A Survey of Macroeconomic Models for Policy Analysis and Forecasting in South Africa

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Abstract

As South Africa attains ten years of democracy, a major issue in the discourse on economic policies and performance relates to how the country can move on to a much faster all inclusive growth path that will benefit the poorer majority of its citizens. It is opportune to contemplate the future of economic models in economic policy-making. This study undertakes a survey of macroeconomic models for policy analysis and forecasting in South Africa. It is of the view that macroeconomic models are increasingly being integrated into forecasting and policy analysis in South Africa. However, the use of these models by policy-makers, with the exception of the Reserve Bank is still limited due to the perceived complexity of these models and the concentration of capacity within a small number of academic or related institutions. The external orientation of most of the models also poses problems regarding their relevance and maintenance. Arguably, with the exception of the University of Pretoria Macroeconometric Model and the IFPRI/TIPs Computable general equilibrium model, existing models have not been revised and updated periodically in line with new theoretical insight and data. Macroeconomic modeling teams should strive to be at the frontier of knowledge in modeling and theory with a view to incorporating new insights notably in applied econometrics, game theory, supply side modeling and the modeling of expectation and learning.

1. Introduction[1]

In the course of policy formulation, it is impractical to rely on unassisted intuition. Models provide a logical abstract template to sort out complicated chains of cause and effect, and influence between the numerous interacting variables in an economy. By virtue of their logically consistent framework, they can provide the analyst and policymaker with a valuable economic representation of the sector and a laboratory for testing ideas and policy proposals (Hazel and Norton, 1986:2). Though imperfect abstractions, economists can experiment, at least logically, the effect of alternative policy options. Models have become a useful devise for formulating plans and investigating trade-offs. They are used mainly for forecasting, consistency checks and optimisation. It must be emphasized that while models provide a formal and quantified framework that is an irreplaceable adjunct to the processes of policy thought, they are not substitutes for the exercise of reasoning, judgement and political choice.

More than sixty years of experimentation, since Jan Tinbergen formulated the first structural macroeconomic model for the Dutch economy in 1936, has brought considerable progress in the field. Macroeconomic models have undergone a lot of refinement in line with the changing economic paradigm, new research on economic theory, development of new algorithms to solve large non-linear systems of equations, and advances in computer hardware and software, which have led to richer and more complex models. A wide spectrum of choice is now available, ranging from sectoral to economy-wide models, static to dynamic and short to long term incorporating insights of many theoretical approaches including Keynesian, neoclassical, monetarist, supply-side, and rational expectations.

The transition to a multiracial democracy in 1994 posed difficult political, social and economic challenges. On the economic front, the new government inherited a dysfunctional and distorted economy reflecting several decades of isolation. South Africa's noteworthy achievements in surmounting these challenges, especially the attainment and restoration of macroeconomic stability have been widely recognized (Lewis, 2001). Despite the apparent success, concerns over slow growth, unemployment, poverty and inequality are widespread and mounting. The real growth performance over the last decade has failed to reverse the secular deterioration that has been occurring for decades. Thus, as the nation attains ten years of democracy and begins a new phase in its history, a major issue in the discourse on economic policies and performance relates to how South Africa can move on to a much faster all inclusive growth path that will benefit the poorer majority of its citizens. In the light of a decade of post-apartheid experience in development thought and practice, it is opportune and challenging to contemplate the future of economic models in economic policy-making. What is the state of the art in economic modelling? Have models lived up to expectation? This study intends to provide answers to the above questions. It undertakes a survey of macroeconomic models for policy analysis in South Africa.

The depth of the topic requires some selectivity. We focus on models with policy relevance. The description of the structure and dynamics of models as well as the analysis of their key properties is based on official publications, discussions with modelers and responses to a questionnaire on model properties. Some of the models involved in this research project are, however, subject to ongoing modification. With time, the versions described may change.

The models surveyed include the Reserve Bank quarterly Econometric Model although it is not available for public scrutiny, the Macroeconometric Model of University of Pretoria which originated in the work of Late Geet de Wet and Jan Dreyer who built the first quarterly econometric model for South Africa in the 1970s. Others are the model simulated by Aron and Muellbauer (2000) highlighting the conduct of monetary policy in South Africa and the subsequent models developed by the Center for the Study of African Economies, Department of Economics, Oxford, in conjunction with the South African Reserve Bank and the Bureau for Economic Research. Since the beginning of 1990s, South Africa has also witnessed a considerable increase in the use of computable general equilibrium (CGE) models for economy-wide policy analysis. They have found applications in various spheres including trade liberalisation, green trade restrictions, currency devaluation, government expenditure and restructuring. The pioneering attempt was by Gelb et al (1992) who constructed a dynamic one-sector model based on a SAM for 1990 and simulated the impact of negative external shock and a programme of government stimuli. Naude and Brixen (1993) also examined the impact of an increase in government expenditure, export demand, world price, and a lowering of import tariffs under various sets of closure rules using a rigid, albeit multisectoral-modeling template previously developed at the World Bank. Several large-scale multisectoral CGE models were subsequently

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developed by the Industrial Development Corporation (Coetzee et al, 1997), the World Bank/OECD (van der Mensbrugghe, 1995; Devarajan and van der Mensbrugghe, 2000), and the Development Bank of Southern Africa (DBSA, Gibson and van Seventer, 1996a), the International Food Policy Research Institute (IFPRI) model described in Lofgren et al. (2002) and Thurlow and van Seventer (2002). Other models, which have found applications in South Africa, include the IMF's financial programming model and the World Bank's revised minimum standard model adopted by Tarp and Brixen (1996) to simulate exchange rate devaluation, external borrowing and international reserves. The emergence of a new interest, the economic impact of HIV/AIDS has also led to the application of several models in the evaluation of the macroeconomic impact of the AID pandemic (Arndt and Lewis, 2000 and BER, 2003).

The evaluation leads us to some broad conclusions. Macroeconomic models are increasingly being integrated into forecasting and policy analysis in South Africa. However, the use of these models by policy-makers, with the exception of the Reserve Bank is still limited due to the perceived complexity of the analytical framework and the concentration of capacity within a small number of academic or related institutions. The external orientation of most of the models also poses problems regarding their relevance and maintenance.

The paper is structured in five sections. Section 2 examines the evolution in development theorizing and modeling, section 3 appraises the typology of models while section 4 reviews models of the South African economy. Section 5 concludes.

2. Evolution in Development theorizing and Modeling

There has been a fundamental change in development theorizing over the last 50 years. As Adelman (2001) rightly observes, no area of economics has experienced as many abrupt changes in its leading paradigms since the Second World War as has development economics. The 'twists and turns' in the field have had profound implications not only for development policy but also economic models. At the heart of this is the role of government in accelerating development.

After the Second World War, there was a distrust of the market as a result of the experience of the great depression and implicit confidence in the ability of government to take an active and productive role in directing investment. At the onset in the 1950s, development economists formulated grand models of development strategies that involved structural transformation and extensive government involvement in development programming or planning to correct pervasive market failures. Due to pervasive market failure, the policy advice then was for a developmental state which should promote capital accumulation and utilize reserves of surplus labour to secure rapid growth in per capita income. It was perceived that capital was the problem. The central focus of these models was on capital accumulation (Meier, 2001).

The Harrod-Dommar model though formulated for conditions of full employment growth in developed economies gained widespread application in estimating capital requirement requirements in developing countries. In its simplest form, the Harrod-Domar equation for growth is:

$$\frac{\Delta Y}{Y} = \frac{s}{\kappa} \qquad \ldots\ldots\ldots\ldots\ldots \qquad (1)$$

Where
$\Delta Y/Y$ = rate of growth of Gross national product
S = average savings rate and
K = k/y, the capital output ratio

Growth accounting also emphasized the contribution of capital (Solow, 1957). The simple Solow (1957) decomposition of growth into factor contribution is based on the differentiation of a production function

$$Y = f(K, L, t) \qquad \ldots\ldots\ldots\ldots\ldots \qquad (2)$$

such that

$$\frac{\bar{Y}}{Y} = \left(\frac{FkK}{Y}\right)\frac{\bar{K}}{K} + \left(\frac{F\ell L}{Y}\right)\frac{\bar{L}}{L} + \frac{Ft}{Y} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (3)$$

Where subscript denote partial derivatives[2].

Ranis (2004) observe that these models seemed to have relatively little relevance for societies not primarily concerned with business cycles or steady state properties. Most contemporary growth models, in other words, were seen as advanced country-related, relatively abstract theoretical constructs, faithful to the dominant assumptions of neoclassical macro-theory: full employment, market clearing and perfect competition, all of which seemed to have little relevance for the segmented commodity, labour and credit markets of poor countries.

Due to widespread adoption of development planning, two gap models, dynamic programming and growth models were subsequently adopted to conduct consistency checks, balance and feasibility of plans mainly by expartriate missions in collaboration with local planning agencies.

By the late 1960s and early 1970s, deficiencies in planning had become acute. Erstwhile advocates of development planning lamented the "crisis in planning" (Streeten and Lipton 1969; Faber and Seers 1972). As a result of disillusion with development planning, both the models and policy advice of large government were severely criticized. It was felt that the models lacked empirical content (Hla Myints, 1967).

Although the rationale for government interventions had been to remedy market failure, the perverse result was only too often government failure. There was a resurgence of neoclassical economics and emphasis was on "getting the price right" as a result of distortions in wages, interest rates and exchange rates (Little, 1982).

It became evident that economic rationality characterized agents. Consequently, highly aggregative models gave way to disaggregated micro studies in which the unit of analysis was production units and households.
Quantitative analytical tools were used more extensively for empirical analysis of micro-phenomena that were country, industry or project specific. Computable general equilibrium (CGE) models became popular and they were widely used to study the distributional effects of economic policies and the economic implications of economic shocks. Over the past 25 years, computable general equilibrium (CGE) models have become a standard tool of empirical economic analysis. In recent years, improvements in model specification, data availability, and computer technology have improved the payoffs and reduced the costs of policy analysis based on CGE models, paving the way for their widespread use by policy analysts throughout the world.

In the 1970s, concern about poverty became more prominent, notably as a result of Robert McNamara's celebrated speech to the World Bank Board of Governors in Nairobi in 1973[3], and the subsequent publication of *Redistribution with Growth* (Chenery, et. al. 1994). The definition of poverty, beginning with a focus of income has expanded to embrace other dimensions of living standards such as longevity, literacy, and health, concern with vulnerability, risks, powerlessness and lack of voice.

With time, the initial concentration on physical capital accumulation gave way to the concept of investment in human capital and its implications for development. It was increasingly recognized that development depended on productive human agents who, through their acquisition of knowledge, better health and nutrition, and increase in skills, could raise total factor productivity. A new body of knowledge also emerged, emphasizing knowledge and ideas. The new endogenous growth theory (Roemer, 1986, 1990 and Lucas, 1988) brought about marked changes in the analysis of aggregate production function. Instead of the earlier Solow version of diminishing returns to physical

[2] There were also other models, including those of Mahalanobis 1955.

[3] In a stirring conclusion, he asked all parties to seek to eradicate poverty by the end of the twentieth century, eliminating malnutrition and illiteracy, and raising life expectancy across the developing world. His speech forcefully initiated a tradition of identifying global problems, setting bold objectives, and then attempting to tackle them no matter how complicated the undertaking.

capital and labour separately and constant returns to both factors jointly with technological progress as a residual, the new growth theory examines production function that have increasing returns due to an expanding stock of human capital and as result of specialization and investment in knowledge capital (Meier, 2001). The micro founded approach has also changed the way of doing research on growth. Departing from the cross- country regression wave of the early 1990s, more recent contribution have explored in greater details, productivity growth.

Since the mid-1980s, a wave of market–oriented reforms got under way in several developing countries and economies in transition. These economies engaged in unprecedented efforts to alter their economic structures. The reform package, usually at the behest of the World Bank and the International Monetary Fund, entails introduction of first generation reforms. These normally include removal of quantitative restrictions on imports, major reductions in tariffs, privatization of key state-owned enterprises, changes in the regulatory regime for the private sector, removal of subsidies and reform of welfare systems. These are usually accompanied by a number of 'second-stage' reforms targeted at increasing economic efficiency and enhancing growth.

The weaknesses of the Washington consensus, which was paraded as the intellectual showpiece of the so-called reform movement, have been widely discussed[4]. It is widely acknowledged that it did not provide the kind of solutions required by developing countries to address the serious developmental challenges they face. There is growing awareness of the inadequacy of the standard market-based stabilization packages to correct the peculiar structural and socioeconomic problems facing each of the individual countries in the very diverse developing world. It is clear that solutions to the problems facing developing countries require an eclectic approach to development that takes cognizance of the peculiar cultural, historical and geo-political conditions and varied experiences of each country (Taylor, 1988).

A modification of neoclassical analysis occurred in the 1980s and 1990s as a result of 'new market failures'. Due to the recognition of the existence of imperfect and costly information, incomplete or missing market, transaction costs (Stiglitz, 1988) and institutions (North, 1990), economic theory has turned more towards the study of information based market failures, coordination failures, multiple role of prices and the general idea of the potential complexity of markets (Badhan, 1993). The new market failures have prompted a reexamination of two hitherto neglected areas, capital market imperfections and requirements for more efficient financial policies and agriculture. Following the seminal work of Stiglitz on adverse selection as a source of credit market imperfections and credit rationing, there have been new waves of theoretical models based on detailed formalization of the imperfections in the capital market. The theory of rural organization was advanced through the use of information, risk and contract analysis (Binswanger and Rosenzweig, 1981 and Stiglitz, 1981).

The elimination of widespread poverty and growing income inequality is once again at the core of development. In September 2000, the 189 member states of the United Nations adopted the Millenium Declaration which mainstreams a set of inter-connected and mutually reinforcing development goals into a global agenda. The development goals contained in "Millennium Development Goals" (MDGs) commit the international community to an expanded vision of development, one that vigorously promotes human development as the key to sustaining social and economic progress in all countries, and recognizes the importance of creating a global partnership for development.

3. Typology of Models

Models of the macro economy range from those which have a strong emphasis upon understanding the mechanisms that might be at work, and so tend to be towards the theoretical end of the spectrum, to those which are better regarded as purely statistical models that attempt to provide a close match to the data. Where the emphasis is placed by an investigator often depends upon the use to which they will be put. There are three broad categories of

[4] See Stiglitz, J. 1988. More Instruments and Broader Goals: Moving Towards the Post Washington Consensus. WIDER Annual Lectures 2. Helsinki. Williamson, J. 2003, "From Reform Agenda to Damaged Brand Name. A Short History of the Washington Consensus and What to Do". Redrafting the Reform Agenda. *Finance and Development*, September and Manuel, T. A. 2003. "Africa: Finding the Right Path", Redrafting the Reform Agenda, *Finance and Development,* September.

macroeconomic models. One category contains calibrated or estimated general equilibrium (GE) models, which are closely based on a detailed theoretical structure that features explicitly optimizing businesses and consumers. The second types of models are structural macroeconometric models. While continuing a line of research over 50 years old, they have been updated during the past decade or so with explicit expectations and better long-run properties. The third category of models contains those that are almost purely statistical in nature, particularly vector autoregressive models. However, it is necessary to evaluate briefly, their underlying theoretical construct.

Although macroeconomics appear to have been in a state of crisis during the past half-century, there is no denying the significant conflicts of opinion that exist between the different schools of thought[5]. A number of goals have become generally accepted as the objectives of macroeconomic policy and a move towards their attainment is deemed to lead to macroeconomic stability[6] and increased national welfare. These objectives are (a) full employment or a low level of unemployment: (b) price stability; (c) balance of payments equilibrium: (d) economic growth (and development in the case of developing countries): and (e) a fair distribution of income between people and regions.

In the 1960s, large policy models incorporating adaptive expectation and Keynesian aggregate demand framework were used to quantify the impact of macroeconomic policies. Arguably, the most important conceptual developments in the 1950s and early 1960s have been the Phillips curve, the relationship between the rate of change in money wages and the rate of unemployment (Phillips, 1958), and the "natural rate of unemployment" hypothesis (Phelps, 1967 and Friedman, 1968). Following Phillips' (1958) discovery of an empirical regularity between the rate of unemployment and money wage inflation in the UK, the Phillips curve was integrated in macroeconomics through a series of papers in the 1960s. Samuelson and Solow (1960) interpreted it as trade-off facing policy makers, and Lipsey (1960) was the first to estimate Phillips curves with multivariate regression techniques. Lipsey interpreted the relationship from the perspective of classical price dynamics, with the rate of unemployment acting as a proxy for excess demand and friction in the labour market. Importantly, Lipsey included consumer price growth as an explanatory variable in his regressions, and thus formulated what have become known as the expectations augmented Phillips curve. Subsequent developments include the distinction between the short run Phillips curve, where inflation deviates from expected inflation, and the long run Phillips curve, where inflation expectations are fulfilled. Finally, the concept of a natural rate of unemployment was defined as the steady-state rate of unemployment corresponding to a vertical long-run curve [see Phelps (1968), and Friedman (1968)].

By the late 1970s, the Keynesian framework had become obsolete. In the wake of the great inflation of the 1970s, the implication that output could be raised permanently by injecting aggregate demand through monetary and fiscal policy was recognized as a flaw. The New Classical Economics emerged as a school in Macroeconomics. As opposed to Keynesian macroeconomics, it builds its analysis on an entirely neoclassical framework which changed the foundations of macroeconomic theory, arguing that a macroeconomic model should have micro-foundations. The development of rational expectations highlighted how expectations matter in macroeconomic models. Other insights include the policy ineffectiveness debate, time-inconsistency and its resolution. The defining characteristics of the New Keynesian Phillips curve are strict microeconomic foundations together with rational expectations of "forward" variables.

The rational expectation models were however susceptible to the Lucas critique- (that policy analysis using reduced form equations that fit the data but were loosely tied to theory was fraught with danger). Such models could not adequately account for the resultant shifts in behaviour (Lucas, 1976). The main preoccupation in academic cycles in the 1980s and early 1990s was on developing rational-expectations models incorporating the explicit microeconomic structure advocated by Lucas. Initially this took the form of "real-business-cycle" models in which prices were assumed to be fully flexible (Kydland and Prescott, 1982, and Mendoza, 1991). However, the

[5] Economists tend to disagree more over theoretical issues, empirical evidence and the choice of policy instruments than they do over the ultimate objectives of policy.

[6] Macroeconomic stability is usually identified with internal and external balances i.e.; price stability, full employment and balance of payments equilibrium. As indicated in the World Development Report (1991), the experience of the 1970s and 1980s reveals that macroeconomic stability is necessary for sustained growth. Durable growth requires sustainable policies - ones that do not give rise to accelerating inflation, unsustainable fiscal and current account deficits, exchange rate instability and high rate of unemployment.

assumption of flexible prices largely obviated the impact of macroeconomic policies on real activity, making these models of little value in analyzing such policies. Consequently, large policy models generally remained in the reduced-form Keynesian framework, although with an increased focus on adding supply-side linkages (IMF, 2004). Over time, it became increasingly clear that the short-term dynamics of real-business cycle models could be improved by introducing some form of nominal inertia. Theoretical developments in the microeconomics of wage and price setting with imperfect competition led to monetary models that combined the explicit microeconomic foundations typical in real business cycle models with price stickiness (Christiano, Eichenbaum and Evans, 2001). The new models merged the microeconomic foundations (of the type advocated by Lucas) with sticky prices, combining production, consumption, nominal rigidities, trade, and international financial markets in a coherent theoretical structure.

A growing body of literature also attempts to address open economy issues in a dynamic general equilibrium version of the open economy with nominal rigidities and market imperfections. These intertemporal maximising models have a number of advantages over their older Mundell-Fleming variants. Work on such models has exploded in recent years[7]. The micro foundations allow the examination of more exacting models. While the Mundell-Fleming model continues to be the dominant model of open economy macroeconomics, these new innovations have and hope to continue to yield new insights into the questions that interest those working in the field.

3.1 Econometric Models

These models essentially follow the pioneering works of Klein (1950) and Klein and Goldberger (1955). They flourished in the 1960s and 1970s during the golden age of Keynesianism. With a Keynesian foundation, most of the models in this class were demand-driven. Thus, the crucial closure rule is that supply adapts itself to demand and prices do not play an integral role in short-run adjustments to imbalances (Soludo, 2002).

A typical macroeconometric model is dynamic, nonlinear, simultaneous, and has error terms that may be correlated across equations and with their lagged values. A number of techniques have been developed for the estimation of such models. Techniques that do not take account of the correlation of the error terms across equations (limited information techniques) include two stage least squares (2SLS) and two stage least absolute deviations (2SLAD). Techniques that do account for this correlation (full information techniques) include full information maximum likelihood (FIML) and three stage least squares (3SLS). These models clearly state the assumption inherent and identify the endogenous and exogenous variables. Another distinguishing feature of these models is that they spell out the behavioral, technical and institutional equations, in addition to identities and equilibrium conditions. Some of the early macroeconometric models were linear, but this soon gave way to the specification of nonlinear models.

The nonlinear case could be written as:

$$f_i(y_t, x_t, a_i) = u_{it}, (i=1,...,n), (t=1,...,T) \qquad \text{.....(4)}$$

where y_t is an n-dimensional vector of endogenous variables, x_t is a vector of predetermined variables (including lagged endogenous variables), a_i is a vector of unknown coefficients, and u_{it} is the error term for equation i for observation t. For equations that are identities, u_{it} is identically zero for all t. Specification consists of choosing 1) the variables that appear in each equation with nonzero coefficients, 2) the functional form of each equation, and 3) the probability structure for u_{it}. Economic theory is used to guide the choice of variables.

In the last decade or so, time series econometrics has constituted itself as a separate branch of econometrics, with its own methodological issues. Following this development, there has been a reconstruction of several macroeconometric models to incorporate modern econometric concepts of cointegration and causality. In recent times, sufficient assumptions have to be made about stationarity. The assumption, either explicit or implicit, of most macroeconometric model building work is that the variables are trend stationary. If in fact some variables are not stationary, this may make the asymptotic distributions that are used for hypothesis testing inaccurate.

[7] See Sarno (2000) and Lane (2001) for a survey of these models.

Advances in computer hardware have considerably lessened the computational burden of working with large-scale models. In particular, the availability of fast, inexpensive computers has greatly expanded the ways in which models can be tested and analyzed. Interest in large macroeconometric models has, however, waned in recent years. A major consequence of the Lucas critique has been narrowing of the number of endogenous variables in a model from probably a hundred or more to generally no more than three or four.

Macroeconometric modeling has been criticized on three main grounds. First, for having too shallow micro-foundations, second, that their "structural" parameters are not policy-invariant and therefore the potential policy advice derived from them can be misleading and third, the extensive data requirements mainly time series, which are still a luxury in developing countries. While these lines of criticism are acknowledged, they do not invalidate their uses especially in short-term forecasting.

3.2 Micro-based, multisectoral models

The second class of models includes those with strong microeconomic foundations based on individual and firm optimization behaviour. The Walrasian (neoclassical) general equilibrium framework provides the intellectual foundation, while many of the empirical models owe much to the works of Leontief (1937) and Arrow and Debreu (1954). Different model typologies have spawned from this framework, ranging from the input-output model, the linear programming and dynamic and non-linear programming models, to the more recent applied or computable general equilibrium models (CGE models). Since the early 1970s, CGE models have grown to encompass the input-output and various programming models, and are now the most popular multisectoral models in use.

3.2.1 Input-Output Models

Input-output modeling owes its development to the pioneering work of Wassily Leontief (1936). In a restricted sense, it constitutes a general equilibrium analysis to the extent that it analyzes the structural interdependence among productive activities in the different sectors in an economy. The scope of its application includes checking for internal consistency; analyzing the interdependence of the different sectors in an economy; estimation of resource requirements; and forecasting (Olofin, et al. 1993). The input- output (I-O) framework is based on three major assumptions (Gerking, 1977). First, a given economy can be segmented into interrelated finite number of sectors, each of which produces a single homogenous product. Second is fixed technical coefficients, indicating constant returns to scale in a production process and third, there is a fixed correspondence between levels of output and input requirements in all sectors.

1. The basic I-O model can be expressed mathematically as:

$$X = (I - A)^{-1} D \qquad \ldots\ldots\ldots\ldots \qquad (5)$$

and

$$\Delta X = (I - A)^{-1} \Delta D \qquad \ldots\ldots\ldots\ldots \qquad (6)$$

Where I is (n x n) identity matrix, A is (n x n) matrix of technical coefficients, X is (n x 1) vector of the total outputs of the producing sectors, Y is (n x 1) vector of the final demands for the total outputs of the producing sectors, $(I - A)^{-1}$ is the Leontief inverse matrix and Δ means change. From equation (5), the outputs of sector X, can be estimated given values of the final demand for D. Also, change in output due to some change in demand can be measured using equation (6).

The dynamic I-O model addresses the issue of time in the I-O framework. Since there are several types of dynamic I-O models, only the basic model is presented below. Basically, the dynamic I-O model assumes that some inputs in the production process are not used up in a single year but serves as a capital stock for use in future years. Skipping mathematical derivations, the basic dynamic I-O model is a revision of the basic static I-O model given in equation (5) as follows

$$(I - A + B)\, X^t - BX^{t+1} = D_t \qquad \ldots\ldots\ldots\ldots \qquad (7)$$

or

$$BX^{t+1} = (I - A + B)\, X^t - D^t \qquad \text{.....} \qquad (8)$$

Where B is (n x n) capital stock coefficients matrix and the b_{ij}s are the amount of the output of a sector reserved as a capital stock by another sector and the superscript indicate years. The basic dynamic I-O model and its more complicated variants have not been widely applied in developing countries, primarily because the data requirements for measuring the capital stock coefficients B.

3.2.2 Computable or Applied General Equilibrium Models

This genre of models are an extension of Wassily Lenontief's work on empirical Walrasian models based on fixed input-output coefficients by incorporating substitution effects in both production and demand, and by including more than one consumer. Earlier work by two economists (Johansen l960 and Scarf 1973) provided the background for much of this activity. Leif Johansen (l960) formulated the first empirically based, multi-sector, price-endogenous model analyzing resource allocation issues and applied this model to policy questions in Norway. A final important source of stimulus has been an ingenious computer algorithm for the numerical determination of the equilibrium of a Walrasian system, developed extensions to his original algorithm, and more recently the use of alternative solution techniques. Scarf's work has been instrumental in persuading some of the recent generation of mathematically-trained economists to approach general equilibrium from a computational and, ultimately, a practical perspective. The value of these computational models is that much more details and complexity can be incorporated than in simple analytic models. Models involving 40 or more sectors and industries are commonly employed, providing substantial detail for policy-makers concerned with feedback effects of policy initiatives directed only at specified products or industries.

Equilibrium in this model is characterized by a set of prices and levels of production in each industry such that market demand equals supply for all commodities (including disposal if any commodity is a free good). Since producers are assumed to maximize profits, this implies that in the constant-return-to-scale case, no activity (or cost-minimizing techniques for production functions) does any better than break even at the equilibrium prices. Typically, calibration involves only one year's data, or a single observation represented as an average over a number of years. A crucial point in using calibration is that because of the reliance on a single observation, the benchmark data typically do not identify a unique set of values for the parameters in any model. Parameter values for the relevant elasticities are usually specified on the basis of other research. This typically places a lot of reliance on literature surveys of elasticities and, as many of the modelers have observed in discussing their own work, it is surprising how sparse (and sometimes contradictory) the literature is on some elasticity values. Also, although this procedure might sound straightforward, it is often exceedingly difficult because each study is different from every other and recognizing and taking account of these differences is necessary.

Most Applied general equilibrium models are based on social accounting matrix (SAM) as the underlying statistical framework. A social accounting matrix (SAM) is a logical arrangement of statistical information in a country within a particular time period (usually a year). It is a single accounting framework, which arranges income flows to the institutions and sectors into an equal number of rows and columns. The number of rows and columns is flexible, changing in accordance with the nature of an economy and the purpose for which the SAM is required. It provides a conceptual basis to analyze both distributional and growth issues within a single framework. 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: first, organizing information about the economic and social structure of a country over a period of time and 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.

A SAM brings disparate data (including input-output tables, household surveys, producer surveys, trade statistics, national accounts data, balance of payments statistics, and government budget information) into a unified framework. It is broader than an input-output table and typical national account, showing more detail about all kinds of transactions within an economy. If the SAM is to support analyses of poverty and inequality, it must include a detailed disaggregation of households on the basis of their incomes sources or other socioeconomic characteristics (IFPRI, 2000).

Early applied models either used Herbert Scarf's algorithm (l967, l973) for solution or approximated an equilibrium using Johansen's (l960) procedure. Some recent models continue to rely on Scarf-type methods, but use faster variants of his algorithm due to Merrill (l972). The introduction of GAMs, an acronym for general algebraic modeling system by Alexander Meeraus, previously at the World Bank has simplified and popularized these models in recent years. Work with CGE models in GAMS commenced in the mid-1980s with the "Cameroun Model" by Shanta Devarajan, which was based on the CGE model code in Fortran in the book by Dervis, de Melo, and Robinson. Since then, there have been a number of "standard", flexible, single-country models. GAMS is a high-level modeling system for mathematical programming problems. It is tailored for complex, large-scale modeling applications. It consists of a language compiler and a stable of integrated high performance solvers.

A question frequently addressed by these models is whether any particular policy change is welfare-improving. In this instance, policy appraisal using these techniques usually relies upon a comparison between an existing equilibrium (i.e., with unchanged policies), and a counterfactual equilibrium computed with modified policies. Because underlying theoretical structure of these models is firmly rooted in traditional micro-theory, a common procedure is to construct numerical welfare measures of the gain or loss. The measures most widely employed are Hicksian compensating and equivalent variations associated with the equilibrium comparison. The compensating variation (CV) takes the new equilibrium incomes and prices, and asks how much income must be taken away or added in order to return households to their pre-change utility level. The equivalent variation (EV) takes the old equilibrium income and prices and computes the change needed to achieve new equilibrium utilities. For a welfare-improving change, the CV is negative and the EV is positive, although it is quite common to employ a sign convention so that a positive value for either measure indicates a welfare improvement.

$$\text{Thus } CV = \frac{(U^N - U^o)}{U^N} \cdot I^N \quad \text{.....} \quad (9)$$

$$EV = \frac{(U^N - U^o)}{U^o} \cdot I^o \quad \text{.....} \quad (10)$$

Where U^N , U^o , and I^N ,I^o denote the old and new levels of utility and income respectively.

The traditional approach to applied general equilibrium modeling has been criticized by Jorgensen (1984), Wilcoxen (1988), Diewert and Lawrence (1994) and others on several grounds. First, selection of a single base year means that whatever stochastic anomalies are present in observations for that period will be unduly influential on the model structure. Second, parameters drawn from eclectic sources may be outdated, or refer to different industry, commodity, or regional aggregates than those defined in the model. Third, the functional forms typically used are those nested in CES aggregators, which impose strong a priori restrictions on behavioral responses to price changes.

An alternative methodology has been developed by Jorgensen, which addresses each of these concerns. The key innovation is that the model is estimated econometrically on a single, contemporary time-series database, which maintains consistent industry and commodity definitions throughout, matching those maintained in the model. In addition, flexible functional forms are used in the estimations, allowing a the model to embody a less restrictive representation of underlying technologies

Applied general-equilibrium models have been applied to policy issues in various economic fields over the last two decades including public finance, international trade, evaluation of alternative development strategies, implications of energy policies and environmental related issues.

3.3 Vector Autoregressions (VARs).

Following the seminal work by Sims (1980)[8], macroeconomists have increasingly been interested in studying the sources of economic fluctuations and the dynamic effect of various shocks using vector autoregressive models (VAR). They are widely used in forecasting and in analysis of the effects of structural shocks. A typical VAR model takes the form:

$$\phi(L)\, yt = \mu + \xi\, Dt + vt\,, \quad t=1,2,\ldots, T\,; \qquad \ldots\ldots. \quad (11)$$
$$vt \sim N(0, \Omega)\,,\ vt \text{ is i.i.d. and } \Omega \text{ is diagonal.}$$

Where yt = a (n x 1) column vector;
D_t = column vector with deterministic variables;
$\phi(L) = \phi o - \phi 1\, L - \ldots. - \phi p\, L^p$ is a polynomial in the lag operator L; and
μ = the vector with the equation's constant terms.

Consider equation "i" of the structural VAR :

$$yit = \mu_i + \xi_i\, D_t - \sum_{s \neq i} \phi^i_{so}\; y_{st} + \sum_{s \neq 1} \phi^i_S\,(L)\, y_{st} + v_{it} \qquad \ldots\ldots\ldots \qquad (12)$$

where: y_{st} is the observed value of variable s, at period t; $\sum_{s \neq i} \phi^i_{sk}$ = coefficient of variable s, with lag k, in equation i; and $\phi^i_s(L) = \sum_{k=1}^{p} \phi^i_{sk} L^K$.

Equation (12) can be estimated by different methods and, if the values of the variables are measured by their logarithms, the elasticities for different steps-ahead, of variable i with respect to variable s, can be computed. In order to compute the elasticities, it is necessary to impose certain restrictions.

When VAR was first introduced, the analysis was conducted using levels of variables. Subsequently, it was realized that this is valid only if the variables are stationary. It is now recognized that this solution is inappropriate if the non-stationary variables are co-integrated, because the VAR model omits the cointegrating residuals. This misspecification is remedied by the use of a vector error correction mode (VECM). Their strengths are short-term forecasting (usually six months to a year or so) and the generation of stylized facts. However, they are much less useful for longer-term forecasting and, because they lack any economic structure, they are less relevant for policy analysis.

3.4 Other Models

3.4.1 The World Bank's Revised Minimum Standard Model

Following the stunning success of the Marshall plan in the reconstruction of post-war Europe, the World Bank shifted attention towards the provision of long-term finance for growth and development in developing countries. The Bank, until recently, mainly provided funding for specific investment projects, although its policy agenda has changed significantly since the later period of the 1970s.

The main analytical tool of the World Bank in macroeconomic management is the Revised Minimum Standard Model[9] (RMSM). RMSM was designed in 1973 based on contributions by *Chenery*, *Strout*, *Weisskopf* and

[8] The use of VAR models to describe the data and in particular to analyse the impulse response functions of macroeconomic variables was first proposed by Sims (1980). His argument is that conventional structural models incredible identifying restrictions, which are untested and provide a spurious number of degrees of freedom.

8. Currently, the model is known as the Revised Minimum Standard Model extended (RMSM-X). We consider the basic features of both models although there are substantial differences between them.

Blomqvist to set up a consistent approach to projections among countries and facilitate comparisons among beneficiaries. Its theoretical background can be found in *Harrod and Domar* two-gap growth model for an open economy. It is an expansion of the Harrod-Domar growth model that relates investment, imports and savings with output.

RMSM is generally an accounting framework, linking the national accounts and BOP, with particular emphasis paid to the foreign financing gap and projections of foreign borrowing (Khan, *et al.*, 1990). The model highlights the importance of the relationship among savings, foreign capital flux, investment and growth. It has evolved over time and as at 1992, it had about 425 variables (Mills and Nallari,1992: 105).

The framework initially used by the Bank in their '*empty*' framework are aggregated by the following identities[10]:

$Y = C + I + (X - Z)$	Production and expenditure balance	(1)
$Y = C + S$	Income - savings balance	(2)
$I - S = Z - X$	Savings and trade gaps	(3)

From these identities, income is used either for savings or consumption. Investment must be sourced either from domestic savings or inflow of foreign capital (imports). Domestic savings is needed to finance targeted level of investment. Given that most developing countries experience low levels of domestic savings, imports should be larger than exports with a high proportion of imports constituting investment goods or intermediate inputs in the production process. The identity also implies that foreign resources need to be injected in the economy for financing of investment projects. Financing of capital inflows could be from foreign reserves. However, if foreign reserves are limited, as is often the case in most developing countries, then foreign borrowing is utilized to finance the gap.

This is expressed by the following identity:

$S - I = \Delta NFA + \Delta R$, …….. (4)

where,

ΔNFA is the additional foreign borrowing by the public and private sector ΔNFB. The two gap growth model is derived from the following identities. In a closed economy, real output Y is determined by savings and investments. Thus:

$Y = C + I$ …….. (5)

In equilibrium, ex-ante investment is equal to ex-ante savings while saving is a function of real income:

$I = sY$ …... (6)

where,
I = Investment
s = Marginal propensity to save

Since I is equal to ΔK, the rate of capital accumulation is given by:

$g = \Delta K/K = s/k$ where $k = K/Y$ …….. *(7)*

Assuming *k* is constant, the growth in real output ($\Delta Y/Y$) will be the same as the growth in capital stock.

Thus,

[10] The specification of equations in both the World Bank RMSM model and the IMF Programming framework draws substantially from Trap, (1993), Sen, (1999) and Murinde, (1993).

$g = \Delta K/K = \Delta Y/Y = s/k$ …….. (8)

Equation [8] basically relates to the Harrod-Domar equation, which indicates that the rate of growth is determined by the savings rate and the capital-output ratio. The identity implies that growth in developing countries could be generated by targeting savings and translating these savings into effective investment. The growth rate also depends on the efficiency of investment which is measured by the incremental capital-output ratio (ICOR) or *k*. From Equation [8], given the level of savings and investments, the rate of economic growth can be determined. The identity is used by the Bank as a planning tool to establish how much investment and savings is needed to attain a targeted level of growth, which is expressed as:

$\Delta Y^* = I/k,$ (9)

where,

ΔY^* = target level of growth.

Since developing countries face savings constraint, then the required level of foreign borrowing to finance inflow of capital can be determined from the equation:

$S - I = \Delta NFA + \Delta R,$ (10)

where,
$\Delta NFA = \Delta NFB,$

Thus the additional foreign borrowing required to finance capital inflows is given by:

$\Delta NFB = k\,\Delta Y^* - sY + \Delta R = (\Delta R - sY\text{-}1\,) + (k - S)\,\Delta Y^*.$ (11)

Furthermore, given the trade gap experienced by these countries, the additional foreign borrowing by the private and public sector to close the trade gap is given as (Tarp, 1993):

$\Delta NFB = m1\,k\,\Delta y^* + m_2\,y - X + \Delta R$ (12)
$= (\Delta R - X + m_2\,y\text{-}1\,) + (m1 + m2\,)\,\Delta y^*.$

Tarp (1993) highlights four main equations which forms the core of RMSM:
$\Delta Y = \Delta Y^*$ (13)
$I = k\,\Delta Y^*$ (14)
$X = X$ (15)
$Z = mY$ (16)

The Bank programming and projections primarily focus on real rather than monetary variables. The projections on investment and savings are generally a planning aid to target the level of growth in the economy. Given the savings constraint of most developing countries, foreign financing is estimated to finance investment level that is consistent in achieving the targeted level of economic growth.

While the major appeal of the RMSM framework is its simplicity and conformity to standard national income accounting, it has been severely criticized. OECD (2003) notes that the focus on real variables completely occludes the monetary side of the economy. There is no public finance, hence no link between government deficit and potential inflation which may result when the government deficit is financed though money creation. Qualitative results may differ, depending on the choice of the closure. Furthermore, the supply side is not modeled. The standard RMSM also relies on neoclassical equations assuming that equilibria solve instantly though flexible prices, without modeling any of the structural rigidity that is crucial in developing countries.

3.4.2 The International Monetary Fund (IMF) Financial Programming Model

The IMF approach to economic stabilization (generally referred to as financial programming) is based on the models designed in the 1950s and 1960s by J. J. Polak. The theoretical foundations of financial programming have remained largely unchanged in the last 40 years. The model is utilized by the IMF in line with its mandate of ensuring a stable world economy in financing temporary balance of payments (BOP) disequilibria. It has constituted the backbone of analysis of IMF conditionality, the policy actions that a borrowing country agrees to implement as a precondition for receiving IMF credit (Polak, 1997).

Financial programming is an accounting framework that integrates a system of accounts, including national income and expenditure, current and capital accounts of the BOP, accounts of the central bank, the banking system and the government. These accounts are all integrated into the flow of funds account and the monetary survey of the central bank. Consequently, the basic structure of the IMF programmes is built on a financial analysis that ensures consistency between the impact of proposed policy measures and the desired BOP outcome (IMF,1987).

The financial programming framework links the financial sector with the BOP as illustrated by the following identities:

$$Y = GDP - NF \quad (1)$$
$$GDP = C + I + (X - Z) \quad (2)$$
$$DA = C + I \quad (3)$$
$$CA = X - Z - NF \quad (4)$$

where,
Y = national income,
DA = domestic absorption,
CA = the balance on current account of BOP, and
NF = net factor payments to abroad.

The substitution of [2-4] into [1] gives the following identity;

$$Y = C + I + (X-Z) - NF \Rightarrow Y = C + I + (X-Z) - NF \Rightarrow Y = DA + CA,$$

thus,

$$CA = Y - DA \quad (5)$$

This implies that the current account deficit is equal to the difference between national income and domestic absorption. By implication, the current account shows a surplus if income is greater than domestic absorption and a deficit in the reverse case. Thus, a current account deficit can be reduced by a decline in absorption (relative to income) or by an increase in income (relative to absorption). Similarly, a change in reserves will be equal to the current account balance plus any net inflows of foreign capital (ΔFI).

$$\Delta R = CA + \Delta FI, \quad (6)$$

where,

ΔR = the change in net foreign assets of the banking system, and
ΔFI = the change in the net inflow of foreign capital.
Combining equations [5] and [6], one obtains,

$$\Delta R = Y - DA + \Delta FI \quad (7)$$

Equation (7) indicates the excess of domestic absorption over income not financed entirely by foreign borrowing, leading to a rundown of net foreign assets. Since the stock of such assets is limited in developing countries, the financing of domestic absorption in this manner is greatly limited. Demand management policies directly influence

domestic absorption and thereby the internal balance which refers to the conformity between aggregate expenditure (equal to absorption plus exports minus imports) and potential output at stable prices.

From the monetary balance identity:
$\Delta M = \Delta R + \Delta DC$ *(8)*

Equation (8) shows a balance sheet relationship for the banking system, where the change in domestic money stock is equal to the sum of changes in foreign and in domestic assets. It also assumes that money demand is a function of income, prices and the opportunity costs of holding money, which takes the form:

$\Delta M\mu = f(\Delta Y, \Delta P)$ *(9)*

Rearranging to relate the change in nominal money ($M\mu$) to changes in nominal income (ΔY):

$\Delta M\mu = k\,\Delta Y,$ *(10)*

where,
k = the inverse of the income velocity of money.

Equilibrium condition in the money market is:
$\Delta M\mu = \Delta M$ *(11)*

Hence, equations [9], [10] and [11] can be combined to relate the change in net foreign assets, in which BOP is given by the difference between the change in money stock (equal to $\Delta M\mu$) and the change in domestic credit (Tarp,1993; Polak,1997).

$\Delta R = \Delta M - \Delta DC = f(\Delta y, \Delta P, ...) - \Delta DC$ (12)

Thus, a change in net foreign assets will be positive (BOP surplus) to the extent that the change in the total money stock exceeds the change in domestic credit. Real income is treated as exogenous. In the design of the IMF programmes, the implications of policies for both output and the price level are analysed carefully and output and inflation targets are major factors in deciding upon the policy package.

Equation [5] indicates the gap between income and domestic absorption, which is equal to the current account. The current account must be matched by the change in net foreign assets which is also equal to the difference between the change in the money supply and the change in domestic credit from the balance of the banking system. Combining the equation gives:

$CA + \Delta FI = \Delta M - \Delta DC$ *(13)*

Substituting equation [6] into the equation gives:

$Y - A + \Delta FI = \Delta M - \Delta DC$ (14)

Given the overall financial programming framework, the relationship between change in net foreign assets and changes in domestic credit can be used in the design of a financial programme. The IMF uses expenditure switching or/and expenditure reducing policies to bring about a favourable BOP outcome. Devaluation is the main policy instrument to initiate expenditure switching policies, to change the composition of foreign and domestic expenditure between foreign and domestic goods.

The model relies on simplifying assumptions which has earned it severe criticisms, given the influence of the IMF policy advice in the developing economies (Taylor 1988, Edwards 1989 and Tarp 1993). Balance of payment sustainability is not an objective in its own right, and the focus on monetary issues precludes the modeling of the material balance. The choice of the closure rule depends on assumptions that may not reflect the real world

occurrence. For instance, government deficit and revenue is exogenous, leading public consumption to adjust. Such an assumption outlines the IMF emphasis on expenditure cuts rather than revenue increase. Furthermore, the model relies on neoclassical equations assuming that equilibria solves instantly through flexible prices, without any of the structural rigidities that are crucial in developing countries.

4. Models of the South African Economy

There are several ways of classifying models. Depending on the intended objective, models could be grouped by mathematical structure (optimization or simulation, static or dynamic, linear or nonlinear); methodology (macroeconometric, computable general equilibrium); by policy focus; the underlying theoretical structure; whether for academic or policy analysis; by the nature of agencies that develop such models (e.g. multilateral agencies, national policy institutions, individuals). Several macroeconomic models of the South African economy have been developed. In what follows, we discuss the typologies using a hybrid approach combining model structure and policy focus. With time, we hope to refine this categorisation to allow for model comparison.

4.1 Macroeconomic planning/ Forecasting Models

The National Institute for Economic Policy Model

The NIEP model is an outgrowth of the Macroeconomic Research Group (MERG), established in the early 1990s to fashion out an economic blueprint for the incoming African National Congress led government. The original architects of the MERG model, S. Gelb, B. Gibson and L. Taylor developed a structuralist-Computable General Equilibrium model. However, Peter Brain of the National Institute of Economic and Industry Research in Australia subsequently transformed the model from a structuralist-CGE model to a structuralist-macroeconomic model with 1534 endogenous variables and 60 exogenous variables. The later model was used extensively to formulate MERG's quantitative policy recommendations. Specifically, it simulated the requirements of the Reconstruction and Development Programme (RDP) in terms of employment generation, changing patterns of income distribution, balance of payments sustainability and the government deficit. Others are the requirements for developing the South Africa's infrastructure and the impacts of implementing the tariff reduction schedule under the General Agreement on Trade and Tariff (GATT).

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The underlying theoretical framework is neo-Keynesian structuralist. Like most macroeconometric models, emphasis is on aggregate demand. The major policy recommendations from running extensive simulations using the NIEP model are reported in *Making democracy Work* (MERG, 1993). These recommendations are outlined in Asghar (1996). According to the projections, for the RDP to succeed given the rate of population growth, living standards of the top 20 per cent of households need to remain constant or improve marginally over the next four to five years after which it can improve in line with the growth rate. Fiscal expansion must be targeted at activities which will increase the stock of physical infrastructure, skill formation and physical capital formation. Furthermore, the reform of the tariff system must be gradual enough to encourage enterprises to adjust to international competition and enhance their export capabilities. Over the medium term, it will be necessary to adopt export-oriented incentives for strategic industries in order to partly offset the anti –export bias as a result of tariff reduction and rising imports.

The World Bank Macroeconometric model

The World Bank macroeconometric model evolved from the Bank's 1991 study on post-apartheid policy options for the new South Africa. It was used to simulate the macroeconomic consequences of increased public expenditure, provide indications on the sources of growth and mechanisms to reduce unemployment and income inequalities with emphasis on three main areas; macroeconomic policy, industrial policy and public expenditure alternatives. It quantified the effects of different public programmes of varying sizes; the implications of a shift towards more labour intensive investment, improvement in the international environment for South Africa goods and the impact of excessive wage increases.

The theoretical underpinning is the mainstream IS-LM model. The dynamic of short run economic activity is determined using the Keynesian aggregate demand model under excess capacity, while the long term activity is determined by neoclassical equilibrium market clearing conditions. In each period, the model calculates the GDP from the national account identity and neoclassical production function and then takes whichever value is lower. The switching feature of the model allows for a demand-constrained model during demand-constrained years and a supply-constrained model during supply-constrained years. Spare capacity allows a quick supply response when aggregate demand is stimulated. The neoclassical production function used is based on a CES formulation with three factors (Fallon Da Silva, 1994). Factor demand is determined by the relative prices and the relative factor cost. Investment and capital stocks are disaggregated by four economic agents: the private firms, households, the parastatals and the government. The Private (non-residential) investment expenditure is a function of the GDP growth rate, the real interest rate, the aggregate ratio of corporate savings over income and a lagged depends variable. Private investment in residential building depends on real disposable income, relative price of investment and the consumer price index, the real interest rate (as proxy for the maintenance cost) and the inflation rates between South Africa and the OECD (as indicator of portfolio optimisation behaviour of the households). The model had 300 endogenous variables and 60 exogenous variables.

The simulation results were evaluated based on the characteristics of the growth path and three sustainability criteria, namely, steady state external debt-GDP ratio, steady state non-interest fiscal deficit-GDP ratio and moderate ratio (10 to 20%) inflation. All the policy scenarios examined assumed similar exchange rate and interest rate policies. The recommendations that derives from comparing the baseline projections with the counterfactual policy induced projections in the model are: increased public investment will lead to GDP growth, higher employment, an increase in the fiscal deficit, a deterioration of the current account, an increase in wages and possibly a higher inflation rate; without supply-enhancing policies, the sustainability of economic growth will be threatened by rapidly rising foreign debt arising from high current account deficits; without a healthy climate for private investment, sustainable growth will not take place; and a sustainable high growth path revolves around a targeted real growth rate of 5 per cent per year, with a maximum current account deficit of about 1 per cent and fiscal deficit of about 5-6 percent of GDP in the medium to long term . These figures were observed to be consistent with foreign debt-to-GDP ratio of between 40 percent and 60 percent.

The Industrial Development Corporation's CGE model

The Industrial Development Corporation model was developed in 1993 with the assistance of the Impact Research Group of Monash University in Australia. The stated objective of the modeling effort is to assist policy-makers in quantifying the impacts of proposed economic policy measures. It evaluated the effects of increase in government spending under different financing methods; the implications of capital flows and trade policy on the industrial sector of the economy; the effects of an increase in government spending on provincial gross products; and the implication of the adoption of Uruguay Round trade liberalisation measures.

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

Simulation results indicate that the income distribution effects of an increase in government spending financed by domestic borrowing and foreign capital inflows are relatively small. It recommended the adoption of counter measures to offset the real exchange rate appreciation, which constrains exports. According to the results, the implementation of the GATT will stimulate both final and intermediate goods, and by reducing domestic costs relative to international price levels stimulate exports.

The Development Bank of Southern Africa (DBSA) Model

The DBSA model is a structuralist-CGE model built by B.Gibson and D. van Seventer in the first half of 1995 to examine the consistency and impact of the new government's policies and to explain the effects of exogenous

shocks on the economy. The origin of the DBSA model dates back to Gelb, Gibson and Taylor's work on the MERG model. It updates and revises Gelb, Gibson, Taylor and Van Seventer (1993).

Unlike the IDC model, it is structuralist in that real-world departures from the Walrasian ideal of competitive markets are recognised and integrated through the incorporation of structural rigidities. This is modelled by assuming that the economy is less responsive to changes in relative prices, at least in the short run (Gibson and Van Seventer, 1995a). The model is calibrated to a real and a financial Social Accounting Matrix (SAM)[11] and parameters are either based on fixed coefficients of the underlying SAMs, or are determined by assumption.

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

The results of several comparative static experiments are presented to demonstrate how the DBSA model behaves in the very short run. In addition to these experiments, the model evaluates the impact of changes in the volume and structure of trade on macroeconomic variables; the effect of contractionary fiscal policy on the economy; and outlines the elements of a growth strategy for the medium term. It examines the implications of an increase in government investment by raising the ratio of the PSBR to GDP by about 0,5 per cent; a proposal to fund low-income housing expenditure by reducing the level of government; the effects of a policy that emphasizes export growth; the impact of a possible devaluation on income distribution, inflation, growth and employment; and the macroeconomic consequences of different government expenditures scenarios.

The simulated results indicate that the effect of export growth on macroeconomic variables depends on the way in which it is brought about. A 1 percent autonomous growth in mining generates more economy wide growth, less inflation, more employment and provides a more equal distribution of the gains. The main effect of a devaluation of the exchange rate is to ease the balance of payments constraint through growth in non-traditional exports; elements of a growth strategy should be the lowering of the marginal capital output ratio in various sectors through increased public sector spending and encouraging small and medium –sized enterprises. The implications of adopting a constractionary fiscal policy are examined under the assumption that the ratio of PSBR to GDP will decline. Policy implications are that an increase in private sector investment will not be sufficient to offset the PSBR decline completely. There will be moderate growth but with increasing unemployment and a decline in public investment. A switch in public expenditure from the current to the capital account (reducing public sector employment to finance an RDP housing programme) will lead to a similar growth path, but there will be more inflation.

International Food Policy and Trade and Industrial Policy Models

As with most CGE modelling, the initial motivation for the research reflected a very practical "applied'" need. It is intended to reduce the initial cost of undertaking CGE analysis in South Africa[12].

The initial effort consist of a standard South African model using the CGE modelling framework developed by Lofgren *et al* (2001) and associated program files which readers are able to download and execute in the GAMS programming language. Although the specified model is essentially neoclassical, it is sufficiently flexible to

[11] The real SAM is a flow matrix and it is based on the SAM for the year 1988 compiled by Van Seventer et al (1992). The SAM was aggregated according to the categories of and updated to the year 1990 using data from the June 1992 issue of the *Quarterly Bulletin* of the South African Reserve Bank. Financial SAMs were prepared for 1989 and 1990, both as stock matrices.

[12] IFPRI has developed a Standard CGE model written in the GAMS (General Algebraic Modeling System) software with the aim of making CGE analysis more cost-effective and more accessible to a wider group of analysts.

accommodate a fairly wide range of views on how the South African economy adjusts to exogenous shocks and the use of policy levers.

It draws from the neoclassical-structuralist modelling tradition originally presented in Dervis *et al* (1982). The model is formulated as a set of simultaneous linear and non- linear equations, which define the behaviour of economic agents, as well as the economic environment in which these agents operate. This environment is described by market equilibrium conditions, macroeconomic balances, and dynamic updating equations.

A 1998 social accounting matrix (SAM) for South Africa is compiled using national accounts information and supply-use tables. The SAM is made consistent with the requirements of IFPRI's standard comparative static computable general equilibrium (CGE) model. This model is then used to simulate the economy-wide impact of a range of hypothetical policy levers, including: increased government spending; the elimination of tariff barriers; and an improvement in total factor productivity under three adjustment rules labelled loosely as *neoclassical*, *Johansen* and *Keynesian.* The three macroeconomic adjustment options differ in their treatment of savings and investment. In the neoclassical case it is assumed that the economy is savings-driven. This implies that the level of investment will adjust to ensure that it equals the level of savings as determined by fixed marginal propensities to save for each domestic non-government institution. Conversely, the Johansen option assumes that the economy is investment-driven and that savings-rates are scaled to ensure the level of savings and investment is balanced. Finally, the Keynesian approach takes the position that both the level of investment and the savings *rates* are fixed. Savings will however still adjust to balance investment in this option in that higher income will generate more savings given a fixed savings *rate*.

The results indicate that assumptions made regarding the mechanisms of macroeconomic adjustment are important in determining the expected impacts of these policies. Firstly, despite mixed results concerning changes in household income distribution, the impact of expansionary fiscal policy appears to be growth enhancing, with the Keynesian style adjustment mechanism producing the most positive results. Secondly, a complete abolition of import tariffs also appears to generate increases in gross domestic product, with negative and positive consequences for aggregate manufacturing and services respectively. Finally, an increase in total factor productivity is growth enhancing, with the most positive results derived under neoclassical assumptions of the macroeconomic adjustment mechanisms.

As with most CGE models, there is no explicit modelling of the financial market in the standard IFPRI model. As the authors rightly pointed out, the static model estimates the impact of a change in policy using comparative static analysis, and as such there is no consideration of the path of adjustment over time, or of any dynamic feedbacks into the economy through changes in investment, technology or productivity. While static CGE models are useful in determining the overall effect of policies after the full adjustment process has been allowed to take its course, these models cannot provide insight into the costs of the adjustment or how long these adjustments may take to complete themselves.

In recognition of this defect, the model has been upgraded by Turlock into a recursive dynamic CGE model. The behaviour of agents is based on adaptive expectations, rather than on the forward-looking expectations that underlie alternative inter-temporal optimisation models. Since a recursive model is solved one period at a time, it is possible to separate the *within-period* component from the *between-period* component, where the latter governs the dynamics of the model.

The structure is basically the same with the static model except that two SAMs are compiled for the years 1993 and 2000. A number of equations have also been added to the IFPRI model that allows the regional disaggregation of international trade; an upward sloping factor supply curve ; and factor-specific productivity adjustments.

It appears the author's objectives are being realized. A number of studies using the model have already been undertaken. They cover a wide range of issues, including health and health policy; social security and public finance; and labour market and trade policies. For example, Ramprasad and Thurlow (2003) use the model to consider the impact of HIV-AIDS and the provision of anti-retroviral treatment on the South African economy. As an extension of the work presented in Thurlow (2002), the author uses the dynamic model to assess the macroeconomic impact of implementing and financing a basic income grant. Davies (2002) considers the effects of

alternative labour market policies on future levels of employment. Finally, Thurlow (2003a and 2003b) assesses the impact of trade liberalisation, reform, and the adoption of regional trading agreements on the South African economy.

4.2 Macroeconometric Model

University of Pretoria Macroeconometric Model

The University of Pretoria model originated in the work of Late Geet de Wet and Jan Dreyer who built the first quarterly econometric model for South Africa in the 1970s. The model has since been upgraded and re-estimated using annual data and extended to include detailed balance of trades. The model is linked to the United Nations through the Project LINK to long run global trends in world trade. The Link center is responsible for the international transmission mechanisms that operate through trade flows, price linkages, capital flows, interest rates, exchange rates, migration, technology transfers, and global commodity markets, including the maintenance and operation of the fully linked world model.

The model can be characterized as a demand driven, open macroeconomic model in spite of the fact that supply side is modeled to highlight supply side constraints. The presentation of the factor demand and prices follows standard macroeconomic theory, with proper allowance for country specific structural features such as the transmission of monetary and fiscal policies and institutional detailed in both the private and the public sector. The monetary and the trade blocks are also included in the model.

An interesting feature of the University of Pretoria model is the level of disaggregation to capture the peculiarities of the South African economy. Labour, for example, is disaggregated into informal and formal sectors as well as skilled and unskilled labour. Wages are also decomposed into unskilled and skilled labour. This makes it possible to appraise the distributional impact of national policies.

The Reserve Bank Econometric Model

The quarterly macroeconometric model of the South African Reserve Bank (SARB) has not wholly been opened to outside scrutiny with the exception of a technical workshop held with private sector and academics in September, 1998 to discuss sectoral equations of the pre-2000 models. A model comprising 400 equations was in use until the year 2000. This has been replaced by a far smaller model of 34 equations responsible for the main forecasts of the SARB inflation targeting. However, some of equations have been published piecemeal in Quarterly Bulletins of the Reserve Bank. What follows is a review of these studies.

The modeling of Inflation Expectations

The model for the inflation expectations equations was estimated for a period of early 1960s to 1993 using quarterly data (Pretorius, 1994). The following models were estimated: actual inflation rate of previous period, the distributed lags of actual rates of inflation, adaptive expectations, the hypothesis of extrapolative expectations, rational expectations and ARIMA-models. On the surface the estimated equations using various models performed well. However, in terms of forecasting ability for 1993 (1) and 1994 (4) period, the rational expectations model where price expectations is a function of growth rate of money supply MR lagged 3 quarters, the percentage change of imported goods lagged two quarters and the inflation rate in the preceding period performed better. (The exclusion of fiscal policy on expectations was due to growing public sector deficit which resulted in the overestimation of inflation expectations). This model is applied in the Reserve Bank model to take inflation expectations into account

Gross Fixed Investment in the Macroeconometric Model of the Reserve Bank

Investment

Two investment equations were estimated. The gross fixed investment equation of the private business sector (Pretorius 1998) and the inventory investment in South Africa Smith and Heever (1995). The modeling and estimation of gross fixed investment model is largely based on the Jorgenson's neoclassical fixed investment theory. The user cost of capital is crucial to the model as it encapsulates the impact changes of interest rates, the prices of

capital goods and tax rates in a single variable. The estimated specification relates gross fixed investment as a function of the desired capital stock, the capacity utilization rate in the manufacturing sector and capital stock.

Inventory accumulation process is explained by aggregate sales, quarter-end level of industrial and commercial inventories, the quarterly average prime interest rate of the clearing banks, percent per annum (prime), and quarterly average real effective exchange rate (Rex). The model was estimated using modern time series techniques, and in particular the Engle and Granger two-step approach.

Exchange Rate Adjustment as an Element of Development Strategy in South Africa (Smal, 1996)
The study was conducted to determine the extent to which exchange rate adjustments as part of outward-oriented policy can contribute to economic growth in South Africa. Using quarterly data from 1985 to 1994, Smal estimated import and export equations using OLS and Cochrane-Ortcutt method. Imports are disaggregated into oil and non oil merchandise goods. The import for oil is treated as exogenous given that oil import is influenced by strategic reasons rather than demand considerations. The demand for non-oil merchandized import is explained by domestic income, the relative prices and domestic capacity utilization. The volume of exports is divided into export of manufactured goods, export of commodities minerals. The export of manufactured goods is explained by the index of import volumes of South Africa's major trading partners, relative prices and aggregate domestic demand. Commodity exports including minerals is determined by the real value added in the agricultural and non gold mining sectors, an index of the imports of South Africa's five major trading partners and relative prices.

The import of non oil merchandize exhibits relatively low price elasticity (0.85) but are highly sensitive to income as depicted by an income elasticity of 1.47. The export elasticity (1.40) of manufactured goods is price sensitive. They are also sensitive to changing internaltional business conditions as depicted by an income elasticity of 1.88. The opposite is true for export of non gold merchandize and commodities and minerals. The Marshal-Lenner condition (1.43) suggests that depreciation is likely to improve the balance of trade.

Linkages of this equation to the main model (Reserve Bank Model) suggest that fluctuation in foreign trade affects domestic production, employment, inflation and the balance on the current account. The simulated effects of currency depreciation without financial policy reaction, in the short run lead to higher levels of income and employment as well as a substantial improvement in the current account of balance of payments but is inflationary. In the medium term there appears to be no gain in growth rate. Depreciation with restrictive financial and fiscal policy leads to sustainable growth rate. Employment is higher and the balance on current account of the balance of payments improves as well. Provided that inflationary pressures are contained, inflation is expected not to worsen as a result of depreciation.

4.3 Sectoral policy models

Trade Policy Reform
Deverajan and Lewis (2000) assess the impact of trade reform on households using a fairly standard static neoclassical CGE model. The model derives its structure from the detailed 1992 social accounting matrix (SAM) comprising 94 productive sectors on which it is calibrated. The base social accounting matrix (SAM) is aggregated into 34 sectors, 13 labour skill categories (further subdivided by ethnic group) and 24 households (4 ethnic groups, each subdivided into 6 income classes). Government current expenditures are divided into five classifications, and investment is divided into its public and private components. The SAM—and the model—also distinguish many sources of transfers, including transfers from government to households, as well as across households.

Production is modeled using nested constant elasticity of substitution (CES) functions, and constant returns to scale, household demand using the Extended Linear Expenditure and trade using the Armington assumption for import demand, and a constant elasticity of transformation (CET) for export supply. The small country assumption is assumed for all sectors, hence world import and export prices are given and the terms of trade are fixed. All markets are assumed to clear through prices except for the labour market for unskilled black workers where real wage is

assumed fixed and unemployment clears the labuor market. For each labour skill type, labour is assumed to be perfectly mobile across sectors, and thus there is a single nation-wide equilibrating wage rate for each labour type

All households are assumed to have the same utility function, albeit with different parameters. The model uses a modified Stone-Geary linear expenditure system known as the extended linear expenditure system (ELES). Consumer demand for any good (including demand for savings) has two components: a subsistence minimum and a fixed fraction of "supernumerary income", or disposable income less expenditures on all the subsistence minima. Four trade reforms were simulations. A complete removal of all tariffs, with two different assumptions on capital mobility and two different closure rules.

The results demonstrated that trade liberalization could benefit black South Africans, albeit at the expense of wealthier white South Africans. Furthermore, income distribution among blacks could worsen, while that within whites could improve. The major deficiency of the model perhaps is the derivation of elasticities, some of which crucially affect the outcome of simulations. They are based on informed judgement, rather than estimated econometrically.

Monetary Policy

The Centre for the Study of African Economies (CSAE), Oxford, has developed strong links with the South African Reserve Bank and the Bureau for Economic Research to provide comprehensive and sophisticated analysis to evaluate the design and operation of the new monetary policy regime and its implications for sustainable growth, currently the subject of considerable domestic policy debate. This initiative does involve a lot of modeling. For example, the study conducted by Aron and Muellbauer (2000) was intended to highlight the lack of attention given to regime shifts, such as financial liberalisation in South Africa.

South African monetary policy has experienced major shifts, with three broad monetary policy regimes since the 1960s. The study analyses the conduct of monetary policy, describing the historical record and institutions of monetary policy, and formally modelling extended Taylor rules to estimate the weights applied to different policy objectives in the interest rate rule. The equation estimated was:

$$i_t = \delta_0 + \delta_1 i_{t-1} + \delta_2 \Delta_4 \ln P_{t+k}^F + \delta_3 x_{t+m}^F + \delta_4 z_t^F + \delta_5 i_{t-1}^{USA} + \varepsilon_t \ \ldots\ldots \qquad (42)$$

where i_t is the central bank's short term interest rate, $\Delta_4 \ln P_{t+k}$ is the annual rate of change of the consumer price deflator over the horizon of *k* quarters and x_{t+m} is the output gap at $t = m$ quarters. *F* denotes the forecasted value of these two variables using information available at $t-1$. The horizon *k* and *m* is at the discretion of the central bank but will be constrained by its forecasting ability. z_t consists of other variables such as deviations in money growth, exchange rate and balance of payments effects which are included in the original Taylor rule equation. Finally, i_{t-1}^{USA} is the foreign short term interest rate (three month Treasury bill rate)

The model is estimated using quarterly data on inflation and output gap forecasts. Regression results testing Taylor Rules with partial adjustment and foreign rates for all specifications yields perverse results. Taylor rules, augmented for foreign interest rate influences and interest rate smoothing, and based either on forecast, or actual, inflation and output gap measures, poorly describe the behavior of the discount rate. A satisfactory model includes the deviation of money growth from target in the rule and controls for the extensive financial liberalisation occurring in the period. In practice, the central bank emphasized current inflation, giving a low weight to the output gap. They find weak evidence for structural breaks reflecting competing balance of payments considerations.

In the same vein, Aron, Muellbauer and Smit (2004) recently built a 4-equation model of the inflation process in South Africa including the exchange rate, consumer prices, producer price, and import prices. This provides useful information on the speed and extent of exchange rate pass-through, and illuminates the various channels through which monetary policy influences inflation. The model is in the tradition of central bank models of the inflation process, but carefully tests for asymmetries, structural breaks and expectations effects, and applies a range of

econometric tests and methods to refute the charge by Sims (1980) that such models necessarily impose incredible restrictions, especially in the light of the rational expectations hypothesis.

Poverty and Income Distribution

The distribution of income and wealth in South Africa is amongst the most skewed in the world. There is a striking dualism due to several decades of apartheid. About 13 percent of the population are in the "first world", with access to education, low infant mortality rates, and minimal poverty while around 53 percent of the population, half of which have less than a primary school education, suffer from chronic malnutrition and maximal poverty (World Bank, 2000). The experience of most South African households is of outright poverty and continuing vulnerability to being poor. Despite this awkward scenario, models explicitly emphasizing poverty are surprisingly few. The notable exception is the CGE model by Humphreys.

Humpreys (2000)

Humphreys (2000) appraised the impact of liberalization on poverty in South Africa using a CGE model of a small open economy. The model is restrictive in the sense that goods are aggregated into just three types; primary goods including mining and agriculture; industrial goods and services. Furthermore, it considered only three types of consumers - non poor, poor and very poor; three factors capital, skilled and unskilled labour; and nine goods non traded, import and export variety from each of the three sectors. The model is essentially walrasian except that it allows for unemployment. It is based on a simplified version of the 1992 SAM with supplemented by labour market and tariff rate data from other sources. Most of the parameters are borrowed from Devarajan and Van de Mensbrugghe (1991) and labour market information from Kingdom and Knight (1999).

The classical closure rule is adopted in which a fixed savings rate is assumed for government and all consumers. Aggregate investment then adjusts to ensure that the investment-savings identity holds. The scenarios evaluated are gradual reduction in the tariff rate of each protected sector from 25 % to 0 % and a 5 % increment. The simulation results indicate that government revenue fall ambiguously from liberalization. The fall in government revenue imply a general fall in transfers from government to households and a reduction in government services. The drop in government transfers has little impact on the growth of real income of non-poor and poor consumers for whom these transfers constitute a small share of income. For the very poor however, the drop in tariffs results in a much more modest growth of real income.

4.4 Military expenditure and growth in South Africa

Econometric analyses of the relation between military spending and growth in South Africa have followed the standard approaches in the literature. These include the neoclassical growth models typified by estimation of the Feder-Ram model (McMillan, 1996 and Batchelor, Dunne, and Saal, 1998), a Keynesian simultaneous equation model with an aggregate production function (Roux, 1996 and Dunne, Nikolaidou, and Roux, 2000), and Granger causality and cointegration techniques (Dunne and Vougas, 1999 and Birdi and Dunne, 2000). There have also been attempts to use industrial level panel data, e.g., by Birdi, Dunne, and Saal (2000).

The simple Feder-Ram model has been a fancy for defense analyst, mainly because of its ability to explicitly treat externality effects of the military on the non-military sector (Birdi and Dunne, 2000). The basic model assumes two distinct sectors military (M) and non-military (C), that labour L and capital K are the divisible inputs, and that the military sector has an externality effect on the rest of the economy. Usually, the model estimated is of the form:

$$QD = â\ LD + á\ (I / Y) + ((ä / 1 + ä) - CM)\ MD\ (M / Q) \quad \ldots\ldots\ldots\ldots \quad (43)$$

where YD = dY/Y; LD = dL/L ; MD = dM/M. The coefficient on the last term is the sum of the externality and factor productivity differential effects of military spending. Initially, these models were applied on cross sectional data, but increasingly have been applied to time series for individual countries.

Following Biswas and Ram (1986), Batchelor, Dunne, and Saal (2000) assumed that the externality parameter is not CM but CM (M/C) and is denoted by è, allowing them to reformulate the equation as:

$$QD = â\ LD + á\ (I / Y) + ((ä / 1 + ä) - è)\ MD\ (M / Q) + è\ MD \quad \ldots\ldots\ldots\ldots.. \quad (44)$$

To operationalize the model for empirical application the instantaneous rates of change of the variables are replaced by their discrete equivalents giving:

ÄYt/Yt-1 = á0 + á1 ÄLt/Lt-1 + á2 It/Yt-1 + á3 ÄMt/Mt-1 (Mt/Yt-1) + á4 ÄMt/Mt-1… (45)

This model was estimated using data for the period 1964-95. These results suggest that economic growth in South Africa can be only partly explained by the model, although the specification seems to be reasonable according to the different statistical tests. The R^2 suggests that the equation only explains 59 percent of the variation in the dependent variable, which in a time series regression is relatively poor. In addition, only the employment variable is statistically significant at the 5 percent significance level. This variable is the growth in non-agricultural labor which is used to approximate the labor force. Surprisingly, the investment term is insignificant. The military spending coefficient estimates suggest a positive externality effect, but a negative size effect, but these are only significant at 10 percent. There are of course problems of multicollinearity with an equation of this form particularly between the two military spending terms. This will mean that although the estimates are unbiased they are imprecise and unstable. One would expect a high F statistic, but low individual significance, which is what we observe. However, the joint test of zero restrictions on the military variables' coefficients cannot be rejected, suggesting that there is no significant impact of military spending on growth.

Concerns about the Feder-Ram model, in terms of its specification and dynamics, led Dunne, and Saal, (2000) to adopt an aggregate production function, estimated using cointegrating VAR methods. The results were rather disappointing when the model was estimated using GDP, but suggested a negative though insignificant effect of military expenditure on growth. When estimated at the level of manufacturing the results show a positive long-run relation between military spending and growth, but a negative short-run effect. The composite effect of the short-run coefficient on military spending and the error correction term suggests that the short-run impact of cuts in military expenditure will at worst not be significant. As we have seen, most of the empirical evidence tends to suggest a negative or insignificant effect of military spending on growth in South Africa. The results of this study, while providing some advance in the econometric analysis, do appear to be consistent with the previous findings.

4.5 The Macroeconomic Impact of HIV /AIDs

Research interest on the economic impact of HIV/AIDS in South Africa is intense and growing fast. This stems from a realization that South Africa currently faces one of the highest HIV prevalence rates in the world, with different estimates putting the number of HIV infected South Africans between 4 and 6 million. Four models that have attained prominence within this body of literature are examined. These modeling exercises typically follow a pattern of reporting "with" and "without AIDS" scenarios. While the methodological approach to modeling the economic impact of HIV/AIDS are different, the overriding message that these models convey remains the same: the cost of HIV/AIDS to South Africa will be significant in economic, social and human terms. However, these studies have been discussed elaborately[13] (Ford *et al*., 2002, Davies, 2003 and Booysen, et. al., 2003).

They have been described as highly aggregated. The impact primarily manifests in terms of the demographic and labour market aspects of the HIV/AIDS epidemic. Furthermore, the focus is on the formal sector, and the deductions are then made regarding the rest of the economy and labour force. This impacts negatively on the accuracy of the models as most Africans live and work in the informal sectors, in which market valuation of activities leaves much to be desired. It is expected that the direct modelling approach will become more accurate as demographic projections improve and as necessary micro-level research allows more precise assumptions to be made (Ford *et al*., 2002).

It been suggested that micro-simulation approaches are more appropriate in modeling HIV/AIDs since they combines micro- and macro-level data with CGE in modeling macroeconomic outcomes (Davies, 2003). An example is the work of Cogneau and Grimm (2003) investigating the impact of the epidemic on poverty and income

[13] These studies have received a lot of attention from researchers. They have been evaluated in http://www.jointcenter.org/international/hiv-aids/1_households.htm, for an

inequality. It combines data from several household income surveys, a Demographic and Health Survey, a migration survey, a population census, and demographic projections by the United Nations.

Broomberg et al
The approach adopted by Broomberg is based on a methodology developed by Rice, and adapted to HIV/AIDS. It makes use of what is essentially a cost-benefit framework in that it focuses on those directly affected by the epidemic and excludes from consideration the rest of society. The impact of the epidemic is understood to comprise the total annual costs of the disease to society, cumulated over a specified period. Costs are divided into direct and indirect, where direct costs include the costs of health services provided by public and private sectors at all stages of the disease as well as testing, prevention research and education. Indirect costs include estimates of the morbidity, disability and premature mortality as a result of HIV/AIDS per annum, by summing lost future earnings (discounted at an appropriate social discount rate) over all cases (structured by race, age and gender). This total is adjusted downwards to account for replacement of ill and deceased workers by unemployed workers, to give a proxy for lost production in the economy as a whole. All the unskilled workers and half of the semi-skilled are assumed to be replaceable once forced to leave the labour force due to illness or death.

Broomberg et al 1991 analysis was based on demographic input from the Doyle model which suggested at the time that prevalence in South Africa would peak at about 30% of the adult population, leading to a reduction in population growth rates by 2005. Even with behavioural changes, prevalence would still reach about 18% before levelling off. The analysis combines this input with estimates of cost of care and wage rates, to calculate the various components of total costs. It then attempts to provide some perspective on costs by relating them to total health care expenditures and to GDP.

They suggest that total costs of the epidemic incurred in 2000 would be between 2.3% and 4% of GDP in that year, with the *direct* costs making up the majority of this total, between 1.8% and 3.6%. In 2005, the equivalent proportions would be 5.1%-9% for total costs, and 3.8%-8% for direct costs. It is similarly argued that direct AIDS-related costs would amount to between 19 and 40% of total (public plus private) health care expenditure in 2000. These numbers are very high, indeed too high to be credible, and suggest some problems in the underlying assumptions, as well as perhaps some of the difficulties in using the human capital methodology to generate estimates of aggregate economic impact.

There are several problems in applying the human capital approach to examine macroeconomic implication of AIDs. It is better suited to estimating the marginal benefit of preventing a single case of HIV infection, than assessing the aggregate income and growth impact (Cuddington, 1993a, 188). Nonetheless, it does place useful emphasis on accurate estimation of the costs of health care, an issue over which there remains considerable confusion, but which is an essential input for more strictly macroeconomic methodologies (ING Barings, 2000: 16).

ING Barings

The methods of econometric modeling in the ING Barings Report are based on the ASSA demographic model, adding infection and mortality profiles by skills levels and for selected sectors. No changes were assumed for the calculations on the second cycle (2000-2015). The impact of the counterbalancing effects of the AIDS epidemic were explored with WEFA annual macroeconometric modeling framework (long-term forecasts being trend forecasts, excluding considerations of business cycles; based on a full supply-demand econometric model. It takes both the supply and the demand factors into account in the econometric modelling and, unlike the Arndt and Lewis (2000) model, the economic forecasts are mainly of a long-term nature.

The key results are that the growth rate of GDP declines by 0.2%-0.3% up to 2005, and thereafter by 0.3%-0.4%. Since population growth declines by more than 1.33% up to 2005, per capita income will actually be higher until

2005, as compared with a no AIDS situation, if the model's projections are accurate. After 2005, the decline in population growth averages 0.12% per annum, which is less than the decline in the growth rate of GDP, so per capita income will be lower than without the epidemic.

While the methods of econometric modeling are clearly spelt out, and detailed data on sectoral impact are provided, the calculations and projections of the Report have come under critical scrutiny, primarily on the basis of the problematic calculations of seroprevalence rates and the overlay of various sets of data whose links can be described as tenuous at best (Acott, 2000). The model used has also been described as highly aggregated, and ill-suited to model expenditure switching programmes, which are probably the key to management of health care costs in the face of AIDS (Acott, 2000).

The World Bank: Computable general equilibrium (CGE) model

Arndt and Lewis (2000) employ a supply-constrained Computable General Equilibrium (CGE) model in estimating the macroeconomic impact of HIV/AIDS. It generate and compare two scenarios: a hypothetical "no-AIDS" scenario in which the economy continues to perform as it has over the last several years, and an "AIDS" scenario in which the key AIDS-related factors affect economic performance.

The model is a Solow-type aggregated (one-sector, one-class) version of the standard neo-classical CGE. It has the same macroeconomic structure with a standard CGE model but lacks the distributional richness. Institutional rigidities and imperfect markets are captured by the exogenous imposition of features such as immobile sectoral capital stocks, labor market segmentation, and a fixed exchange rate, which together limit a neoclassical interpretation of the models but permit their more realistic application to developing countries.

The basic data is derived from an aggregated version of a 1997 Social Accounting Matrix estimated by WEFA, a South African consulting firm. The WEFA SAM has 45 productive sectors, and a household structure differentiated by deciles (with the upper decile further broken down into five groups).

The model contains fourteen productive sectors, including three service sectors of particular relevance to analysis of HIV/AIDS: medical and health services, social services, and government services. There are five primary factors of production (professional, skilled, and unskilled labor, informal labor, and physical capital), five household categories representing income distribution quintiles, seven different government functional spending categories, and three government investment categories. Sectoral production occurs according to a translog production function that determines how capital and labour inputs are combined together in generating value added. The value added aggregate is then combined with intermediate (material) inputs to produce output according to a fixed coefficients technology. Profit-maximization by producers is assumed, implying that each factor is demanded so that marginal revenue product equals marginal cost. However, factors need not receive a uniform wage or "rental" (for capital) across sectors; sectoral factor market distortions are imposed that fix the ratio of the sectoral return to a factor relative to the economywide average return for that factor.

On the demand side, the model maintains the standard CGE assumption that domestic goods are imperfect substitutes for traded goods (both exports and imports). Sectoral exports are assumed different from output sold domestically, and are combined using a constant elasticity of transformation (CET) function to form domestic output. As with exports, sectoral imports and domestically produced goods are imperfect substitutes in both intermediate and final uses.

Arndt and Lewis rely on many of the same epidemiological inputs and assumptions as the ING Barings study. But where they differ, they take a significantly more pessimistic view. They introduce a decline in total factor productivity (TFP) as a result of the epidemic, over and above the loss of *labour* productivity, which increases the negative macroeconomic impact. Total factor productivity refers to efficiency improvements (or declines) which are not attributable solely to one or other of the two factor inputs (labour and capital), but rather to their combination in production. Arndt and Lewis justify the inclusion of this effect on the grounds that HIV/AIDS will reduce the productivity of management and of capital (due to increased downtime linked to absenteeism), as well as lower morale amongst the workforce. While this seems plausible, what is unclear is why they tie the reduction of TFP growth to unskilled, as opposed to skilled, labour, since it is the activities of the latter that are involved.

The Bureau for Economic Research (BER)
In 2001, the Bureau for Economic Research (BER) used its macro-econometric forecasting model to forecast the impact of HIV/AIDS on the South African economy. The BER estimated that overall economic growth could be 0.5% lower per annum between 2002 and 2015 than it would have been in the absence of HIV/AIDS. The negative impact on real GDP growth is gradual and ranges on average from 0,3% to 0,6%. They incorporate both the latest ASSA demographic projections, as well as those of the Doyle-Metropolitan model into their econometric simulations.

The macro-econometric simulation exercise is conducted by identifying five key macro-economic impact channels, analysing the impact of each of these independently, and then combining them to obtain aggregated simulation results. The five identified channels are : a lower overall population and labour force; direct costs to the private business sector; indirect costs to the private business sector; higher government expenditure due to the increased direct and indirect costs; the increased demand for public sector health services; and household additional out-of-pocket spending on health care products and services as well as funerals.

According to the results, potential GDP will be substantially lower due to the adverse impact of HIV/AIDS on the labour force. Similarly, actual GDP will also be lower as a result of lower levels of employment. The model results indicate that HIV/AIDS would reduce the supply of available workers to such an extent that skilled and unskilled unemployment rates would decline, putting upward pressure on wage rates. Higher wage rates, in turn, reduce the demand for labour.

5. Conclusion

The preceeding sections have surveyed macroeconomic models in South Africa. From this evaluation, it is glaring that macroeconomic models are increasingly being integrated into forecasting and policy analysis in South Africa. Macroeconometric models are in continuous use in macroeconomic forecasting and policy analysis, and are continuously developing. However, the use of these models by policy-makers, with the exception of the Reserve Bank is still limited due to what (Thurlow and Seventer, 2002) described as the perceived complexity of the analytical framework and the concentration of capacity within a small number of academic or related institutions.

The external orientation of most of the models also poses problems regarding their relevance and maintenance. Most of the modeling efforts have not been sustained. Arguably, with the exception of the University of Pretoria Macroeconometric Model and the IFPRI/TIPs Computable general equilibrium model, existing models have not been revised and updated periodically in line with new theoretical insight and data.

Policy makers have to recognize explicitely that macroeconomic models play an important role in policy making. They provide the means to carry out policy simulations, explore alternative scenarios and to understand the past better by replaying history with alternative counterfactual assumptions (Currie, 1994). Macroeconomic modeling teams, on the other hand, should strive to be at the frontier of knowledge in modeling and theory with a view to incorporating new insights notably in applied econometrics, game theory, supply side modeling and the modeling of expectation and learning.

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