General equilibrium modelling in South Africa: What the future holds

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Abstract

This paper provides an overview of the main research contributions of the past decade using general equilibrium models to analyse agricultural issues in South Africa. The methodological developments since the change to democracy ten years ago are viewed in the context of developments in this area of research carried out internationally. It will be shown in this paper that the modelling and computing techniques have vastly improved during the past decade, both in an ongoing attempt to refine existing models, and in an attempt to extend the modelling framework to make provision for issues that cannot be sufficiently captured in the standard comparative static models. These extensions include dynamic modelling, global modelling, environmental modelling and micro simulation. The paper highlights the non-trivial data requirements of this type of modelling. The national statistical agency, Statistics South Africa, supports general equilibrium modellers by their development of input-output tables, social accounting matrices and, more recently, supply and use tables. This decade has therefore witnessed an improvement in the data for the construction of national level social accounting matrices. Requirements for provincial level data have however not been met sufficiently, posing huge challenges for provincial and regional modelling. The lack of primary data has however stimulated development of advanced data estimation techniques that can be applied to overcome this data challenge. Application of general equilibrium techniques to analyse agricultural issues in South Africa still remains limited and substantial support and training of researcher is still needed to expand domestic capacity in this field of research.

1. Introduction

This paper provides an overview of the developments in the area of general equilibrium modelling with specific reference to domestic research contributions focusing on agricultural issues. Although general equilibrium modelling from a theoretical perspective is strongly rooted in the field of Economics rather than Agricultural Economics, the potential of general equilibrium modelling to inform policy analysis with regard to the agricultural industry makes it of interest to Economists and Agricultural

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Economists alike. The agricultural industry has been the focus of numerous studies using these techniques and the distinction between agricultural production vs. non-agricultural production and rural vs. urban households is often retained even in the most aggregated of models for developed and developing countries. This phenomenon conveys that the agricultural sector and the rural populations who derive their livelihoods from the land, are considered to have unique characteristics that warrants careful consideration in policy analysis.

In the context of this paper general equilibrium modelling refers to whole economy models that recognise interindustry interdependencies in an economy when estimating the impact of an exogenous shock to an economy. Specifically reference will be made in this paper to Input-Output models, SAM-Leontief models and Computable General Equilibrium (CGE) models and the distinctive underlying data required to calibrate the respective models. In an attempt by researchers to address a diverse range of issues with general equilibrium models, variants of the core models have emerged over time, some of which are highlighted in the discussion.

The next section reviews the concept of the circular flow in the economy to provide a base for the discussion of the developments of databases used in general equilibrium modelling that follows in sections three and four respectively. In order to grasp the extent of the contributions in general equilibrium modelling it is necessary to view it in a global context. Model developments internationally and domestically are therefore discussed in section four. Section five indicates the areas of future developments in the area of databases and CGE modelling. Section six draws on the previous sections in providing a summary of some of the economic questions that can be suitably addressed using the general equilibrium framework. As part of this section an overview is given of current initiatives in South Africa to address some of these issues. The paper concludes with the authors' perspective on the way forward.

2. An overview of general equilibrium models

One approach to an understanding of the development of general equilibrium models is to consider them in context of the circular flow (see Figure 1). Early developments based upon Leontief's input-output schema, with its emphasis upon inter-industry transactions, did not fully satisfy the concept of a general equilibrium due to a discontinuity in the circular flow because transactions between households and factor markets, and between factor markets and the rest of the world were not articulated (this is indicated by the dotted lines in Figure 1). This requires that substantial components of economic systems are treated as exogenous in models calibrated using input-output data, e.g. the volumes of final demand and labour supply, and relative prices (or very occasionally relative quantities) were held constant. The development of national accounts after the second world war, largely inspired by Richard Stone and James Meade, provided the impetus to extend Leontief's schema to capture the full circular flow (see Stone, 1961) and to use the information content to extend the depth of economic analyses by endogenising all the major economic relationships (see Stone and Croft-Murray, 1959 and Stone, 1962). Subsequently the concern increasingly focused upon the impact of changes in economic relationships upon the lives of those in society (Stone 1982, 1984, 1985) and income distribution (Stone, 1985 and Pyatt *et al*, 1977). Early developments along this route were achieved by extending Leontief's input-output database to generate social accounting matrices (Stone and the Cambridge Growth Project) and adapting Leontief's model to the context of a SAM in the form of SAM-Leontief (multiplier) models. Such models however retained the limitations whereby substantial components of economic systems were treated as exogenous and relative prices (or occasionally relative quantities) were held constant. The subsequent relaxation of these limitations whereby 'all' prices and quantities were rendered endogenous is the realm of modern day computable general equilibrium (CGE) models.

Any review of the literature of applied general equilibrium (AGE) models rapidly reveals how intimate has been the development of data and models, and how developments in the realm of data have allowed developments in the realm of models, and how pressures to extend the scope of models has encouraged developments of the databases. Despite this the discussion will proceed by first examining the development of general equilibrium (GE) databases and then by examining the development of GE models; however while this separation between the two is somewhat artificial it not only aids exposition, but also serves to emphasise the fact that models and associated databases are functionally separate with the databases being *ex-post* accounting identities while the behavioural relationships are embedded in the models. Hence any one database can support a multitude of different models, where the model differences are embedded in the behavioural specifications.

3. Databases

Stone (1978), Miller and Blair (1985) and Naudé (1993) provide detailed historic overviews of the development of social accounting and general equilibrium modelling. In short, the precursors to modern day general equilibrium modelling can be traced back to the seventeenth century when William Petty reported the first estimates of national income of Britain and Gregory King compiled what can be considered the first social accounting matrices for England, France and Holland with the purpose of determining the contribution made to wealth by various groups in society. In 1758 Francois Quesnay, French economist and physician of Louis XV, published an Economic Table that was a diagrammatic representation of how expenditures can be traced through an economy in a systematic way. He used this table to warn of the imminent danger of revolution in France. It was however not till many years later that the concepts we are familiar with today were formalised.

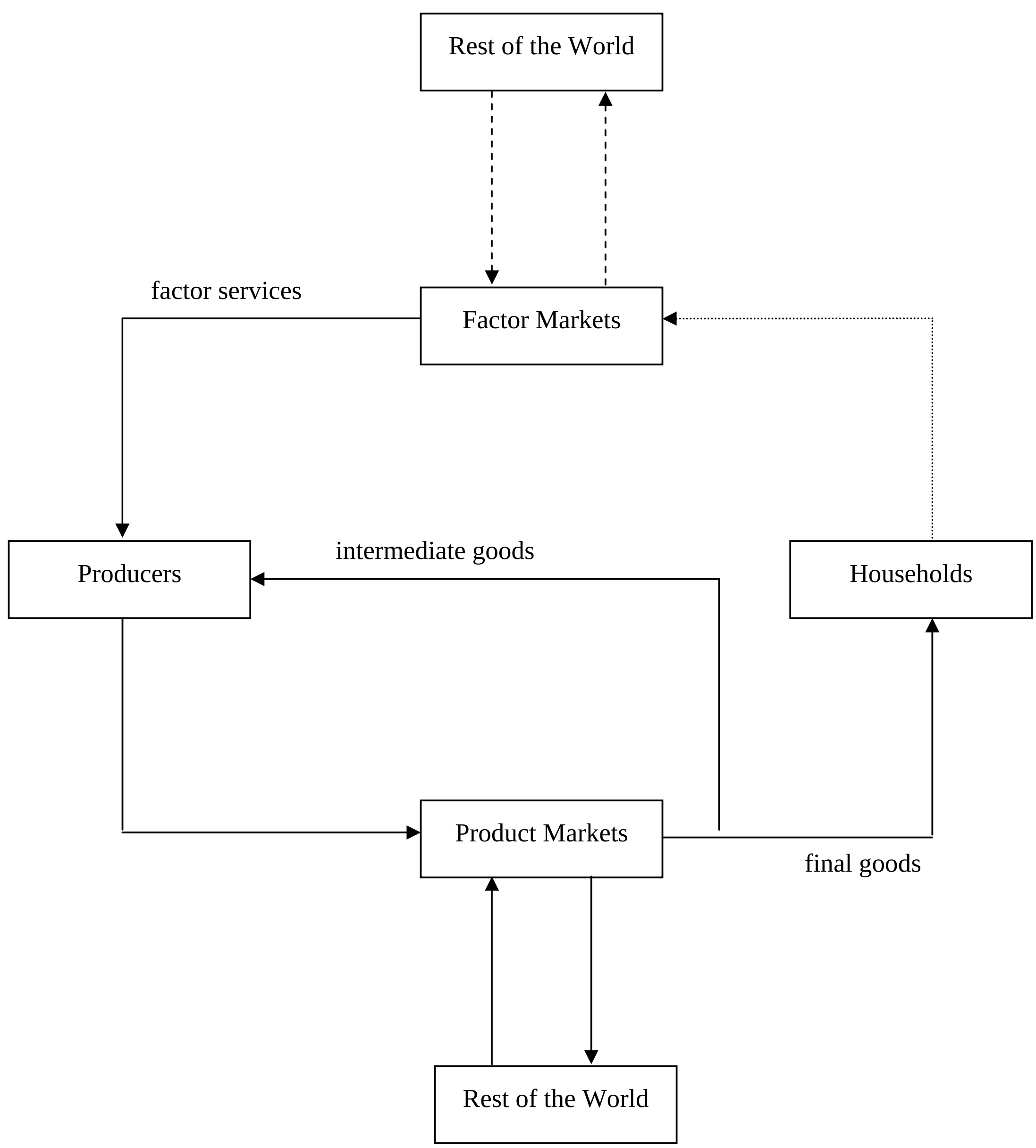

Figure 1: The Circular Flow[3]

[3] *In this representation the arrows indicate the direction of physical flows; financial transactions flow in the reverse direction.*

At the heart of all quantitative analyses of economic systems, be it a modern macroeconomic model and/or some other form of whole economy model, will be found estimates of national accounts. Indeed so central are such national accounts to the work of economists it is easy to forget how short is the history of (formal/institutionalised) national accounting, especially since the 'wealth of a nation' appears to be a concept that has lain at the very root of economic analyses for more than two centuries (Stone, 1978, provides a brief historical review). But despite the importance of national accounts it is surprising to find how ill-informed many economists are about the issues and problems faced by national account statisticians; with the gap between economists and statisticians seeming to grow with the increasing sophistication of modern economics. This is arguably a source of substantial concern since it suggests that economists are forgetting that the development of national accounts was inspired directly by developments in macroeconomics, especially the Keynesian revolution, and with it the attendant need to understand how economic systems actually operate. This is not just of historical interest. In the development of national accounts there has been a strong history of dialogue between the compilers and the users of national accounts; this dialogue has had important consequences in that it has ensured that conventions for the compiling of national accounts have incorporated considerations about the use of national accounts in economic analyses. Indeed this is one of the enduring legacies of Richard Stone's contribution to economics. This has meant that national accounts, if compiled in line with SNA guidelines, adopt definitions and conventions that ensure they can be used meaningfully as a basis for economic analyses and not solely as a mechanical accounting exercise that describes an economy at a particular point in time. Consequently it is disappointing that so many economists fail to recognise the difficulties confronted by national account statisticians and the extent to which the task of compiling national accounts is often as much art as science.

Below is a brief review of national accounts followed by a more detailed review of disaggregated South African national accounts (see United Nations, 1968; 1993, for detailed descriptions of national accounting conventions).

3.1 National accounts

3.1.1 T-accounts

The most well known form for the presentation of detailed national accounts is as a series of T-accounts, which follow the standard double entry bookkeeping practice where incomes are recorded in the left hand column and expenditures in the right hand column. Table 1 provides a stylised T-account for the private household; income comes from three sources – employment, property and transfers – and there are four forms of expenditure – consumption, taxes, transfers and savings. Consequently it would be expected that savings and income taxes by the private household will also be recorded as incomes in the capital and government accounts respectively. If each T-account is fully reconciled with ALL other T-accounts, i.e., each and every income item has a matching expenditure item in another account, then the accounts will be consistent. Note also how the fundamental *ex-post* accounting identity that total income equals total expenditure is satisfied; if it not satisfied for all the T-accounts then the system of accounts is incomplete. A complete and consistent set of national accounts will record the full circular flow of an economy. Such a system of national accounts underlies the national accounts for South Africa (see South African Reserve Bank Quarterly Bulletins).

Table 1: Stylised T-account for private household

Incomes		**Expenditures**	
Income from employment	75	Private consumption	63
Income from property	15		
		Income taxes	12
Transfers from government	8		
Transfers from rest of world	2	Transfers to rest of world	4
		Savings	21
Total	100	**Total**	100

The familiarity of this representation to economists should not be surprising since it underpins Keynesian macroeconomics and such national accounts were primarily driven by the needs of Keynesian macroeconomics literature and the need to quantify the major macroeconomic aggregates.

3.1.2 Input-output and national accounts

A substantial omission from aggregate national accounts is detail about transactions between the agents within each aggregate. Thus while aggregate national accounts identify payments to labour and capital in the production accounts they often do not provide details about the use of labour and capital by different activities nor do they provide information about purchases and sales of intermediate inputs. However in the late 1930's Wassily Leontief produced a data framework that is known today as an input-output table (Leontief, 1953), and whose fundamental objective is to provide data about transactions between industries in an economy.

An important development in national accounting was the integration of input-output data into national accounts (see Stone, 1961), which was made a central feature of the revised 1968 System of National Accounts (SNA). However it is important to note that the input-output data were presented in two or three tables; a make/supply table and one or two absorption/use tables.[4] An input-output table is symmetric in that the row and column labels and totals are identical, and therefore the table is square, whereas supply and use tables are asymmetric in that the row and column labels and totals are not necessarily identical, and therefore the tables are not necessarily square. In supply and use tables the row accounts are for products/commodities and the column accounts are for activities; each column of the supply table therefore identifies the values of different commodities produced by each (multi-product) activity while each column of the use table(s) identifies the values of different inputs used by each activity. The standard (SNA) approach is to collect data in supply and use formats and then to derive an input-output (or analytical) table as a reduced form by adjusting the use matrix using information from the supply matrix.[5]

By combining and reconciling the information in aggregate macroeconomic accounts and input-output databases a much richer characterisation of the production and consumption structures of economies was produced. But aggregate macroeconomic and input-output data provide limited information about factor use and inter-institutional transactions; typically they identify only a single household account and two or three factor accounts. It is this limitation that Stone and colleagues addressed with the development of Social Accounting Matrices (SAMs).

3.1.3 Social accounting matrices

A SAM is an extension of an input-output table and includes more detailed information on institutions and production factors. The development of fully articulated SAMs was largely undertaken by the Cambridge Growth Project and, in the context of developing countries, by Graham Pyatt and associates. The first modern SAM for a developing country was produced in 1972 for Iran by Graham Pyatt; subsequently Pyatt and various associates produced SAMs for Sri Lanka (Pyatt *et al*, 1977) and several other developing countries (e.g. the country studies in Pyatt & Round, 1985).

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[4] *The earlier literature used the labels make and absorption for these tables, but in recent years the labels supply and use have become the norm. The modern labels will be used for the rest of this paper.*

[5] *This approach greatly simplifies the collection and compilation of data, but it does have the arguable disadvantage of meaning that there is no such thing as a unique input-output table (see Millar & Blair, 1985 for an introduction to the methods for forming symmetric input-output tables). Leontief endorsed the supply and use approach by the US Bureau of Economic Analysis (Landefeld & McCulla, 1999).*

While the revised 1968 SNA established the integration of macroeconomic and input-output data, SAMs did not become an integral part of the SNA until the 1993 revision (United Nation, 1993). Moreover, as is made clear in the SNA, a SAM provides a comprehensive synthesis of the (real) macroeconomic accounts, input-output data and inter-institutional transactions for an economy; as such it is the most comprehensive method for presenting data for the real economy at an aggregate level. In most SAMs the focus is however still on the production structure, at the expense of details about the distribution of factor payments to households; but this is mostly a reflection of data collection, estimation and reconciliation problems rather than an inherent limitation of the SNA. (Some advances in data estimation techniques are discussed in section 3.3.)

In fact a SAM is little more than a single entry representation of the T-accounts for each and every agent identified by the row and column labels, and if a SAM is complete and consistent then the row and column totals will be identical, i.e., incomes and expenditures will be identical for each and every agent. A stylised representation of a SAM is provided in Table 2.[6] In general SAMs are constructed with 6 types of account and each type may contain numerous (sub) accounts:

- Commodity accounts
- Activity (or production) accounts
- Factor accounts
- Institutional accounts
- Capital accounts
- Rest of the World accounts.

Commodity accounts record the demand for and supply of commodities in the economy. The row accounts identify the distribution of commodities between intermediate and final demand. Final demands for commodities can be sub-divided into domestic final demand and foreign final demand. The domestic components consist of demand from different institutions, i.e., households, government and incorporated enterprises, and for investment, both in terms of gross domestic fixed capital formation and inventory changes. The rest of the

[6] *This stylised SAM is a reduced form of the SAM structure presented in the 1993 SNA; it is adopted here because it is adequate for the current needs and it saves space.*

Table 2: A stylised social accounting matrix

	Commodities	Activities	Factors	Households	Enterprises	Government	Capital	RoW	Total
Commodities	0	Intermediate Inputs (USE)	0	Household Demand	Enterprise Demand	Government Demand	Investment Demand	Commodity Exports	Total Commodity Demand
Activities	Domestic Production (SUPPLY)	0	0	0	0	0	0	0	Gross Output
Factors	0	Factor Demand	0	0	0	0	0	Factor Income from RoW	Factor Income
Households	0	0	Distributed Factor Income	Inter-Household Transfers	Distributed Dividends	Transfers	0	Remittances	Total Household Income
Enterprises	0	0	(Un)Distributed Factor Income	0	0	Fixed (Real) Transfers	0	Transfers	Total Enterprise Income
Enterprises	0	0	(Un)Distributed Factor Income	0	0	Fixed (Real) Transfers	0	Transfers	Total Enterprise Income
Government	Tariff Revenue VAT Other Taxes on Commodities	Indirect Taxes on Activities	Distributed Factor Income	Direct Taxes on Household Income	Direct Taxes on Enterprise Income	0	0	Transfers	Total Government Income
Capital	0	0	Depreciation	Household Savings	Enterprise Savings	Government Savings (Internal Balance)	0	Current Account 'Deficit'	Total Savings
Rest of World	Commodity Imports	0	Distributed Factor Income	0	0	0	0	0	Total 'Expenditure' Abroad
Total	Total Commodity Supply	Total Activity Inputs	Total Factor Expenditure	Total Household Expenditure	Total Enterprise Expenditure	Total Government Expenditure	Total Investment	Total 'Income' from Abroad	

world account records the exports of goods and services, valued in domestic currency terms at the prices paid by the rest of the world, i.e., free on board (fob).[7] Commodities can be supplied to an economy from two different sources. The supply matrix records the total value of all commodities manufactured by domestically based activities, whereas the rest of the world account identifies the carriage, insurance and freight (cif) value, in domestic currency terms of imported goods and services. The trade and marketing margins are recorded in the commodity-by-commodity matrix, and by definition sum to zero because of the negative entries in the columns for transport and marketing services. Commodity taxes cover trade taxes (tariffs and export taxes) and sales taxes; each tax should be linked to the transactions to which it refers.

The *activity accounts* record transactions by the productive activities of an economic system and provide information about the generation of value added within the economy. The column entries identify purchases of intermediate inputs, both domestic and imported, payments to factors of production and production taxes/subsidies. The total value of payments to factors and indirect taxes constitutes gross domestic product (GDP), and the column sums record the total inputs to productive activities. Entries in the activity rows identify the commodities produced by each activity - the so-called supply matrix.

Incomes to *factors* can come from employment of factors by domestic activities or as payments for domestically owned factors used in the rest of the world. The former constitutes Gross Domestic Product (GDP) whereas the combination of the two is Gross National Product (GNP), both at factor cost. As with factor incomes, the payments for factor services to the rest of the world are often in respect of capital services.[8] Typically households own all labour services. Consequently, payments to domestically based factor owners are distributed across the different types of households as labour income and distributed profits, and to (incorporated) enterprises as non-distributed profits. These distributions take place after the payment of factor specific taxes, e.g. social security and unemployment insurance contributions, to the

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[7] *An important alternative that is used in the majority of CGE models is that exports and export subsidies are treated as activity (row) accounts. The commodity accounts then emphasise domestic production for the domestic market, and require the supply matrix to have entries only on the principal diagonal. Furthermore, if the supply matrix is diagonal the use matrix is a symmetric input-output table. In this case all imports are treated as competitive, as opposed to complementary. An input-output SAM is thus derived by eliminating the activity row and the commodity column. Hence intermediate inputs in the use matrix will be only domestically produced goods, while the activity row will record imports.*

[8] *Historically remittances by migrant workers based in South Africa to other regions of southern Africa were important to the recipient economies.*

government. The degree of disaggregation in the factor accounts is important. If the SAM is to serve as the basis for assessing the income distribution implications of policy changes for different households there needs to be sufficient disaggregation of the factor accounts to ensure the distributional implications of policy changes/shocks feed down to the household level (see Pyatt, 1994a). This becomes a particularly important consideration when a SAM is being used to calibrate an economic model.

The *institutional accounts* include different households, enterprises and the government. Much of the richness of economic detail provided by a SAM is recorded through the transactions by and between institutions. The decisions about the *household* classification scheme are critical. The choice of household groups should reflect the socio-economic structure of households in the economy, and if the SAM is to provide a sound basis for economic models the classification should distinguish between households on the basis that they have different preferences/behaviours. Thus simply classifying households on the basis of relative income levels may not be appropriate if there are identifiable sub-groups with distinctly different preferences, e.g. consumption patterns may be influenced by social and religious customs. *Households* receive incomes from a wide variety of sources, although their principal source of income is generally from the sale of labour and, to a lesser, extent capital services. This reflects the presumption that households ultimately own factors of production, either domestic or foreign. Other sources of income include transfers from incorporated enterprises and the government and inter household transfers. In some economies remittance incomes are an important component of household incomes, and economic models have indicated that large remittance incomes can have appreciable economic implications. Household expenditures are distributed between direct taxes paid to government, savings, transfer (domestic and foreign) and consumption expenditure.

A major reason for including incorporated *enterprises* derives from the treatment of the 'undistributed profits' of activities. Typically activities only distribute a proportion of the payments for capital services directly to households with the remainder being paid to enterprises that make decisions about investments and dividends to shareholders out of profits. This is often supplemented by profits 'repatriated' from activities operating overseas and, less often, by transfers from government. On the expenditure side the major items are usually savings, i.e., the direction of profits towards investment via the capital account, and direct taxes on enterprises (often called corporation tax). Lesser items are transfers to households and the rest of the world.

The degree of detail in the *government accounts* is an important determinant of the richness of policy detail that can be captured in models calibrated using the SAM. The government income accounts should provide details about the revenue from all the substantive tax instruments available to and used by the government. These different sorts of revenue may also be differentiated by reference to the layer of government, e.g. national, provincial or municipal, responsible for collecting and/or setting the rates. The expenditure side of the government accounts is usually much simpler. Commodity expenditures are limited to the products of the government's productive activities. Getting details on the patterns of transfers to households can be difficult, but is often important because of the information it conveys about the (revealed) preferences of government. The most important entry however is government saving, also known as the internal balance or the government's budget deficit/surplus. Not only is this important because it is often used to assess the performance of the government, but also because it is commonly used as a target of government (fiscal) policy, e.g. 'the government aims to reduce its budget deficit this year'.

The *capital account* refers to investment and its funding. Income to the capital account comes from savings by institutions – households, enterprises and the government – and this is gathered together in the row.[9] To these savings, which originate domestically, must be added savings in the economy by foreign agents, i.e. the surplus/deficit on the capital account of the balance of payments (external balance). The balance of payments serves as an important indicator of the effectiveness of government policy/management. Expenditures by the capital account, in the column, record investments; and are often limited to investment expenditure (Gross Domestic Fixed Capital formation).

The *rest of the world accounts* record the trade transactions, which are important if trade policy issues are to be analysed. These include current and capital accounts, and visible and invisible trade. The number of accounts for the rest of the world depends on the research questions and the availability of data. In the South African context there are reasons to differentiate between the trade relations with other SACU states – that are tariff free – and other countries against whom their are trade duties.

3.2 Input-output and social accounting matrices in South Africa

South Africa has never published an official version of a fully articulated input-output table. For many years Statistics South Africa (StatsSA), and its

[9] *It is common for allowances for depreciation to be treated as an income item to the savings account.*

predecessor the Central Statistical Service (CSS)[10], produced a series of tables that were called input-output tables but were in fact asymmetric USE tables – the absence of matching SUPPLY tables made the derivation of true/symmetric input-output tables impossible. The recent publication of Supply and Use tables by StatsSA (StatsSA, 2003) has gone a long way towards addressing these deficiencies but some residual problems remain. Specifically the published Supply and Use tables are not fully reconciled with the macroeconomic aggregates published by the South African Reserve Bank of (SARB) – see the residual errors column.[11]

This absence of supply side information carried over into the early, so-called, SAMs for South Africa and the Western Cape (Eckert and Van Seventer, 1995); by definition these SAMs were neither complete nor consistent and hence their immediate usability for CGE models was substantially compromised. Nevertheless these data have, over the years, been used to develop SAMs for use in CGE models of South Africa, which means that users must have reconciled the accounts, but explicit statements about how these reconciliations were achieved are very rare.[12]

3.2.1 Official 'input-output' tables and social accounting matrices

In South Africa national input-output/use tables were compiled by StatsSA for 1967, 1971, 1975, 1978, 1981, 1984 and 1988, 1989 and 1993 (StatsSA, 2004a), and for at least some of these years produced both domestic and imports use matrices, although all the tables were not always published. More recently StatsSA has released supply and use tables, for 1993, 1998, 1999 and 2000 (StatsSA, 2004a). The absence of the information in supply tables means that it is not possible to use conventional methods to derive symmetric/true input-output tables from the earlier use matrices, while the absence of (published) imports use matrices for the latter period mean it remains difficult to derive input-output tables by conventional methods. Three national SAMs have been published by StatsSA, for 1978, 1988 and 1998 (StatsSA, 2004a). The 'SAMs' for 1978 and 1988 do not strictly meet the definition of a SAM (see below), but the

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[10] *For convenience the text will refer to Statistics South Africa and the Central Statistical Service using the current name, i.e, StatsSA.*

[11] *The decision by StatsSA to publish these errors is praiseworthy since it avoids the implication that the data are fully reconciled and alerts users to some of the potential problems with the data.*

[12] *McDonald and Robinson (1998) report on the use of entropy econometrics to estimate the missing supply table.*

SAM for 1998, which was based on the first supply and use tables, does fully conform to the definition of a SAM.

The SAMs for 1978 and 1988 lacked the information that would have been provided by a supply table; in effect the SAMs were formed by deleting the activity account rows and the commodity account columns (see Table 2 to visualise the process), by treating imports as complementary, i.e., as purchases by agents rather than by the commodity accounts[13], and allowing for secondary production by domestic by including two rows of 'transfers' that ensured the row and column totals equated.[14] It is unclear however precisely what the valuation basis was for these SAMs. For the 1998 SAM StatsSA closely followed the System of National Accounts (SNA) in its structure, by using a two stage, first and second, mapping for the distribution of income. This is entirely appropriate and consistent from the perspective of using the SAM as a database to get a complete and consistent representation of the national accounts data. The resulting SAM is clearly a substantial advance on the earlier SAMs since it contains a much more complete representation of the production structure of the economy, although arguably this is at the expense of detail about people, although the absence of a full reconciliation of the data with the macroeconomic aggregates published by SARB is a cause for concern.

It is arguable that the SAM is limited for two/three reasons; the limited number of factor and (representative) household accounts and, from a food and agriculture perspective, the lack of disaggregation of the activity and commodity accounts for agriculture. The first two affect the information on factor and household incomes and mean that the SAM is not a rich source of information about income distribution in South Africa. While the use of single agricultural commodity and activity accounts does not do justice to the range of agricultural production systems and commodities produced in South Africa. These perceived weaknesses have prompted academia, government and consultants to become involved in the estimation of SAMs that provide richer sources of information to support modelling exercises that place greater emphasis upon income distribution and agriculture.

3.2.2 Unofficial social accounting matrices

For a variety of reasons, including the issues raised in the previous section, a number of 'unofficial' SAMs for South Africa have emerged over time from

[13] This step made use of the information in the imports use matrices.

[14] These transfers actually identify the sums of the off-diagonal entries in an (implicit) supply table. McDonald and Robinson (1998) used this information to estimate a supply table for South Africa.

different sources; most of these have been inspired by the needs of various GE models. The economists at the World Bank have conducted a number of CGE studies of the South African economy, e.g. Devarajan and Van der Mensbrugghe (1994), Arndt and Lewis (2000) and Go *et al* (2004)[15], all of which were based upon SAM databases. Other SAMs were developed in association with the International Food Policy Research Institute, e.g. Thurlow and Van Seventer (2002), through research projects at the University of Pretoria and the Department of Agriculture in the Western Cape, e.g. McDonald *et al* (2001), and by Conningarth Consultants. Other databases that should be able to satisfy the criteria to be classed as SAMs have also been developed. For a number of years the Industrial Development Corporation ran a CGE model developed for them by Centre for Policy Studies in Australia, the data for this would conform to the properties of a SAM, and there was a CGE model in the mid 1990s inspired by the Development Bank of Southern Africa whose database probably could have been represented in a SAM format, see Gibson and Van Seventer (1996).

All these SAMs made use, to a greater or lesser extent, of the inter-industry data published by StatsSA, but sought to augment those data with additional information about factors, primarily labour, and representative households. The rich and freely available data sources provided by the national Income and Expenditure, the October Household and Labour Force Surveys are potentially great resources for this research, which have been, arguably, under utilised. From the limited information available for these SAMs the disaggregation of the labour (factor) and (representative) household accounts has not progressed beyond that used in the 1978 and 1988 'SAMs', and in many cases seems to be less detailed. Consequently it is arguable that there has been overinvestment in modelling the South African economy while at the same time there has been underinvestment in the development of the databases that underpin the models.

3.2.3 Provincial data

The SAMs mentioned so far are national SAM, which by definition subsume the intricate interactions taking place between and within different regions in an economy. Analysis of a country as diverse country as South Africa and whose population distribution has been so influenced by political decisions, suggests that provincial SAMs may be particularly useful. In the late eighties and early nineties the Central Economic Advisory Services (CEAS) was actively involved in compiling and applying regional and later provincial

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[15] *The SAM for this study was developed by Claude van der Merwe, a private consultant. Macro economic analysis at National Treasury uses this SAM.*

input-output tables for South Africa (Van Seventer, 1999). There also operated an Office for Regional Development and Regional Development Advisory Committee as part of the National Regional Development Programme that disseminated statistical information per development region. Information disseminated by these organisations formed the basis for various regional applications in the nineties (Nel and Vivier (1995), Eckert and Van Seventer (1995) and Van Seventer (1999)). The research conducted at these two organisations was discontinued, leaving a void where there once was substantial support for regional data generation. The result is that regional information is generally outdated since detailed provincial level data from StatsSA are limited. The consulting firm Global Insight has taken the initiative to fill this gap at least partially by keeping an updated Regional Economic Focus dataset that contains certain indicators at provincial level, magisterial and even municipality level.

A number of provincial matrices have been developed. Nel and Vivier (1995) developed an interregional input-output table for South Africa using the Leontief-Strout and RAS method for estimation of interregional transactions. Their input-output table covers the country as a whole. Van Seventer (1999) develops regional input-output tables, expressing each province together with the rest of South Africa in a two region framework, by using a variation of the simple location quotient technique to estimate the locally supplied component of each intermediate and final demand delivery. And Eckert and Van Seventer (1995) compiled an extended input-output table for the Western Cape.

A SAM for the Western Cape, based on the structure of the 1978 and 1988 national SAMs, was developed as part of the SM3 (Strategic Macro and Micro Modelling) project of the Department of Agriculture in the Western Cape (Eckert *et al,* 1997a). As more recent data became available and techniques improved a supply and use SAM for the Western Cape was developed (McDonald & Punt, 2001). The SAMs for the Western Cape developed by the Department of Agriculture in the Western Cape are similar in structure to single country SAMs since these provincial SAMs are not fully integrated with a SAM for South Africa. All the mentioned SAMs for the Western Cape has a focus on agriculture obtained through the multiple agricultural commodity/industry accounts.

3.2.4 Satellite accounts

Occasionally a research study requires the incorporation of information on physical quantities, as opposed to value data, into the SAM framework. Typical data would include employment figures, water usage, etc. These data can be incorporated as satellite accounts in the SAM and hence provide additional information for the calibration of models. Employment figures were included as a satellite account in the 1993 Western Cape agricultural SAM to estimate the employment multipliers using a semi input-output model (Eckert *et al*, 1997b; 1997c). Land values per defined agricultural activity in the Western Cape were incorporated in the 1993 Western Cape SAM to allow for the estimation of the impact of the introduction of a land tax the Western Cape (McDonald & Punt, 2003a). StatsSA released a set of natural resource (water) accounts for nineteen water management areas (StatsSA, 2004b). The CSIR are also involved in satellite account development (Hassan, 1998).

3.3 Advances in data estimation techniques

The lack of consistent data covering every aspect of an economy is the main constraint on developing SAMs.[16] This common problem has lead to much effort being devoted to derive techniques that allows the reconciliation of inconsistent data, the estimation of missing data and the ability to update a consistent data set from one base period to another. For updating matrices of data one of the most common approaches is to make the problem determinate by imposing additional restrictions as in the case of the RAS method of biproportional adjustment (Schneider and Zenios (1990) as cited in Golan *et al* (1994) and Bacharach (1970) as cited in Lahr and De Mesnard (2004)). Considerable effort has been devoted to the development of variants of the RAS technique, see the special issue on biproportional techniques in input-output analysis in Economic Systems Research and the review therein (Lahr & De Mesnard, 2004). However while the RAS method and its variants are still frequently used, arguably because of their relative simplicity, there are well known problems with the method. In particular they are not well suited to ill-posed, underdetermined problems, which are often the case in SAM development.

Subsequent developments include the Stone-Byron method that requires the user to impose information about the variances on each cell in the matrix and then uses generalised least squares to derive estimates of the values of the cells that are consistent with the accounting requirements (see Stone, 1985 and Round, 2003, for descriptions of this technique). However the information requirements of the Stone-Byron method are still very great, in particular the need for subjective estimates of the variances. Golan *et al* (1994) partially address this by applying information theory and entropy econometrics techniques to estimate a SAM. They convert the problem into an ill-posed, underdetermined pure inverse problem, which they optimise subject to a

[16] *This is a global problem, see Stone (1985) for comments on this issue.*

nonlinear criterion function, and adding up and consistency constraints. Robinson *et al* (2001) extend the method to situation where there are different kinds of information available than knowledge of row and column sums; available information typically includes priors from raw data and/or earlier SAMs, moment constraints, economic aggregates, inequality constraints and zeros.[17] The guiding principal is to use all the available information while allowing the estimation technique to fill the information gaps rather than imposing assumptions that may be arbitrary. This method has been further refined to develop a fully stochastic estimation procedure (McDonald & Robinson, 2004) that is both more flexible and easier to use than earlier entropy based techniques.[18]

An important qualification about these techniques is needed. The advances in techniques and solution algorithms have allowed practitioners to solve estimation problems that were impossible even five years ago, and hence risk encouraging users to assume that the effort needed to develop multi sector databases has greatly diminished. In reality the advances in mathematical techniques place an even greater emphasis on the data gathering and organising phases and upon the knowledge of the data gathers about the detailed operations of the economy; indeed viewing these techniques as substitutes for the collection and application of information violates their guiding principles.

4. General equilibrium models

4.1 Input-output and SAM-Leontief model

4.1.1 Development

Input-output models were pioneered by Leontief in the 1930s with this first phase in the development of the techniques resulting in the publication in 1953 of *Studies in the Structure of the American Economy* (Leontief *et al* (1953). The defining behavioural assumptions of Leontief's model were that relative prices were fixed and there was excess capacity in the economy; the latter assumption ensured that these models were firmly rooted in the then dominant Keynesian vision. This is reinforced in the Open (with respect to final demand) Leontief model by the designation of some accounts, typically

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[17] *McDonald and Robinson (1998) used an early version of this method to estimate a supply matrix for South Africa.*

[18] *While the stochastic method remains computer intensive the developments in solution algorithms over the last few years now made it possible to solve problems many times bigger than could be solved in 2002.*

government, investment and exports, being exogenously determined. The fundamental insight provided by input-output analysis is the extent of interdependence within an economy, and hence how changes that directly affect one sector of an economy can have substantial indirect affects upon other sectors. Examples of input-output analysis abound in the literature.

Subsequently the depth of analyses provided by the standard input-output model has been substantially extended. The standard input-output multipliers, derived from the input (Leontief) inverse, that measure the backward linkages, have been complemented with forward linkages derived from the output inverse (Jones, 1976), while total linkages can be calculated using an extraction method (Cella, 1984). In addition a wide range of different analytical techniques have been developed; in the main these have concentrated upon providing greater insights into the patterns of economic interdependence, e.g. decomposition methods, but others have sought to address limitations imposed by the core behavioural assumptions, e.g. mixed multipliers, and inter regional effects, e.g. Leontief and Strout (1963) and Polenske (1970). Techniques have also been developed that examine the formation of prices by analysing the properties of the price dual in the input-output model; in these models the assumption of fixed relative prices is replaced by an assumption of fixed relative quantities. A comprehensive overview of input-output analysis and its applications is provided by Miller and Blair (1985),[19] while Economic Systems Research, the journal of the International Input-Output Association, is the main journal for modern developments in input-output techniques.

The extension of Leontief's model to a SAM based model, the SAM-Leontief model, was primarily motivated by the importance of completing the circular flow so as to provide greater insights into the distribution of income. A SAM-Leontief model is a linear model comparable to an input-output model, but it is calibrated to a social accounting matrix (SAM) as opposed to an input output table. However it retains the key assumptions of fixed relative prices and excess capacity. Different types of multipliers have been derived using a SAM-Leontief model. The 'standard' accounting multipliers, which are based on average expenditure propensities, have been augmented by fixed price multipliers, which are based on marginal expenditure propensities (Pyatt & Round, 1979); the assumption of perfectly elastic supply functions can be relaxed by using mixed multiplier models e.g. Subramanian and Sadoulet (1990) and Lewis and Thorbecke (1992); and Roland-Holst and Sancho (1995) have developed the dual price model to calculate price transmission

[19] *See also O'Connor and Henry (1975) and United Nations (1999).*

multipliers that examine the processes of price formation. A wide range of decomposition techniques have also been developed so to provide greater insight into the patterns of interdependence; the decomposition methods developed Pyatt and Round (1979) and Stone (1985) were among the first while structural path analyses (Defourny & Thorbecke, 1984) probably remains the most comprehensive.

While input-output and SAM-Leontief analyses retain a degree of popularity their appeal has declined in recent years. In particular economists have sought to relax the restrictive nature of the key assumptions. The fact that some accounts were exogenously determined was an early source of concern and prompted the development of the Closed Leontief model, which although theoretically more appealing was found to have limited empirical content. Similarly the perceived weaknesses of the static Leontief model prompted the development of the dynamic input-output model to address investment issues, but this model raised concerns about stability (see Dervis *et al,* 1982). Ultimately however the most enduring concern has been with the assumptions of fixed relative prices and excess capacity, which were key driving forces behind the development of modern flexible price models.

4.1.2 Application to South Africa

Townsend and McDonald (1998) used linear SAM-based models calibrated with the 1988 SAM for South Africa published by the Central Statistical Service to analyse the effects of changes in agricultural policies on income distribution. They use the standard SAM-Leontief model to estimate accounting multipliers and the price formation and cost transmission variant (Roland-Holst & Sancho, 1995) to estimate the impact of price support mechanisms in agriculture. They also carry out multiplier decomposition.

Eckert and Van Seventer (1995) used an extended multiregional input-output model to inform policy decisions in the Western Cape. They applied a mixed multiplier model to relax the standard multiplier models' assumption of excess capacity and they relaxed this assumption for the Western Cape agricultural sector. The SAM for the Western Cape that was developed as part of the SM3 (Strategic Macro and Micro Modelling) project of the Department of Agriculture in the Western Cape (Eckert *et al,* 1997a) was used by Eckert *et al* (1997b) and (1997c) to estimate various provincial multipliers in an analysis following a semi-closed input-output approach proposed by Wang and Mullins (1988). This SAM was also used to calibrate a mixed multiplier SAM-Leontief model to estimate some implications of trade liberalisation within a supply constraint environment (McDonald & Punt, 2002). The supply and use SAM for the Western Cape (McDonald & Punt, 2001) was used in SAM

Leontief analysis to estimate the impact of the introduction of a Basic Income Grant, fuel price changes and an increase in the demand for exports respectively (McDonald & Punt, 2004).

Hassan (1997) integrates an environmental module in the standard Leontief input-output model to capture the environmental impacts of economic adjustments induced by trade liberalisation and environmental policy changes. Hassan (1998) reviews the principles and techniques of national environmental accounting and presents a synthesis of results from applications in Africa. Conningarth Consultants are involved in agricultural research; studies include estimates of the regional comparative advantage of water use in the Orange River Basin (Conningarth Consultants (2000) in Nieuwoudt *et al* (2004)), and the macroeconomic impact of the wine industry in the Western Cape (Conningarth Consultants (2000) and (2004)).

4.2 Computable general equilibrium models

4.2.1 Development

Dervis *et al* (1982) describe a CGE model as an economy wide model that includes the feedback between demand, income and production structure and where all prices adjust until production decisions are consistent with demand decisions. CGE models are therefore strongly rooted in micro-economic theory, while retaining macro-economic balances for the economy as a whole. The key features of CGE models are that prices are flexible, all accounts are endogenously determined and that agents are optimisers; typically many of the behavioural relationships are non-linear. As such they relax the most restrictive of the assumptions of the Leontief input-output model. The first (true) computable general equilibrium (CGE) model is widely credited to Johansen (1960), but the widespread development of CGE models did not occur until the 1970s when three strands in the research emerged at broadly the same time: Shoven and Whalley (e.g. 1974), Dixon *et al* (1977) and Adelman and Robinson (1978). These strands of research were largely complementary with Shoven and Whalley emphasising taxes, Dixon *et al* production and Adelman and Robinson income distribution. Since these early developments the sophistication and size of models has increased enormously due to developments in both solution algorithms and economic theory; nowadays modern CGE modellers are primarily concerned with the identification of important (policy) questions rather than the ability to solve numerical problems. The core data for all CGE models can be expressed in the form of a SAM, supported by satellite accounts that contain additional information, e.g. factor quantities and elasticities.

General equilibrium models have been used frequently by international agencies, e.g. the World Bank, the International Monetary Fund (IMF) and the World Trade Organisation (WTO), and national governments. In both developed and developing countries general equilibrium models have been used to analyse a wide range of policy options, e.g. structural adjustment programmes, trade policy reform, fiscal/taxation policies, environmental policies (especially carbon emissions), sectoral policies (especially those relating to agriculture), the income distribution implications of economic policies etc. General equilibrium models have been used widely to assess the effects of global and regional institutional and policy changes, e.g. WTO/GATT, NAFTA, preferential trade agreements (e.g. the Lomé Convention, Cotonou Agreement, MERCUSOR), environmental policies etc.

The most commonly used type of CGE model remains the comparative static single country/region model, but increasingly the models are becoming more complex, e.g. the IFPRI standard model (Lofgren *et al*, 2002). There now exist a number of multi region comparative static models that are calibrated with the Global Trade Analysis Project (GTAP); these include the GTAP (Hertel, 1997) and the MRT-Globe (McDonald *et al*, 2005) models. A range of dynamic CGE models has also been developed to examine policy issues where the timing of policy changes is believed to be critical to the results; examples include Rutherford and Tarr (2002), and the GTAPDyn (Ianchovichina & McDougall, 2000) and LINKAGE (Van der Mensbrugghe, 2003) models. While trade and fiscal policies and structural issues remain the most common CGE applications, there have been numerous applications to agriculture (see Adelman (1984); Winters *et al* (1998)), environmental issues (see Wiig *et al*, 2001 on soil degradation). Comprehensive reviews of the CGE literature are provided by Robinson (1989), Gunning and Keyzer (1995) and Devarajan and Robinson (2002).

4.2.2 Application to South Africa

There was a considerable increase in the use of CGE models in economy wide policy analysis in South Africa since the early 1990s. However few of the initial CGE analyses focused on agricultural issues. Thurlow and Van Seventer (2002) provides an overview of these earlier models, which include amongst other the dynamic one sector computable general equilibrium (CGE) model extended to include financial variables of Gelb *et al* (1992) as quoted by Thurlow and Van Seventer (2002), CGE models developed by the Industrial Development Corporation, the World Band/OECD and the Development Bank of South Africa. Applications include investigations in trade liberalization, green trade restrictions, currency devaluations and government expenditure and restructuring. Thurlow and Van Seventer (2002) note that a substantial number of recent applications of CGE analysis in South Africa are developed outside the country and mainly by the World Bank. Among the known examples of research that has been conducted using SAM databases for South Africa are the activities of IDC (using a Monash based ORANI model), the World Bank (3 different generations of model), Thurlow (IFPRI model) and McDonald (Sheffield Model).

McDonald and Kirsten (1999) used a CGE model to analyse the impact of a drop in the world gold price on the agricultural sector. The CGE model was developed in conjunction with the MERRISA project and as such one of the first to allow for secondary production. The CGE model was calibrated with a SAM for South Africa estimated with entropy procedures using as base the 1988 SAM for South Africa published by the Central Statistical Service (McDonald and Robinson (1998) in McDonald and Kirsten (1999)).

Thurlow and Van Seventer (2002) presented a comparative static CGE model for South Africa based on the standard static IFPRI model, which also provided the basis for Kearney's (2003) extension to assess the implications of different value added options. An example of an environmental application is found in De Wet and Van Heerden (2003). Thurlow (2003) extends the static model into a recursive dynamic model. Although neither of these models are applied directly to agricultural issues, the comparative static model presents an overview of different closures relevant to the South African economy, while the dynamic model can be adopted when analysing issues that will impact on agriculture, e.g. investment in rural infrastructure, the impact of AIDS, etc.

Van Schoor and Burrows (2003) adapts the standard IFPRI CGE model to account for imperfect competition and returns to scale. They use this model to analyse the impacts of unilateral free trade and a reduction in conjectural variations in all sectors of the economy. They show that it is theoretically possible to use a CGE model for market structure analysis and for competition policy analysis. The lack of underlying data however remains a challenge.

Provincial level CGE applications exist for the Western Cape. A CGE model was developed for the Western Cape (McDonald, 2002) and used to analyse trade liberalisation effects (Chant *et al*, 2001), implications of a Basic Income Grant in the Western Cape (McDonald & Punt, 2003a) and some welfare implication of a land tax in the Western Cape (McDonald & Punt, 2003b).

5. Future developments

In the early days of CGE modelling the databases often contained more detail than could be fully exploited by the models since the analysts often had to concentrate upon the practical problem of achieving model convergence (solution). But over time the solution algorithms and the models have typically been developed at a faster rate that the databases; indeed it could be argued that there has been over investment in models and under investment in databases. This consideration of future developments therefore starts by looking at database developments and then moves onto model developments; in reality these developments should take place in tandem.

5.1 Databases

One major problem faced by national account statisticians is that the data they are using to compile national accounts, and in particular SAMs, have often been gathered for other purposes, e.g. income and expenditure surveys are conducted primarily to derive weights for (consumer) price indices. It is therefore common to find that the data on the linkages between factor and institutional incomes are not well covered by existing surveys, and therefore the data about the functional distribution of income are often limited. If the data collecting activities of government statistical organisations were more closely coordinated it should be possible to substantially increase the amount of information about the functional distribution of income at relatively low marginal cost. One major advantage of such additional information would be a substantial increase in the ability to analyse the interactions between the operations of labour markets and income distribution.

A critical feature of CGE models is the identification of the interdependency effects associated with the price formation process of an economy (see Pyatt, 1987), which is fundamentally influenced by the structure of taxes in an economy. SNA compliant national accounts data is not a particularly rich source of information on taxes – it is common to only find data on aggregate taxes by commodity and activity – and the ability to model the effects of changes in taxes is consequently compromised.[20] This is particularly the case with trade taxes; in a world of proliferating preferential trade agreements it is increasingly important to identify trade by both commodity and country of source and destination. Greater detail about the structure of taxes would therefore substantially improve the usability of national accounts data.

A large proportion of the other suggested database developments could be captured by making use of the concept of satellite accounts (see United

[20] *It is important in this context to recognise that SNA compliant supply and use tables and SAM are based on a well developed system of price relationships; the comments here are about the level of detail in the available databases not the underlying price structure. However he SNA system of prices is not universally supported; see Pyatt (1994a; 1994b).*

Nations, 1993). Because of the importance of labour markets an obvious starting point is the creation of matrices of factor use by activities; to be truly useful however it will be important to increase the number of factor accounts in line with the number of household accounts. The application of satellite accounts to environmental data is already well developed and is detailed in both the SNA and System of Economic and Environmental Accounts (SEEA) (United Nations, 2003), but the data content of environmental accounts is still relatively limited. The development of environmental databases will be important to future developments in environmental modelling.

Satellite accounts also provide a framework within which large bodies of other useful information about economic, physical and social relationships can be collated. One aspect that has already been explored is demographic accounts (see Stone, 1971; 1984); such accounts can include *inter alia* information on human capital, family structure and demographic transitions. One potentially important area of development is the identification of activities that are out with the SNA's production boundary; for instance data on time use and domestic production for non-market purposes could be used to greatly improve understanding of how households allocate their resources between market and non-market activities.

While there is little that can be done directly by economists about gaps in data availability there is a substantial case for economists seeking to re-establish a dialogue with the national account statisticians so that both parties are more familiar with the constraints the other faces. Indeed such a dialogue was critical during the development of national accounts but economists seem increasingly reluctant to engage with statisticians.

5.2 Computable general equilibrium models

The scope for developing CGE modelling capabilities is potentially enormous although it is important to recognise the inherent limitations of the techniques, in particular the underlying assumption that modellers can observe and model equilibrium states. There are however a number areas for development that are of interest, and, given the advances in computer technologies and the software used to solve CGE models[21], accessible.

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[21] *The two main software packages for general equilibrium modelling are GEMPACK and GAMS (General Algebraic Modelling System).*

5.2.1 Trade relations

The use of the Armington (1969) insight to model trade relations in terms of imperfect substitution was massively important in allowing economists to give empirical content to the modelling of trade relations. However it does contain a number of potentially serious limitations that are all too often overlooked; a number of these are worthy of comment. (1) CGE models have difficulty accommodating trade in 'new' products, where 'new' products include trade in products that have been previously excluded by quantitative restrictions. (2) The Armington specification endows trading partners with a degree of monopoly power; in the context of a global model this typically results in large terms of trade effects (Brown, 1987) that are often considered excessive and therefore require the imposition of (arbitrary/atheoretical) methods to damp down these effects. (3) In many single region models only a single trade/rest of the world account is identified which limits the ability of the model to identify the extent to which, for instance, trade agreements may impact upon the patterns of trade. The replacement of the typical CES functions with more flexible functional forms may provide a partial solution to these problems, but this is a topic that clearly deserves attention.

5.2.2 Functional forms and parameter estimation

The CGE literature is dominated by the constant elasticity of substitution (CES) functional form. This functional form has great benefits from the perspective of model performance - its properties are well known - and its parameterisation is parsimonious; moreover its flexibility can be greatly increased by the nesting of CES function (see Perroni & Rutherford, 1995). Nevertheless the presumption of a CES form is restrictive, which indicates that there may be benefits from the adoption of more flexible functional forms; e.g. translog and generalised Leontief, but to do so will substantially increase the number of parameters needed to calibrate a model. This highlights the substantial need to increase the empirical basis of many of the parameters, especially elasticities that are used to calibrate models. In essence this is a data problem, since econometric estimates require substantial databases that are typically unavailable; one approach to this problem, which seeks to be parsimonious in the use of data, is explored by Arndt *et al* (2002).

5.2.3 Representative household groups

CGE models make extensive use of the concept of representative household groups (RHG), which while they provide good information on inter household effects of the policy simulations, provide no information on intra household effects. Adelman and Robinson (1978) sought to address this problem by using within group distribution parameters to provide greater insights into how policy changes effect sub groups with each RHG; until early in this century this remained the state of the art method for getting more information about income distribution effects. Recently this subject has become the focus of additional research. Cockburn (2001) reports a model with a large number of households each based on one household from a survey. In essence this remains a RHG approach since each household in the survey is assumed to represent a segment of the population, but it does increase the potential richness of the insights. Substantial disadvantages with this approach are that it places large emphases on both the accuracy of the information about each household and the representativeness of the sample, and if the sample is very large produces substantial difficulties in producing a balanced database. An alternative approach is to combine CGE and microsimulation techniques; the CGE model can use RHGs while the intra group heterogeneity is captured by the microsimulation component of the model (see Bourguignon *et al*, 2002). This research is in its infancy and at this stage the CGE and microsimulation models are being solved sequentially rather than simultaneously, although some studies are solving the models iteratively. Nevertheless the preliminary evidence is that this type of exercise, whereby the potential complementarities between different types of models can be exploited, has the potential to provide substantially greater insights (see Bourguignon & Pereira Da Silva, 2003).

5.2.4 Integrating national and global computable general equilibrium models

A similar process of model integration is possible in the context of global and single region models. Typically the extent of institutional information in a global model is limited while the information on global trade relationships is extensive[22], while the information on institutional information in a country model may be extensive while the information on trade relationships is limited. Hence there is the potential to use these models in a complementary manner by embedding a single region model within a global model. Technically this is not too complicated, but there are issues to do with the reconciliation of data that are more difficult to resolve.

5.2.5 Labour markets and imperfect competition

Understanding the implications of policy changes for poverty and income distribution place a great emphasis upon the operation of labour markets, since for most poor households their labour is the only substantial asset they own. But most models retain the assumption that labour markets are perfectly competitive with the consequence that they can provide only limited

[22] *This is certainly the case in the dominant GTAP database.*

information[23]. Worse still many such models use very simplistic representations of the degrees of substitutability between different types of factor, i.e. labour and capital, and between different types of labour, i.e. skilled, semi-skilled and unskilled. Since the distribution of assets is often even more unequal than the distribution of income, and the ownership of assets is often related to the degree of market power there is clearly a case for the consideration of the implications of market power on the operation of labour markets More generally there is a case for a more generalised treatment of imperfect competition in CGE models.

6. Informing the policy debate in South Africa

6.1 Economic questions suitable for the SAM/CGE framework

From the above discussion it emerges that the SAM/CGE techniques can be suitably used to address a range of issues. Input-output techniques were originally developed for analysis of production linkages in the economy. The development into SAM-based CGE analysis took place because of the increased interest in the impact of policy options on poverty and income redistribution. More recently models (and databases) have been adapted to analyse environmental issues such as the impact of CO2 emissions, Kyoto protocol scenarios, water related issues, soil degradation (Wiig *et al*, 2001) etc. Lange *et al* (2003) discuss environmental accounting principals in a Southern African context. In some of the more recent CGE models the treatment of taxes have been refined (Kearney, 2003), and in models for developing countries home production for home consumption have been included (Thurlow & Wobst, 2003). Work is also underway with regard to global modelling of trade related issues in a multiregion CGE framework (using GAMS software) as opposed to the Purdue Global Trade Analysis Project (GTAP) (using GEMPACK software) framework.

Insofar as the CGE model can be used to derive results pertaining to all sectors of the economy it implies that any technical developments in a CGE model will have an impact on results with regard to agriculture. Hence even if a specific version of a CGE model has not been applied directly to analyse an agricultural issue, it could be used in this regard. All model developments should therefore be viewed as having the potential to contribute to the agricultural policy debate. However, a balance must always be retained between model sophistication and data requirements. Issues that can be

[23] *The impact of the presumptions about the nature of competition in labour markets can substantially affect the results from analyses of labour market performance; in the context of minimum/regulated wages in agriculture see Dickens et al (1995).*

suitably addressed within this framework include land reform, environmental issues, trade negotiations, production linkages, price changes, impact on employment and poverty, welfare, taxation and investment.

6.2 Current South African initiatives

The Provincial Decision-making Enabling (PROVIDE) project is a national project with the Department of Agriculture (national) and the nine provincial departments of agriculture as stakeholders and funders of the project. The objectives of the project include the development of a national SAM for South Africa, four regional SAMs and a multiregional SAM with each of the four regions explicit in the SAM. The SAMs obtain an agricultural focus through the inclusion of multiple commodity and activity accounts for agriculture. The SAMs developed as part of the PROVIDE Project are balanced using the latest entropy techniques. At the time of writing this paper a first version of the national SAM has been completed as well as preliminary unbalanced versions of the regional SAMs. As part of the PROVIDE Project a single region and a multiregion CGE model have been developed (PROVIDE, 2003). At the time of writing this paper the single region model is being used in the estimation some of the implications of sugar trade liberalisation, fuel price increases, technology change and increases in the wheat import tariff.

Economics Department of Universities of Potchefstroom, Cape Town, Pretoria and Stellenbosch and Agricultural Economics at Pretoria have been or are involved in teaching general equilibrium techniques as part of their graduate courses. During the past three years the University of Cape Town has organised three introductory and one advanced short course in SAM-based CGE analysis. A number of international experts presented the bulk of the lectures during these courses and the availability of these experts to the students and professionals who attended these courses were invaluable. The Trade and Industrial Policy Secretariat (TIPS) presents annual short courses on SAM-based and CGE modelling. With regard to short courses it is often an individual that drives the process as opposed to the institution, hence the continuation of these efforts into the future remains somewhat uncertain.

Another initiative, which does not focus directly on agriculture but which will establish domestic CGE modelling capacity, is the CGE analysis component that has been established at the National Treasury. At the same time researchers at the provincial treasury departments of KwaZulu-Natal and Free State are attempting to develop provincial SAMs as a first step in creating capacity in provincial level general equilibrium modelling for analysing the implications of changes in taxation policy.

The Agricultural Economics Department of the University of Pretoria has been applying the techniques to analyse agricultural issues, while the Department of Economics of Pretoria University is actively involved in GEMPACK based GE modelling with an environmental orientation. The Department of Agriculture (National) is in the process of creating capacity in the use of the GEMPACK based trade model developed and maintained by the Global Trade Analysis Project (GTAP) based in Purdue, USA. This model is a multiregion model to analyse the implications of trade negotiations on different countries.

7. Concluding comments: The way forward

Although there exists a general awareness of general equilibrium modelling amongst economists in South Africa, only a limited number of researchers are actively involved in using this technique in studying issues of importance to the agricultural sector. Typically the results that emerge from these models are informative rather than predictive because of the nature of the "what if" questions that are addressed. The estimations carried out in this framework can be likened to a controlled laboratory experiment, the aim of which is to isolate the impact of a single change in the economy in order to better understand the nature of the impact. The majority of data needed for national level analysis is available, but detailed data to focus specifically on agriculture or on regions within South Africa are limited and hence data estimation techniques are required. Recent advances in data estimation techniques have made sector specific and sub-national analysis possible at a time when earlier efforts to gather sub-national data have not been maintained and supported.

The challenge in expanding the use of GE modelling in agriculture domestically is a direct result of the fact that GE modelling has its roots in economic principles as opposed to traditional agricultural economics. The requirements for a researcher to be a good modeller are multiple. Besides the need for sound computing and programming skills, the person also require good theoretical foundation in micro and macro economics and an understanding of the socio-economic conditions of the country or region being analysed. It is apparent therefore that the potential modellers are not necessarily absorbed into our agricultural economics mainstream. At the same time students with a lively interest in agriculture are not often required to enrol for the necessary courses at the Economics departments, which include the fundamental principles of mathematical economics, and advanced micro-economic theory and macro-economic theory. Closer cooperation between Economics and Agricultural Economics Departments could pave the way for increasing the domestic capacity with regard to GE analysis in agriculture. The role envisaged for agricultural economics university departments is to create awareness of this type of modelling at an early stage in order to ensure that the subject choices of students will provide them with the necessary background.

Clearly the range of skills required to support programmes of research are extensive and are unlikely to be met by any single individual; indeed the vast majority of CGE based research is carried out by teams. Moreover the fixed costs of developing the requisite skills are high. This leads to two conclusions; first, that a critical mass of research is needed to sustain a CGE programme of research, and second, that given the time and cost implications of training researchers in GE modelling it follows that the existing capacity should be nurtured.[24] Since the available evidence indicates that a critical mass of researchers using these techniques has not yet been achieved in South Africa there is a strong case for developing collaborative research programmes. This could be helped by the formalisation of a network in South Africa that allows training, contact sessions with international experts and open communication and information sharing between members of the network. For some time it will probably be necessary to engage closely with outside expertise since the technical skills used in CGE modelling are not well developed amongst the academic and/or research communities in South Africa. The most recent thrust with regard to short courses presented by international lecturers are those organised by the Departments of Economics at the Universities of Cape Town and Pretoria, and those organised by the Trade and Industry Policy Secretariat (TIPS).

Consequently it is envisaged that capacity training should be a joint effort between academia and government. Government institutions can use internships as a vehicle for new modellers to get practical experience and confidence in modelling, while the theoretical foundations should be laid with relevant coursework. Such a combined effort will promote the strive for a balance between two often conflicting objectives, namely maintaining a high level of technical accuracy, but at the same time reaching policy makers with timely information.

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[24] *There is a global market for those with this type of technical skills, which means that those with these skills are likely to be able to readily find employment elsewhere.*

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