# Fiscal Policy Design in South Africa – An Intertemporal CGE Model with Perfect Foresight[1]

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20 October 2003
**This version: 27 October 2003**

**ABSTRACT**

A macrodynamic model for South Africa is developed to analyse macroeconomic policies, exogenous shocks and structural adjustment. The relationship between stabilisation policies and structural change is of particular interest because of recent experiences. After independence, South Africa has achieved macroeconomic stability at the expense of slow economic growth. While inflation and the budget deficit have been contained, per capita incomes have been stagnant. The role of macroeconomic policy is a key issue addressed in the project. We approach these questions by simulating policy reform and shocks. The policies must be understood in a macroeconomic framework since essential stabilisation problems are involved. A dynamic setting is essential as intertemporal issues such as savings and investment are at the heart of the major interactions between policy and the economy. At the same time, the policies are directed towards production sectors of different character, so that the macroeconomic performance is linked to sectoral balances – the macroeconomic framework must be integrated with an understanding of sectoral balances. The proposed model is thus a dynamic computable general equilibrium model with perfect foresight.

[1] Revised Research Proposal Submitted to the Poverty and Economic Policy (PEP) Research Network for possible funding.

## 1. Background and overview

After almost a decade of independence, South Africa still finds itself with social problems that possess the characteristics of a developing country; the annual rate of unemployment in the country is 30%, approximately 50% of the population lives below the poverty line and it is estimated that about 20% of the population is infected with the AIDS virus (World Factbook, 2002; South African Yearbook 2000/1). At the same time, authorities have largely succeeded in stabilising and disinflating the economy. This success means that, within the set of possible policy choices, there is now a range of viable alternatives to address the country's social problems. While the overriding development policy issue is poverty reduction, employment expansion is also a major closely related policy issue. At the same time, there is a strong commitment to further trade policy liberalization. Thus, there are at least two policy agendas for South Africa:

1. policies for employment reduction expansion and poverty reduction
2. trade liberalisation and further opening of the economy to globalization

These policies must be understood in a macroeconomic framework since essential stabilisation problems are involved. At the same time, the policies are directed towards production sectors of different character, so that the macroeconomic performance is linked to sectoral balances – the macroeconomic framework must be integrated with an understanding of sectoral balances. The dynamic setting is essential, as most of the major interactions are dynamic in nature: the presence of perfect foresight and intertemporal investment-saving decisions. The potential economic impact of exogenous shocks also demands attention. For instance, exogenous supply shocks generate shifting agricultural supply, the revenues of mining vary with fluctuating world market prices and the HIV/AIDS pandemic is likely to have profound effects on families and the health delivery system. The proposed model is thus a dynamic computable general equilibrium (CGE) model with perfect foresight. Analytical treatment of aggregate economic growth on which such models are usually based has its origin in the work of early theorists such as Ramsey (1928), Solow (1956), and Koopmans (1965).

Much of the issues surrounding these questions are essentially macroeconomic in nature. CGE models used to date to analyse similar issues are largely static in nature. Based on a robust and widely accepted modelling of agents' behaviour, such models are able to provide a detailed description of the impact of such shocks on the economy (see e.g., Shoven and Whalley (1984) and Devarajan *et al* (1990)). They are ideally suited to look at the economy as a whole and, in particular, the relationship between relative prices and the flow of goods and services. But they are not really *macroeconomic* models. They typically do not take into account the dynamic side of policy impacts which may be important. Such models are therefore not always ideally structured to address aspects of macroeconomic policy.

The impacts of the dynamic issues are typically analysed using (a) recursive-dynamic specification and (b) forward looking specification. Recursive (sequential) CGE models assume that economic agents are myopic. This kind of dynamics is not the result of intertemporal program maximization but the resolution of a sequence of static models where only the stock of capital and population growth are taken into account. In this case the investment demand function is an ad hoc assumption and not an optimisation result (see Annabi (2003a) for a careful exposition of modelling recursive dynamics in CGE models). There are now a number of alternative specifications of the investment by destination functions in the literature (see e.g., Bchir, Decreux, Guérin and Jean (2002) and Jung and Thorbecke (2000)). The most well known follows from the work of Bourguignon, Branson and De Melo (1989) and later elaborated on in Annabi (2003a) and takes the form:

$$\frac{INV_t^i}{K_t^i} = \kappa_{1i}\left(\frac{R_t^i}{U_t}\right)^2 + \kappa_{2i}\left(\frac{R_t^i}{U_t}\right)$$

where $\kappa_{1i}$ and $\kappa_{2i}$ are positive parameters calibrated on the basis of the investment elasticity and the investment equilibrium equation. The investment rate ($INV_t^i$) is increasing with respect to the ratio of the rate of physical return to capital ($R_t^i$) and its user cost($U_t$)[2].

The forward-looking model is based on intertemporal utility maximization for consumers and cash flow maximization for firms. It is typically a standard Ramsey-type CGE model with perfect foresight. This approach has the advantage over recursive dynamic models that agents use both current and future states of the economy to make a decision, which intertemporal aspect is absent from recursive dynamic models[3]. Because of their heavy computational requirements, true dynamic extensions of CGE models are a fairly recent development. In the past few years, authors such as Summers and Goulder (1989), Jorgenson and Wilcoxen (1990), and Rutherford and others (1997) have begun to use dynamic CGE models to explore a variety of policy issues using a single consuming agent. The introduction of capital adjustment costs (Gould (1968), Hamermesh and Pfann (1996) and Bigsten *et al* (1999)) results in a Tobin's q investment demand function and the equality between marginal and average q is needed (conditions proved by Hayashi (1982)). We can find in Romer (1996) and Obstfeld and Rogoff (1996) theoretical developments of dynamic models with perfect foresight. Devarajan and Go (1998) present very simple truly dynamic CGE models. Other recent works presenting truly dynamic multi-sectoral CGE models are Go (1994), Keushnig and Kohler (1994,1995), Dissou and Decaluwé (1995), Annabi and Rajhi (2001), Dissou (2002) and Annabi (2003b).

The policy relevance of the proposed work is as follows:

- these issues have immense policy relevance for South Africa. For example, policy makers need to know the likely direction of intersectoral changes emanating from their interventions
- the analysis provides some quantitative benchmarks against which different macroeconomic policy arrangements can be compared

[2] Hall and Jorgenson (1967).

[3] This advantage should be toned down because of the observation that empirical estimates suggest that consumers in reality look ahead to some extent but not as far as infinity (see Srinivasan (1982) and Ballard and Goulder (1985)). This suggests that forward looking and recursive dynamic models may provide two extreme cases between which lies reality.

- to help our understanding of the likely impacts and limitations of policy reform in a highly complicated economic system
- to help us design possible interventions that minimize the losses arising from the adjustment process

The rest of the paper is organised as follows. Section 2 gives a review of some CGE based analysis in South Africa while the next section presents the rubrics of a proposed intertemporal CGE model for South Africa. Section 4 discusses data and calibration issues, while section 5 discusses the policy simulations that are proposed.

## 2. Recent CGE models for policy analysis in South Africa

Similar to trends in the international literature, within the CGE tradition, one finds two main ways of exploring the relationship between macroeconomic shocks and policies on the South African economy. The first limits itself to static analysis and the second incorporates some rudimentary dynamics. Prominent examples in the static CGE tradition include Coetzee *et al* (1997), Devarajan and van der Mensbrugghe (2000) and Cameron (1994). These models resulted in a number of applications including: investigations in trade liberalization, currency devaluations and evaluation of government expenditure and restructuring. More recent applications of CGE in the same genre of models in South Africa include Arndt and Lewis (2000), Lewis (2001), Thurlow and van Seventer (2002) and Thurlow (2002). Below we go into a bit of detail on some of these model applications in order to give a flavour of what to expect from policy interventions in the country.

The CGE model developed by Arndt and Lewis (2000) is designed to estimate the aggregate macroeconomic impacts of the HIV/AIDS pandemic in South Africa. In the model, AIDS has the effects of raising firms' insurance/benefits which affects costs, profits and savings. Worker absenteeism goes up which affects overall productivity. As well, worker experience generally falls as a result of AIDS thereby affecting labor productivity. The cost of skilled labor goes up and there is substitution of capital for labor. For the government, three main effects are captured in the modelling. First, AIDS spending goes up which affects other spending and hence the deficit. Second, production structure shifts affect VAT and income tax. Finally, household incomes and patterns shift which also affects taxes and transfers. For the household, job losses as a result of AIDS increase the likelihood of vulnerable households to require transfers. Caring for HIV/AIDS leads to changed expenditure patterns, reduced savings and lower investment in human capital. For the macro-economy, lower investment in both physical and human assets leads to a reduced growth trajectory. The increased shortage of skills leads to rising wage differentials, worsening income distribution and further capital-labour substitution. They found that, despite dramatically lower rates of growth of the unskilled labour pool relative to the "no AIDS" trend, estimated unemployment rates for unskilled labour in their base "AIDS" scenario increased absolutely over most of the upcoming decade and are essentially the same as the rates estimated for a fictional "no AIDS" scenario.

The purpose of the work of Devarajan and van der Mensbrugghe (2000) is the assessment of the removal of trade barriers and their impact on household incomes and income distribution. The model has 34 sectors as well as 24 types of households identified by ethnic background and income classification and labor disaggregated into 13 different categories. Government current expenditures are divided into five classifications and investment is divided into its public and private components. Production is modeled using nested constant elasticity of substitution (CES) functions and constant returns to scale is assumed. Household demand is modeled using the Extended Linear Expenditure System (ELES). The other final demand accounts assume a fixed-coefficient expenditure function. Trade is modeled using the Armington assumption for import demand, and a constant elasticity of transformation (CET) for export supply. All markets are assumed to clear through prices except for the labor market for unskilled black workers. In the case of the latter, the real wage is fixed and unemployment clears the labor market. The main finding of the paper is that trade reform will most likely improve the average welfare of black households but reduce that of white households. Within ethnic groups, richer black and poorer white households stand to benefit.

Another recent prominent model is the work of Thurlow and van Seventer (2002). Their model is a South African version of the standard International Food Policy Institute (IFPRI) static CGE model. It uses the 1998 SAM. Three separate simulations were run: (i) a 10% increase in the level of government expenditure, (ii) a full elimination of tariffs and (iii) a 1% increase in factor productivity. They find that the macroeconomic closure chosen influences results. Expansionary fiscal policy enhances growth under a Keynesian closure. Tariff removal is also expansionary overall, although it hurts the manufacturing sector and reduces government revenues. An increase in total factor productivity enhances growth especially under a neoclassical closure.

There is now a sizable number of CGEs focusing on multilateral trade reform issues. Davies (1998) — using GTAP data and modeling framework — simulates a Free Trade Area (FTA) between the European Union (EU) and South Africa and finds strong potential trade diversion following an FTA. Lewis (2001) asks similar questions and examines the implications of South African trade reform and pursuit of different regional trade agreements (RTAs) on economic performance, using single country model to incorporate more institutional detail. The Social Accounting Matrix (SAM) has imports/exports by 12 origins/destinations. The tariff data is modified to reflect bilateral tariff patterns. Lewis also modifies specification to the key functional forms allowing greater tailoring to particular markets, for example the use of an Almost Ideal Demand System (AIDS), export market constraints, etc. Lewis *et al* (1999) use data for 1995 from GTAP version 4. They focus on the interaction between three countries: the EU, South Africa, and the Rest of Southern Africa (an aggregate of Botswana, Malawi, Mozambique, Tanzania, Zambia, Zimbabwe and the Rest of SADC). They find that (1) South Africa is not big enough to be a growth pole for the region and (2) the Rest of Southern Africa does better with a trilateral FTA with the EU rather than global tariff liberalization of 50 percent. The later result reflects the Rest of Southern Africa's high trade dependence on the EU and the EU's high initial trade barriers against the EU.

From this review and in line with the purpose of this study, we can point out that the key aspects of experiences of South African CGE modeling is that the models are generally static. As a result, factor supplies do not change in the course of any experiment. Government expenditures only have demand-side effects (no government investment). Since the models are static, there is no capital accumulation and no supply-side effect of private investment. However, since the models used represent actual economies, macroeconomic phenomenon of an explicitly intertemporal nature appears. But these are modelled in a rudimentary fashion. Typically, households save a given proportion of income, government expenditures are exogenous and either investment is exogenous or is savings-determined. The implication is that a mechanism is required each period to reconcile aggregate savings and investment (what is commonly known as closure rules). For instance, Naude and Brixen (1993) and Thurlow and van Seventer (2002) discuss their results under various sets of closure rules, namely Keynesian, Classical, Johansen and Kaldorian. However, none of the mechanisms leaves the CGE models well suited to the analysis of the links among macroeconomic policy and economic outcomes. This is because all of them have the effect of leaving investment exogenous or determined by savings. To address the links between macroeconomic policies/shocks and the economy requires inclusion of an independent investment function that responds endogenously to current and expected future macroeconomic variables. Since these intertemporal links are omitted, dynamics in traditional CGE models are too simple to address these macroeconomic phenomenon.

There is some recent work in South Africa that has begun to incorporate these more sophisticated macroeconomic relationships embedded in the work of Gelb et al (1994), Gibson and van Seventer (1996,1997,2000) and Arndt and Lewis (2001). Gelb *et al* (1994) developed a dynamic one sector CGE model of the South African economy, based on an aggregate SAM for the year 1990. This model, which was extended to include financial variables, was used to evaluate the impact of a negative external shock to the economy as well as a program of government stimuli. Gibson and van Seventer modelling work builds on the model of Gelb *et* al. The model employed is a nine sector, 2-class structuralist CGE system with real and financial sectors. The models feature an independent investment function so that output adjusts to bring savings into balance with investment. The accelerator, costs of capital and a crowd-in term drive investment. In each period, output is demand-determined but supply side factors play a role across periods – accumulated past investment determine the capital stock which in turn sets the level of capacity output.

The work by Arndt and Lewis (2001) seeks to further investigate the interactions between unemployment and AIDS using the basic modelling approach set forth in Arndt and Lewis (2000). The model contains fourteen productive sectors, five primary factors of production, 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. Sectoral private consumption is determined through the fixed expenditure shares under the assumption that households have a Cobb-Douglas utility function. Government consumption is also allocated using fixed expenditure shares. Final demand for intermediate goods is the sum of the intermediate demands generated in each producing sector. Investment is allocated using dynamic updating rules discussed in more detail below. Final demand for investment goods is obtained using an activity specific capital coefficients matrix. As a recursive dynamic model, the model contains a set of cumulation and updating rules (e.g. investment adds to capital stock, after depreciation; labour force growth by skill category;

productivity growth). The purpose of these dynamic equations is to "update" various parameters and variables from one year to the next, and for the most part, the relationships are straightforward. Growth in the total supply of each labour skill category is specified exogenously, and for the informal, unskilled and skilled labour groups (for which inflexible wages leads to unemployment), the growth trajectory of real wages is also provided. Sectoral capital stocks are adjusted each year based on investment, net of depreciation, and investment is assumed to respond to differential sectoral profit rates so as to preserve the rental rate differentials observed in the base year data. Sectoral productivity growth (TFP) is specified exogenously.

Note that these models are not "dynamic" in the full economic sense of the word, since there are no multi-period optimising equations and hence no attempt to ensure *intertemporal* optimality. The simulations are best thought of as a sequence of "lurching equilibria," in which *within* period (static) equilibrium is first attained, then the model "lurches" forward to the next period, and a new (static) equilibrium is found. These modifications bring the models close to the 'dependent economy' macroeconomic simulation models (Agénor *et al* (2002)). Still, dynamic behaviour is left rather simple and ad hoc. Intertemporal optimisation on the part of households and firms based on forward-looking expectations remains absent.

## 3. Structure of the Model (Preliminary)

The model proposed is an intertemporal dynamic CGE model of an open economy. The model is disaggregated into six producing sectors, one household category, a foreign sector and the government. The model does not include monetary variables: there is no endogenous inflation and asset market modelled. The intertemporal extension is based largely on Annabi (2003b). Discounted lifetime utility of the whole population is maximised by choosing optimal consumption and investment paths. Firms produce one good. Perfect competition and full employment are assumed. International trade flows are characterised by imperfect substitution between domestic and foreign goods. The final good is allocated between domestic sales and exports through a constant elasticity of transformation (CET) function. Total absorption is differentiated among four uses – private consumption, government consumption, intermediate input and investment. It is an Armington composite of the domestic and imported good. The domestic country is assumed to be a price-taker in the international markets. Below we go into some details on the main model features, emphasising the intertemporal aspects.

### *Household*

The model features identical and infinitely lived households (see Abel and Blanchard (1993)). The population grows at a constant rate n. Households derive welfare from consumption of goods and do not value leisure. In each period, the household is endowed with one unit of labour, supplied inelastically to the market which generates labour income. Wealth generated income derives from assets' holdings that consist of government bonds, firm shares and foreign assets. Households also receive lump-sum transfers from government and the rest of the world – they are taxed on labour income.

In each period, the representative household consumes a basket of goods and services. The household seeks in each period, to determine the optimal path of its savings and commodity consumption. Its behaviour is considered as a *sequential* decision, where it decides first on the optimal path of its aggregate spending (or full consumption), which is then allocated within each period among different goods.

Full consumption is allocated over time so as to maximise an intertemporal additive utility function, discounted by a constant time preference rate (adjusted by population growth rate n) $\rho$, subject to the condition that the intertemporal budget constraint is respected. The intertemporal problem is a dynamic optimisation programme:

$$\underset{C_t}{Max}\, U = \sum_{0}^{\infty} \ln(C_t) \left[\frac{1+n}{1+\rho}\right]^t$$

Subject to: $RF_{t+1}(1+n) = (1+r)RF_t + (1-\tau_y)W_t LSO + TG_t - TH^{ROW} - PCD_t C_t$

where Ct is full consumption, RFt represents the household's financial wealth (inclusive of the total value of firms, government and external debt), Wt the wage rate, r is interest rate, $\tau_y$ the tax rate on labour income, $LSO$ the employment level/labour supply and $TG_t$ the government's exogenous transfers to households. $TH^{ROW}$ represents the exogenous net transfers of the rest of the world to households and PCDt the consumer price index (also the price of full consumption or consumption dual price).

Households are subject to the *transversality* condition, that is, in each period, the total present value of current and future income receipts has to be equal to the present value of current and future spending. The *necessary* conditions of the household' dynamic problem are:

$$\frac{C_{t+1}}{C_t} = \left[\frac{1+r}{1+n}\frac{PCD_t}{PCD_{t+1}}\right]$$

$$RF_{t+1}(1+n) = (1+r)RF_t + (1-\tau_y)W_t \sum_i LD_t^i + TH^{ROW} + TH_t - PCD_t C_t$$

These are Euler equations and the budget constraint. The Euler equations give the full consumption growth rate $\left[\frac{C_{t+1}}{C_t}\right]$ as a function of the discount rate, the interest rate and the growth rate of the full consumption price. It embodies a forward-looking behaviour – current full consumption incorporates expectations about all future prices in the economy. As full consumption price depends on domestic, as well import prices, the reform will affect the optimal path of aggregate consumption, Ct.

Combining the Euler equation with the budget constraint and the transversality condition, the level of full consumption, Ct, can be determined each period (i.e., the intra-period consumption). It will depend on households' permanent income, which itself is a function of current and future labour and financial incomes. One may write the explicit analytical expression of the full consumption in each period but in this case where we are looking for a numerical solution, the solution strategy we adopt may make this unnecessary. As full consumption, Ct is a Cobb Douglas function of different commodities, $C_t^i$, thus total consumption spending is allocated across consumption commodities in fixed expenditure shares, within each period, that is

Intraperiod consumption: $PC_t^i C_t^i = s_i PCD_t C_t$

Finally, the expression of consumer price index, $PCD_t$, is derived as the dual price of the within-period optimisation, that is, the consumption dual price is

$$PCD_t = \frac{1}{AC}\prod_i \left(\frac{PC_t^i}{s_i}\right)^{s_i}$$

where $PC_t^i$ is the composite price and $s_i$ are expenditure share parameters.

### *Firms and Investment*

It is assumed that the representative firm in each sector operates with constant returns to scale technology. Output is produced using capital, labour and intermediate goods. A simple nesting structure is used for production relationships. Sectoral output ($XS_t^j$) is produced by combining value added ($VA_t^j$) and total intermediate goods consumption ($CI_t^j$) in fixed proportion (Leontief), that is:

$$XS_t^j = \min\left[\frac{CI_t^j}{io_j}, \frac{VA_t^j}{v_j}\right]$$

Total intermediate consumption is a fixed proportion of sectoral output while intermediate consumption of good i in activity j ($DI_t^{i,j}$) is assumed to be a fixed proportion of total intermediate consumption:

$$CI_j^t = io_j XS_j^t$$

$$DI_t^{i,j} = aij_{i,j} CI_t^j$$

We assume that value added consists of a Cobb Douglas aggregate of labour ($LD_{j,t}$) and capital ($KD_{j,t}$), $\alpha_i$ and A are production function parameters with the usual interpretation:

$$VA_t^j = A_j LD_{j,t}^{\alpha_j} KD_{j,t}^{1-\alpha_j}$$

The demand for the two production factors is then given by:

$$LD_t^j = \frac{\alpha_j PV_t^j VA_t^j}{w_t}$$

$$KD_t^j = \frac{(1-\alpha_j) PV_t^j VA_t^j}{R_t^j}$$

Capital is accumulated over time only through investment. Following Hayashi (1982), investment expenditures include both acquisition costs as well as adjustment costs. As in Dissou (2002), the adjustment costs are assumed to be quadratic in investment and capital stock:

$$J = INV_t + \left( \frac{\gamma}{2} \frac{INV_t^t}{K_t} \right)$$

where $INV_t$ is investment by destination and $K_t$ is the capital stock. Firms pay investment expenditures from retained earnings and pay dividends to households. The representative firm chooses, at each time period, the input levels and intermediate goods and makes investment decisions so as to maximise the present value of net returns (value of the firm (VF)), subject to the capital accumulation equation. Formally,

$$Max\ VF_{i,t} = \sum_{t=0}^{\infty} RN_t^i \left[ \frac{1+n}{1+r} \right]^t$$

$$s.t\ K_{t+1}^i (1+n) = (1-\delta_i) K_t^i + INV_t^i$$

where $RN_t^i = PV_t^t VA_t^i - W_t LD_t^i - PK_t INV_t^i \left( 1 + \frac{\gamma}{2} \frac{INV_t^i}{K_t^i} \right)$

where $Q_t^i$ and $P_t^i$ respectively represent the composite output and the price of the composite output. $RN_t^i$, $INV_t^i$ and $K_t^i$ symbolize returns, investment by destination sector and the stock of capital respectively. $N_t^i$ is the volume of the composite intermediate inputs. $\gamma$ and $\delta_i$ are parameters of the adjustment cost function and the capital depreciation rate respectively. Finally, $PK_t$ denotes the purchase price of capital good, or the capital replacement price and is given by:

$$PK_t = \prod_i \left( \frac{PC_t^i}{\mu_i} \right)^{\mu_i}$$

where $\mu_i \neq 0$ is a fixed investment share matrix.

The first order conditions resulting from the firms' values maximizations are[4]: (1) the investment demand function, (2) the Euler equations for the shadow price of capital (or equivalently Tobin's q), (3) the capital accumulation equation

1. Investment demand function: $\dfrac{INV_t^i}{K_t^i} = \dfrac{1}{\gamma} \left( \dfrac{q_t^i}{PK_t} - 1 \right)$

[4] Note also that the first order conditions give the equality between the marginal productivity of labour and its wage rate and the transversality condition.

2. Motion Law of shadow price of capital:

$$q_{t+1}^{i}(1-\delta)=q_{t}^{i}(1+r)-R_{t+1}^{i}-PK_{t+1}\frac{\gamma}{2}\left(\frac{INV_{t+1}^{i}}{K_{t+1}^{i}}\right)$$

3. Capital accumulation equation: $K_{t+1}^{i}(1+n)=(1-\delta_{i})K_{t}^{i}+INV_{t}^{i}$

where $q_t^i$ is the Lagrange multiplier representing the shadow price of capital and $R_t^i$ is the physical marginal productivity of capital. The investment is positive only if the real shadow price of capital is greater than 1. With given investment, capital, capital replacement price and the adjustment cost parameter the investment equation is used to calibrate the base run shadow price of capital as follows:

$$q_{t}^{i}=PK_{t}\left(1+\gamma\frac{INV_{t}^{i}}{K_{t}^{i}}\right)$$

Note that:

(a) the shadow price of capital is equal to its marginal cost

(b) there is a positive relation between investment and Tobin's q

Following Annabi and Rahji (2001)'s interpretation of Hayashi (1982), with linear adjustment cost function, homogenous in investment and capital and a constant return to scale production function, we obtain, by imposing the required transversality condition, the identity between the marginal average Tobin'q so that the value of the firm is

$$VF_{t+1}^{i}=q_{t}^{i}K_{t+1}^{i}$$

### *Government*

The government has three interrelated functions in the model: collect taxes, distribute transfer payments and purchase goods and services. The model distinguishes three types of taxes, *viz*, *direct income taxes* ($DTH_t$) set at a given ratio of private income; *indirect taxes* ($TI_t^i$) levied on the gross output value in each sector; and *trade taxes* ($TIM_t^i$) implemented on ad valorem basis on imports:

$$YG_{t}=\sum_{i}TI_{t}^{i}+DTH_{t}+\sum_{i}TIM_{t}^{i}$$

$$TI_{t}^{i}=tx_{i}\left(P_{t}^{i}XS_{i}^{i}-PE_{t}^{i}EX_{t}^{i}\right)$$

$$TIM_{t}^{i}=tm_{i}\ e_{t}PWM_{i}M_{i}$$

$$DTH_{t}=\tau_{y}YH_{t}$$

It allocates its expenditure between goods and services in fixed proportions, pays public wages, makes transfers to households and paying interest on debt, $DG_t$. $DG_t$ is assumed to be a given ratio value added:

$$DG_{t}=ratio\sum_{i}PV_{t}^{i}VA_{t}^{i}$$

Government savings ($SG_t$) is obtained as a residual:

$SG_t = YG_t - G_t - TG_t$

### *Income*

The representative household receives income payment for producers' use of their factors of production and pay direct taxes to government (based on fixed tax rates) and make transfers to the rest of the world:

$$YH_t = w_t LSO$$

$$YDH_t = YH_t - DTH_t + TG_t - TH^{ROW}$$

### *Demand*

Besides the exogenous government demand, the model includes two other broad demand components: investment demand and total demand for intermediates. These are determined as follows:

$$INV_t^i = \frac{\mu_i IT_t}{PC_t^i}$$

$$DIT_t^i = \sum_j aij_{i,j} CI_j^t$$

### *Prices*

The main prices are determined in the usual way, except that we add time subscripts:

$$PV_t^j = \frac{P_t^j XS_t^j - \sum_j PC_j^i DI_t^j}{VA_t^j}$$

$$PD_t^i = (1 + tx_i) PL_t^i$$

$$PM_t^i = (1 + tm_i) e_t PWM_i$$

$$PE_t^i = e_t PWE_t$$

$$PC_t^i = \frac{\left(PD_t^i D_t^i + PM_t^i M_t^i\right)}{Q_t^i}$$

$$P_t^i = \frac{\left(PL_t^i D_t^i + PE_t^i EX_t^i\right)}{XS_t^i}$$

$$PINDEX = \sum_j \delta_j PV_j$$

where the variables are respectively:

$P_t^t$ : Producer price of good $i$ at period $t$

$PC_t^i$ : Consumer price of composite good $i$ at period $t$

$PD_t^i$ : Domestic price of good $i$ including taxes at period $t$

$PE_t^i$ : Domestic price of exported good $i$ at period $t$

$PINDEX$ : GDP deflator

$PL_t^i$ : Domestic price of good $i$ (excluding taxes) at period $t$

$PM_t^i$ : Domestic price of imported good $i$ at period $t$

$PV_t^j$ : Value added price for activity $j$ at period $t$

### *Foreign trade*

The model makes a distinction between an internationally tradable and domestic variant of a good in each sector. Each producer and consumer is a price taker in all tradable goods markets but domestic goods and factor prices are fully flexible. In *production*, substitution possibilities exist between production for the domestic and the foreign markets, but this substitution is not without cost. This decision of producers is governed by a constant elasticity of transformation (CET) function which distinguishes between exported and domestic goods, and by doing so, captures any time or quality differences between the two products,

$$X_t^i = A_i^T \left[\beta_i^T EX_{i,t}^{\rho T_i} + \left(1 - \beta_i^T\right) D_{it}^{\rho T_i}\right]^{\frac{1}{\rho T_i}}$$

where $\rho T_i = \dfrac{1 + \Omega_i}{\Omega_i}$ and $\Omega_i$ is the (constant) elasticity of transformation, $\beta_i^T$ is a share parameter and $A_i^T$ is a scaling factor (both are defined by base line data). Profit maximization drives producers to sell in those markets where they can achieve the highest returns. These returns are based on domestic and export prices (where the latter is determined by the world price times the exchange rate adjusted for any taxes). Under the small-country assumption, South Africa is assumed to face a perfectly elastic world demand at a fixed world price. The optimal allocation of output between the two markets (ratio of exports to domestic goods) is the solution to maximising composite output subject to relative domestic producer price of the domestic and export variety ($\dfrac{PE_t^i}{PD_t^i}$)– the first order condition defines the export supply function for $i$,

$$\left(\frac{EX_t^i}{D_t^i}\right) = \left[\frac{\left(1 - \beta_i^T\right)}{\beta_i^T}\left(\frac{PE_t^i}{PD_t^i}\right)\right]^{\Omega_i}$$

where $EX$ are exports and $D$ are domestic goods. The supply equation says that an optimal allocation between the 2 markets is determined by the endogenous interaction of relative prices for these two commodity types. This relative price is a kind of an export real exchange rate for a particular sector i.

On the consumption side, further substitution possibilities exist between imported and domestic goods under a CES Armington specification,

$$Q_t^i = A_i^M \left[\psi_i^M M_{i,t}^{-\rho C_i} + \left(1-\psi_i^M\right) D_{i,t}^{-\rho C_i}\right]^{-\frac{1}{\rho C_i}}$$

where $\sigma_i = \dfrac{1}{1+\rho C_i}$ is the elasticity of substitution in consumption, $A_i^M$ is a shift parameter and $\psi$ is a share parameter. Such substitution can take place both in final and intermediates usage. The Armington elasticities vary across sectors, with lower elasticities reflecting greater differences between domestic and imported goods. Again under the small country assumption, South Africa is assumed to face infinitely elastic world supply at fixed world prices. The final ratio of imports to domestic goods is determined by the cost minimizing decision-making of domestic demanders based on the relative prices of imports and domestic goods (both of which include relevant taxes) and is given by.

$$\left(\frac{M_t^i}{D_t^i}\right) = \left[\left(\frac{\psi_i}{1-\psi_i}\right)\left(\frac{PD_t^i}{PM_t^i}\right)\right]^{\sigma_i}$$

$\left(\dfrac{PD}{PM}\right)$ can also be thought of as the import real exchange rate. Note that because each sector has its own import and export real exchange rate, terms of trade changes or trade policy will have different impacts on these real exchange rates.

The current account balance is given by:

$$CAB_t = e_t \sum_i PWM_i M_t^i + TH^{ROW} - e_t \sum_i PWE_i EX_t^i$$

where $e$ denotes the nominal exchange rate.

### *Debt accumulation*

We assume that government issues bonds to finance its deficit, $SG_t$. With all variables expressed in efficient unit, government debt at t+1 is:

$$(1+n)DG_{t+1} = (1+r)DG_t - SG_t$$

Similarly, the dynamic external debt, which is also included in household welfare, is given as:

$$(1+n)DF_{t+1} = (1+r)DF_t + CAB_t$$

### *Equilibrium and terminal conditions*

The model requires that the goods and factor market be in equilibrium, that total investment ($IT$) is equal to value of investment by origin ($INO$) and that household financial wealth is brought together with value of the firm, domestic and foreign debt. The No Ponzi Game condition applies and the nominal exchange rate is chosen to be the *numeraire*. The conditions for equilibrium are:

$$Q_t^i = DIT_t^i + C_t + INV_t^i$$

$$LSO = \sum_j LD_t^j$$

$$IT_i = PK_t \sum_i INO_t^i$$

$$RF_t = \sum_i VF_t^i + DG_t - DF_t$$

The steady state and terminal conditions are given as

$$(n-r)RF_t = w_t LSO + TG_t - PCD_t C_t - DTH_t - TH^{ROW}$$

$$q_t^i(\delta + r) = PV_t^i R_t^i + PK_t \frac{\gamma}{2}\left(\frac{INV_t^i}{K_t^i}\right)^2$$

$$\frac{INO_t^i}{K_t^i} = (n+\delta)$$

$$VF_t^i = q_t^i K_t^i$$

$$DG_t = \frac{SG_t}{(n-r)}$$

$$DF_t = \frac{CAB_t}{(n-r)}$$

## 4. Data and calibration

The key data set underlying the model is a Social Accounting Matrix (SAM) for South Africa calibrated to calendar year 2000. The designers of the South African CGE model have modified the SAM and as a consequence it incorporates a number of restrictive assumptions and simplification justified solely by features incorporated in the model. The most important of these is that the economy is assumed to be in a steady state in 2000, which is crucial for the calibration. The main parameters to be used in the calibration and for which we will need data are:

| | | |
|---|---|---|
| $r$ | Interest rate | $= \rho$ (via Euler eq in SS) |
| $\rho$ | Rate of time preference | = r (in steady state) |
| $n$ | Labour force growth | Population/labour force surveys |
| $\Omega_i$ | Armington elasticity of transformation | Obtained from SA econometric literature |
| $\sigma_i$ | Armington elasticity of substitution | Obtained from SA econometric literature |
| $\delta$ | Depreciation rate | Guestimated |
| $\gamma$ | Adjustment cost parameter | Literature search |

The original 27 sector SAM is aggregated into 5 productive sectors plus the government sector. In the present version of the model, there is only representative household. Each sector is assumed to produce a single homogeneous good which may be sold to the domestic or export market. The productive sectors/commodities are:

| ACRONYM | DESCRIPTION |
|---|---|
| AGR | Agriculture |
| MIN | Mining |
| MAN | Manufactured goods |
| SERV | Marketed services (including electricity and water) |
| CON | Construction |
| PUB | Public Services |
| | |

What is the rationale for this disaggregation? First and foremost, this is to allow the model to capture the macroeconomic importance of sectoral interdependencies. The multisectoral model can be seen as an extension of models with 2 sector dichotomies between agriculture and industry and between traded (agriculture, mining and manufactured goods) and non-traded (construction, services) goods. Note that the latter is just a matter of degree rather than absolute categorization of tradedness. Furthermore, there is a case to have a stand alone Agriculture sector because a major concern of this work is aimed at poverty analysis – it is known that the bulk of the poor in South Africa are located in the agriculture sector while poor people in general spend a disproportionately higher share of their income on food. Mining and manufacturing are singled out so as to capture their central role in the production economy of South Africa.

Domestic production by an individual firm/sector is assumed to require intermediate inputs from itself and from all other productive sectors (excluding PUB) and value added from the factors of production. Factors employed in production are compensated in all the private sectors. However capital used in the production of government services is not rewarded, with the only factor payment being to labour.

The leading role of the public sector is taken care of by an explicit formulation of the tax financing and expenditure. Note that public firms are handled as part of the private sectors. The government sector denoted (PUB) is assumed to produce government services. Government services may be consumed directly by the private sector, but since they are not paid for directly by the consumer, they are treated as being consumed solely by the government.

## 5. Policy Simulations

The model is implemented by means of the mathematical software GAMS (General Algebraic Modeling System) as a Non-Linear Program (NLP). Many dynamic scenarios of macroeconomic policy reform are considered. Macroeconomic policy as used here is in the broadest sense to include not just stabilization policies but structural policies also. With this in mind, the role played by trade policy enters the policy space. The main instruments in the hands of the government now are the budget, investment controls and trade policy. The room to manoeuvre in macroeconomic policy is felt to be small when most economists are against large budget deficits. The current policy climate in economic theory is negatively inclined towards expansive fiscal policy, because of the presumed negative consequences of large public sectors. Unless such interventions are analysed in the broader macroeconomic context, and can be shown to have positive net effects, it is unlikely that such policy recommendations will be accepted. Trade policy on the other hand may be strongly expansive or may have fiscal revenue implications, in which case there may be a need for a trade liberalizing devaluation or complementary fiscal policy. We also investigate the impact of exogenous shocks on the economy. We now have the following proposed simulations:

### *Fiscal policy*

The base year government current deficit indicates an expansionary fiscal policy common to neighbouring sub-Saharan African countries. The fiscal deficit is probably a result of separate decisions regarding taxes and expenditures more than a conscious business cycle management. The deficit is structural. The effect of this kind of policy is investigated in an experiment assuming a 10% increase in public employment. In the present unemployment situation, such a policy easily can mobilize public support.

Bearing in mind the point that the model could be used to simulate the effects of domestic tax reform but only to capture a “medium term growth bonus”, we propose another fiscal policy scenario that would reduce taxes, which could stimulate economic growth and hence increase revenues and expenditures in the longer term. These tax measures can take several forms, but essentially, instead of increasing its own spending, government could put the money instead into the private sector and shift the spending decisions to private firms or individuals.

The final fiscal policy scenario focuses on changes in public expenditure, in particular the balance between investment in infrastructure and provision of government services. While all government expenditure has direct aggregate demand effects in typical Keynesian fashion, the infrastructure provision also directly affects the supply side of the economy by augmenting private sector production. Government sector specific investment (offices, schools, hospitals) influence only the cost of producing services (by altering the marginal product of labour), while direct current expenditure on public services has only pure demand side effects. Although public services are not purchased through the market and hence do not enter private expenditure decisions, they do have direct consumption value to households – this could be reflected by allowing government current consumption to enter household utility function directly. This model will then be a short to medium term model in the sense that there are no long run returns to recurrent public expenditure on health and education – the value of this is not felt on the steady state, hence there is no feedback on this activity. The IMMPA model (Agénor *et al* (2002) incorporates this feedback effect but has not yet been subjected to empirical testing?

### *Trade Policy*

Over the years, the dependence of the South African economy on exports of gold, platinum, and diamonds has led to overvaluation of the rand in relation to what the exchange rate should have been if there were a more diversified export base. In addition, protection against imports resulted in further overvaluation, as well as a bias against exports and in favour of import-competing activities. As a result, many South African products are no longer competitive in neighbouring countries or on the world market. In the past, to make exports competitive, the government relied on cash rebates to exporters under the General Export Incentive System (GEIS), a scheme that was highly biased in favour of larger, less labour-intensive firms. But this is no longer an option as South Africa is now a fully-fledged member of the World Trade Organisation. This has an important implication. It implies that tariff rates would need to be further reduced and that that quantitative restrictions on trade should be eliminated. To compensate for trade liberalisation, the South African government will need complementary policies. We study these predicted policy responses in a trade policy simulation. The purpose of this simulation is to answer the following questions, using the dynamic CGE model:

1. How does trade liberalization affect the economy?
2. What is the dynamic side of the potential impact?

In the past, static models have been used to analyse such questions. These are powerful as a starting point and in addressing resource allocation effects of policy. However, they are unsatisfactory for a specific treatment of household savings behaviour and firms' investments, which are intrinsically intertemporal. In such a context, the inability of the static framework to adequately explain the impact of trade reform on the current account balance, which is closely linked to savings and investment decisions, becomes obvious. This scenario is a simulation of a decrease in customs tariff revenue with complementary fiscal policy. The trade liberalization can be a dramatic once off tariff reduction or it can be phased in over a period.

Within a given country, the extent and impact of trade policy depend upon the initial level of tariffs and on the volume of trade with the rest of the world. So for a particular country such as South Africa, we need the following sets of information to evaluate the impact of trade policy:

- What is the level of tariff protection afforded domestic industries in South Africa?
- How dependent is government on tariff revenue?

### *Economic shocks*

Variations in export prices have economywide effects. The shocks are largely exogenous, caused by world market excess demand. Export prices of raw materials (gold, platinum and diamonds) tend to fluctuate and is typically considered the main contractionary factor when GDP performance is interpreted. A model experiment is constructed to investigate the consequences of such shocks – we simulate a foreign terms of trade shift assuming a 5% increase in export prices.

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