A Historical CGE Analysis of the South African Economy from 2007-2013

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1. Introduction

There are many reasons why analysts may wish to investigate past economic outcomes. The majority of these involve producing evidence that would allow economic agents to make smarter decisions going forward. As a consequence, understanding the reasons for past successes or failures, or identifying certain trends that are likely to persist in future have always been sought after information.

In computable general equilibrium (CGE) modelling, historical simulations have become a popular tool for estimating movements in factor productivity, technical change and preference variables that are compatible with observed data at both an industry and macro level. The primary aim of this paper is to provide some initial estimates for movements in such variables for South Africa over the period 2007-2013 using the historical decomposition methodology introduced in Dixon & Rimmer (2002). We focus, in particular, on movements in the labour market and primary sector over this period. In conducting our quantitative analysis, two further benefits emerge. The first is the identification of recent trends that may be used to inform our baseline projections in policy work, and the second is the updating of the model's underlying supply-use database to improve the accuracy of policy simulation results. The model used in this study is the dynamic version of the University of Pretoria General Equilibrium Model (UPGEM).

The paper is set out as follows: Section 2 describes the UPGEM model in broad detail. Section 3 describes how to find the appropriate model closure for our historical analysis and summarizes the observed movements between 2007 and 2013. Section 4 presents the results of the simulation and Section 5 draws some conclusions.

2. The UPGEM Model

The University of Pretoria General Equilibrium Model (UPGEM) is a recursive-dynamic computable general equilibrium (CGE) model of the South African economy.[1] The theoretical specification of UPGEM is based on the well-documented MONASH (Dixon & Rimmer, 2002) model of Australia. The database used in this study distinguishes 33 industries and commodities, and in combination with the model's theoretical specification, describes the main inter-linkages in the South African economy.

[1] Similar to other MONASH-style CGE models such as MMRF (Adams et al, 2010), UPGEM is a flexible model that can be configured to run in either comparative-static or recursive-dynamic (year-on-year) mode.

Following the Johansen-style of implementing a CGE model, the general equilibrium core of the MONASH-based UPGEM model is made up of a linearized system of equations describing the theory underlying the behaviour of participants in the economy. It contains equations describing i) the nature of markets; ii) demands for inputs to be used in the production of commodities; iii) household demands; iv) demands for inputs to capital creation and the determination of investment; v) government demands for commodities; vi) foreign demand for exported goods; and its dynamic components describing vii) physical capital accumulation; viii) lagged adjustment processes in the labour market; and ix) government fiscal accounts.

UPGEM allows each industry to produce multiple commodities, using as inputs combinations of domestic and imported commodities, different types of labour, capital and land. The multi-input, multi-output production specification is kept manageable by a series of separability assumptions. This nested production structure reduces the number of estimated parameters required by the model. Optimising equations determining the commodity composition of industry output are derived subject to a CET function, while functions determining industry inputs are determined by a series of nests. At the top level, intermediate commodity composites and a primary-factor composite are combined using a Leontief or fixed proportions production function. Consequently, they are all demanded in direct proportion to industry output or activity. Each commodity composite is a CES function of a domestic good and its imported equivalent. This incorporates Armington's assumption of imperfect substitutability for goods by place of production (Armington, 1969). The primary-factor composite is a CES aggregate of composite labour, capital and land, with composite labour itself a CES aggregate of different labour types. In UPGEM, all industries share this common production structure, but input proportions and behavioural parameters vary between industries based on available data and econometric estimates.

Demand and supply equations for industries and households are derived from the solutions to the optimisation problems which are assumed to underlie the behaviour of private sector agents in conventional neo-classical microeconomics. Each industry minimises cost subject to given input prices and a constant returns to scale production function. Households maximise a Klein-Rubin utility function subject to their budget constraint. Units of new industry-specific capital are determined as cost-minimising combinations of domestic and imported commodities. Imperfect substitutability between sources of commodities is modelled using the Armington CES assumptions. The export demand for any local commodity is inversely related to its foreign-currency price. The price of imports is exogenous, consistent with the assumption of South Africa being a small open economy. Government consumption and the details of direct and indirect taxation are also recognised in the model. Markets are assumed to be competitive which implies that the basic price and marginal cost of goods will be equal. The model also recognises margin commodities such as retail trade and road transport freight. The costs of the margins are included in purchaser's prices but not in basic prices of goods and services.

The dynamic elements of UPGEM allow for inter-temporal links describing i) physical capital accumulation; ii) lagged adjustment processes for labour; and iii) government fiscal accounts allowing for financial asset or liability accumulation. Capital accumulation is specified separately for each industry, and linked to industry-specific net investment in the preceding period. Investment in each industry is positively related to its expected rate of return on

capital. Investment this period therefore only affects capital stock in the next period. A similar mechanism for financial asset/liability accumulation is specified. Adjustments to the national net foreign liability position of households are related to the annual investment/savings imbalance, revaluations of assets and liabilities, and remittance flows during the year. Changes in the public sector debt are related to the public sector deficit incurred during the year. In policy simulations, the labour market follows a lagged adjustment path where wage rates are allowed to respond over time to gaps between demand and supply for labour.

3. The Historical Model Closure and Observed Movements from 2007-2013

For detailed CGE models such as UPGEM the number of variables *(n)* will always exceed the number of equations *(m)*. To close the model and compute a solution, *(n-m)* variables must therefore be treated as exogenous. Alternatively stated, the number of endogenous variables must equal the number of equations for the model closure to be valid. The selection of the *(n-m)* exogenous variables is largely user-determined, but should be chosen to best describe the economic environment for which the simulation is run.

UPGEM provides modellers with a significant amount of flexibility in the choice of closure. In comparative-static mode, UPGEM can set up to conduct policy simulations over a short-run or long-run time span depending, in chief, on the treatment of capital and labour. For example, in the long-run a typical model closure may have aggregate employment and industry-level returns to capital set as exogenous, with real wages and capital stocks endogenously determined. Once the time span has been determined, further changes to the model closure can impose various behavioural assumptions on particular agents in the model. For instance, government consumption can be set to follow changes in household consumption, move in line with a desired budget position, or remain exogenous.

With the dynamic MONASH model, the idea of flexible closures was fully extended with the development of four basic model closures: long-run decomposition, historical, forecasting and policy (Dixon & Rimmer, 2002:233-277). In this paper, we apply a historical closure to the UPGEM model to conduct our analysis of the South African economy over the period 2007-2013.[2] Historical closures include in their exogenous set two types of variables: observables and assignables. Observables are those for which movements can be readily observed from data sources for the period of interest, such as real GDP or trade figures. Assignable variables are naturally exogenous and can be assigned a value without contradicting anything that we have observed about the historical period or wish to assume about that period. Historical closures may be considered somewhat unusual in that many variables which we would consider naturally endogenous in policy modelling, such as real GDP and its determinants from the demand side, are now exogenously set at their historically observed values. A number of naturally exogenous variables, such as technical change or the positions of export demand curves, must therefore be allowed to move endogenously for the model to maintain its compatibility with the given observed values and various parameter estimates over the historical period. These results will be discussed in the following section. Swaps to the standard model closure and additional industry-level swaps to produce the historical closure used in this analysis are shown in Appendix 1.

[2] The base year data in this version of UPGEM is for 2006.

With base year data for 2006, Table 1 shows the variables that were set as exogenous and assigned their observed annual movements from 2007-2013. Values represent year-on-year percentage point changes. These exogenously imposed values are consistent with available statistical data. Capital stock may be considered a pseudo-exogenous variable since the variables that determine its net change in any given period, investment and depreciation, are exogenously set. To a large extent, this also applies to Real GDP, with the variables that determine it from both the income and expenditure side set as exogenous. Apart from the main macro variables, we also show selected industry variables in the gold and electricity sector that were assigned their observed values. For the electricity sector, rising electricity prices and increased investment expenditure were noticeable. For the gold sector, its falling levels of production along with significant increases in the gold price were equally striking.

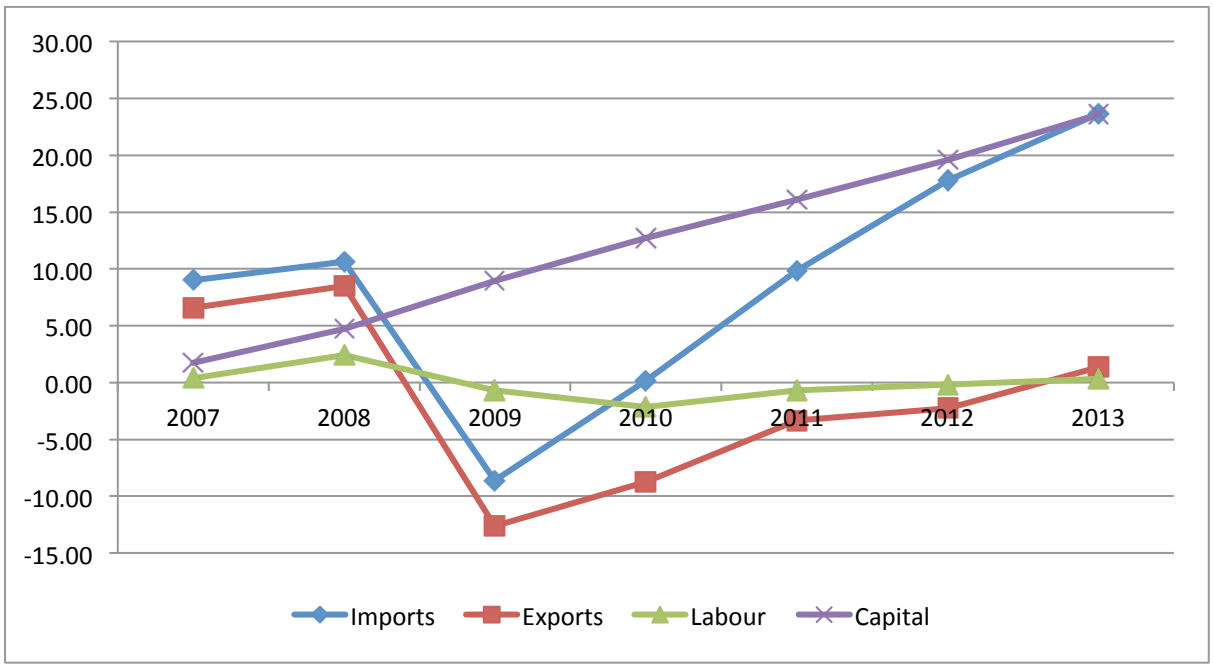
Table 1: Observed annual percentage change to selected exogenous variables (2007-2013)

Macro variables	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013***
Real GDP (x0gdpexp)	*5.5*	*3.6*	*-1.5*	*2.9*	*3.1*	*2.4*	*2.0*
Consumption (x3tot)	5.5	2.2	-1.6	3.7	5.0	3.3	2.3
Investment (x2tot_i)	14.0	14.1	-3.2	-1.6	4.4	6.3	5.5
Government (x5tot)	3.9	4.5	4.6	4.8	4.5	3.8	3.3
Imports (x0cif_c)	9.0	1.5	-17.4	9.6	9.7	7.2	5.0
Exports (x4tot)	6.6	1.8	-19.5	4.5	5.9	1.1	3.7
Govt/consump ratio (f5tot)	*-1.5*	*2.2*	*6.3*	*1.1*	*-0.5*	*0.5*	*1.0*
Consumer price index (p3tot)	6.1	9.9	7.1	4.3	5.0	5.7	5.8
Real wages (real_wage_c)	1.0	2.5	2.5	3.0	1.0	1.5	1.5
Terms of trade (p0toft)	2.0	0.0	8.0	7.2	2.3	0.5	0.5
Nominal exchange rate (phi)	-0.5	-6.0	5.0	1.0	-3.0	-3.5	-3.5
Labour (emp_jobs)	0.4	2.0	-3.0	-1.5	1.5	0.5	0.5
Capital stock (x1cap)	*1.7*	*2.9*	*4.0*	*3.5*	*3.0*	*3.1*	*3.4*
Industry variables	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013***
Gold price (p4)	31.0	4.0	25.0	30.5	7.5	8.5	-15.0
Gold production (x4)	-5.5	-15.0	-6.0	-4.0	-4.0	-10.0	-5.0
Electricity price (p0dom)	5.1	27.5	31.3	24.8	25.8	16.0	8.0
Electricity investment (x2tot)	15.0	14.0	13.0	12.0	10.0	9.0	8.5
Electricity output (z)	4.0	-1.0	-2.0	4.0	2.0	2.0	4.0

Source: SARB, StatsSA, UPGEM simulation results

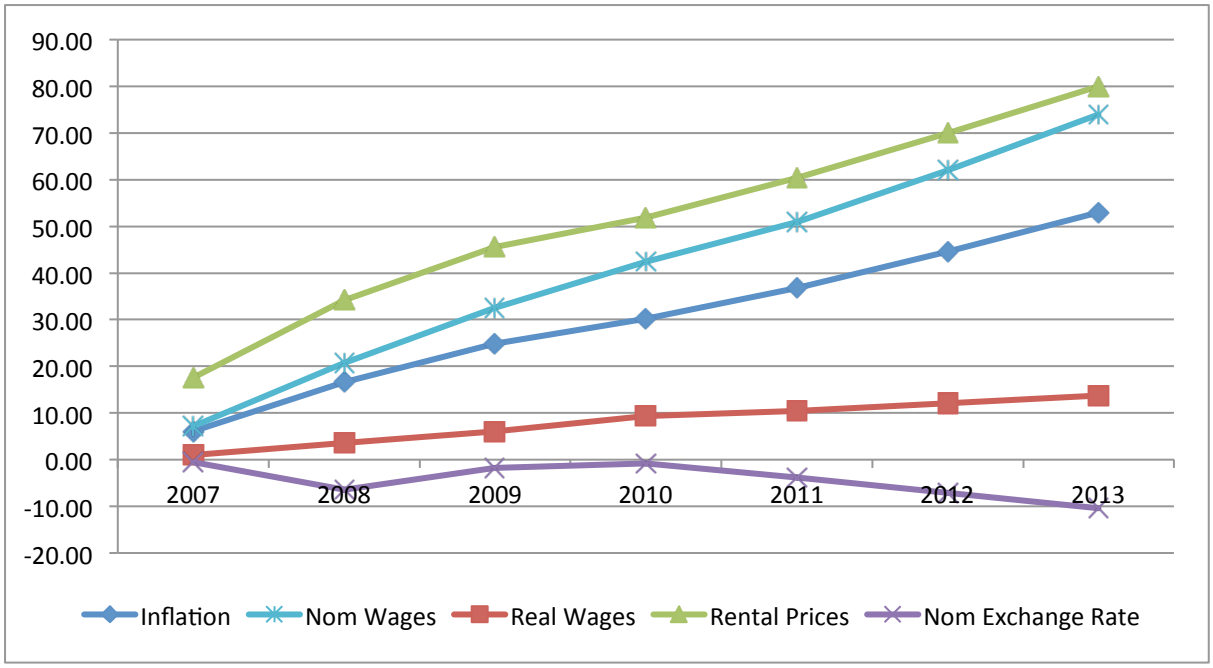
Figure 1 and 2 displays the same movements from Table 1 for selected macro variables, but as cumulative percentage changes over the period relative to the 2006 base year data. Figure 1 shows movements in imports versus exports and employment of labour versus capital. South Africa's widening trade deficit and the impact of the global financial crisis in 2008/09 on trade are clearly evident, as well as the poor performance of the labour market in terms of employment numbers relative to the growth in the capital stock. Figure 2 shows the movements in important price variables. Two movements stand out in this regard. The first is the relative increase in the use of capital relative to labour, despite increases in the relative price of capital rentals (endogenously determined here) to wages. The second is the widening trade deficit, despite the weakening of the Rand. In the following section we show the movements in variables that were endogenously determined in the UPGEM model that help explain some of the observed movements just discussed.

Figure 1: Cumulative percentage change to trade, capital and labour variables (2007-2013)



Source: SARB, StatsSA

Figure 2: Cumulative percentage change to selected price variables (2007-2013)



Source: SARB, StatsSA, UPGEM simulation results

4. Endogenous Results for the Historical Simulation from 2006-2013

Given the choice of closure and 'historical' exogenous shocks to the model over the 2007-2013 period, UPGEM determines the movement in a large number of endogenous variables. In this section we focus on the most relevant variables to the current economic situation in South Africa: movements in overall factor productivity, preference shifts between capital and labour, shifts in the rest of the world's demand for our exports, and also productivity changes in the gold industry. Results in Table 2 are shown as cumulative changes and in Table 3 as annual changes.

Table 2: Cumulative percentage change to selected endogenous variables (2007–2013)

Endogenized macro variables	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013***
Factor productivity (ff_a1prim)*	-4.9	-8.1	-6.3	-7.2	-9.1	-10.3	-11.0
Import/domestic pref (twist_c)	1.8	-6.9	-36.0	-32.4	-29.3	-26.0	-26.4
Import demand shift (f_pf0cif_c)	5.9	9.4	14.5	14.0	13.6	15.8	16.2
Export demand shift (f4gen)	10.7	18.2	18.1	26.2	32.8	38.0	45.1
Labour/capital preference (twist_i)	3.4	4.5	16.1	22.6	23.6	26.9	30.6
Endogenized industry variables	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013***
Gold export demand shift (f4q)	20.6	-10.8	27.1	67.3	58.4	44.2	-5.5
Gold factor productivity (f_a1prim)*	16.7	38.7	44.7	59.6	76.9	101.2	99.0

Source: UPGEM simulation results

Table 3: Annual percentage change to selected endogenous variables (2007–2013)

Endogenized macro variables	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013***
Factor productivity (ff_a1prim)*	-4.9	-3.3	1.9	-0.9	-2.1	-1.3	-0.7
Import/domestic pref (twist_c)	1.8	-8.6	-31.3	5.7	4.5	4.7	-0.6
Import demand shift (f_pf0cif_c)	5.9	3.2	4.7	-0.4	-0.3	1.9	0.3
Export demand shift (f4gen)	10.7	18.2	18.1	26.2	32.8	38.0	45.1
Labour/capital preference (twist_i)	3.4	1.1	11.0	5.6	0.8	2.6	2.9
Endogenized industry variables	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013***
Gold export demand shift (f4q)	20.6	-25.4	41.4	31.5	-5.3	-8.9	-34.5
Gold factor productivity (f_a1prim)*	16.7	18.9	4.3	10.3	10.8	13.8	-1.1

Source: UPGEM simulation results

With all components of GDP from the expenditure side set at their observed values, real GDP growth of 20 per cent was achieved between 2007 and 2013. This is equivalent to an average annual growth rate of around 2.5 per cent over the 7 year period. Investment expenditure (x2tot) was shown to grow at a faster rate than household consumption (x3tot), with a slight increase in the average propensity to save also found. The Global Financial Crisis is the main reason for the relatively slow growth witnessed over the 2008/09 period, with household expenditure and trade most severely impacted. Social spending from government, along with the finalising of FIFA World Cup related projects, are the main reasons that the ratio of public to private consumption (f5tot) increased up to 2010. The recovery in household consumption allows this ratio to fall somewhat in later years. With the sluggish recovery in the economy, the budget deficit to GDP ratio was also observed to deteriorate slightly over this period.

The historical data in Section 3 shows an increase in the capital-labour (K/L) ratio over the 2007-2013 period. Cumulatively, capital stocks (x1cap) increased by around 23.6 per cent on the back of strong investment (x2tot) growth, with the number of jobs (emp_jobs) remaining relatively stagnant. As highlighted in Figure 2, the real rental price of using capital, shown in the notation below as (Q/P_y) increased relative to the real cost of labour, shown in the notation below as (W/P_y). Contrary to a fall in the K/L ratio, expected on the base of these relative price and marginal product changes, our exogenous historical shocks impose a rise in the K/L ratio. To calibrate this increase in the K/L ratio with the historical increase in effective cost of using capital relative to labour, a cost-neutral labour/capital preference twist, shown below as (TWLK), is introduced. As may be expected, a cost-neutral twist in preferences by users holding back labour in the primary-factor composite is generated by the model. The positive value of 30.6 per cent generated for TWLK (twist_i) over the period, as shown in Table 2, reflects this strong shift in preferences away from the use of labour required by the model to reconcile the seemingly incompatible exogenously given values of the K/L ratio and primary-factor prices with each other.

To better explain this result we must look at the theoretical specification of TWLK within UPGEM. Input demand equations by industries are derived subject to a CES aggregation function with substitution elasticities (σ) between primary factors set at 0.2. With $\sigma \neq 1$ in the linearized input demand equations, this allows cost-neutral preference twists (TWLK) accommodating exogenous forecasts in the primary-factor market to be introduced and converted into technical or taste changes.[3] For readers familiar with GEMPACK, equations (E1) and (E2) show these linearized demand equations as they appear in the UPGEM model code.

$$cap = z - \sigma S_L \left(p_{cap} - p_{lab} \right) + S_L TWLK \qquad \text{(E1)}$$

$$lab = z - \sigma S_K \left(p_{lab} - p_{cap} \right) - S_K TWLK \qquad \text{(E2)}$$

Following our notational convention, *cap* and *lab* represent the percentage change in industry demands for capital (K) and labour (L), respectively. We note that in the absence of any change in output (z) and relative factor prices ($p_{cap} - p_{lab}$), this representation gives $\left[cap - lab = TWLK \right]$ and $\left[S_K * cap + S_L * lab = 0 \right]$. Thus, if the K/L ratio in UPGEM increases by 10 per cent beyond what is explained by relative factor price movements, then TWLK will equal 10. The twist is therefore equivalent to movements in A_K and A_L that satisfy equations (E3) and (E4).

$$S_L TWLK = a_K - \sigma S_L \left(a_K - a_L \right) \qquad \text{(E3)}$$

$$-S_K TWLK = a_L - \sigma S_K \left(a_L - a_K \right) \qquad \text{(E4)}$$

[3] This method of implementing cost-neutral preference twists eliminates a problem arising with these variables when set as exogenous in policy simulations. The same method is used to implement cost-neutral import/domestic preference twists. For a more technical explanation, see Dixon & Rimmer (2004).

We can further show that by implementing the twist via the technical change variables, we are in effect assuming that $\left[a_K = \frac{S_L}{1-\sigma} * TWLK\right]$ and $\left[a_L = -\frac{S_K}{1-\sigma} * TWLK\right]$. With σ below one, a positive TWLK value is equivalent to a cost-neutral capital-using technical change combined with a labour-saving technical change.

To provide additional insight into the composition of our K/L movements, we use the two 'back-of-the-envelope' equations shown in (E5) and (E6).[4] Assuming competitive conditions, the marginal products of capital and labour would equal their respective factor payments. In our exposition of (E5) we recognise that the marginal product of capital (F_K) is negatively related to the K/L ratio. In (E6) we recognise that the marginal product of labour (F_L) is positively related to the K/L ratio. In determining (E5) we assume that the rate of return on capital (RoR) can be expressed as (Q/P_i) with Q the factor payment to capital and P_i the price index for new investments. We then assume Q is determined by the value of the marginal product of capital, written as (F_K*P_y). With (F_K) a function of the K/L ratio, and technical change (A) and (P_y/P_i) a function of the terms of trade (TofT), we are able to summarise this relationship through equation (E5). In similar fashion, we are able to write (E6) linking the real wage (W/P_c) to the K/L ratio, technical change, and the terms of trade effect.

$$F_K\ A\left[\frac{\left(K/A_K\right)}{\left(L/A_L\right)}\right] \approx \frac{Q}{P_i} * \frac{P_i}{P_y} \qquad \text{(E5)}$$

$$F_L\ A\left[\frac{\left(K/A_K\right)}{\left(L/A_L\right)}\right] \approx \frac{W}{P_c} * \frac{P_c}{P_y} \qquad \text{(E6)}$$

Given the implementation of our labour/capital twist via the technical change variables, we are now able to use our 'back-of-the-envelope' equations to help interpret the results for TWLK. In (E5), a preference twist affecting capital will therefore be transmitted via the technical change variable (A_K). In (E6), a preference twist affecting labour will similarly be transmitted via the technical change variable (A_L). Our results show strong primary-factor technical change in favour of capital and against labour between 2007 and 2013. This is reflected in the positive value of 30.6 per cent generated for TWLK (twist_i) by the UPGEM model. We may equate this result to an increase in A_K in (E5) which will decrease the marginal product of capital requiring a rise in the relative amount of capital used. For labour, this may be equated to a decrease in A_L in (E6) which will increase the marginal product of labour requiring a fall in the relative amount of labour used. In the absence of this cost-neutral preference twist, captured via the technical change variables, forecasts related to the K/L ratio and relative primary-factor payments as applied here could not have been accommodated simultaneously.

With employment (emp_jobs) exogenous and capital growth (x1cap) linked to investment expenditure (x2tot) via the capital accumulation mechanism, economy-wide technical change (ff_a1prim) of 11.0 per cent is required to balance GDP from the supply side. Given the exogenous export demand (x4tot) and terms of trade (p0toft) settings, a cumulative shift

[4] The two BOTE equations in (E5) and (E6) are easily derived by maximising economy-wide profits, $P_y.Y - (W.L + Q.K)$, subject to a Cobb-Douglas production function where $Y = A[L^{\beta}.K^{(1-\beta)}]$

in world demand for exports (f4gen) of 45.1 per cent over the period is endogenously determined by the model. The shift in export demand reflects the growth in world trade and demand for locally-produced exports, consistent with the exogenous trade data imposed on the model. This result is equivalent to an annual average growth rate, or outward shift, of around 5 per cent in (f4gen) over the 7 year period. At first glance, the 45.1 per cent shift of the export-demand curve may seem large compared to some of the other results in Table 1. Recall from Section 2 that the export-demand curve is downward sloping in the theoretical specification of UPGEM. A large shift in (f4gen) is therefore required for the model to reconcile the slight exogenously given increase in real exports (x4tot) with the increase in the TofT (p0toft) of 23 per cent. The result produced here also reflects the given export elasticities in UPGEM of between 1.5 and 3 for all commodities.

The lower levels of trade relative to GDP (x0gdpexp) in the 2008/09 period reflects the impact of the Global Financial Crisis on imports (x0cif_c) and exports (x4tot). The terms of trade (p0toft) is shown to have improved between 2007 and 2013. This is defined as an increase in export prices relative to import prices. A natural shift towards relatively cheaper imports in the local import/domestic sales mix should therefore occur. However, the observed values for imports and exports do not suggest any significant change in the import/domestic mix relative to the given change in the terms of trade. To calibrate the forecasted values for the trade balance with the terms of trade, a cost neutral import/domestic preference twist (twist_c) is introduced. As may be expected, a cost-neutral twist in preferences by users holding back imports in the local/import domestic mix of sales is generated by the model. The negative value of 26.4 per cent generated for the import/domestic preference twist (twist_c) reflects this shift in preferences away from the use of imports required by the model to reconcile the different exogenously given values of imports, exports and terms of trade in Table 1 with each other. One reason for this shift may be attributed to changes in government procurement policies favouring locally produced goods.

5. Conclusions

South Africa's GDP growth and unemployment problems have been well documented in the literature. This paper seeks to quantify some of the factors underlying the country's struggles in this regard. Using the UPGEM CGE model, it is found that there has been a significant shift in preferences away from labour towards capital given the relative factor price movements between 2007 and 2013. In essence, what this result suggests is that industry technology on average changed so that at any given ratio of the real wage to real rental price of capital, industries would choose a K/L ratio 26 per cent higher in 2013 than in 2006. Other findings include a slight improvement in overall primary-factor technical change, but a deterioration in productivity in the gold sector, perhaps as a result of the increasing difficulty associated with deep underground mining. A slight preference twist towards the use of domestically produced goods relative to imports was also found. The findings from this paper lay the groundwork for improved baseline forecasts for the UPGEM model and a better understanding of recent trends in the economy.

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Appendix 1 Table 1: Macro swaps applied for historical closure

Exogenous in standard long-run closure	**Exogenous in historical closure**
ff_a1prim	x0gdpexp
apc_gnp	x3tot
d_f_eeqror	x2tot_i
f5tot	x5tot
twist_c	x0cif_c
phi	p3tot
f_pf0cif_c	p0toft
twist_i	real_wage_c

Appendix 1 Table 2: Industry-level swaps applied for historical closure

Exogenous in standard long-run closure	**Exogenous in historical closure**
f4q("gold")	p4("gold")
f_a1prim("gold")	x4("gold")
fa1c("elec")	p0dom("elec")
d_f_eeqror_j("elec")	x2tot("elec")
f_a1prim("elec")	z("elec")

Appendix 2: Key labour market indicators (2006-2013)

Variable	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013***
Number of Employed ('000)	13,419	13,467	13,867	13,455	13,061	13,265	13,447	
% Change from previous year	5.09	0.36	2.96	-2.97	-2.94	1.56	1.37	
Unemployment Rate (Official)	22.6	22.3	22.8	23.9	24.9	24.9	24.9	
Absorption Rate	44.9	44.4	44.8	42.7	40.8	40.8	40.9	
Unit Labour Cost								