the world discussed as a possible way forward. In this chapter the hypothesis that RAGE models can make a positive contribution towards policy analysis on a regional level in South Africa is further confirmed by using an AGE model in a top-down fashion to illustrate the potential usefulness.

Therefore, the aim of this chapter is two-fold. First, to provide an illustrative application of regional impacts based on an existing but very dated model for South Africa with top-down regional elements. Second, to indicate at a high level with stylised examples how one could go about to develop a hybrid regional AGE that will be achievable in practice subject to South African data constraints.

The chapter is structured as follows. Section 5.2 provides a high level description of the IDCGEM as it stood in 1994/1995, while section 5.3 provides more detail on the top-down regional aspects of the model. In section 5.4 the implications of a simulation based on current events in the South African electricity sector is model is discussed, with a focus on the

regional implications in section 5.4.4. In section 5.5 some thoughts are put forward on how to move toward creating a “pure” bottom-up RAGE model for South Africa, while section 5.6 proposes a more realistic hybrid approach subject to data constraints. Section 5.7 summarises.

5.2. Description of the IDC GEM

IDC-GEM is an AGE model of the South African economy, based closely on the Australian ORANI-F model (Horridge *et al.* 1993). A very brief outline of the model is given below from Cameron *et al.* (1994). The model contains 103 single-product industries, 2 margins commodities, 65 categories of labour (13 occupations by (4 races plus migrant workers)) and 24 households (4 races by six income levels). A top-down provincial (9) by sectors (103) regional Gross Domestic Product (GDP) was also estimated.

The SAM database used at that time was compiled by Claude van der Merwe of Economic Analysis Systems Pty Ltd, based on the work of 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 sector, as well as the provincial sectoral share estimates of GDP. The following detail broad assumptions about the various economic actors contained in the model:

Assumptions about producers

- single-product industries
- price takers
- minimise costs

- nested Leontief/Constant Elasticity of Substitution (CES⁷) production functions allowing substitution between
 - sources of produced inputs
 - labour, capital and land
 - occupations
 - race groups

Assumptions about investors

- price takers
- minimise costs
- production functions allow substitution between sources
- aggregate investment normally exogenous but composition depends on relative rates of return

Assumptions about households

- disaggregated by race group and income
- consumption proportional to disposable income
- substitution between commodities and between sources

International exports

- downward-sloping demand curves for individual traditional exports and for a composite non-traditional export

Government

- consumption exogenous

⁷ Depending on the application one could also use a Constant Elasticity of Transformation function (CET) if required. Refer to Horridge (2001) for a CET application example in ORANI-G.

- articulation of revenue sources

Trade and transport margins

- fixed proportions to commodity flows

Prices

- zero pure profits conditions and constant returns to scale imply basic values are functions just of input prices
- purchasers' prices are sums of basic values, sales taxes and margins

Market clearing

- for commodities
- labour market need not clear

Identities define macro variables

- e.g., GDP, trade balance, price indexes
- macro equation system structured around a SAM

Regional disaggregation

- top-down disaggregation to nine provinces

The 1994 version of the IDC-GEM contains more disaggregated specifications of the labour market and of the household sector than did the ORANI-F model at that point in time. In addition, the labour force is disaggregated by occupation and race group segmentation. The model's nested production functions specify an industry's aggregate labour input as a CES combination of occupation-specific labour inputs, each of which is a CES combination of labour drawn from the different race groups. Employers will therefore substitute between occupations and race groups depending on changes in relative wages. Households in the IDC-GEM are also disaggregated by race

group and income levels, defined as divisions of the race group's income distribution.

Another distinguishing feature of the IDC-GEM is the way the gold industry is treated in the model. The Gold Mining industry (industry 3 in the 103 disaggregation as well as in the 46 sector aggregation) includes the extraction of gold ore and its refinement. For heuristic purposes, the output of the industry can be thought of as "ounces of refined gold" not "tons of gold ore"⁸. With the exception of a small amount sold to the domestic Jewellery industry, the rest of gold output is exported.

The IDC-GEM specification recognises that in the short run employment in the Gold industry and the amount of ore extracted is unresponsive to variations in the Rand gold price net of ore-extraction and refining costs⁹. It also recognises that industry policy is to vary the quality of the ore extracted with the net gold price. That is, if the net price rises (falls), lower gold yielding (higher gold yielding) ore is mined, resulting in an approximately constant profitability of the extraction/refining process. There is therefore a negative short-run relationship between the net gold price and the output of refined gold in the model. This is achieved through:

⁸ More specifically, the quantity units in the model should be interpreted as base-period monetary worth rather than "ounces" or "tons".

⁹ Note that changes in the net gold price could be generated by changes in the foreign-currency gold price, by changes in the Rand/foreign-currency exchange rate or by changes in input costs.

- an equation linking the percentage changes in the rental rate on the industry's capital and the average wage which it pays for labour; and
- endogenising the industry's all-input-using rate of technical change.

The export-demand elasticity for Gold is also set at -100 in order to ensure that variations in export volumes will have no effect on the foreign-currency gold price.

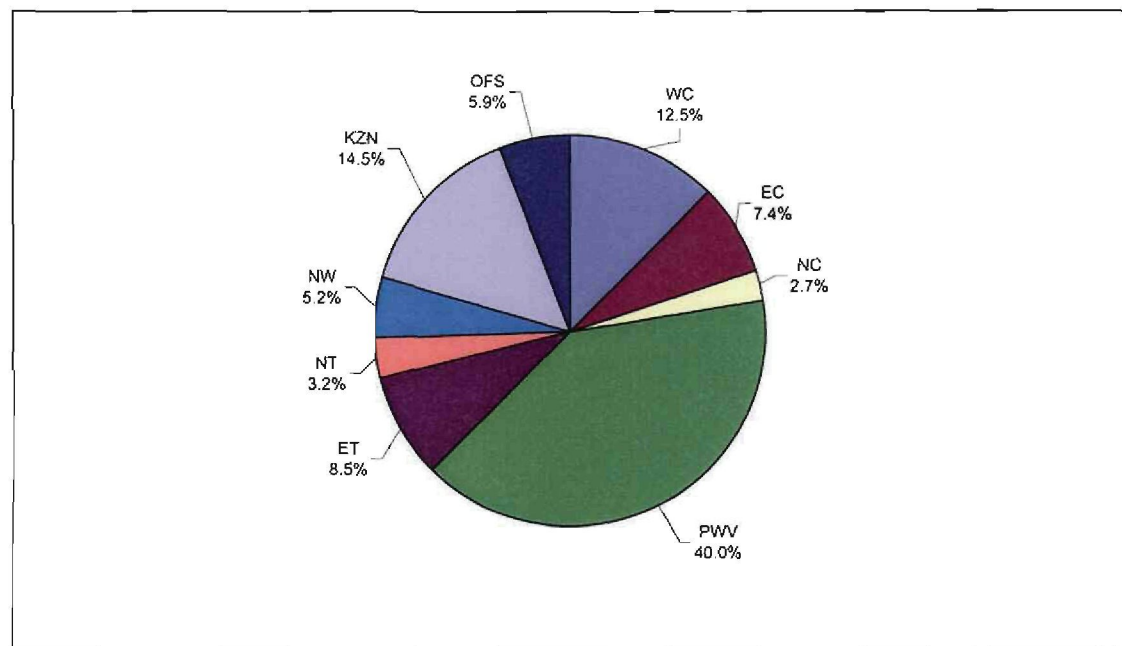
A more detailed technical description of the basic model can be found in Horridge *et al.* (1993) as the basis of the model was the ORANI-F model.

5.3. IDCGEM regional disaggregation

The database used in the IDCGEM was based on the geography of the pre-1994 provinces of Western Cape, Eastern Cape, Northern Cape, Pretoria-Witwatersrand-Vereeniging, Eastern Transvaal, Northern Transvaal, North West Transvaal, Kwa-Zulu Natal, and the Orange Free State. The regions contained in the IDCGEM therefore do not correspond directly with the provinces of the modern (2008) South Africa.

The GEMPACK source code describing the regional top-down extension is provided in annexure A of this study. For a more detailed explanation of the syntax of the GEMPACK language refer to the GEMPACK manuals, alternatively Horridge *et al.* (1993) provides an easy to follow explanation of the general syntax and linearization of equations required.

Figure 6: IDCGEM provincial shares of GDP



Source: IDCGEM database 1994, Statistics South Africa (2007) Table 16c.

Figure 6 provides the regional contributions by province and sector as applied in the database (1992) of the IDCGEM to use as shares to re-allocate national level impacts to provinces. In the IDCGEM database the PWV province contributed 40% to the national economy, followed by Kwa-Zulu Natal at 14.5% and Western Cape at 12.5%.

Although the geographies and economic contribution estimates are not directly comparable, Table 3 presents a superficial comparison with the latest Statistics South Africa (3rd quarter 2007) estimates of provincial contributions for information only.

Table 3: Comparison between regional contributions estimates - IDCGEM & StatsSA

IDCGEM (1992)	1992 Share of National GDP	StatsSA (2007)	1995 Share of National GDP	Difference
Western Cape (WC)	12.5%	Western Cape	14.1%	1.6%
Eastern Cape (EC)	7.4%	Eastern Cape	8.4%	0.9%
Northern Cape (NC)	2.7%	Northern Cape	2.3%	-0.3%
Pretoria-Witwatersrand- Vereeniging (PWW)	40.0%	Gauteng	33.4%	-6.6%
Eastern Transvaal (ET)	8.5%	Mpumalanga	6.6%	-1.8%
Northern Transvaal (NT)	3.2%	Limpopo	6.3%	3.1%
North West Transvaal (NW)	5.2%	North West	6.8%	1.6%
Kwa-Zulu Natal (KZN)	14.5%	KwaZulu-Natal	16.4%	1.8%
Orange Free State (OFS)	5.9%	Free State	5.6%	-0.3%
Total	100.0%		100.0%	

Source: IDCGEM database 1994 (estimates for 1992), Statistics South Africa (2007) Table 16c

Evident from Table 3 is that the major difference (ignoring the differences in time and geographic basis of estimates) lays with the Gauteng (6.6% lower in the IDCGEM estimates) and Limpopo (3.1% more in the IDCGEM estimates) provinces. The author did not apply any of this new information in the model as applied in this section. The information serves an illustrative purpose only.

The sectoral dimensions used in the IDCGEM estimates and that which is available from StatsSA today differ significantly and it serves no purpose to attempt a direct comparison on a sectoral level in this research. Table 4 shows the shares aggregated to 46 sector level for ease of representing, but the shares were originally at 103 sector level.

Table 4: IDCGEM provincial sectoral shares

46 Sector Aggregation	Province									
	1 WC	2 EC	3 NC	4 PWV	5 ET	6 NT	7 NW	8 KZN	9 OFS	RSA
1 AGRICULTURE	0.0540	0.0390	0.1404	0.0068	0.0717	0.0740	0.0992	0.0343	0.0764	0.0393
2 COAL MINING	0.0005	0.0002	0.0076	0.0014	0.1423	0.0212	0.0017	0.0187	0.0106	0.0170
3 GOLD MINING	0.0007	0.0007	0.0019	0.0469	0.0355	0.0092	0.2236	0.0021	0.2702	0.0503
4 OTHER MINING	0.0099	0.0021	0.2105	0.0129	0.0197	0.1263	0.1700	0.0070	0.0182	0.0289
5 FOOD	0.0230	0.0216	0.0212	0.0157	0.0188	0.0116	0.0174	0.0247	0.0311	0.0196
6 BEVERAGES	0.0308	0.0129	0.0181	0.0050	0.0047	0.0036	0.0155	0.0120	0.0311	0.0122
7 TOBACCO	0.0010	0.0015	0.0002	0.0015	0.0002	0.0002	0.0001	0.0015	0.0003	0.0011
8 TEXTILES	0.0134	0.0177	0.0025	0.0030	0.0043	0.0021	0.0009	0.0215	0.0038	0.0081
9 CLOTHING	0.0233	0.0076	0.0030	0.0034	0.0002	0.0002	0.0002	0.0138	0.0010	0.0070
10 LEATHER	0.0009	0.0003	0.0001	0.0004	0.0000	0.0000	0.0000	0.0003	0.0000	0.0003
11 FOOTWEAR	0.0046	0.0054	0.0005	0.0003	0.0027	0.0011	0.0002	0.0082	0.0008	0.0026
12 WOOD	0.0032	0.0045	0.0001	0.0020	0.0119	0.0047	0.0002	0.0048	0.0021	0.0035
13 FURNITURE	0.0035	0.0026	0.0004	0.0037	0.0003	0.0007	0.0007	0.0028	0.0009	0.0027
14 PAPER	0.0125	0.0171	0.0034	0.0122	0.0170	0.0073	0.0014	0.0444	0.0048	0.0163
15 PRINTING	0.0175	0.0036	0.0016	0.0109	0.0011	0.0009	0.0025	0.0078	0.0029	0.0084
16 BASIC CHEMICAL	0.0036	0.0006	0.0000	0.0092	0.0032	0.0000	0.0000	0.0136	0.0000	0.0064
17 OTHER CHEMICAL	0.0141	0.0106	0.0000	0.0263	0.0070	0.0000	0.0002	0.0236	0.0007	0.0222
18 PETROLEUM	0.0011	0.0692	0.0000	0.0071	0.0000	0.0000	0.0000	0.0119	0.0000	0.0098
19 RUBBER	0.0004	0.0241	0.0000	0.0025	0.0000	0.0000	0.0000	0.0041	0.0000	0.0034
20 PLASTIC	0.0065	0.0036	0.0000	0.0093	0.0000	0.0000	0.0000	0.0044	0.0017	0.0056
21 POTTERY	0.0004	0.0003	0.0004	0.0006	0.0001	0.0001	0.0015	0.0000	0.0000	0.0004
22 GLASS	0.0014	0.0012	0.0016	0.0023	0.0005	0.0005	0.0059	0.0008	0.0012	0.0018
23 OTHER NON-METALLIC MINERALS	0.0056	0.0046	0.0079	0.0085	0.0023	0.0022	0.0255	0.0041	0.0049	0.0071
24 BASIC METALS	0.0017	0.0011	0.0015	0.0355	0.0536	0.0013	0.0031	0.0100	0.0007	0.0208
25 BASIC NON-FERROUS METALS	0.0005	0.0010	0.0005	0.0135	0.0005	0.0004	0.0010	0.0102	0.0009	0.0072
26 FABRICATED METALS	0.0076	0.0047	0.0017	0.0264	0.0022	0.0019	0.0040	0.0079	0.0038	0.0137
27 NON-ELECTRICAL MACHINERY	0.0086	0.0061	0.0006	0.0274	0.0020	0.0010	0.0110	0.0058	0.0058	0.0145
28 ELECTRIC MACHINERY	0.0044	0.0213	0.0002	0.0158	0.0004	0.0038	0.0007	0.0027	0.0005	0.0091
29 MOTOR VEHICLE PARTS & ACCESSORIES	0.0106	0.2003	0.0019	0.0367	0.0018	0.0027	0.0030	0.0244	0.0024	0.0350
30 TRANSPORT EQUIPMENT	0.0014	0.0236	0.0003	0.0057	0.0002	0.0004	0.0004	0.0032	0.0004	0.0047
31 OTHER MANUFACTURING	0.0075	0.0085	0.0040	0.0033	0.0024	0.0139	0.0231	0.0009	0.0116	0.0057
32 ELECTRICITY	0.0326	0.0165	0.0393	0.0332	0.1515	0.0401	0.0169	0.0264	0.0388	0.0408
33 WATER	0.0019	0.0011	0.0058	0.0023	0.0012	0.0023	0.0021	0.0023	0.0018	0.0021
34 CONSTRUCTION	0.0292	0.0155	0.0168	0.0185	0.0189	0.0230	0.0131	0.0190	0.0162	0.0194
35 CIVIL ENGINEERING	0.0123	0.0080	0.0104	0.0105	0.0118	0.0075	0.0081	0.0114	0.0083	0.0104
36 TRADE	0.1457	0.1055	0.1082	0.1421	0.0902	0.1248	0.0997	0.1380	0.1151	0.1296
37 ACCOMMODATION	0.0107	0.0058	0.0060	0.0072	0.0051	0.0076	0.0055	0.0087	0.0039	0.0074
38 TRANSPORT	0.0549	0.0470	0.0718	0.0535	0.0448	0.0405	0.0254	0.0735	0.0493	0.0537
39 COMMUNITY	0.0388	0.0282	0.0411	0.0322	0.0138	0.0180	0.0216	0.0257	0.0237	0.0290
40 FINANCIAL SERVICES	0.0521	0.0249	0.0235	0.0527	0.0145	0.0164	0.0208	0.0287	0.0241	0.0385
41 BUSINESS SERVICES	0.1043	0.0474	0.0338	0.1209	0.0255	0.0303	0.0320	0.0752	0.0374	0.0638
42 MEDICAL SERVICES	0.0083	0.0051	0.0030	0.0072	0.0085	0.0108	0.0042	0.0107	0.0044	0.0075
43 COMMUNITY SERVICES	0.0218	0.0133	0.0080	0.0189	0.0222	0.0284	0.0110	0.0279	0.0116	0.0196
44 NOT CLASSIFIED	0.0050	0.0060	0.0056	0.0072	0.0043	0.0047	0.0058	0.0071	0.0077	0.0064
45 HOUSEHOLD SERVICES	0.0138	0.0089	0.0159	0.0099	0.0062	0.0178	0.0094	0.0099	0.0131	0.0107
46 GOVERNMENT INDUSTRIES	0.1945	0.1491	0.1787	0.1278	0.1130	0.3363	0.1113	0.2031	0.1556	0.1563
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Total Share of National GDP for Region	12.5%	7.4%	2.7%	40.0%	8.5%	3.2%	5.2%	14.5%	5.9%	100.0%

Source: IDCGEM database 1994 (estimates for 1992).

The version of the IDCGEM applied for the illustrative purposes in this section has a top-down regional disaggregation procedure that is applied to re-distribute national economy wide impacts based on the historical economic base of each region for key variables such as economic output, investment, consumption export and "other" which equates to government. The shares in Table 4 above are applied for this purpose.

Based on the top-down methodology applied in the IDCGEM, differences in the provincial impacts depend primarily on differences in the economic base (or industrial structures) of the various provinces. A specific province's gross product will tend to increase faster than national GDP if the province has large shares (relative to the corresponding national shares) of fast growing industries and small shares of slow growing sectors.

Conversely, small shares of fast growing sectors and large shares of slow growing sectors will reduce a province's share in national GDP. The approach do allow for regional multipliers operating through regional balance constraints imposed on industries that are “localised” – such as the services industries (refer to Dixon *et al.* 1982, chapter 6 for a more detailed technical exposé). There is however no explicit feedback linkage back to the national level equations and this top-down approach therefore purely “re-distributes” the national impacts to regional levels.

Table 5: Regional local versus national industries

Nr	Sector	National	Local
1	AGRICULTURE	X	
2	COAL MINING	X	
3	GOLD MINING	X	
4	OTHER MINING	X	
5	FOOD	X	
6	BEVERAGES	X	
7	TOBACCO	X	
8	TEXTILES	X	
9	CLOTHING	X	
10	LEATHER	X	
11	FOOTWEAR	X	
12	WOOD	X	
13	FURNITURE	X	
14	PAPER	X	
15	PRINTING	X	
16	BASIC CHEMICAL	X	
17	OTHER CHEMICAL	X	
18	PETROLEUM	X	
19	RUBBER	X	
20	PLASTIC	X	
21	POTTERY	X	
22	GLASS	X	
23	OTHER NON-METALLIC MINERALS	X	
24	BASIC METALS	X	
25	BASIC NON-FERROUS METALS	X	
26	FABRICATED METALS	X	
27	NON_ELECTRICAL MACHINERY	X	
28	ELECTRIC MACHINERY	X	
29	MOTOR VEHICLE PARTS & ACCESSORIES	X	
30	TRANSPORT EQUIPMENT	X	
31	OTHER MANUFACTURING	X	
32	ELECTRICITY	X	
33	WATER		X
34	CONSTRUCTION		X
35	CIVIL ENGINEERING		X
36	TRADE		X
37	ACCOMMODATION		X
38	TRANSPORT		X
39	COMMUNITY		X
40	FINANCIAL SERVICES	X	
41	BUSINESS SERVICES		X
42	MEDICAL SERVICES		X
43	COMMUNITY SERVICES		X
44	NOT CLASSIFIED	X	
45	HOUSEHOLD SERVICES		X
46	GOVERNMENT INDUSTRIES	X	X

Source: IDCGEM database 1994.

The allocations between local and national sectors in the IDCGEM are listed in Table 5. The reason why the Government sector is both local and national is due to the fact that some activities such as Government Administration, Police and Defence activities are classified in the model as National, while Education, Health, Housing, Social and Other government services are classified as local.

5.4. Illustrative scenario - simulating electricity load shedding

In order to illustrate the usefulness as well as shortcomings of the current top-down approach existing in the IDCGEM, the author has selected a scenario

that is currently quite topical in South Africa, and of extreme relevance to economic policy makers and infrastructure planners.

5.4.1. Background to the scenario

As recently as January 2008 South Africa suffered a series of electricity “blackouts” as a result of load shedding in various regions. The electricity utility provider in South Africa (ESKOM) has requested mining and industrial customers to voluntarily save (or shed) approximately 10 per cent of their consumption of electricity. Questions have been asked as to the potential implications of such disruptions on the output of the sectors involved. Furthermore, in March of 2008 Eskom has submitted a request to the National Energy Regulator of South Africa (NERSA) to immediately increase electricity tariffs in order to fund the required interventions to ensure that South Africa’s future electricity demands will be met. The magnitude of this increase could be as much as 53 per cent in 2008/09 financial year and 43 per cent in 2009/10 financial year (Eskom submission 2008).

However, this question is not a straight forward one to answer and one can only attempt to do so in a very crude way with our current model without conducting some extensive expansion to the model and database itself. The whole issue of the current electricity shortage in South Africa is a major research topic in itself, and the author does not want to attempt to go into too much detail as part of this study. However, it does serve to illustrate a relevant regional application of the IDCGEM.

This illustrative application therefore attempts to quantify answers to the question of what the potential impacts could be of a sustained 10 per cent reduction in supply (achieved through reduced consumption) of electricity combined with a shock of approximately 53 per cent in the output price of the electricity industry.

5.4.2. Model closure applied and other assumptions

The general closure (refer to section 2.7 on closure rules for AGE models) assumptions for the illustrative short-run comparative-static simulations conducted are:

- the numeraire is the world average price of all goods;
- capital stock is assumed fixed in each industry;
- no relative change in government consumption expenditure is assumed;
- slack labour markets for all labour categories are assumed;
- average real wages are kept constant – so wage rates adjust with inflation;
- household consumption moves with disposable income for all households; and
- the industrial structure of private investment responds to changes in relative rates of return.

For the specific scenario to model the combination of a price hike of approximately 53 per cent in year one as well as a 10 per cent decrease in output of the Electricity industry we have to make certain industry-specific assumptions over and above the general close described above. We therefore have to assume that:

- electricity under these circumstance will not be exported – we know this in practice not to be the case, but the current treatment of the electricity industry in the model assumes no imports or exports for the sector; and
- employment in the electricity sector will not be shed in reaction to the decline in output as most other sectors under normal market circumstances would. Since this is a parastatal organisation subject to labour union pressure labour shedding is not a short term option;

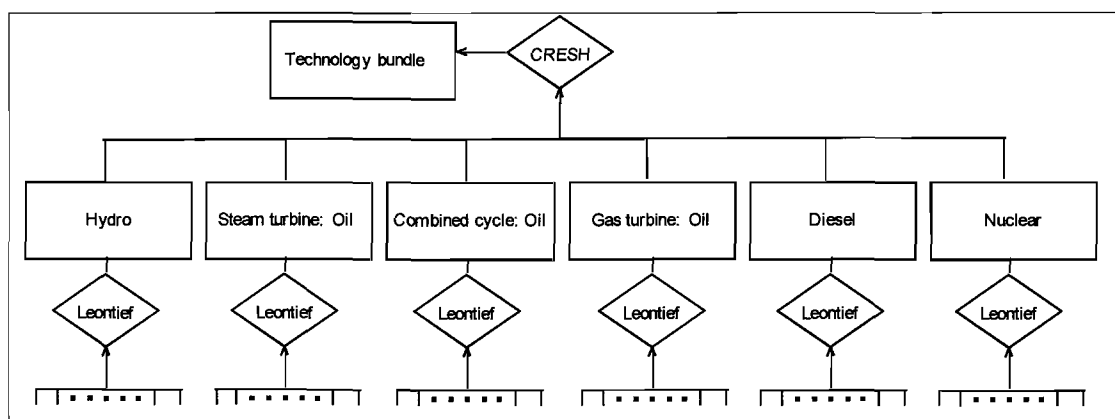
As with any attempt to simplify and quantify real world processes and actions with a mathematical representation, one has to make a host of assumptions. This is captured by the well-known broad assumption *ceteribus paribus*¹⁰ – all other things assumed constant. Therefore this implies some of the following (non-exhaustive) more detailed assumptions below:

- Assumption of no mitigation: No change in the production technology of mining for these sectors is effected to mitigate the impacts of the lower consumption of electricity.
- Assumption of no alternative energy sources applied.
- Assumption of no international market demand changes as a result of changes in output (especially of commodities such as gold, platinum etc.).

¹⁰ Latin phrase that translates approximately to "holding other things constant" and is usually rendered in English as "all other things being equal". In economics and finance, the term is used as a short-hand for indicating the effect of one economic variable on another, holding constant all other variables that may affect the second variable.

The structure of the model implicitly does not allow for switching of energy technologies. In order to really study this type of switching one would need to expand the model to a similar extent than done by for example Li et al. (2000) for the TAIGEM-D (**TAI**wan **G**eneral **E**quilibrium **M**odel – **D**ynamic). Figure 7 illustrates the type of alternative technologies built into the model to investigate specific energy related issues.

Figure 7: Example of energy specific model technical adjustments



Source: Adapted from Li *et al.* (2000) p. 5.

As is evident from the illustration various electricity generation options with specific switching possibilities have been built into the TAIGEM-D through a constant ratio of elasticity of substitution, homothetic¹¹ (CRESH). The main purpose of these extensions was for climate change studies and specifically for emission abatement scenarios. For another example of energy substitution in AGE models refer to Jaforullah (1992). The aim of this study is however not

¹¹ For producers optimizing subject to homothetic utility or production functions the ratios of goods demanded depend purely on relative prices and not on income or scale (Deardorff's *Glossary of International Economics*, 2001).

to investigate the electricity crisis in South Africa in detail. The author selected this topic for simulation with the IDCGEM as it is also relevant for policy makers in the current and future economic planning environment.

5.4.3. Analysis of the national level impacts of the scenario

The national level impacts of the simulation are presented in Table 6. This illustrative analysis mainly focuses on two variables, that of overall economic output measured by GDP and employment. The results are presented in annualised percentage change format (for a review of the interpretation of these types of comparative static results refer to section 2.8 earlier in this study).

Table 6: National level impacts

Annualized % Change	Electricity 10% reduction & 53% Price Increase
Gross Domestic Product (GDP)	-2.58
Employment	-3.68
Average Real Wage Rate	0.00
Domestic Consumption	-6.15
Consumer Price Index	-4.54
Government Consumption	0.00
Exports (Volume Index FOB)	0.11
Export Price Index	0.02
Imports (Volume Index CIF)	-5.04
Import Price Index	0.00

Source: IDCGEM simulations conducted by the author.

The cause-effect logic of the simulation would be that as a result of both the decline in electricity output and electricity price increase, total production

declines and is propagated through the inter-industry input-output linkages. Since producers are assumed to maximise profits, employment loss is the result of reduced outputs. The employment loss in turn leads to a smaller wage bill being paid to labour, with the resulting feedback of declining household income.

The decline in household income in turn leads to lower demand for final products due to household budget pressures, placing downward pressure on domestic prices. In order to achieve equilibrium in both the demand and supply side of the economy, nominal prices have to decline even further, and the spiral effect leads to even less production, less employment etc. until all endogenous variables reaches equilibrium values. The final result is that GDP ends up at 2.6 percent lower per annum than compared to the base case, while employment declines even more by 3.7 percent. Domestic consumption suffers to the extent that it is 6.2 percent lower and the resulting general domestic price decrease that needs to take place is approximately 4.5 percent.

The combined decline in household income and production output causes imported commodity volumes to decline by approximately 5 percent, while the imported price index stays constant as South Africa is assumed to be a price taker in the international market. Although the lower domestic prices should provide some competitive advantage on the export front, the lower domestic prices only feed through to the international market to a negligible extent (0.02 percent) as a result of the decline in output at the same time. The result is

only a very small (0.1 percent) gain in export volumes due to the relatively lower domestic price levels.

The above scenario and results must be interpreted in the context of the assumptions. In real economic life, firms will adjust to circumstances and may for instance switch to alternative electricity generation sources such as diesel generators, change their efficiency of production processes to still produce the same output with less electricity and various other innovations. All of these innovations and mitigating actions could also be modelled to obtain a better understanding of the potential overall implications for this scenario.

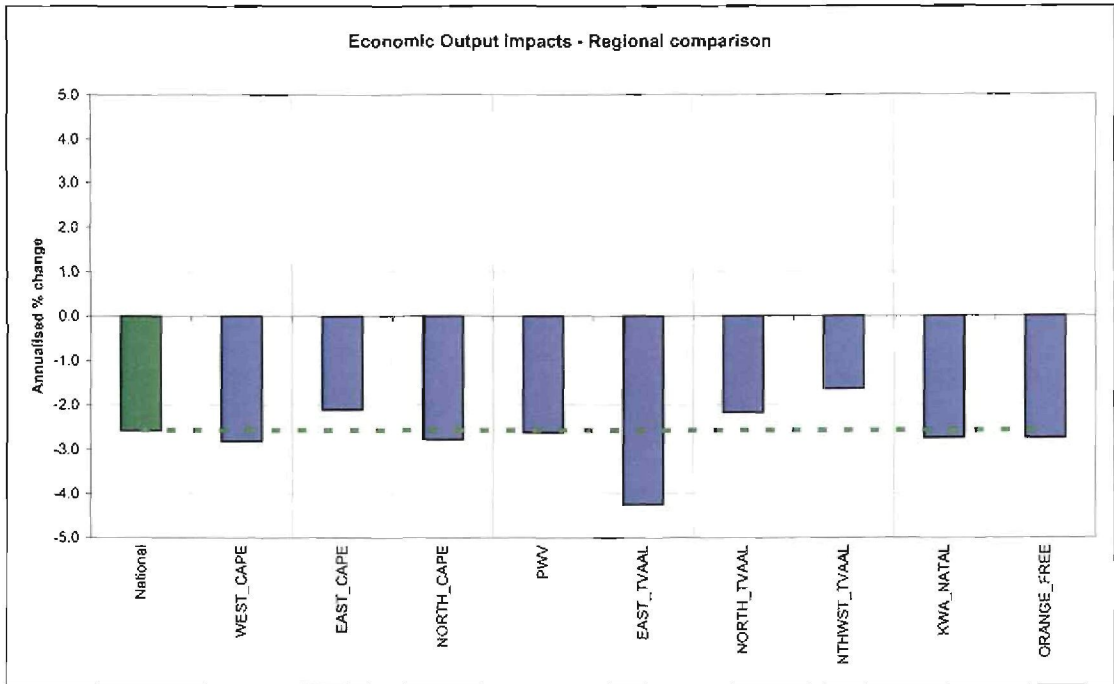
However, a full analysis of the results of this scenario is not presented in this study. The focus is rather placed on the regional aspects relevant to main problem statement of this study, namely that currently there exists no such RAGE model of sufficient regional detail and sophistication in order to conduct a sufficiently useful analysis of this nature, while there is a demonstrated and very real need to have such a policy tool – now probably more than ever before in the history of South African infrastructure planning and development.

5.4.4. Analysis of the regional level impacts of the scenario

The study's main interest lies with the regional (provincial) impacts of this scenario. On a national level it would seem that as modelled, subject to various assumptions, GDP could decline by as much as 2.6 per cent per annum as a result of the impact of a simultaneous increase in prices as well as a decline of electricity output volumes, while overall employment could contract by 3.7 per cent per year. Table 7 is provided with 46 sector

aggregation¹² results for both the national as well as provincial impacts on GDP and employment. However, the details are not discussed in this study.

Figure 8: Regional GDP impacts of scenario



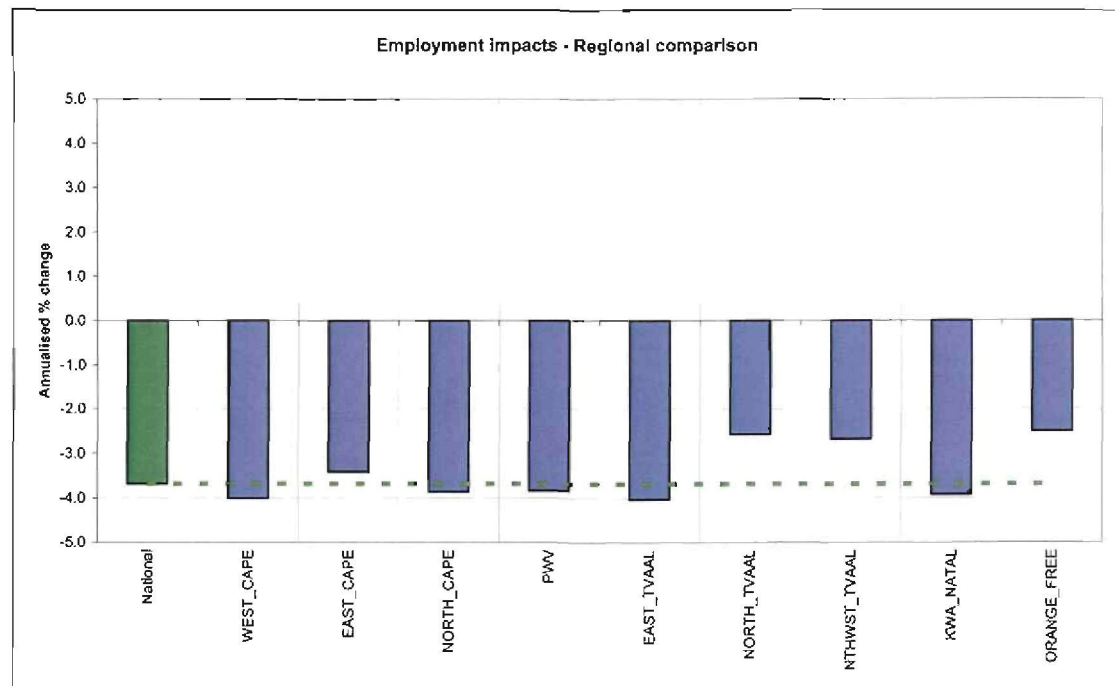
Source: IDCGEM simulations conducted by the author.

Evident from the Figure 8 is that it would seem that the Eastern Transvaal (or Mpumalanga in today's terms) would stand to loose the most economic output as a result of this scenario. While at face value this may seem reasonable, as most of the generation activity of South Africa is located in the province, on closer inspection this may not be as plausible, as will be motivated later on. An investigation of the employment impacts reveal that in relative terms the

¹² Although the model contains 103 sectors, for presentation purposes the results are aggregated to 46 sectors.

scenario has a much more evenly spread impact between provinces for this variable.

Figure 9: Regional Employment impacts of scenario



Source: IDCGEM simulations conducted by the author.

Although the direct effect of a decline of electricity volumes would impact on both the economic output and employment in the provinces where the activity of generation of electricity is located (mainly Mpumalanga / Eastern Transvaal), the reality is that the rest of the economy is very much dependant on electricity as a primary input required for production. The question then remains as to what extent the South African economy (including the manufacturing industries) is dependent on the electricity sector for its operation and survival. To this end, the electricity generation and provision should be viewed as an enabling industry without which few other industries would be able to survive.

Table 7: Regional 46 sector results

Sectoral Annualised % change		National		WEST CAPE		EAST CAPE		NORTH CAPE		PWV		EAST TAAAL		NORTH TAAAL		NTHWST TAAAL		KWA NATAL		ORANGE FREE	
Sector		Output Volume	Employment	Output Volume	Employment	Output Volume	Employment	Output Volume	Employment	Output Volume	Employment	Output Volume	Employment	Output Volume	Employment	Output Volume	Employment	Output Volume	Employment	Output Volume	Employment
1	AGRICULTURE	-2.0	-7.0	-2.0	-7.0	-2.0	-7.0	-2.0	-7.0	-2.0	-7.0	-2.0	-7.0	-2.0	-7.0	-2.0	-7.0	-2.0	-7.0	-2.0	-7.0
2	COAL MINING	-5.4	-4.0	-5.4	-4.0	-5.4	-4.0	-5.4	-4.0	-5.4	-4.0	-5.4	-4.0	-5.4	-4.0	-5.4	-4.0	-5.4	-4.0	-5.4	-4.0
3	GOLD MINING	0.2	0.4	0.2	0.4	0.2	0.4	0.2	0.4	0.2	0.4	0.2	0.4	0.2	0.4	0.2	0.4	0.2	0.4	0.2	0.4
4	OTHER MINING	-2.4	-3.8	-2.4	-3.8	-2.4	-3.8	-2.4	-3.8	-2.4	-3.8	-2.4	-3.8	-2.4	-3.8	-2.4	-3.8	-2.4	-3.8	-2.4	-3.8
5	FOOD	-4.3	-9.1	-3.9	-7.9	-3.8	-7.6	-3.5	-6.9	-4.4	-10.0	-5.5	-12.8	-4.0	-7.9	-4.4	-9.0	-4.1	-7.9	-4.7	-10.1
6	BEVERAGES	-2.1	-9.1	-1.9	-7.9	-2.0	-8.8	-2.0	-9.2	-2.0	-9.2	-2.3	-10.8	-2.1	-9.1	-2.0	-9.8	-2.1	-10.3	-2.0	-10.0
7	TOBACCO	-6.6	-12.7	-6.6	-12.7	-6.5	-12.7	-6.6	-12.7	-6.6	-12.7	-6.6	-12.7	-6.6	-12.7	-6.6	-12.7	-6.6	-12.7	-6.6	-12.7
8	TEXTILES	-1.3	-2.0	-1.5	-2.3	-1.0	-1.6	-1.4	-2.2	-1.3	-2.0	-0.9	-1.4	-1.4	-2.2	-1.3	-2.1	-1.4	-2.1	-1.4	-2.2
9	CLOTHING	-7.4	-9.7	-7.8	-10.0	-3.4	-5.5	-7.4	-9.7	-3.6	-9.5	-3.8	-4.3	-3.6	-4.3	-3.6	-4.3	-8.0	-10.2	-7.4	-9.7
10	LEATHER	-5.5	-8.0	-5.5	-8.0	-5.5	-8.0	-5.5	-8.0	-5.5	-8.0	-5.5	-8.0	-5.5	-8.0	-5.5	-8.0	-5.5	-8.0	-5.5	-8.0
11	FOOTWEAR	-9.0	-12.5	-9.0	-12.5	-9.0	-12.5	-9.0	-12.5	-9.0	-12.5	-9.0	-12.5	-9.0	-12.5	-9.0	-12.5	-9.0	-12.5	-9.0	-12.5
12	WOOD	-0.6	-1.1	-0.6	-1.1	-0.6	-1.1	-0.6	-1.1	-0.6	-1.1	-0.6	-1.1	-0.6	-1.1	-0.6	-1.1	-0.6	-1.1	-0.6	-1.1
13	FURNITURE	-1.8	-2.3	-1.8	-2.3	-1.8	-2.3	-1.8	-2.3	-1.8	-2.3	-1.8	-2.3	-1.8	-2.3	-1.8	-2.3	-1.8	-2.3	-1.8	-2.3
14	PAPER	-3.0	-7.4	-3.0	-6.3	-2.9	-9.9	-2.9	-11.5	-2.9	-6.2	-3.0	-6.5	-3.0	-6.5	-2.9	-11.5	-3.1	-8.4	-3.0	-8.5
15	PRINTING	-3.2	-4.9	-3.2	-4.9	-3.2	-4.9	-3.2	-4.9	-3.2	-4.9	-3.2	-4.9	-3.2	-4.9	-3.2	-4.9	-3.2	-4.9	-3.2	-4.9
16	BASIC CHEMICAL	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1
17	OTHER CHEMICAL	-2.0	-4.5	-2.2	-4.7	-2.0	-4.3	-2.0	-4.5	-2.0	-4.5	-2.2	-4.2	-2.0	-4.5	-2.0	-4.5	-2.1	-4.6	-2.0	-4.5
18	PETROLEUM	-3.9	-8.1	-3.9	-8.1	-3.9	-8.1	-3.4	-7.3	-3.4	-8.1	-3.4	-7.3	-3.4	-7.3	-3.4	-7.3	-3.9	-8.1	-3.4	-7.3
19	RUBBER	-1.6	-3.1	-1.6	-3.1	-1.6	-3.1	-1.7	-3.2	-1.7	-3.1	-1.7	-3.2	-1.7	-3.2	-1.7	-3.2	-1.6	-3.1	-1.7	-3.2
20	PLASTIC	-2.6	-5.3	-2.6	-5.3	-2.6	-5.3	-2.6	-5.3	-2.6	-5.3	-2.6	-5.3	-2.6	-5.3	-2.6	-5.3	-2.6	-5.3	-2.6	-5.3
21	POTTERY	-1.8	-2.4	-1.8	-2.4	-1.8	-2.4	-1.8	-2.4	-1.8	-2.4	-1.8	-2.4	-1.8	-2.4	-1.8	-2.4	-1.8	-2.4	-1.8	-2.4
22	GLASS	-0.7	-2.5	-0.7	-2.5	-0.7	-2.5	-0.7	-2.5	-0.7	-2.5	-0.7	-2.5	-0.7	-2.5	-0.7	-2.5	-0.7	-2.5	-0.7	-2.5
23	OTHER NON-METALLIC MINERALS	-0.7	-1.5	-0.8	-1.9	-0.8	-2.0	-0.7	-1.4	-0.7	-1.4	-0.8	-2.2	-0.7	-1.5	-0.7	-1.2	-0.8	-1.8	-0.9	-2.2
24	BASIC METALS	-5.4	-8.6	-5.4	-8.6	-5.4	-8.6	-5.4	-8.6	-5.4	-8.6	-5.4	-8.6	-5.4	-8.6	-5.4	-8.6	-5.4	-8.6	-5.4	-8.6
25	BASIC NON-FERROUS METALS	-5.4	-10.2	-5.4	-10.2	-5.4	-10.2	-5.4	-10.2	-5.4	-10.2	-5.4	-10.2	-5.4	-10.2	-5.4	-10.2	-5.4	-10.2	-5.4	-10.2
26	FABRICATED METALS	-1.5	-2.1	-1.5	-2.2	-1.6	-2.3	-0.5	-0.7	-1.1	-2.1	-1.7	-2.4	-1.9	-2.8	-1.1	-1.6	-1.6	-2.3	-1.2	-1.8
27	NON-ELECTRICAL MACHINERY	-0.9	-1.3	-0.4	-0.5	-0.6	-0.8	0.7	0.8	-1.4	-1.3	-1.7	-2.3	-0.1	-0.1	-1.4	-1.9	-0.8	-1.1	-1.2	-1.5
28	ELECTRIC MACHINERY	-0.3	-0.6	0.0	0.0	-0.8	-1.9	-0.5	-1.2	-0.3	-0.4	-0.5	-1.2	0.4	0.8	-0.3	-0.4	-0.6	-1.2	-0.5	-1.2
29	MOTOR VEHICLE PARTS & ACCESSORIES	-0.7	-1.4	-0.7	-1.4	-0.5	-0.9	-1.3	-1.6	-1.3	-1.8	-1.3	-1.8	-1.3	-1.6	-1.3	-1.6	-0.8	-1.5	-1.3	-1.6
30	TRANSPORT EQUIPMENT	0.5	0.7	0.5	0.7	0.7	0.9	0.2	-0.2	0.2	0.6	0.2	-0.2	0.2	-0.2	0.2	-0.2	0.6	0.8	-0.6	-2.4
31	OTHER MANUFACTURING	0.2	0.3	0.2	0.4	0.2	0.4	0.2	0.3	0.2	0.2	0.1	0.2	0.2	0.3	0.2	0.3	0.2	0.3	0.1	0.3
32	ELECTRICITY	-10.0	0.0	-10.0	0.0	-10.0	0.0	-10.0	0.0	-10.0	0.0	-10.0	0.0	-10.0	0.0	-10.0	0.0	-10.0	0.0	-10.0	0.0
33	WATER	-9.2	-21.9	-8.4	-22.2	-9.1	-21.8	-9.0	-21.8	-8.2	-22.1	-10.3	-23.4	-7.8	-20.0	-8.2	-20.5	-9.4	-22.2	-8.4	-20.8
34	CONSTRUCTION	-0.3	-0.4	-0.7	-0.7	0.4	0.3	-3.0	-3.0	-0.7	-0.5	0.6	0.6	-1.1	-1.2	-0.7	-0.7	-0.3	-0.3	1.5	1.4
35	CIVIL ENGINEERING	-1.6	-2.1	-1.6	-2.2	-0.3	-0.8	-4.2	-4.7	-1.1	-2.0	-4.0	-4.6	-2.1	-2.6	-1.1	-1.7	-1.0	-1.6	0.0	-0.5
36	TRADE	-4.3	-8.6	-4.6	-7.2	-3.0	-5.4	-4.8	-7.1	-3.5	-6.9	-5.2	-7.7	-3.7	-6.2	-3.5	-5.9	-4.5	-7.1	-3.6	-6.0
37	ACCOMMODATION	-5.1	-8.1	-5.0	-8.0	-4.9	-7.9	-5.3	-8.3	-4.9	-8.0	-6.5	-9.6	-5.0	-8.0	-4.9	-7.9	-5.0	-8.0	-5.0	-8.0
38	TRANSPORT	-2.8	-4.6	-2.9	-4.8	-2.6	-4.5	-2.1	-3.9	-2.3	-5.0	-2.8	-4.6	-2.3	-4.1	-2.3	-4.1	-2.5	-4.4	-2.3	-4.1
39	COMMUNITY	-3.0	-6.8	-3.0	-6.8	-3.0	-6.8	-3.0	-6.8	-3.0	-6.8	-3.0	-6.8	-3.0	-6.8	-3.0	-6.8	-3.0	-6.8	-3.0	-6.8
40	FINANCIAL SERVICES	-3.3	-3.5	-3.3	-3.5	-3.3	-3.5	-3.3	-3.5	-3.3	-3.5	-3.3	-3.5	-3.3	-3.5	-3.3	-3.5	-3.3	-3.5	-3.3	-3.5
41	BUSINESS SERVICES	-1.6	-7.2	-1.8	-7.3	-0.9	-6.8	-1.3	-7.0	-0.5	-7.1	-2.1	-7.9	-0.5	-6.3	-0.5	-6.5	-1.8	-7.4	-0.6	-6.6
42	MEDICAL SERVICES	-3.6	-8.9	-3.8	-8.9	-3.7	-8.7	-3.4	-8.4	-3.2	-9.1	-3.9	-9.0	-2.9	-7.9	-3.2	-8.2	-3.9	-8.9	-3.1	-8.1
43	COMMUNITY SERVICES	-8.0	-10.0	-8.5	-10.6	-7.4	-9.4	-8.9	-10.9	-7.4	-9.9	-8.6	-10.7	-7.2	-9.1	-7.4	-9.3	-8.1	-10.1	-7.0	-8.9
44	NOT CLASSIFIED	-3.8	-7.8	-3.8	-7.8	-3.8	-7.8	-3.8	-7.8	-3.8	-7.8	-3.8	-7.8	-3.8	-7.8	-3.8	-7.8	-3.8	-7.8	-3.8	-7.8
45	HOUSEHOLD SERVICES	-11.5	-11.5	-12.1	-12.1	-11.1	-11.1	-11.6	-11.6	-9.9	-11.8	-12.1	-12.1	-9.7	-9.8	-9.9	-11.9	-11.9	-9.6	-9.6	-9.6
46	GOVERNMENT INDUSTRIES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aggregate Provincial Impact		-2.6	-3.7	-2.8	-4.0	-2.1	-3.4	-2.8	-3.9	-2.6	-3.8	-4.2	-4.0	-2.2	-2.6	-1.6	-2.7	-2.7	-3.9	-2.7	-2.5

Source: IDCGEM simulations conducted by the author.

Owing to the current lack of information regarding electricity dependency for the South African economic sectors in the context of this analysis, the author conducted a brief international literature scan on the topic. One of the research papers that were identified as being most pertinent to the subject matter under study, i.e. the impact of power shortages and/or poor power quality, is the Tata Energy Research Institute (TERI) report on “Cost of Un-served Energy”, prepared for the World Bank and Department of International Development, in the year 2001. Although conducted for the South Asia Region, the findings in this report could guide our approach for the South African case.

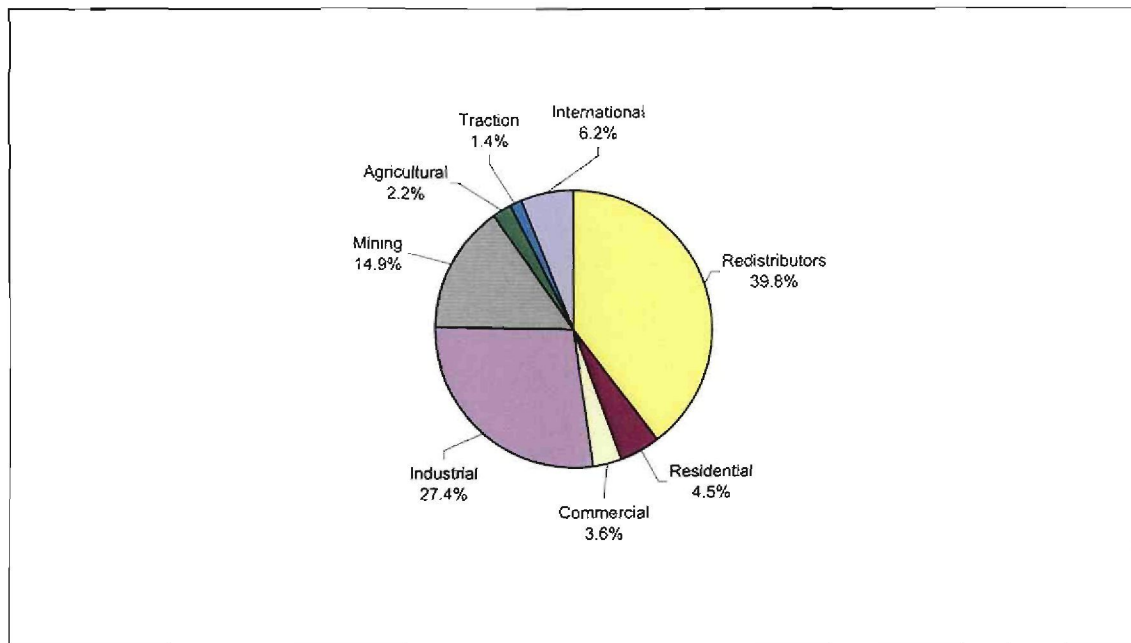
The report indicates that, at the aggregate national/regional level, chronic power shortages have not only had adverse economic impacts in terms of reduction in value added or GDP, but also in terms of reduced growth rates in value added and reduced growth rates in per capita income. Thus, the TERI report indicates that, for example for the year 1998-99, shortages in the availability of power to the manufacturing sector resulted in loss of value added (GDP) to the extent 1% and 2.2% of the total manufacturing sector value added (GDP) in the Indian States of Haryana and Karnataka respectively. The report also indicates that for the year 1998-99, shortages in the availability of power to the agricultural sector resulted in loss of value added (GDP) to the extent 3.1% and 13.3% of the total agricultural sector value added (GDP) in the States of Haryana and Karnataka respectively.

Comparing the results obtained in this study with the relative magnitudes found in the TERI 2001 study for India, it would seem that the findings from the IDCGEM may well be plausible from a magnitude point of view, but not necessarily from a geographic or regional distribution point of view.

Obvious from the results for the provinces, is that the top-down allocation of national level effects based on the current approach applied does not take into consideration inter-regional linkages. For this specific scenario, the dependency of electricity by sectors such as mining, base metals and the electricity distribution sector (not all located only in the Mpumalanga province) is not adequately captured by the top-down approach. Due to the fact that the intermediate and final demand and supply is solved on a national level for a national market, the potential for understatement of impacts (both positive and negative) is large with this approach.

If one investigates the structure of electricity consumers in South Africa, one will notice that the mining and industrial categories together account for approximately 42 per cent of total electricity consumed in the national economy. Based on the information from Eskom (2007) this is a conservative estimate, for there are some industrial customers that are supplied by the municipalities (redistributors in Figure 10 below), which will inflate this share even further if their relevant electricity consumption could be isolated from the redistributors category.

Figure 10: Electricity usage by customer category



Source: Eskom Annual Report (2007) Table 4, p189.

The Gauteng province (PWV in the model) is the main supplier of inputs to the mining and industrial sectors in South Africa, and in turn the mines are very dependant on electricity for operations (especially underground mines from a water pumping, hoisting and safety perspective). If the model had the ability to model the intermediate flows on a provincial level, it is the opinion of the author that a more pronounced knock-on effect would be observed for provinces such as Gauteng and Kwa-Zulu Natal, as many of the industries located in these two provinces have strong supply links with the mining sector, not only in Mpumalanga, but also in the Northern Cape, North West and Northern region.

Furthermore, in the modern economy many activities produce relative high value added (economic definition) for relatively low inputs of electricity (i.e. ratio of electricity consumption to value added is low) which would lead us at a

superficial level to conclude that such an activity has a low electricity intensity, and therefore large changes in the electricity input will reflect small changes in the value added measurement of output. In reality though, such activities may very well be very dependent on electricity for their operations, and the previous conclusion may actually be totally the opposite, for although using relatively little electricity, if electricity is not available their production processes may grind to a halt. An example would be the financial and banking sector and software development. An alternate example could be the rail or traction sector. Here, although an electric locomotive is very electricity intensive, the mode of transport has the ability in theory to easily switch an electric locomotive for a diesel locomotive, which would then imply that although the activity is electricity intensive, it is less electricity dependent than some other cases.

In this context of dependency versus intensity, the services sectors contribute substantially to the economies of Gauteng (24.3 per cent based on constant 2000 basic prices, StatsSA 2007) and 10 per cent respectively for Western Cape and Kwa-Zulu Natal. These service sectors, although not very electricity intense (only 3.6 per cent of electricity consumed), are very dependent on electricity for their operations. This means that any electricity supply interruptions would have a major economic impact on such sectors and in turn on these provincial economies, not observed from the top-down results presented for the illustrative scenario.

Unfortunately we do not have readily available quantifications of electricity dependency per sector and electricity intensity per sector is used as a proxy. As illustrated above, this causes us to potentially introduce a bias in the determination of economic costs per sector or activity.

In contrast to the national level results, the cause and effect relationships between production output, labour, wages, household income, imports, exports and prices cannot be analysed on a regional basis as a result of the fact that there is not sufficient detail and regional interaction embedded in the top-down approach. The above discussion serves to illustrate the need for models that have the ability to represent the interactions between sectors and geography in a more sophisticated and realistic way.

5.5. Suggested future extensions

The technology and theory exists that will allow improvement of the models we have to be able to cater for more realistic regional modelling. However, as mentioned previously in section 4.3, one of the main constraints of this type of modelling is the availability of sufficient detailed data in order to achieve the required level of detail.

In the ideal modelling world the RAGE modeller wishing to construct a detailed bottom-up model would like to have information on inter-industry (between industries within a region) intra-regional (between industries from different regions) flows, household demand by product and region (again within a region and between regions), imports and export demand by product and region and more.

In Figure 11 a stylised expansion required for the production function of such a model in the Monash ORANI-style model is presented, but for a region as opposed to the national economy as in the original. The light shaded (light blue) elements have been added to the original diagram of the structure of production of the national economy ORANI approach (see Horridge *et al.* 1993, p.109) to illustrate the additional elements (and data) that would be required to create inter and intra-regional (including international) relationships for factor supplies in the production equations of a bottom-up regional AGE model. The conventions used to denote the various geographies or locations referred to are:

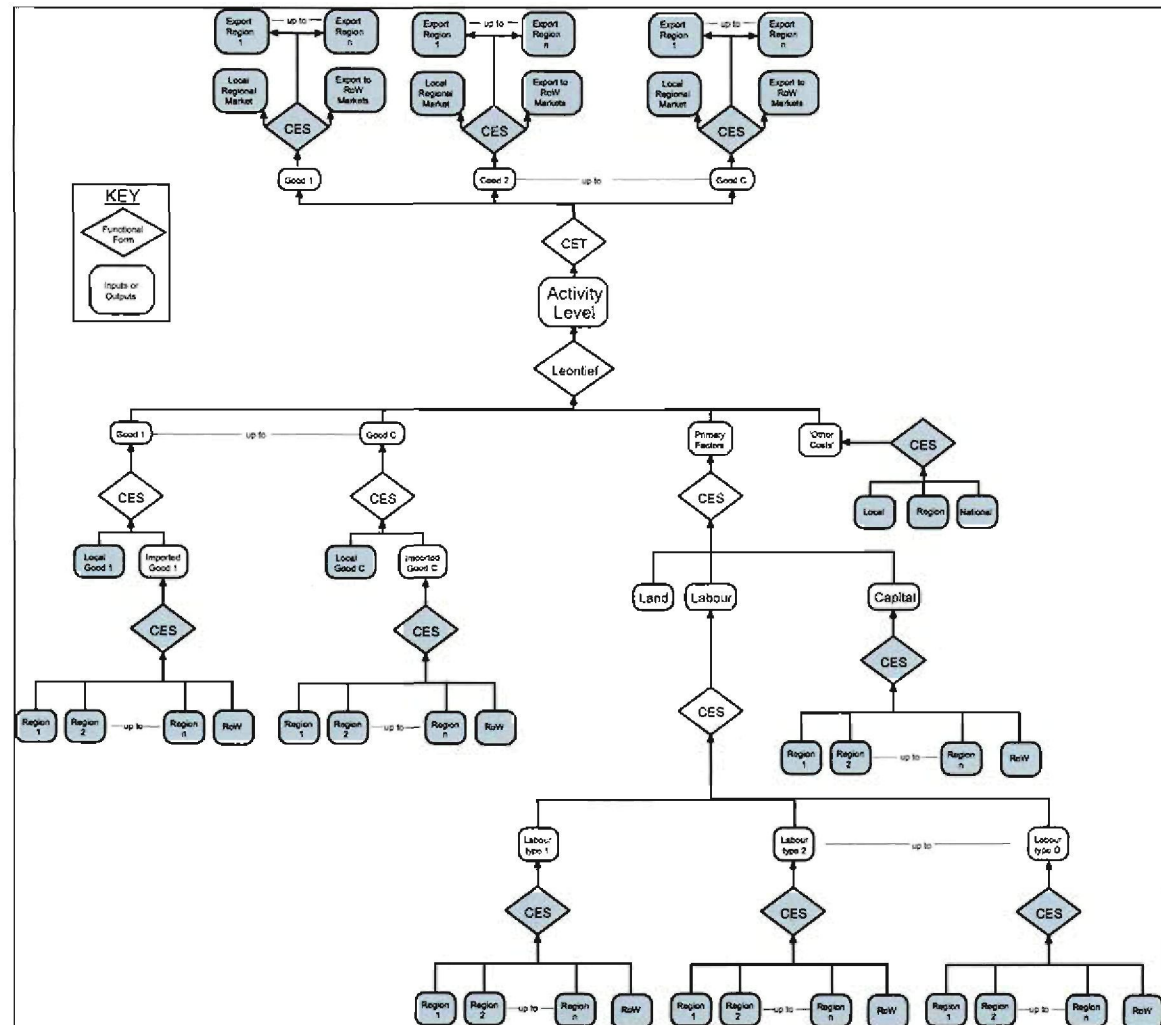
- Local – refers to within the region only. This term replaces the “domestic” term in the original diagram by Horridge (1993).
- Region – refers to an area within the national economy.
- National – refers to the national economy (aggregate of all the regions in an economy).
- International (or Rest of World [RoW]) – refers to the external market outside of the national economy.

Primary factor sourcing

We start with labour sourced for the production function (typically a CES or CET function). The data would need to cater for labour supply from within the region itself, labour from other domestic regions, as well as possible labour from international markets. In practice the assumption would probably be made that for short-term comparative static type applications labour would be immobile, but as we move to medium-term dynamic style models this assumption would probably need to be relaxed. Capital would also possibly

be sourced from local supply versus other regions and internationally. Similar assumptions that apply for labour would also apply to capital in terms of short and long term. Land is geographically fixed and therefore only applicable to the specific region in which it is located.

Figure 11: Extensions to production function required for a bottom-up RAGE model



Source: Author based on Horridge *et al.* (1993).

Other costs

The other costs component refers to government in this case, and as indicated on the diagram a split between local government within the region and national government activities would need to be introduced. Typically services such as defence, police and central government would exist at

national level only, while health, education and municipal services would exist at a local regional level. Substitutability between government products/services would be limited due to statutory and regulatory issues, but this will be addressed in the elasticity of substitution parameters of the CES function applied in actual modelling.

Intermediate inputs sourcing

The ORANI approach applies the Armington (1969; 1970) assumption that imports are imperfect substitutes for domestic supplies. Figure 11 shows that the commodity demand function would need to be expanded to include not only domestic and imported goods as in the original application, but that for imported goods into a region a distinction between imports from other regions versus direct international imports need to be made. This will allow for a more realistic flow of goods within the national economy between regions as well as from outside the national economy into regional specific destinations. Such distinction will be valuable when analysing for example policies related to import tariffs, protection and other related international trade questions.

Product output destination

Output of commodities produced by a specific region distinguish between production for local markets (within the same region), for exports to other regions or to international markets directly.

Data requirements

To achieve the extensions illustrated above, one would need extensive data on inter-regional and international flows, which in practice would be nearly impossible to achieve in the South African environment. The only comprehensive attempt at constructing inter-regional input-output tables for South Africa was attempted by Nel in his doctoral thesis in 1993 (Nel and Vivier, 1995:111), based on information for the nine so-called development regions that existed during the middle eighties with information for the year 1985 for South Africa. Nel and Vivier (1995:111) also mention some attempts by Mirrilees (in 1984) and Mohr and Van Seventer (in 1988) in this regard. One of the key issues when modelling inter-regional flows is the treatment of the propensity of regions to trade with each other. Nel proposes an approach based on the Leontief-Strout gravity model methodology, combined with an alternative proposed approach to estimate the important trade coefficient needed to estimate inter-regional trade flows. Due to the fact that this study is not focusing on the compilation of intra-regional flows, the topic is left for the moment, but may be returned to it in future work to refine the estimates applied in future intra-regional matrices.

Currently, one would therefore not be in a position to construct a regional AGE with the level of interaction and detail required for a “pure” bottom-up model, unless a process to construct such inter-regional datasets containing all the required inter and intra regional flows is first completed.

5.6. A pragmatic hybrid approach

The French writer Voltaire coined a phrase “*Le mieux est l'ennemi du bien*”, which can be translated as “The perfect is the enemy of the good”¹³. In this case if one were to attempt to have a complete bottom-up model for South Africa, one would be striving for perfection for ever, while it is possible to create a hybrid model that would be good enough for the types of analysis required. Fortunately the process of empirical research is an iterative and forgiving one in the sense that it allows one to start with less complex and less detailed models, moving towards more complicated and more complex models as knowledge and information on the particular topic improves.

The key is data availability

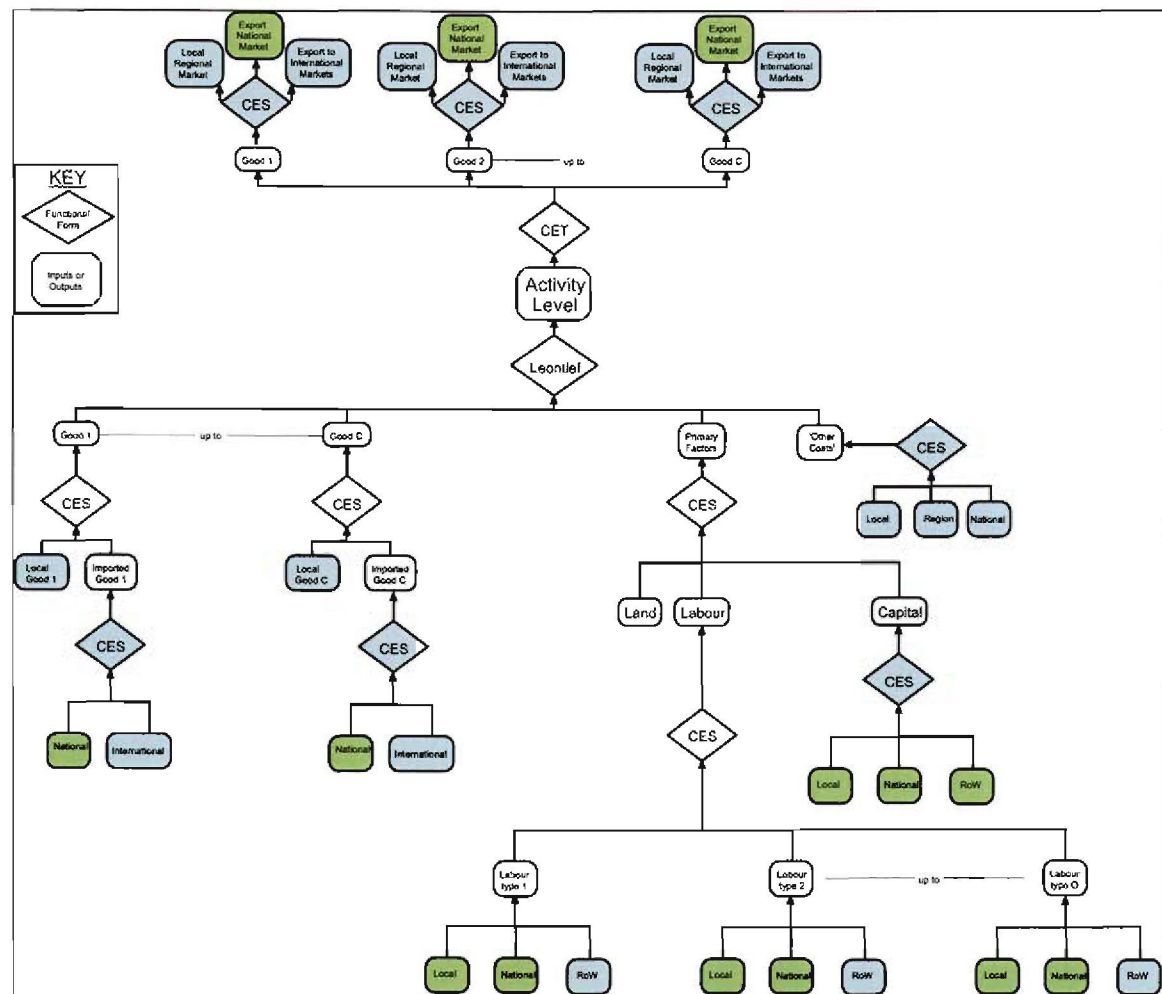
As stated by Parmenter *et al.* (1985:1), one of the key determinants to construct a sufficiently detailed regional model is the availability of data. We therefore focus on what is possible given the current information availability in the South African context, as this will guide the level of detail possible with a regional AGE model.

South Africa's information compilation level of sophistication and detail has improved over the last 20 years, and as mentioned previously in section 4.4 there currently is a programme to actively compile a set of social accounting matrices for the nine provinces of South Africa. Since the availability of data dictates the construction of such a model, it is proposed that this approach is

¹³ <http://en.wikiquote.org/wiki/Voltaire>

based on what potentially is available from this initiative managed by the DBSA.

Figure 12: Extensions to production function required for a hybrid bottom-up RAGE model



Source: Author based on Horridge *et al.* (1993).

Based on the details of the SAM constructed for the North West province (Conningarth Economists, 2006) changes proposed to the production structure presented previously in Figure 11 are depicted in Figure 12. The major difference between the “true” bottom-up and proposed hybrid approach lies with the treatment of inter-regional flows. The darker shaded (green) elements in Figure 12 illustrate the differences in the production structure proposed.

Primary factor sourcing

Since the dynamics of labour flow between regions and across national borders is quite complex, the proposal around labour for this approach would be to distinguish only between labour sourced locally from within the region, then labour sourced from the “national” pool of excess labour and some from the rest of the world. The real problematic directional inter-regional (between) flows is circumvented in this way for now. The same assumptions than before would hold, i.e. that for short-term comparative static type applications labour would be immobile, but as we move to medium-term dynamic style models this assumption would probably need to be relaxed. In the same fashion capital would also be sourced from local, national and the rest of the world.

Other costs

The treatment of government will remain as discussed in the previous section.

Intermediate inputs sourcing

Figure 12 illustrates that in contrast to the bottom-up approach illustrated in Figure 11, the commodity demand function would include imported goods from the national market into a region, as well as from the rest of the world. It seems from the research by Conningarth Economists (2006) that two methodologies were applied to obtain estimates of exports for each province, namely the residual method as well as surveys. Imports seem to have been determined purely on the residual method. The author proposes that this dimension of the SAMs could possibly be improved by also considering import and export data available on a postal code level of detail from the South

African Revenue Services, Department of Customs and Excise. However, the improvement of the SAM estimates is a topic for another study all together.

Product output destination

Similar with the previous discussion, the destinations for output of commodities produced by a region would distinguish between the local market (within the same region), but for exports to a national market as opposed to directly inter-regional exports. Direct exports to international markets remain a destination as before.

Data requirements

The data that would be available for use for the proposed approach as mentioned before would be based on the provincial SAMs under construction by Conningarth Economists.

The North-West SAM contains 12 occupational and 4 skill types. Final household expenditure is distinguished by 12 expenditure categories. The production and commodity dimensions are square but presented in supply and use blocks containing 39 industries and commodities. Government is split in National, Provincial and Local government activities, while the capital account is split in Government and a composite Corporate and Household sector. Imports and exports are split between the rest of South Africa and the rest of the world. The product and activity dimensions of the consolidated set of SAMs will in all probability be comparable on 2 digit Standard Industrial Classification (SIC) detail. For a full description and detail of the North-West

SAM refer to Conningarth Economists (2006). Furthermore, the typical product and sector dimensions contained in these provincial SAMs are illustrated by Table 8 based on the current North-West province SAM.

Table 8: Activities included in the North-West SAM

<i>Activities</i>	<i>Sub-Divisions</i>
PRIMARY INDUSTRIES	
Agriculture	Commercial Agriculture Subsistence Agriculture
Mining	Platinum Mining Gold Mining Other Mining
SECONDARY INDUSTRIES	
Manufacturing	Meat, Fish, Fruit, Vegetables, Oils and Fat Products Dairy Products Grain Mill, Bakery and Animal Feed Products Other Food Products Beverages and Tobacco Products Textiles, Clothing, Leather Products and Footwear Wood and Wood Products Furniture Paper and Paper Products Publishing and Printing Chemicals and Chemical Products (incl. Plastic Products) Rubber Products Non-Metallic Mineral Products Basic Metal Products Structural Metal Products Other Fabricated Metal Products Machinery and Equipment Electrical Machinery and Apparatus Communication, and Other Electronic Equipment Manufacturing of Transport Equipment Handcrafts and Curios Other Manufacturing and Recycling Informal Manufacturing
Electricity and Water	Electricity Water
Construction	Buildings Other Construction Informal Construction
TERTIARY INDUSTRIES	
Trade and Accommodation	Trade Accommodation Informal Trade, Accommodation and Entertainment
Transport and Communication	Transport Services Communications Transport – Combi Taxis
Financial and Business Services	Insurance Real Estate Business Activities
Community and Social Services	General Government Health and Social Work Activities/Services
	Other Informal Services

Source: Conningarth Economists (2006).

The programme to compile provincial SAMs for the 9 provinces of South Africa would provide a first round major building block in the process of creating an up-to-date and relevant regional AGE for South Africa. According to the DBSA the aim of the project is to compile SAMs relevant to each province in isolation first, after which the set of SAMs will be reconciled to a national SAM for the 1996 base year. The potential therefore exists that a consistent full set of national and 9 provincial SAMs will be available in the near future.

5.7. Summary

This chapter provided a high level description of the IDCGEM model as well as its regional dimensions and characteristics. An illustrative application modelling a sustained 10 per cent reduction in electricity supply (achieved through reduced consumption) of combined with a shock of approximately 53 per cent in the output price of the electricity industry attempts to quantify answers to the question of what the potential impacts could be with a focus on the regional impacts.

Obvious from the results for the provinces, is that the top-down allocation of national level effects based on the current approach applied does not take into consideration inter-regional linkages. For this specific scenario, the dependency of electricity by sectors such as mining, base metals and the electricity distribution sector (not all located only in the Mpumalanga province) is not adequately captured by the top-down approach. Due to the fact that the intermediate and final demand and supply is solved on a national level for a national market, the potential for understatement of impacts (both positive and

negative) is large with this approach. Furthermore, in contrast to the national level analysis, the cause and effect relationships between production output, labour, wages, household income, imports, exports and prices cannot be analysed on a regional basis as a result of the fact that there is not sufficient detail and regional interaction embedded in the top-down approach.

A stylised bottom-up extension to the existing ORANI modelling approach was illustrated, but the recommendation is to aim for an approach that will be less onerous with regards to data requirements. For this reason a hybrid approach was also detailed which would allow one to construct a RAGE model based on the SAMs that are currently under construction as part of a project managed by the DBSA. The dimensions and characteristics of the set of SAMs were briefly discussed based on the already completed SAM for the North West province. The full set of provincial SAMs should be available by the end of 2008.

CHAPTER 6: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.8. Summary

One of the legacies of the policies of the apartheid regime manifested in the South African economy today is the uneven economic development of South Africa's sub-national or regional economies. In addition to data and information, access to modelling tools with a regional or sub-national dimension that enables policy makers to analyse potential impacts of proposed strategies or test "what-if" scenarios would complement the policy makers' arsenal of resources to apply to these questions.

However, modelling tools addressing this spatial or regional dimension are limited in the South African context. Currently, to the author's knowledge, there exists no such model of sufficient regional detail and sophistication in order to conduct useful analysis of this nature.

The research question that this study attempted to address was firstly to illustrate the appropriateness and feasibility of a regional AGE model in the South African context for South African policy makers, and secondly to forward some thoughts and ideas on how a regional AGE model can be constructed to assist South African policy-makers to investigate spatial or regional (sub-national) impacts and policy-choices with a more sophisticated approach (other than a simplified top-down approach).

The objectives set for this study therefore were the following:

- a. To illustrate the appropriateness of RAGE model as a modelling framework for regional / spatial or sub-national policy analysis.
- b. To identify various ways and methodologies in which a RAGE model can be constructed in the South African context.
- c. To construct a simplified top-down model and illustrate its use based on South African topical issues.

5.9. Conclusions

The hypothesis underlying this study that a RAGE models can be of use to better understand the economic challenges faced by South African policy makers on a sub-national (regional or local) level was supported and illustrated through the study.

The appropriateness of RAGE model as a modeling framework for regional / spatial or sub-national policy analysis was demonstrated by informing the reader as to the background and applicability of AGE models in general in chapter 2. The lack of RAGE models in the South African context was demonstrated in chapter 3 with a chronology of AGE modelling developments in South Africa since the 1990's. The focus was placed on the fact the very few regional / sub-national applications exist and are / were applied in South Africa. Section 4 provided an overview of regional development challenges and highlighted the need for RAGE models. Examples of RAGE models internationally applied were provided in motivation of the applicability and suitability of RAGE models for policy analysis.

Identifying various ways and methodologies in which a RAGE model can be constructed in the South African context was illustrated in section 4.3 which provided an overview of the various approaches to RAGE modelling – bottom-up, top-down and hybrid approaches and highlighted the specific relevance of such a RAGE model in the South African context.

The application of a simplified top-down model and illustrating its use based on South African topical issues was demonstrated in chapter 5. An illustrative top-down application based on the dated IDCgem AGE model was applied and a topical scenario on electricity supply and price was simulated. The focus was placed on the implications of a simultaneous price increase and volume decrease in the electricity sector of South Africa.

What was evident is that in contrast to the national level analysis, the cause and effect relationships between production output, labour, wages, household income, imports, exports and prices cannot be analysed on a regional basis as a result of the fact that there is not sufficient detail and regional interaction embedded in the top-down approach. Furthermore analysis of the regional results indicated that the magnitude of the impacts in relative terms seemed realistic when compared to other similar international studies, but that the allocation of the impacts on a geographic (sub-national) basis did not seem accurate. Both these findings support the hypothesis of the study.

5.10. Recommendations

One of the key issues or constraints to constructing such a regional AGE highlighted in the study is the existence and availability of suitably detailed inter-regional data sets to inform such a model. Through this research the author has also illustrated the feasibility to construct a more pragmatic (due to data constraints) hybrid (mix between pure top-down and bottom-up) model with the potential to be realised in the short to medium term based on the work (lead by the DBSA) currently being conducted to construct provincial SAMs for South Africa for the base year 2006.

The recommendation from the study is that further work need to be conducted in order to realise such a model. This would entail the following activities:

- a) Consolidating and extending the provincial and national SAMs into a coherent database suitable for use with a regional AGE model. In this case the Monash ORANI-style modelling would be proposed, as a lot of previous experience and knowledge with this specific approach have been gained in South Africa over the last 15 years. This approach has also been applied in various other countries for regional AGE models.
- b) Constructing the relevant equations and relationships as illustrated in the stylised proposed hybrid model in section 5.6.

Once this model is operational and has been tested, relevant policy issues can be analysed to provide insight and assistance to policy makers with regards to sub-national/provincial implications of various policies. An example of such a topic was provided in terms of the electricity sector scenario in section 5.4.

Although this study aimed to illustrate the need, viability and requirements in the South African context for a new, current regional AGE model, the actual development of such a regional AGE is left for future research.

ANNEXURE A – GEMPACK SOURCE CODE FOR REGIONAL EXTENSION OF IDCGEM

Below the GEMPACK source code applied for the regional extension of the IDCGEM is listed based on the work of Mark Horridge, 1994. For an explanation of the syntax of the GEMPACK language in the context of the ORANI-style models refer to Horridge *et al.* 1993.

```
! *****
Module to be appended to existing IDCGEM tab file          26/5/94
Disaggregates national results to region level
In the spirit of DPSV ORES, but more general
Main assumptions:
    Prices, industry technology and capital creation
    technology are uniform across regions.
    All industries are single-product
    Import/domestic preferences uniform across regions.
!

! Excerpt 0 of Regional Extension: !
! Preliminaries
Within the regional extension we ignore the income/race distinctions among
households. So we must define average expenditure elasticities !

Coefficient
(All,c,COM) V3PUR_SHR(c) # Total Household expenditure by good #;
(All,c,COM) EPS_HR(c) # Average Household expenditure elasticities #;
    TOTEPS # Temporary sum of expenditure elasticities #;
Zerodivide Default 1.0;
Formula
(All,c,COM) V3PUR_SHR(c) = Sum(h,HTYPE, Sum(r,RACE, V3PUR_S(c,h,r) ));
(All,c,COM) EPS_HR(c)=
    Sum(h,HTYPE, Sum(r,RACE, V3PUR_S(c,h,r)*EPS(c,h,r) ))/V3PUR_SHR(c);
! Now we scale the EPS_HR so that expenditure share weighted sum is unity !
! Is this really necessary ? !
TOTEPS = Sum(c,COM, V3PUR_SHR(c)*EPS_HR(c) )/V3TOT_HR;
(All,c,COM) EPS_HR(c)= EPS_HR(c)/TOTEPS;
Display TOTEPS; ! should be near to unity, one would hope !
    V3PUR_SHR;
Zerodivide Off;

! Excerpt 1 of Regional Extension: !
! Sets !
Set REG ( WEST_CAPE, EAST_CAPE, NORTH_CAPE, PWV, EAST_TVAAL, NORTH_TVAAL,
    NTHWST_TVAAL, KWA_NATAL, ORANGE_FREE ); ! Subscript r !

Set
    NATCOM # National Commodities (Set H, DPSV p.259) # (
AGRICULTURE, COAL_MINING, GOLD_MINING, DIAMONDS, MEAT_PRCs,
DAIRY_PRODS, VEG_CANNING, FISH_PRCs, OILS_FATS, GRAIN_MILLNG,
BAKERY_PRODS, SUGAR_REFNG, CONFECTIONRY, OTH_FOOD_PRD, ANIMAL_FEED,
WINE_SPIRITS, MALT_LIQUORS, SOFT_DRINKS, TOBACCO_PRDS, WOOL_COTTON,
SPIN_WEAVE, TEXTILES_NW, GARMENT_KNIT, OTH_KNITTING, CARPETS_RUGS,
CORD_ROPE, TEXTILES_NEC, CLOTHING, LEATHER_TAN, LEATHER_PRD,
FOOTWEAR, WOOD_PRODS, FURNITURE, PULP_PAPER, PAPER_CNTNRS,
OTH_PAPER_PR, PRINT_PUB, BASIC_CHEM, FERTILIZERS, RESINS_PLAST,
PAINTS_ETC, DRUGS_MEDICN, SOAP_COSMETC, OTH_CHEM_PRD, PETROL_REFIN,
PETROL_COAL, TYRES_ETC, OTH_RUBBER, OTH_PLASTICS, POTTERY_ETC,
GLASS_ETC, BRICKS_TILES, CEMENT, NNMTL_MIN_PR, BASIC_IRON,
NONFERR_METL, CUTLRY_HRDWR, FURN_FIXTURS, STRUCT_METAL, OTH_METAL_PR,
ENGINES_ETC, AGRICLT_MCHN, MTLWOOD_MCHN, SPECIAL_MCHN, OFFICE_MCHN,
OTH_MCHN, ELECTRC_MCHN, RADIO_TV_EQU, ELEC_APPLNCS, OTH_ELEC_EQ,
SHIP_BOATS, RAILWAY_EQU, MOTOR_VEHICL, AIRCRAFT, MOT_VEH_PART,
OTH_TRANS_EQ, JEWELLERY, OTH_MANUFAC, ELEC_GAS_STM,

COMMUNICATON, FIN_INSURNCE, MCHN_RENT,
```

```

GOV_ADMIN,      GOV_DEFENCE,  GOV_POLICE      GOODS_NEC,

);

Subset NATCOM is subset of COM;

Set
  LOCCOM          # Local Commodities (Set L, DPSV p.259) # (
    BUILDNG_CNST,  OTH_CONSTRCT,  TRADE,          CATERNG,          WATER_SUPPLY,
    MEDICAL_ETC,   SRVC_PRFT,     REAL_ESTATE,    BUSINSS_SRVC,     TRANS,
    GOV_HOUSING,   GOV_SOCIAL,     SRVC_NONPRFT,   GOV_EDUCATN,      DOMESTIC_SRV,
    GOV_OTHER,                                           GOV_HEALTH,
  );
Subset LOCCOM is subset of SEC;
! local commodities must be produced in region of use
  or, for exports to ROW, in source region !

Set MARLOCCOM #Local margin commodities# (TRADE, TRANS);
Subset MARLOCCOM is subset of MAR;
Subset MARLOCCOM is subset of LOCCOM;
! margin local commodities must be produced in region of use
  of underlying basic flow !

Set NONMARLOCCOM #Local non-margin commodities# (
    BUILDNG_CNST,  OTH_CONSTRCT,  CATERNG,          WATER_SUPPLY,
    MEDICAL_ETC,   SRVC_PRFT,     REAL_ESTATE,    BUSINSS_SRVC,     DOMESTIC_SRV,
    GOV_HOUSING,   GOV_SOCIAL,     SRVC_NONPRFT,   GOV_EDUCATN,      GOV_HEALTH,
    GOV_OTHER,                                           GOV_HEALTH,
  );
Subset NONMARLOCCOM is subset of NONMAR;
Subset NONMARLOCCOM is subset of LOCCOM;

Set
  NATIND          # National Industries (Set N, DPSV p.259) # (
    AGRICULTURE,   COAL_MINING,   GOLD_MINING,    DIAMONDS,         MEAT_PRCS,
    DAIRY_PRODS,   VEG_CANNING,   FISH_PRCS,      OILS_FATS,        GRAIN_MILLNG,
    BAKERY_PRODS,   SUGAR_REFNG,   CONFECTIONRY,   OTH_FOOD_PRD,     ANIMAL_FEED,
    WINE_SPIRITS,   MALT_LIQUORS,   SOFT_DRINKS,    TOBACCO_PRDS,     WOOL_COTTON,
    SPIN_WEAVE,     TEXTILES_NW,   GARMENT_KNIT,   OTH_KNITTING,     CARPETS_RUGS,
    CORD_ROPE,      TEXTILES_NEC,  CLOTHING,       LEATHER_TAN,      LEATHER_PRD,
    FOOTWEAR,       WOOD_PRODS,   FURNITURE,      PULP_PAPER,       PAPER_CNTNRS,
    OTH_PAPER_PR,   PRINT_PUB,     BASIC_CHEM,     FERTILIZERS,      RESINS_PLAST,
    PAINTS_ETC,     DRUGS_MEDICN,  SOAP_COSMETC,   OTH_CHEM_PRD,     PETROL_REFIN,
    PETROL_COAL,    TYRES_ETC,     OTH_RUBBER,     OTH_PLASTICS,     POTTERY_ETC,
    GLASS_ETC,      BRICKS_TILES,  CEMENT,         NMNTL_MIN_PR,     BASIC_IRON,
    NONFERR_METL,   CUTLRY_HRDWR,  FURN_FIXTURS,   STRUCT_METAL,     OTH_METAL_PR,
    ENGINES_ETC,    AGRICLT_MCHN,  MTLWOOD_MCHN,   SPECIAL_MCHN,     OFFICE_MCHN,
    OTH_MCHN,       ELECTRC_MCHN,  RADIO_TV_EQU,   ELEC_APPLNCS,     OTH_ELEC_EQ,
    SHIP_BOATS,     RAILWAY_EQUP,  MOTOR_VEHICL,   AIRCRAFT,         MOT_VEH_PART,
    OTH_TRANS_EQ,   JEWELLERY,     OTH_MANUFAC,    ELEC_GAS_STM,
    COMMUNICATON,   FIN_INSURNCE,  MCHN_RENT,
    GOV_ADMIN,      GOV_DEFENCE,   GOV_POLICE      GOODS_NEC,
  );
Subset NATIND is subset of IND;

! Subset COM is Subset of IND;          needed GP50 only - delete for GP51 ? !

! Excerpt 2 of Regional Extension: !
! Variables !

Variable
  (All,c,LOCCOM) (All,r,REG)
  regx0(c,r) # regional usage of local commodities #;
  (All,i,IND) (All,r,REG)
  regxltot
  (i,r) # output of regional industries #;
  (All,r,REG)
  regwllab_iol(r) # wage bills by region #;

  (All,c,COM) (All,s,SRC) (All,i,IND) (All,r,REG)

```

```

    regx1(c,s,i,r) # regional demands for intermediate inputs #;
    (All,c,COM) (All,s,SRC) (All,i,IND) (All,r,REG)
    regx2(c,s,i,r) # regional demands for inputs for investment #;
    (All,c,COM) (All,s,SRC) (All,r,REG)
    regx3_hr(c,s,r) # Household demand for goods#;
    (All,c,COM) (All,r,REG)
    regx4(c,r) # exports by region #;
    (All,c,COM) (All,s,SRC) (All,r,REG)
    regx5(c,s,r) # Demands for inputs for "Other" demands #;

    (All,c,COM) (All,s,SRC) (All,i,IND) (All,m,MAR) (All,r,REG)
    regx1mar(c,s,i,m,r) # Margins - production #;
    (All,c,COM) (All,s,SRC) (All,i,IND) (All,m,MAR) (All,r,REG)
    regx2mar(c,s,i,m,r) # Margins - capital creation #;
    (All,c,COM) (All,s,SRC) (All,m,MAR) (All,r,REG)
    regx3mar_hr(c,s,m,r) # Margins - households #;
    (All,c,COM) (All,m,MAR) (All,r,REG)
    regx4mar(c,m,r) # Margins - exports #;
    (All,c,COM) (All,s,SRC) (All,m,MAR) (All,r,REG)
    regx5mar(c,s,m,r) # Margins - "Other" #;

    (All,i,IND) rsum1(i) # addup term - should be zero #;
    (All,i,IND) rsum2(i) # addup term - should be zero #;
    (All,c,COM) rsum3(c) # addup term - should be zero #;
    (All,c,COM) rsum4(c) # addup term - should be zero #;
    (All,c,COM) rsum5(c) # addup term - should be zero #;
    (All,i,IND) ffreg1(i) # complement of rsum1 #;
    (All,i,IND) ffreg2(i) # complement of rsum2 #;
    (All,c,COM) ffreg3(c) # complement of rsum3 #;
    (All,c,COM) ffreg4(c) # complement of rsum4 #;
    (All,c,COM) ffreg5(c) # complement of rsum5 #;
    (All,i,IND) (All,r,REG) rgshr1(i,r) # regional share Variable #;
    (All,i,IND) (All,r,REG) rgshr2(i,r) # regional share Variable #;
    (All,c,COM) (All,r,REG) rgshr3(c,r) # regional share Variable #;
    (All,c,COM) (All,r,REG) rgshr4(c,r) # regional share Variable #;
    (All,c,COM) (All,r,REG) rgshr5(c,r) # regional share Variable #;
    (All,i,IND) (All,r,REG) freg1(i,r) # regional share shifter #;
    (All,i,IND) (All,r,REG) freg2(i,r) # regional share shifter #;
    (All,c,COM) (All,r,REG) freg3(c,r) # regional share shifter #;
    (All,c,COM) (All,r,REG) freg4(c,r) # regional share shifter #;
    (All,c,COM) (All,r,REG) freg5(c,r) # regional share shifter #;

! Excerpt 3 of Regional Extension: !
! Regional Data !

Coefficient
(All,i,IND) (All,r,REG) REGSHR1(i,r) # regional output shares #;
(All,i,IND) (All,r,REG) REGSHR2(i,r) # regional investment shares #;
(All,c,COM) (All,r,REG) REGSHR3(c,r) # regional consumption shares #;
(All,c,COM) (All,r,REG) REGSHR4(c,r) # regional export shares #;
(All,c,COM) (All,r,REG) REGSHR5(c,r) # regional 'other' shares #;
Update
(All,i,IND) (All,r,REG) REGSHR1(i,r) = rgshr1(i,r);
(All,i,IND) (All,r,REG) REGSHR2(i,r) = rgshr2(i,r);
(All,c,COM) (All,r,REG) REGSHR3(c,r) = rgshr3(c,r);
(All,c,COM) (All,r,REG) REGSHR4(c,r) = rgshr4(c,r);
(All,c,COM) (All,r,REG) REGSHR5(c,r) = rgshr5(c,r);

Read
REGSHR1 From File KDATA Header "R001";
REGSHR2 From File KDATA Header "R002";
REGSHR3 From File KDATA Header "R003";
REGSHR4 From File KDATA Header "R004";
REGSHR5 From File KDATA Header "R005";

! Regional Income Shares are calculated from regional production shares: !
Coefficient
(All,i,IND) (All,r,REG) REGV1LAB_OL(i,r) # labour bills #;
(All,r,REG) REGV1LAB_IOL(r) # labour bills #;
(All,r,REG) REGINCshr(r) # share region r in national labour bill #;
Formula
(All,i,IND) (All,r,REG) REGV1LAB_OL(i,r) = V1LAB_OL(i)*REGSHR1(i,r);
(All,r,REG) REGV1LAB_IOL(r) = Sum(i,IND, REGV1LAB_OL(i,r));
(All,r,REG) REGINCshr(r) = REGV1LAB_IOL(r)/ V1LAB_IOL;
Display
REGV1LAB_IOL;

```

```

REGINCSHR;      ! Total should be unity !

Coefficient      ! check shares add to 1 !
(All,i,IND) REGSHRCHECK1(i) # regional output shares #;
(All,i,IND) REGSHRCHECK2(i) # regional investment shares #;
(All,c,COM) REGSHRCHECK3(c) # regional consumption shares #;
(All,c,COM) REGSHRCHECK4(c) # regional export shares #;
(All,c,COM) REGSHRCHECK5(c) # regional 'other' shares #;

Formula
(All,i,IND) REGSHRCHECK1(i) = Sum(r,REG,REGSHR1(i,r));
(All,i,IND) REGSHRCHECK2(i) = Sum(r,REG,REGSHR2(i,r));
(All,c,COM) REGSHRCHECK3(c) = Sum(r,REG,REGSHR3(c,r));
(All,c,COM) REGSHRCHECK4(c) = Sum(r,REG,REGSHR4(c,r));
(All,c,COM) REGSHRCHECK5(c) = Sum(r,REG,REGSHR5(c,r));

Display          ! should all be 1 !
REGSHRCHECK1;
REGSHRCHECK2;
REGSHRCHECK3;
REGSHRCHECK4;
REGSHRCHECK5;

! Excerpt 4 of Regional Extension: !
! Regional Coefficients !

Coefficient (All,i,IND) (all,r,REG)
TOTSUPREG(i,r) # supply of local good i region r #;
Formula (all,i,IND) (all,r,REG)
TOTSUPREG(i,r) = V1TOT(i)*REGSHR1(i,r);

Coefficient (all,c,COM) (all,r,REG)
TOTDEMREG(c,r) # all basic + margin use of local good c, region r #;
Formula
(All,c,MAR) (All,r,REG)
TOTDEMREG(c,r) =
  Sum(i,IND,REGSHR1(i,r)*V1BAS(c,"dom",i)
    + REGSHR2(i,r)*V2BAS(c,"dom",i) )
+
  REGSHR3(c,r)*V3BAS_HR(c,"dom")
+
  REGSHR4(c,r)*V4BAS(c)
+
  REGSHR5(c,r)*V5BAS(c,"dom")
+ Sum(u,COM,REGSHR4(u,r)*V4MAR(u,c)
  +Sum(s,SRC,REGSHR3(u,r)*V3MAR_HR(u,s,c)
    + REGSHR5(u,r)*V5MAR(u,s,c)
  +Sum(i,IND,REGSHR1(i,r)*V1MAR(u,s,i,c)
    + REGSHR2(i,r)*V2MAR(u,s,i,c)   ));

Formula
(All,c,NONMAR) (All,r,REG)
TOTDEMREG(c,r) =
  Sum(i,IND,REGSHR1(i,r)*V1BAS(c,"dom",i)
    + REGSHR2(i,r)*V2BAS(c,"dom",i) )
+
  REGSHR3(c,r)*V3BAS_HR(c,"dom")
+
  REGSHR4(c,r)*V4BAS(c)
+
  REGSHR5(c,r)*V5BAS(c,"dom");

Coefficient (all,s,SEC) (all,r,REG) DEMRATIO(s,r) # zero ? #;
Formula (All,s,SEC) (All,r,REG)
DEMRATIO(s,r) = (TINY + TOTDEMREG(s,r))/(TINY + TOTSUPREG(s,r));
Display DEMRATIO;
! this will be 1 if region is just self-sufficient in a commodity !

! Excerpt 5 of Regional Extension: !
! Regional Equations !

! direct and marginal demands follow regional shares !

Equation E_regx1 # direct intermediate demands by industry and region #
(All,c,COM) (All,s,SRC) (All,i,ind) (All,r,REG)
regx1(c,s,i,r) = x1(c,s,i) + rgshr1(i,r);
Equation E_regx2 # direct investment demands by industry and region #
(All,c,COM) (All,s,SRC) (All,i,ind) (All,r,REG)
regx2(c,s,i,r) = x2(c,s,i) + rgshr2(i,r);
Equation E_regx3_hr # consumption by region #
(All,c,COM) (All,r,REG) (All,s,SRC)
regx3_hr(c,s,r) = x3_hr(c,s) + rgshr3(c,r);
Equation E_regx4 # exports by region #

```

```

(All,c,COM) (All,r,REG)
regx4(c,r) = x4(c) + rgshr4(c,r);
Equation E_regx5 # other demands by region #
(All,c,COM) (All,s,src) (All,r,REG)
regx5(c,s,r) = x5(c,s) + rgshr5(c,r);

Equation E_regx1mar # margin intermediate demands by industry and region #
(All,c,COM) (All,s,src) (All,i,IND) (All,m,MAR) (All,r,REG)
regx1mar(c,s,i,m,r) = x1mar(c,s,i,m) + rgshr1(i,r);
Equation E_regx2mar # margin investment demands by industry and region #
(All,c,COM) (All,s,src) (All,i,IND) (All,m,MAR) (All,r,REG)
regx2mar(c,s,i,m,r) = x2mar(c,s,i,m) + rgshr2(i,r);
Equation E_regx3mar_hr # margin consumption by region #
(All,c,COM) (All,s,src) (All,m,MAR) (All,r,REG)
regx3mar_hr(c,s,m,r) = x3mar_hr(c,s,m) + rgshr3(c,r);
Equation E_regx4mar # margin to export by region #
(All,c,COM) (All,m,MAR) (All,r,REG)
regx4mar(c,m,r) = x4mar(c,m) + rgshr4(c,r);
Equation E_regx5mar # margins to other by region #
(All,c,COM) (All,s,src) (All,m,MAR) (All,r,REG)
regx5mar(c,s,m,r) = x5mar(c,s,m) + rgshr5(c,r);

Equation
E_rgshr1 (all,i,IND) (all,r,REG)
rgshr1(i,r) = regx1tot(i,r) - x1tot(i);
E_rgshr2 (all,i,IND) (all,r,REG)
rgshr2(i,r) = rgshr1(i,r) + freg2(i,r) + ffreg2(i);
E_rgshr3 (All,c,COM) (all,r,REG)
rgshr3(c,r) = 1.0*EPS_HR(c)*(regwllab_iol(r) - wllab_iol)
+ freg3(c,r) + ffreg3(c);
!1.0 means regional consumption goes with regional income!
E_rgshr4 (All,c,COM) (all,r,REG) rgshr4(c,r) = freg4(c,r) + ffreg4(c);
E_rgshr5 (All,c,COM) (all,r,REG) rgshr5(c,r) = freg5(c,r) + ffreg5(c);

Equation ! Check (or ensure) that sum of regional shares doesn't change !
E_rsum1 (all,i,IND) Sum(r,REG, REGSHR1(i,r)*rgshr1(i,r)) = rsum1(i);
E_rsum2 (all,i,IND) Sum(r,REG, REGSHR2(i,r)*rgshr2(i,r)) = rsum2(i);
E_rsum3 (All,c,COM) Sum(r,REG, REGSHR3(c,r)*rgshr3(c,r)) = rsum3(c);
E_rsum4 (All,c,COM) Sum(r,REG, REGSHR4(c,r)*rgshr4(c,r)) = rsum4(c);
E_rsum5 (All,c,COM) Sum(r,REG, REGSHR5(c,r)*rgshr5(c,r)) = rsum5(c);
! above used for checking purposes: if endogenous, all rsums should be zero !

! Two possible closures for regional share Equations:
for example user 5 (other)
Green Book Option:
ffreg5(c) exogenous: should be zero
freg5(c,r) exogenous & shocked: weighted sum should be zero
regshr5(c,r) endogenous
rsum5(c) endogenous: should be zero
Modern Option:
ffreg5(c) endogenous: should be zero
freg5(c,r) exogenous & shocked: weighted sum need not be zero
regshr5(c,r) endogenous
rsum5(c) exogenous: should be zero
!

!
following 3 Equation blocks contain, for each region
NONMARLOCCOM + MARLOCCOM + NATIND Equations
= LOCCOM + NATIND Equations
= IND Equations
provided LOCCOM = LOCIND
!

Equation E_regx0_A # usage of nonmargins local commodities, DPSV eq39.8a #
(All,c,NONMARLOCCOM) (All,r,REG)
TOTDEMREG(c,r)*regx0(c,r) =
Sum(i,IND,REGSHR1(i,r)*V1BAS(c,"dom",i) *regx1(c,"dom",i,r)
+ REGSHR2(i,r)*V2BAS(c,"dom",i) *regx2(c,"dom",i,r))
+ REGSHR3(c,r)*V3BAS_HR(c,"dom")*regx3_hr(c,"dom",r)
+ REGSHR4(c,r)*V4BAS(c) *regx4(c,r)
+ REGSHR5(c,r)*V5BAS(c,"dom") *regx5(c,"dom",r);

Equation E_regx0_B # usage of margins local commodities #
(All,c,MARLOCCOM) (All,r,REG)
TOTDEMREG(c,r)*regx0(c,r) =
Sum(i,IND,REGSHR1(i,r)*V1BAS(c,"dom",i) *regx1(c,"dom",i,r)

```

```

+ REGSHR2(i,r)*V2BAS(c,"dom",i) *regx2(c,"dom",i,r))
+ REGSHR3(c,r)*V3BAS_HR(c,"dom")*regx3_hr(c,"dom",r)
+ REGSHR4(c,r)*V4BAS(c) *regx4(c,r)
+ REGSHR5(c,r)*V5BAS(c,"dom") *regx5(c,"dom",r)
+ Sum(u,COM,REGSHR4(u,r)*V4MAR(u,c) *regx4mar(u,c,r)
+Sum(s,SRC,REGSHR3(u,r)*V3MAR_HR(u,s,c) *regx3mar_hr(u,s,c,r)
+ REGSHR5(u,r)*V5MAR(u,s,c) *regx5mar(u,s,c,r)
+Sum(i,IND,REGSHR1(i,r)*V1MAR(u,s,i,c) *regx1mar(u,s,i,c,r)
+ REGSHR2(i,r)*V2MAR(u,s,i,c) *regx2mar(u,s,i,c,r) ));

```

Equation E_regxltot_A # output of national industries eq39.2, DPSV P.260 #
(All,i,NATIND) (All,r,REG)
regxltot(i,r) = xltot(i) + ffreg1(i) + freg1(i,r);

Equation E_regxltot_B # supplies of local commodities #
(All,c,LOCCOM) (All,r,REG)
regxltot(c,r) = regx0(c,r) + ffreg1(c) + freg1(c,r);

Equation E_regwllab_iol # wage bills by region #
(All,r,REG)
REGVLLAB_IOL(r)*regwllab_iol(r) =
Sum(i,IND, REGSHR1(i,r)*
Sum(o, OCC, V1LAB_L(i,o) *{rgshr1(i,r) + pllabb_1(i,o)+xllab_1(i,o)}));

! Excerpt 6 of Regional Extension: !
! Regional Display or Reporting Variables !
! this section could be deleted if desired !

Variable
(All,r,REG) regx1prim_i(r) # gross region products #;
(All,r,REG) regemploy_i(r) # aggregate regional employment #;
(All,i,IND) (All,r,REG) regx1primcon(i,r) # contributions to regional gdp #;
(All,i,IND) (All,r,REG) regemploycon(i,r) # contributions to regional empl #;
(All,i,IND) (All,r,REG) regemploy(i,r) # employment by reg and ind #;

Coefficient
(All,i,IND) (All,r,REG) REGV1PRIM(i,r) # factor bills #;
(All,i,IND) SHRPRIM(i) # share ind i in national output #;
(All,i,IND) (All,r,REG) REGSHRPRIM(i,r) # share ind i in output region r #;
(All,r,REG) REGV1PRIM_I(r) # total factor bill #;

Formula
(All,i,IND) (All,r,REG) REGV1PRIM(i,r) = V1VALAD(i)*REGSHR1(i,r);
(All,r,REG) REGV1PRIM_I(r) = Sum(i,IND,REGV1PRIM(i,r));
(All,i,IND) (All,r,REG) REGSHRPRIM(i,r) = REGV1PRIM(i,r)/REGV1PRIM_I(r);
(All,i,IND) SHRPRIM(i) = V1VALAD(i)/V1PRIM_I;

! By ORANI tradition, regional results have often been reported as a matrix of contributions by industry and region. For example, regx1primcon(i,r) is a breakdown which may be summed over industry to give the 'regional gdp' variable regx1prim_i(r); !

Equation E_regx1primcon
contributions to total regional outputs (primary factor weights) #
(All,i,IND) (All,r,REG)
REGV1PRIM_I(r) * regx1primcon(i,r) = REGV1PRIM(i,r) * regxltot(i,r);

Equation E_regx1prim_i # total regional outputs (primary factor weights) #
(All,r,REG)
regx1prim_i(r) = Sum(i,IND, regx1primcon(i,r));

Equation E_regemploy
employment by reg and ind #
(All,i,IND) (All,r,REG)
regemploy(i,r) = employ(i)+rgshr1(i,r);

Equation E_regemploycon
contributions to total regional employment (wage bill weights) #
(All,i,IND) (All,r,REG)
REGVLLAB_IOL(r)*regemploycon(i,r) = REGVLLAB_OL(i,r)*regemploy(i,r);

Equation E_regemploy_i # aggregate regional employment#
(All,r,REG)
regemploy_i(r) = Sum(i,IND, regemploycon(i,r));

! compute regional employment and output and the contributions by AGGSEC !

```

Variable
(All,agi,AGGSEC) (All,r,REG) aggregxlprimcon(agi,r) #conts to regional gdp #;
(All,agi,AGGSEC) (All,r,REG) aggregemploycon(agi,r) #conts to regional empl #;
(All,agi,AGGSEC) (All,r,REG) aggregemploy(agi,r) #employment by reg and ind #;
(All,agi,AGGSEC) (All,r,REG) aggregxltot(agi,r) #Activity Level/Value-Added#;
!by reg and ind #;!
(All,agi,AGGSEC) (All,r,REG) regadvantage(agi,r) # reg advantage decomposition #;

(All,r,REG) aggregemploy(r) #employment by region only#;
(All,r,REG) agrxlt(r) #Val Added by Region only#;

Equation
E_aggregxlprimcon # conts to regional gdp #
(All,agi,AGGSEC) (All,r,REG) aggregxlprimcon(agi,r) =
Sum(i,SEC:MAP103_46(i)=ORD46(agi),regxlprimcon(i,r));

Equation
E_aggregemploycon # conts to regional employment #
(All,agi,AGGSEC) (All,r,REG) aggregemploycon(agi,r) =
Sum(i,SEC:MAP103_46(i)=ORD46(agi),regemploycon(i,r));

E_aggregemploy # employment by reg and ind #
(All,agi,AGGSEC) (All,r,REG)
Sum(i,SEC:MAP103_46(i)=ORD46(agi),
(TINY+REGVLAB_OL(i,r))*{aggregemploy(agi,r)-regemploy(i,r)})=0;

E_aggregxltot # output by reg and ind #
(All,agi,AGGSEC) (All,r,REG)
Sum(i,SEC:MAP103_46(i)=ORD46(agi),
(TINY+REGVPRIM(i,r))*{aggregxltot(agi,r)-regxltot(i,r)})=0;

E_aggrxlt # output by reg #
(All,r,REG)
Sum(i,IND, (TINY+REGVPRIM(i,r))*{aggrxlt(r)-regxltot(i,r)})=0;

E_aggregemploy # employment by reg and ind #
(All,r,REG)
Sum(i,IND, (TINY+REGVLAB_OL(i,r))*{aggregemploy(r)-regemploy(i,r)})=0;

Equation
E_regadvantage# regional advantage decomposition #
(All,agi,AGGSEC) (All,r,REG)
regadvantage(agi,r) =
Sum(i,SEC:MAP103_46(i)=ORD46(agi),
SHRPRIM(i)*{xlprim_i-xltot(i)} + REGSHRPRIM(i,r)*{regxltot(i,r)-xlprim_i} );

Coefficient
(All,agi,AGGSEC) AGGSHRPRIM(agi) # AGGSEC shares in national output #;
(All,agi,AGGSEC) (All,r,REG)
AGGREGSHRPRM(agi,r) # AGGSEC shares in output region r #;

Formula
(All,agi,AGGSEC) AGGSHRPRIM(agi) =
Sum(i,SEC:MAP103_46(i)=ORD46(agi), SHRPRIM(i) );
(All,agi,AGGSEC) (All,r,REG) AGGREGSHRPRM(agi,r) =
Sum(i,SEC:MAP103_46(i)=ORD46(agi), REGSHRPRIM(i,r) );

Display
AGGSHRPRIM;
AGGREGSHRPRM;

!
REGIONAL ADVANTAGE MATRIX
another decomposition for explaining regional results -

x(r) - x = state gdp relative to national

= SUM_OVER_IND { [S(i,r)-S(i)] * [x(i)-x]
+ S(i,r) * [x(i,r)-x(i)] }

where S(i,r) = share ind i in output region r
and S(i) = share ind i in national output

```

```

expanding:
x(r) - x = SUM_OVER_IND { S(i,r)*x(i) - S(i,r)*x
                        -S(i)*x(i) + S(i)*x
                        + S(i,r)*x(i,r) - S(i,r)*x(i) }

cancelling S(i,r)*x(i) terms:
x(r) - x = SUM_OVER_IND { - S(i,r)*x -S(i)*x(i) + S(i)*x + S(i,r)*x(i,r) }

regrouping:
x(r) - x = SUM_OVER_IND { S(i)*[x-x(i)] + S(i,r)*[x(i,r)-x] }

AIM: report the RHS terms by region and broad ind

check:
using SUM_OVER_IND { - S(i,r)*x } = - x :
and SUM_OVER_IND { S(i)*x } = x
and SUM_OVER_IND { - S(i)*x(i) } = x
x(r) - x = x - x - x + SUM_OVER_IND { S(i,r)*x(i,r) }
          = - x + SUM_OVER_IND { S(i,r)*x(i,r) }
using SUM_OVER_IND { S(i,r)*x(i,r) } = x(r)
          = x(r) - x
!

! end of regional extension !

! *****

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Beleidsanalise in Suid Afrika
met
Regionale Toegepaste Algemene Ewewigsmodelle

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Verhandeling voorgelê ter gedeeltelike nakoming van die vereistes vir
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Uittreksel

Die navorsingsvraag wat aangespreek word in hierdie studie is om eerstens die toepaslikheid en uitvoerbaarheid van 'n Regionale Toegepaste Algemene Ewewigsmodel (RTAE) in die Suid Afrikaanse konteks vir beleidsmakers te illustreer. Tweedens verskaf die studie voorstelle vir die konstruksie van 'n RTAE om beleidsmakers te help om ondersoeke te doen oor ruimtelike of regionale (subnasionale) effekte en beleidskeuses deur middel van 'n meer gesofistikeerde benadering (as net 'n vereenvoudigde bo-na-onder proporsionele aanslag of parsiele ewewigsmodelle) wat sal veroorsaak dat meer konsekwente resultate en effekte verkry word met betrekking tot die ruimtelike of regionale implikasies van sulke effekte.

Hierdie studie is 'n poging om hierdie tekortkoming aan te spreek deur die behoefte na so 'n modelleringsvermoë te ondersoek en te illustreer. Dit word bereik deur die waarde en potensiaal van 'n RTAE te illustreer deur gebruik te maak van 'n vereenvoudigde bo-na-onder proporsionele regionale voorbeeld. Meer spesifiek word die tekortkominge van so 'n benadering uitgewys en die saak gestel vir 'n onder-na-bo aanslag.

'n Literatuurstudie is uitgevoer om te bepaal watter tipes RTAE bestaan, asook om verskillende metodologiese aanslagte vir regionale of ruimtelike Toegepaste Algemene Ewewigsmodelle (TAE) uit te wys. 'n Vereenvoudigde bo-na-onder model gebaseer op die Nywerheids Ontwikkelings Korporasie (NOK) van Suid Afrika se bestaande model was aangewend vir illustratiewe simulاسies. Hierdie illustratiewe simulاسies het sommige van die tekortkominge van 'n bo-na-onder aanslag tot regionale Toegepaste Algemene Ewewigsmodelle uitgelig deur middel van voorbeelde vir elektrisiteitsprys en volume skokke.

Ten slotte bied hierdie studie voorstelle aan vir toekomstige navorsing aangaande die ontwikkeling van Regionale Toegepaste Algemene Ewewigsmodelle vir die Suid Afrikaanse ekonomie. Die huidige werk deur die Ontwikkelingsbank van Suid Afrika aangaande provinsiale sosiale rekeninge matrikse word ook in ag geneem. Die uitvoerbaarheid van 'n gemengde bo-na-onder en onder-na-bo Regionale Toegepaste Algemene Ewewigsmodel word ook geillustreer en moontlike toekomstige ontwikkelinge in die verband word voorgestel.

Sleutelwoorde: Toegepaste Algemene Ewewigsmodel, Berekenbare Algemene Ewewigsmodel, Energie Beleid, Elektrisiteit, Ekonomiese Ontwikkeling, Suid Afrika.