# Modeling climate mitigation and economic growth in relation to employment and skills in South Africa

*Insights from the IMACLIM-SA model*

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**Abstract**:

South Africa is a middle income economy with a high carbon intensity. Its Intended Nationally Determined Contribution (INDC) for COP21 in Paris (in 2015) is to reduce its GHG emissions by 34% in 2020 and by 42% in 2025 relative to business-as-usual (BAU) and conditional on financial and technical support. To do so, among other measures, South Africa plans to establish an economy-wide carbon tax, starting January 2017. However, mitigation is not the only challenge that the South African society faces. Unemployment remains high at an official rate of about 25%. It is particularly prevalent among low educated people, while there is a shortage of high-skill workers. This points at persistently high inequalities in its society. The aim of our paper is to provide insights on the interaction between mitigation and the key employment challenge. Compared to existing literature, our paper adds the combination of a represention of market imperfections, notably for labour, with applying bottom-up (engineering) model rigidities for the electricity sector to our CGE analysis.

For our analysis we use IMACLIM-SA, an open-economy, “hybrid” computable general equilibrium (CGE) model with 10 sectors, of which 5 energy sectors. It consistently accounts for quantities and values of energy flows within the I-O table. We model five household classes. Factor trade-offs in production for all sectors except electricity are modeled with KLEM production functions (nested CES) using four factors of production: capital and 3 labour factors, distinguished by level of skill. We assume complementarity between capital and high-skill labour. Scenarios for the production of electricity are based on outcomes of the South Africa TIMES energy system model (SATIM) from the Energy Research Centre (ERC) of the University of Cape Town. We also assume non-perfect foresight and non-perfect markets. To induce growth, we assume improvements in capital and labour productivity in volume terms, and an increasing trend for exports.

For the labour market we use of a wage curve for each of the three skill segments. Initial explorations of how to model supply and demand for labour showed that defining skills according to a so-called “positional” interpretation is more suitable for South Africa, for a CES approach. Skill segments of labour are thus modeled as constant shares of the labour force.

We explore two values of the carbon tax – respectively 100 and 300 Rand/tonne $CO_2$ ($tCO_2$) – and five strategies for recycling the tax proceeds, namely: reducing public deficits, reducing sales taxes, reducing income and corporate taxes, increasing government expenditure, and transferring proceeds to households on a per capita lump-sum basis. We find that at 100 Rand/$tCO_2$, revenue recycling through sales tax reduction yields a double dividend compared to our reference projection without a

carbon tax. However, 300 Rand/t$CO_2$ is needed to achieve a reduction of $CO_2$ emissions close to South Africa's INDC. At this tax level, we find only minor economic impacts relative to the reference projection when the proceeds are recycled into a reduction of sales tax, but much higher when the proceeds are recycled differently. Though sales tax reduction outperforms other recycling schemes in terms of economic growth and unemployment, it does not lead to reduced inequality compared to the reference projection. With regard to this objective, lumpsum transfers would be the best option. Additionally, we explore the impact of investment in skills of the labour force. We find that only slight positive impacts on productivity are needed to justify investment in skills of the labour force.

Our paper points to some important needs for future research. Firstly, the policy interventions that could improve productivity via spending on education should be explored. Secondly, a better understanding is needed of the link between skills of labour and technological change. Finally, for our model specifically, we are planning a more profound integration of energy system model insights.

**Keywords**: South Africa, Climate Mitigation, Carbon Tax, Recycling schemes, Labour market, Skills

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# 1 Introduction

South Africa is a middle income economy with a high carbon intensity. Abundant coal resources sustain its economic development by allowing for cheap electricity, and even automotive fuels from coal-to-liquid technology. South Africa however in its Intended Nationally Determined Contribution (INDC) for the COP21 in Paris pledged to reduce its GHG emissions by 34% in 2020 and by 42% in 2025, relative to business-as-usual, and conditional on financial and technical support from the international community (UNFCCC, 2015). In 2011 South Africa already issued a Climate Change Response White Paper (RSA, 2011), which generated a carbon tax proposal which, planned for 2015, is now postponed to 2017 to allow for further consultation (RSA, 2015). South Africa also acknowledged its climate change objectives in its Integrated Resource Plan (IRP), an investment plan aiming at urgently easing the tension between supply and demand of electricity (DoE, 2011).

The discussion about mitigation and energy cannot be isolated from the important challenges facing the rapidly transforming South African society. Notably, South African economic growth has not been able to absorb the increase in labor supply from population growth. Unemployment remains high at an official rate of 25% (StatsSA, 2015). It is particularly prevalent among low skill individuals, while there is a shortage of high skill workers. This highlights persisting inequalities within its society, legacy of the Apartheid era. In fact, South Africa has one of the world's highest Gini indexes.

A rich and growing literature analyses the introduction of carbon taxation in South Africa. Van Heerden *et al.* (2006) apply a dynamic CGE model of South Africa to test different recycling schemes with different options for energy or carbon taxation. They find that notably food tax breaks offer perspectives for a 'triple dividend' of decreased GHG emissions, increased GDP and reduced poverty. De Pauw (2007) similarly relies on a dynamic CGE model to analyze the impacts of three policy scenarios with various recycling options, but he finds regressive impacts of a carbon tax on GDP and on employment, regardless of the scenario. Devarajan *et al.* (2009, 2011) also apply a CGE model of the South African economy, but a static one, and one focused on representing market distortions. They test the impacts of a 15% cut in $CO_2$ emissions by the means of a carbon tax, an energy tax or a sales tax on energy-intensive sectors. Their main result is that "labor market distortions such as labor market segmentation or unemployment will likely dominate the welfare and equity implications of a carbon tax for South Africa." (pp.18). Finally, Alton *et al.* (2012, 2014) also rely on a dynamic CGE model, but one that can be linked to the SATIM energy sector model of the Energy Research Centre (ERC) of the University of Cape Town (ERC, 2013). They test a domestic carbon tax, a carbon tax plus border tax adjustment (BTA), and a foreign carbon tax for South Africa's main trading partners plus BTA. Carbon tax revenues are either recycled into lower sales taxes, lower capital taxes, or higher social transfers. They find that a phased-in domestic carbon tax which reaches \$30/t$CO_2$ in 2022 achieves the INDC emissions target. They highlight that the different recycling options have different impacts for income distribution and economic growth.

Our paper aims to provide insights on the interaction between the mitigation objective and the key employment challenge as outlined above. Our analysis makes use of a computable general equilibrium (CGE) model, IMACLIM-SA. Compared to existing literature, our value-added is to combine the strengths of Devarajan *et al.*'s efforts to represent market imperfections (see section 2.1) and Alton *et al.*'s endeavour to link a CGE analysis to the SATIM model (sections 2.1 and 5.3). Besides, we base our modelling on an innovative approach of harmonisation of national accounts and energy balance data, which *inter alia* allows us to model agent-specific prices of homogeneous goods. Lastly, we contribute to the methodology of modeling skill segmentation of labour, specifically in relation to productivity gains and technical change.

We start this paper with a synthetic presentation of the IMACLIM-SA model complemented with detail on its calibration and parameterisation. We then present our reference projection and basic scenario outcomes, before heading on to a discussion about how we model the dynamics of labour supply and demand by skill level. We finally present detailed scenario results by skill and household class and present a discussion of results with a sensitivity analysis and a comparison with findings by others, before turning to our conclusion.

# 2 The IMACLIM-SA model

## 2.1 Model description

### 2.1.1 Introduction

IMACLIM-SA is an open-economy "hybrid" CGE model with 5 energy and 5 non-energy sectors (Table 1); 4 factors of production: capital and 3 labour factors distinguished by the level of skill of the job or worker (high, medium and low); and five household classes.[1] It uses scenarios for the production of electricity on the basis of outcomes of a (TIMES) engineering bottom-up model of the South African

[1] Here we discuss the second version of this model. An older version with another approach to production functions was developed halfway a research project with AFD (*Agence Française de Développement*).

energy system (SATIM) (ERC, 2013). It has non-perfect markets and non-perfect foresight and makes use of dual and consistent accounting of quantities and values of energy flows within the Input-Output (I-O) table. The model consists of a set of simultaneous, non-linear equations under MS-Excel.

**Table 1 Sectors in IMACLIM-SA and corresponding sectors in South Africa's SAM 2005**

| Sector | Full name | Included sectors from SAM 2005 |
|---|---|---|
| COA | Coal | Coal |
| OIL | Oil | Oil resources |
| GAS | Gas | Gas resources, Gas distribution |
| REF | Refineries | Refineries |
| ELC | Electricity | Electricity |
| EIN | Energy Intensive Industries | Gold, Other mining, Petrochemical industry, Other NMM products, Basic iron/steel, Non-ferrous metals |
| MAN | Manufacturing | Food, Footwear, Metals basic manufacturing, Electrical machinery, Radio, Transport equipment, Other manufacturing |
| LSS | Low-Skill Sectors | Agriculture, Construction, Trade, Hotels & restaurants, Domestic & other services |
| HSS | High-Skill Services | Water, Communications, Financial intermediation, Real estate, Business activities, General government, Health and social work, Education |
| TRA | Transport services | Freight transport by air, water and road, and public and air passenger transport |

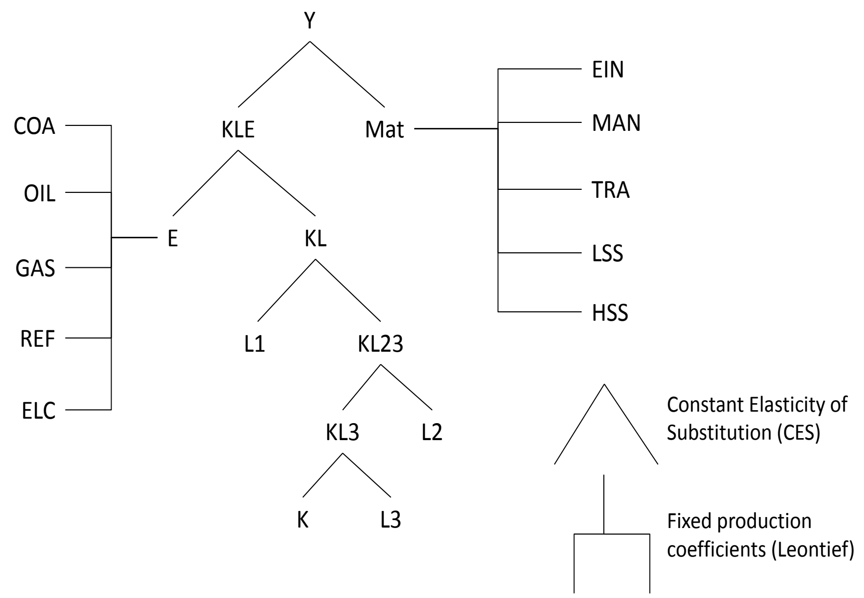
### 2.1.2 Trade-offs in production and international trade

Factor trade-offs in production in all sectors except ELC are modeled using a KLEM production function. Following Van der Werf (2008) we opt for a nested structure combining capital and labour to form a KL aggregate, then KL and an aggregate of energy goods (E) to form a KLE aggregate, ultimately traded-off with a 'materials' aggregate (Mat) of non-energy goods and services to produce output (Figure 1). We use fixed coefficients (Leontief) for both the production of the energy aggregate (E) and the materials aggregate (Mat). All other substitution possibilities follow a constant elasticity of substitution (CES) assumption (see Table 7 in Appendix 1 for elasticities). At the level of sectors we assume complementarity between capital and high-skill labour, as suggested by Krusell *et al.* (2000) who find a skill premium for equipment-capital using U.S. historic data.[2] Also, we assume that the capital (K) - high skill (L3) labour aggregate, KL3, is a substitute for medium skill labour (L2), and that the KL23 aggregate is substitutable by low-skill labour (L1).

For the electricity sector (ELC) we use a different approach: primary and secondary factor intensities of the electricity sector—*i.e.*, the consumption of physical energy and of other intermediate inputs, of capital and of labour, per unit of electricity produced are derived from SATIM model runs. As a result, the IMACLIM-SA reference projection for 2035 incorporates the consequences of the Updated Integrated Resources Plan for the electricity sector (DoE, 2013), which SATIM explicitly models. Similarly, in the runs of IMACLIM-SA with a carbon tax, we use primary and secondary factor intensities for the electricity sector derived from scenario runs of SATIM at comparable rates of a carbon tax. In this way, IMACLIM-SA captures BU information about the way in which electricity supply could react to the introduction of a carbon tax. More information about how we translated SATIM outcomes to inputs for IMACLIM-SA can be found in Schers et al (2015).

[2] Krusell *et al.* have only two types of labour for their estimation model whereas we have three. But our medium- and low-skill categories roughly overlaps with Krusell *et al.*'s unskilled category.

**Figure 1** **Structure of the nested CES production function**




Imports are elastic to the relative price of the domestic over the international good and proportional to the change in domestic output. For the OIL sector no domestic production is assumed and there is no trade-off. Exports are also assumed to be sensitive to their relative price compared to the intenational good, but this elasticity is calculated around an exogenous trend representing growth in the volume of international trade. Domestic and international goods are considered to be homogenous. We incorporate our view on substitutability by our choice of price elasticities differentiated by household class (Table 9 in Appendix 1).

### 2.1.3 Price structure of goods

For all sectors except ELC the trade-offs in production, consumption and international trade are mostly determined by changes in their relative prices and by corresponding price elasticities. The price of a good is built up differently for different users/consumers. It is built up around the *price of the resource of good i*, $pRES_i$. This is the weighted average of the (domestic) *producer price* of good *i* and the *price of the international (or imported) good i*. The producer price of good *i*, $p_{Y,i}$, depends on the cost structure of production of the good, being: the sum of intermediate consumption, labour costs, capital costs, a tax on production, and a mark-up rate corresponding to the net operating surplus. The price of the international (or imported) good *i*, $pM_i$, is good-specific, but we do not assume divergence of international prices in this study, and we treat the vector of international prices as the numéraire of the model. They are consequently assumed constant.

Labour costs (as part of the producer price of good *i*) per skill for each sector are equal to the net wage plus payroll taxes (both employers and employees' social contributions) and pension contributions (both public and employees' private pension contributions). The average wage per level of skill for each sector varies with a constant ratio over the overall average wage per skill. The price of capital is understood as the cost of 'machine' capital. It is obtained as the average price of a (homogenous) investment good.

To set sales prices (per consuming industry or final consumer) in the IMACLIM approach we use a fixed general mark-up rate for Net Operating Surpluss (NOS, part of $pRES_i$) and fixed agent-specific margins, $\tau MS_i$. In IMACLIM-SA we adjust these mark-up rates with gains in capital productivity to maintain a realistic distribution of primary income by making these rates decrease. The general formula for the price of the sales of a good *i* to a sector or agent *j* is as follows:

$$price_{i,j} = \left[ pRES_i \left(1 + \tau MC_i + \tau MT_i + \tau MS_{i,j}\right) + tFUEL_{i,j} + tY_i + tCO2 * eCO2_{i,j} \right] * \left(1 + \tau SALE\right)$$

, with:

$pRES_i$ average resource price of good i

$\tau MC_i$ commercial (trade) margins on sales of good i

$\tau MT_i$ transport margins on sales of good i

$\tau MS_{i,j}$ specific margins on sales of good i to sector or agent j

$tFUEL_{i,j}$ a volume-based fuel levy on consumption of good i (a refinery product) by sector or agent j

$tY_i$ a volume-based product tax or subsidie on good i

*tCO2* a $CO_2$ tax per tonne of $CO_2$ emitted in consumption of a fossil fuel

$eCO2_{i,j}$ emission coefficient of consumption of fossil fuel i by sector or agent j

$\tau SALE$ sales tax (rate) applied only to final consumption

Transport and trade margins for respectively the TRA and LSS, who have negative margins, are adjusted in such a way that in total they sum up to zero. Exports are exempted from *tFUEL*, *tY*, *tCO2* and $\tau SALE$.

### 2.1.4 Distribution of income and behavioural specifications by agent

Production and the sales of goods generate three kinds of primary income:

1. Net wages, accruing to households;
2. Gross operating surpluss (GOS) and specific margins, includes mixed income and imputed rents: it is largely allocated to firms, and partly to government and household income;
3. Taxes (minus subsidies) on production and social and pension contributions. Taxes and social contributions count as income to government. Pension contributions are counted at the same time as an income and as an obligation to households for (financial) firms.

The secondary distribution, or transfers, of income between agents consists of a *'debt service'* for paying or receiving interests, revenue, property and other direct tax payments, *other* transfers, and for households also revenue from pensions, unemployment benefits, and other social benefits.

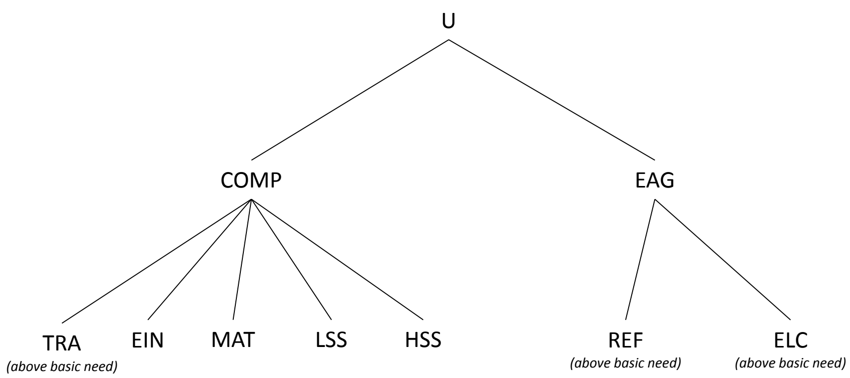
Household Gross Disposable Income ($GDI_H$) is used for consumption and for savings. In case consumption of a class *h* is higher than its GDI the saving rate will be negative. In the base year 2005 the saving rate of households was very low according to SAM data, at an average of 0.1% (StatsSA, 2010b). This is not a sustainable situation, as household savings fuel domestic investment. We assume a higher saving rate for 2035 and additionally that low-income households tend to borrow to consume, whereas high income households save more than lower income households (Table 2). Households' investment (Gross Fixed Capital Formation, $GFCF_H$) is defined separate from their savings and is assumed to be a fixed ratio over a household class's GDI. The difference between savings and investment gives the *auto-financing* capacity of a household class ($AFC_{Hh}$).

**Table 2** **2035 saving rates assumption for all 5 household classes**

| Household class | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 |
|---|---|---|---|---|---|
| Savings rate | 0.5% | 1.0% | 1.0% | 2.5% | 3.5% |

Trade-offs in per capita consumption are settled through nested-CES type specifications too (see Table 8 in Appendix 1 for elasticities). However, taking into consideration the strong inertias in the consumption of energy and transport by households—e.g. inert housing location determining households demand for private transport—, CES flexibility is allowed only beyond basic needs, i.e. exogenously set floors for the volume of per capita consumption of electricity, refined products and transport services. Consumption of coal (for cooking and heating) is exogenously set to go to zero.

**Figure 2** **Household consumption decision tree**




Firms use their income to invest, in other words: for gross fixed capital formation. We assume it to be constant to their gross disposable income. The difference is firms' auto-financing capacity, $AFC_S$. Governmental $GDI_G$, after public expenditure –which is a constant share of GDP and only consists of High Skill Services (administration and public services)—, is only used for public investment $GFCF_G$ which is assumed to be a constant share of GDP too. Subtracting $GFCF_G$ from $GDI_G$ gives the government's auto-financing capacity, $AFC_G$, meaning the public deficit. In IMACLIM-SA we apply a 'constant budget position'-rule as a constraint on public deficit, enforced as a targeted ratio dependent on the reference setting. It is maintained at -2% of GDP. The variables which adjust to meet this constraint are corporate and household income and property revenue tax rates, which are scaled by a common factor.

The rest of the world (ROW) is relevant for the income distribution between the domestic agents in a few cases: First of all, the trade balance causes a monetary flow between South Africa (SA) and the ROW. Secondly, we assume the ROW to balance SA's surplus of other transfers income, and thirdly, the ROW is assumed to automatically balance the sum of debt services of other agents. All behavioural specifications described so far mean a structural surpluss for households and a structural deficit for government and firms. On a net basis South Africa is, like in 2005, assumed to borrow from the ROW. In combination with other transfers being fixed, and the price elasticities of international trade we assumed plus the upward trend in exports, this is paralleled by a trade balance surpluss *and* a reduction in international purchasing power of the Rand.

To calculate the accumulation of debt for each of the agents we assume that gross auto-financing capacity, *i.e. AFC* net of interest payments, evolves linearly over time between our base year and our projection year, *n* years into the future (n=30).

### 2.1.5 Goods, Capital and Labour markets

The model relies on a few market balances which are the main constraints for economic equilibrium both in the BY as in a projection year. The first is the balance in supply and use of goods, meaning that for a good *i* the volume of goods produced domestically plus the volume imported equals that of the volume consumed in IC, FC, by government and for investment plus the volume exported. The same is true for the monetary values of goods.

Supply of capital in money terms (the sum of all agents' Gross Fixed Capital Formation) and demand for capital (total *investment*) are equal. In volume terms, the demand for capital is constrained by the assumption that the ratio of each component of investment to the total of consumption of fixed capital is constant. Meaning, capital immobilised in all sectors is said to be homogeneous and all its components vary with the total consumption of fixed capital in production. To balance the capital market, for technical reasons, we do not adjust interest rates, but the distribution of GOS over firms, households and government, in that way we maintain the rule that firms invest at the same ratio over their GDI as in BY (2005).

For labour, at each level of skill, the monetary market balance implies that the total of net wages paid equals the total of net wages earned. At the sectoral level, we fix the ratio of each skill-related net wage to the economy wide average net wage at that level of skill. The "volumes" market balance is that the total labour endowment by skill minus the number of unemployed by skill level equals the sum of labour by skill level of all sectors. The corresponding unemployment rate is linked to the average net wage for each level of skill through a wage curve in which wages are indexed on the Consumer Price Index, and increase with an assumed percentage (*LPgain*) of the increase in labour productivity.[3] Change in wage with unemployment is determined by the elasticity of the wage curve, set at 0.2 for all skill levels.

## 2.2 Model calibration and projection settings

### 2.2.1 BY calibration

To construct the hybrid Input-Output table we started of with the monetary I-O table of the Final Social Accounting Matrix 2005 (Updated) (Stats SA, 2010b; Stats SA, 2010a). Energy volumes were based on the energy balance of the Department of Energy (DoE, 2009a), the energy balance for South Africa of the IEA (IEA, 2012), and data and estimations provided by the ERC. Energy prices were also taken from several sources (ESKOM, 2005; SAPIA, 2013; NERSA, 2009; DoE, 2009b).[4] Where necessary, additional assumptions were made. For more detail, see Schers et al (2015). Appendix 4 shows the final hybrid I-O table and physical balances. For income distribution we also used several sources (see StatsSA, 2010b; StatsSA, 2012; SARB, 2007; SARB, 2012).

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[3] We relate *LPgain* to negotiation positions on the labour markets. Even in our LEP demography scenario the number of people with high-school or higher degrees increases sharply, whereas the number of people with primary school or lower education decreases relatively and absolutely. We thus assume high/medium/low skill workers to obtain wage increases of 33%/50%/75% of labour productivity gains (at constant unemployment).

[4] For obtaining the majority of this data we are grateful to Bruno Merven and his colleagues of the energy modelling unit of the Energy Research Centre at the University of Cape Town.

For BY composition of population and labour force we use numbers of people employed by job type and by educational attainment from the SAM (Stats SA, 2010b). The SAM does not report on (former) job types of the unemployed, therefore we estimate this on the basis of unemployment rates by level of education from the Quarterly Labour Force Survey (QLFS) (Stats SA, 2008). We include "discouraged workseekers" in unemployment numbers, meaning that we report "broad unemployment", at 38.8% in 2005. For population numbers we use mid-year population estimates (StatsSA, 2013). For the link between job type and skill StatsSA proposes a link to educational attainment, provided in Table 3 (Stats SA, 2010b). In reality there are more people employed at a certain job type level than that have obtained the supposed equivalent level of education (see Table 10 in Appendix 1). We chose to stick to the categorisation of skills by job type for their link to wages in the SAM 2005, and because the job types represent specific roles in production.

Households are disaggregated in five social groups which in the base year are linked to expenditure classes from the SAM 2005 (StatsSA, 2010b) and in the projection year to the evolution of the work force by skill. As the SAM 2005 does not report on the link between household classes and the labour market (job type or level of educational attainment) we decided to assume a certain distribution of the unemployed and the employed by level of skill, as well as their total net wages, over the five household classes (Schers et al, 2015). Our final base year distribution of wages, employed, unemploymed and inactives by household class is given in Table 12 in Appendix 1.

**Table 3 Classification of job types by skill level and corresponding educational attainment in the SAM 2005 and IMACLIM-SA**

| Job type, 2005 SAM | Skill level, 2005 SAM | Skill level, IMACLIM-SA | Corresponding educational attainment, StatsSA (StatsSA, 2005) |
|---|---|---|---|
| Legislator, Senior management, Professional | 4 | 3 / High | University (graduate) or post-graduate degree |
| Technician | 3 | 3 / High | Beyond high-school education lasting 1 to 4 years, starting age 17/18, except university |
| Clerk, Service worker, Skilled ag. worker, Craft worker, Plant/machine operator | 2 | 2 / Medium | Secondary education lasting 5 years, starting at the age of 13/14 |
| Elementary occupation, Domestic worker | 1 | 1 / Low | No education to primary education |

### 2.2.2 Prospective demography, educational attainment and labour supply

The model for supply and demand of labour by skill level which we use in this paper does not use educational degree (see section 4). Educational attainment was considered as a variable for the labour market model though. For this reason we developed a scenario for future educational attainment based on projections by IIASA (K.C. *et al.*, 2013). We considered these to be too optimistic though, and instead assumed enrollment by type of education to remain constant from 2010 onwards, calling this the Low Educational Progress (LEP) scenario (see Table 11 in Appendix 1).[5]

Furthermore, we assume that, for each skill level of labour, the distribution of actives over the five

[5] For scenarios on total population by age group and population by educational attainment, and estimations of expenditure per student we thank Louis de Franclieue for his internship at CIRED (de Franclieu, 2014).

household classes remains the same in 2035 as it was in 2005. To calculate the projection year's wage by skill and household class we use some basic assumptions too, mainly for the ease of model resolution: We calculate the theoretical revenue of each household class on the basis of old wages and the new number of people employed at each skill level, per household class. The share of each household class in this theoretical total net wage then becomes the share in the new total net wage by skill level. The size of population by age group is based on UN population prospects (UN, 2013). For class-specific under 15 and above 65 population additional assumptions were made. Final estimates can be found in Table 13 in Appendix 1.

### 2.2.3 Settings for prospective productivity and international trade

Next to demographic changes, another determinant for South Africa's future economic development is productivity improvement. In IMACLIM models they are determined in volume (or engineering) terms, meaning that they translate into decreased factor intensities. For our RP and all our basic carbon tax revenue recycling scenarios we assume the following exogenous improvements in productivity, that are assumed to be the same for all sectors:

- Capital productivity: +2% per year
- Labour productivity (skill-undifferentiated): +1% per year
- Materials and services productivity[6]: + 0.25% per year

In reality, we can expect a link between labour productivity and the level of skill of workers, but without a proper estimation (our calibration) to endogenise this link (for instance to the level of education, or years of experience) we stick to assumed increases. In the ideal case these would be put out for external review. These gains do not say anything about the origins of the productivity gains. Technically, they only mean a change in volume of output over the input of the corresponding factor. The trend in increase in exports volumes is also significant for our reference and scenario economic growth. It reflects economic growth in South African export markets independent of terms-of-trade variations. We set this parameter (conservatively) at +1.5% a year.

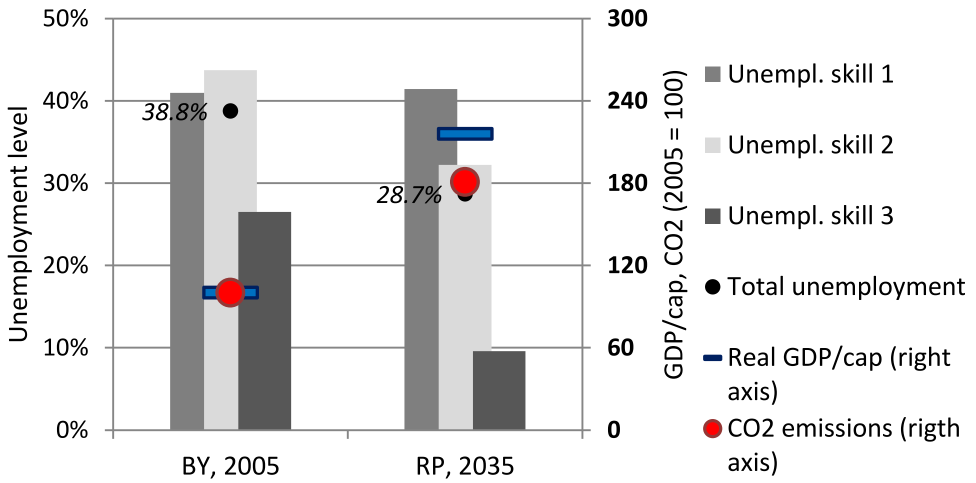
# 3 Modelling results

## 3.1 Reference Projection

The reference projection (RP) is obtained by running the model under the assumptions and parametrisation detailed above without a carbon tax. In RP real[7] *per capita* GDP grows from $ZAR_{05}$ 33k in 2005 to $ZAR_{05}$ 71k in 2035, a +116% increase (Figure 3). The obtained 2035 income equals approximately 13k $USD_{13}$ *per capita*, equivalent to present-day GDP *per capita* in Poland. Total GDP grows 2.7 times compared to 2005. Unemployment decreases from 38.8% in 2005 to 28.7% in 2035, whereas $CO_2$ emissions increase by a factor of *ca.* 1.8 from 443 to 801 Mt, *i.e.*, from 9.3 to 13.5 $tCO_2$ annual *per capita* emissions (see also Table 5).

[6] Materials "productivity" is the inverse of the intensity of production in *non-energy* goods & services.
[7] *Per capita* GDP corrected for Fisher GDP price indexation.

**Figure 3** **Main performance indicators, base year (BY) and reference projection (RP)**

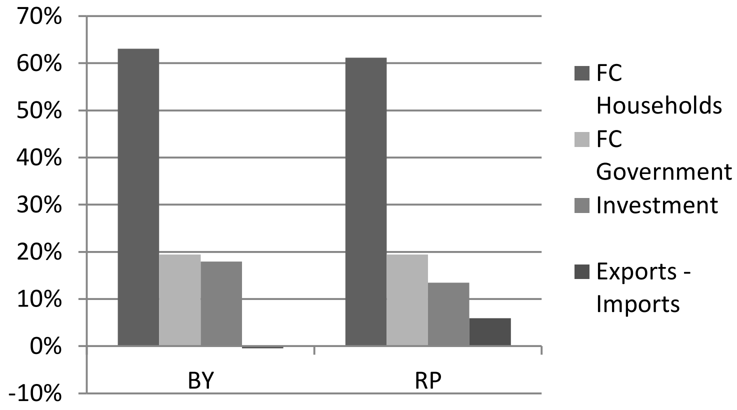



The total number of jobs in RP is 56% higher than in 2005. The distribution of this gain across sectors largely follows their output growth in volumes, which is highest for energy-intensive industries (EIN, +186%) and lowest for transport services (TRA, +92%). The diverging trends in output growth reflect different impacts of changes in relative prices on sectoral cost structures, as well as different price elasticities for final consumption and international trade. Typically, LSS and HSS sectors benefit more than other sectors from labour and capital productivity gains due to a combination of high elasticities of substitution between the KL aggregate and intermediate inputs and a higher share of VA (labour and capital) in their cost structure compared to other sectors (see Table 20 in Appendix 4).

On the expenditure side of GDP the share of the trade balance increases, whereas that of investment decreases (Figure 4). As we have hinted before, domestic prices are substantially scaled down relative to international prices, allowing the trade balance to increase to a positive 5% contribution to GDP. Barring changes in official reserves, this means a need for foreign investment, something which is implied also by our assumption about a continued combined net deficit position of all domestic economic agents. At the sectoral level, imports consequently grow substantially slower than domestic production (2.5 to 3 times slower for EIN, MAN and HSS goods), with the exception of LSS and TRA goods, that are characterised by a low price elasticity of the imported share of its goods. Similarly, exports increase their share in total uses strongly for EIN and MAN sectors, and less for HSS and LSS sectors which have lower export price elasticities (see Table 9 in Appendix 1).

Finally, with our RP benefitting industries, mining and manufacturing, we can explain the close-to-50% growth of *per capita* carbon intensity, as energy sectors (COA, GAS, REF), industries and other mining (EIN) and manufacturing (MAN) account for 59% of $CO_2$ emissions in the BY either directly, or indirectly by their share in electricity consumption (but excluding their share in transport services). In 2035 their combined share has grown to 68% of total $CO_2$ emissions.

**Figure 4** **Expenditures composition of GDP in BY and RP**




## 3.2 Policy scenarios

Our policy scenarios consider carbon taxes of 100 $ZAR_{05}/tCO_2$ and 300 $ZAR_{05}/tCO_2$, *i.e.* tax levels of $ZAR_{13}$ 170 and 510, or $USD_{2013}$ 18 and 55.[8] These rates are higher than the carbon tax expected to come into force in 2017 (120 $ZAR_{17}/tCO_2$, with sectoral exemptions between 60% and 95%, see RSA, 2015). In this way we remain close to the level of the carbon tax in the consulted scenarios of SATIM, plus we anticipate a gradual increase of the tax over time. The *ex-ante* induced effect on 2035 RP prices differs strongly by fuel (Table 4). Coal is the only domestically produced fossil fuel and indirectly subsidised. Compared to its low domestic price the carbon tax has a strong impact.[9] Refined products, already more expensive than primary fuels due to their costs of production, are also subject to a fuel levy. This explains the relatively low impact of a carbon tax on their price.

**Table 4** ***Ex-ante* price impacts of carbon taxes on energy products**

| Carbon tax rate | Coal (COA) price | Oil (OIL) price | Gas (GAS) prices | Refinery products (REF) prices |
|---|---|---|---|---|
| 100 $ZAR_{05}$/tCO2 | +194% (GAS, REF) to +256% (other) | +0.1% | +4.5% (HSS) to +10.3% (EIN) | +2.8% (HHs) to +3.9% (HSS) |
| 300 $ZAR_{05}$/tCO2 | +583% (GAS, REF) to +768% (other) | +0.2% | +13.4% (HSS) to +30.9% (EIN) | +8.5% (HHs) to +11.7% (HSS) |

The difference between scenarios lies in the recycling of tax proceeds: We explore the options of reducing public deficits (possibly leading to a budget surplus) (RDEF), sales taxes (RVAT)[10], or income and corporate taxes (RREV), and of increasing government expenditure (REXP) and transferring

[8] Calculated using a conversion rate of $ZAR_{05}$ to $USD_{05}$ of 6.36 Rand per Dollar, and converting $USD_{05}$ to $USD_{13}$ on the basis of a GDP deflator of 0.861 for 2013 (with 2005 being 1.00).

[9] We overestimate the price effect on coal, as we converted the price *per* tonne to a price *per* PJ on the basis of coal exported to India at 24 MJ/tonne of coal, whereas domestic thermal coal has a lower energy content sometimes as low as 16 MJ/tonne of coal. This gives a coal price *per PJ* that is underestimated by 1/3rd. The *ex-ante* price impact of the carbon tax would be 1/3rd lower too, though still high at +130% to +520%. Another remark is that we have assumed a high efficiency of oil refining, thereby limiting the impact of the carbon price on oil refining, which is the only process with direct (process-related) $CO_2$ emissions from crude oil.

[10] For the sake of simplicity IMACLIM-SA models VAT proceeds as if they were sales tax proceeds.

proceeds to households on a lump-sum *per capita* basis (RSUM). All options except RDEF comply with budget neutrality interpreted in the particular sense of a public deficit maintained at the level of 2% of GDP, as targeted in RP.

All scenarios except RVAT have comparable outcomes in terms of growth, employment and carbon emissions (Table 5). For a 100 $ZAR_{05}/tCO_2$ tax the RDEF, RREV, REXP and RSUM scenarios register, compared to BY, GDP/capita increases between +100% and +105%; unemployment reductions between 6 and 11 percentage points (pct points); and increases of $CO_2$ emissions between 36% and 39%. The RVAT scenario stands out though, with a GDP per *capita* increase of +118% and an unemployment reduction of 13.7 pct points. RVAT thus roughly equals or outperforms RP in terms of GDP and employment with a considerable (20%) reduction of $CO_2$ emissions. However, this 20% reduction is, like the slightly bigger reductions of other scenarios, well below the 2025 pledge of -42% $CO_2$ emissions compared to BAU (Janoska, 2014). A $ZAR_{05}$ 300/$tCO_2$ tax only just achieves a -42% to -46% emission reduction compared to RP in 2035 for tested scenarios. As this reduction is South Africa's target for 2025, it seems that a $ZAR_{05}$ 300/$tCO_2$ carbon tax just falls short for its INDC. At this higher carbon tax level the economic performance of RVAT remains better than that of other scenarios. It outperforms RP in terms of unemployment, although at slightly lower *per capita* GDP.

In all policy scenarios, employment systematically grows between 2005 and 2035 for all sectors, including the energy sectors. The introduction of a carbon tax causes a small shift in the distribution of employment away from energy sectors (COA, GAS, REF, ELC) and energy intensive industries (EIN), towards High Skill Services (HSS). The manufacturing sector (MAN) remains largely unaffected by the carbon tax. The shift of employment towards the HSS sector is also mirrored by the relative growth in volumes of output. When comparing specifically RVAT to RP we notice that at a carbon tax of 100 $ZAR_{05}/tCO_2$ domestic output (Y) of the MAN, HSS, LSS and TRA sectors increases more under RVAT than for RP. Conversely, output of the energy sectors and EIN increases more under RP than under RVAT. Expectedly, imports of most products register slight increases under the carbon tax regime compared to RP. Recall that we did not assume border tax adjustments.

The structural change of output and VA under the influence of the carbon tax is, by construction, reflected in structural change in uses, both in volume as in expenditure terms. While a 100 $ZAR_{05}/tCO_2$ tax under RSUM for instance relatively reduces intermediate consumption overall (IC), with RVAT it forces a relative shift of IC from energy products to non-energy products (compared to the RP). For RVAT final consumption (FC) sees an even stronger relative shift than IC, moving from energy products, EIN, MAN and TRA towards LSS and HSS goods. The same can be observed for RVAT at a 300 $ZAR_{05}/tCO_2$ tax, although volumes now grow less than for the lower tax level.

Another part of the explanation of the main outcomes of scenarios lies in changes in factor intensities. Labour intensities go down less in the RVAT scenario compared to RP, and also compared to for instance RSUM. Labour, as a factor, is necessarily more attractive under a carbon tax regime, with its output coming at a relatively lower cost. One important reason lies in the consumer price indexing of wages which is relatively lower under RVAT than under RSUM due to the sales tax cut.

**Table 5** **Main base year numbers and RP and scenario outcomes**

| | BY (2005) | RP (2035) | RDEF | RVAT | RREV | REXP | RSUM |
|---|---|---|---|---|---|---|---|
| | | | *Results for a $CO_2$ tax of 100 $ZAR_{05}$/tonne $CO_2$* | | | | |
| GDP/capita ($ZAR_{05}$) | 33k | 72k | 66k | 72k | 66k | 68k | 66k |
| *Change vs. BY* | - | *+116%* | *+100%* | *+118%* | *+101%* | *+105%* | *+101%* |
| Unemployment | 38.8% | 28.7% | 32.6% | 25.1% | 31.4% | 28.0% | 31.6% |
| *Change vs. BY* | - | *-11.1pt* | *-6.2pt* | *-13.7pt* | *-7.4pt* | *-10.8pt* | *-7.2pt* |
| $CO_2$ emissions (Mt) | 443 | 801 | 604 | 644 | 610 | 615 | 610 |
| *Change vs. BY* | - | *+81%* | *+36%* | *+45%* | *+38%* | *+39%* | *+38%* |
| *Change vs. RP* | - | - | *-25%* | *-20%* | *-24%* | *-23%* | *-24%* |
| | | | *Results for a $CO_2$ tax of 300 $ZAR_{05}$/tonne $CO_2$* | | | | |
| GDP/capita ($ZAR_{05}$) | | | n/a | 69k | n/a | 63k | 60k |
| *Change vs. BY* | | | | *+109%* | | *+91%* | *+83%* |
| Unemployment | | | | 26.2% | | 30.7% | 35.6% |
| *Change vs. BY* | | | | *-12.8pt* | | *-8.1pt* | *-3.2pt* |
| $CO_2$ emissions (Mt) | | | | 467 | | 434 | 428 |
| *Change vs. BY* | | | | *+5%* | | *-2%* | *-3%* |
| *Change vs. RP* | | | | *-42%* | | *-46%* | *-46%* |

# 4 Demand and supply of labour by skill

## 4.1 Modeling skill differentiation

One of the identified constraints on South African growth is the shortage of high-skill labour, which translates into high costs of high skill labour (Banerjee et al, 2007; Daniels, 2007). To acknowledge this constraint we model demand and supply of labour by skill, with a skill-specific evolution of wages and unemployment rates. We also consider investment in skills as a potential channel to re-direct growth from a fossil-energy based trajectory towards a more environmentally friendly path. A literature review (see Schers et al., 2015) inspired our choice for our approach with nested-CES production functions as presented in section 2.1.2. For the market balance for labour we resort to a simple, although adjusted wage curve (see section 2.1.5). Besides, we model three strictly separated (segmented) skill markets.[11]

[11] Note that modeling 'permeable' skill markets raises both conceptual questions on the meaning of a 'skill' and practical questions on the calibration of inter-skill mobility.

Concerning how to model supply of labour by skill, we initially performed trial runs with a relatively standard definition of skill of labour equaling the level of educational attainment of workers, and assuming skill categories to remain at constant educational levels over time. Implemented in IMACLIM-SA, this 'constant educational attainment' (CEA) approach induces a 280% increase of real GDP *per capita* and a 7-point decrease of aggregate unemployment by 2035.[12] Combined with this growth we find a large drop of the unemployment rate for low skill labour (-20 pct points), some reduction for medium skills (-7 pct points), and a remarkable slight increase for high skill unemployment (+1 pct point). As a consequence, in 2035 the unemployment rate of high skill labour turns out higher than that of low skill labour. Such a result is at odds with South Africa's persisting shortage for high-skill labour, and, to the best of our knowledge, it also contradicts historic developments for the majority of regions around the world. The expectation of a modernizing economy thus seems to be in conflict with some of our assumptions about labour demand, labour market-clearing, and the CEA approach to skill dynamics. This lead us to recognise three possible axes for improving our modeling of supply and demand of labour by level of skill:

*(i) Skills defined positional, as constant shares of the labour force*

Looking firstly to the supply of labour by level of skill, the unexpected distribution of unemployment in our CEA projection could be resolved by changing our approach to segmentation of skills levels. The CEA approach can be summarised to represent the view that firms look for sets of skills with each worker's educational degree being the indicator of the set of skills he or she has acquired. The opposite approach is to consider education as a positional good. In this view, what matters for firms is the relative, not the absolute level of educational attainment of individuals. There is indeed some evidence that education has become increasingly "positional" over time (see e.g. Bol, 2015). A simple way to model this second approach is then to define skills as a constant share of the labour force (CSLF). The shares are still calibrated on the level of educational attainment of the calibration year, but are then kept constant in the projection, irrespective of how nominal attainment evolves.

*(ii) Differentiating income elasticities of consumption*

On the side of the demand for skills, a higher demand for high skilled labour could be encouraged by the introduction of income elasticities of consumption differentiated by good. The rationale is that, as people get richer, they tend to spend a higher share of their income on goods and services other than basic needs, and that these (non-basic-needs) goods and services are high-skill intensive. However, the limited disaggregation in terms of goods of our model does not allow to properly take advantage of this option. Indirectly, our model already incorporates an impact on household budget shares of products, with under a CEA approach a higher skilled population leading to relatively bigger class 4 and 5 population and thus to a relatively bigger consumption that is intensive in high skill workers (see Table 16 in Appendix 2). But, as the outcomes of the CEA projection showed, this effect was not strong enough to absorb all new high skill labour.

[12] We chose to run it under the exact same set of parameters as that of our eventual reference projection (section 2.2.3), notwithstanding the arguable double-counting of productivity improvements this entails. Assuming both a general labour productivity increase and a shift of the skill segmentation in favour of the higher skills amounts double-counting productivity gains compared to an approach with productivity increases only. We disregard this inconsistency for illustrative purposes.

*(iii) Differentiating labour productivity trends by skills*

Differentiating labour productivity trends by level of skill is another way of increasing pressure on the high skill market. As noted, we postulate a uniform 1%-a-year labour productivity improvement across skills and sectors, this might partly go beyond the shift in skills being a cause of labour productivity gains, and it also amounts to an exogenous trend forced upon the labour intensity of sectors, possibly reflecting technological progress. Besides, beyond sheer productivity gains, we could consider composition or quality effects to translate into an exogenous increase of high skill-intensity for some sectors: For example, shifting from producing basic equipment to producing technically complex equipment could require higher engineering costs in manufacturing industries (composition effect). Similarly, better enforcement of building regulations could require more consultancy work in building companies (quality effect).

*Conclusion: Acknowledging the heterogeneity of 2005 vs. 2035 skills and products*

Taking a step back, it appears that the issue we face stems from the fundamental heterogeneity of skills and products modelled in 2005 versus their counterparts a distant 30 years ahead. In the abstract framework of CGE modelling, both heterogeneities hide behind identical naming conventions in 2005 and 2035 (naming of skills and products). From this perspective, all suggested alternatives allow a similar acknowledgment of the hidden heterogeneities through a changed definition of either the skills themselves, their use in production or the complex nature of systems (or technologies) of production that use them. It is thus probable that either of these alternate approaches to skill segmentation could lead to similar projections, if properly calibrated.

For the present study we decided to focus on the most straightforward (if not most explicit) treatment of skill segmentation dynamics: we shift the definition of skills from given educational attainment to the positional interpretation, which leads us to define them as constant shares of the labour force (CSLF approach).

## 4.2 Results of RP and carbon tax scenarios differentiated by skill and class

### 4.2.1 RP employment by level of skill and income distribution

Our RP shows an absolute increase in employment for all skill levels, but growth is stronger for high and medium skill labour (Table 6) which see their share in total employment rise. In Schers *et al* (2015) we report the changes in employment for the RP by sector and by skill level. Those numbers show that it is mainly the LSS sector, and to a lesser extent HSS, EIN and MAN, that contribute to growth of medium skill employment. Growth in high-skill employment mainly takes place in the HSS sector, but is fastest in ELC and EIN. Growth in low-skill employment is almost entirely located in LSS. From this we conclude that structural change (from LSS to HSS, EIN and MAN) only partly explains the shift in jobs by skill level. Meaning that changes in relative prices and productivity add to the shift of employment towards high and medium skill jobs.

In terms of income distribution we see classes 3 and 4 (which both have per capita gross disposable incomes below national average) register the biggest relative increases. This can be explained from the observation that classes 3 to 5 all profit comparably from increases in net wages due to growth in employment for especially medium and high skill labour. But, class 5 sees only a little increase in its returns on capital/receipts of interest. As these make up a larger part of its revenue (19%) than for any other household class it slows down income growth of class 5 in comparison to class 3 and 4. An additional remark to the latter is that, although we assume 2035 savings rates of on average 3 pct point higher than BY saving rates (0.1%), it turns out that this new rate is too low to sustain total households' relative financial asset positions. These decrease from 2.5 times annual total household GDI in BY to 1.3 times their GDI in RP.

**Table 6 Employment disaggregated by level of skill for the BY and the RP**

| | BY 2005 | RP 2035 |
|---|---|---|
| **Total employed (thousands)** | 12 315 | 19 231 |
| **High skill share** | 30% | 32% |
| **Medium skill share** | 47% | 49% |
| **Low skill share** | 22% | 19% |

### 4.2.2 Outcomes of carbon tax scenarios by level of skill and for income distribution

When differentiating employment outcomes of the carbon tax policy scenarios by level of skill we notice a relative shift of employment towards high skill jobs in comparison to RP. This is a logical outcome because of the shift between sectors: the energy sectors and EIN together have below-average high skill shares in labour, whereas HSS has above-average high skill employment intensity.

The Gross Disposable Income (GDI) per capita (deflated on the basis of the CPI) is obviously also different between the RVAT and RSUM scenarios. The lump-sum transfer (RSUM) clearly benefits the lower income classes, for whom an equal sum per capita means more income increase than for the higher classes, with the same per capita transfer making up 29% of income for class 1 compared to only 1% for class 5. Conversely, we observe that class 4 households benefit strongest from recycling through sales tax reduction with their GDI growing 17 percentage points more than for RP. The reason lies in a combination of employment effects (growth in especially medium skill employment), salary growth, and consumer price index effects.

## 4.3 Impacts of investment in skills

Concerning the links between education, skill and productivity, literature offers different visions but does not seem to provide any statistical correlation between investment in education and educational output (in terms of the number of people with degrees). For instance, Grigoli (2014) points to the "inefficiency" of educational spending on secondary education enrollment. Quality of education should also have an impact on the labour productivity impact of the level of educational attainment, but lacks objective measurement and even more so, a link to investment. Next, we therefore present an alternative, counterfactual approach to modelling investment in skill, specific to our model for supply and demand of labour. First though, in the next sub-section, we will discuss some details and considerations of our experience with our labour market model for South Africa.

Besides the revenue recycling options already discussed, we explored the possibility that a part of the carbon tax proceeds is invested in skills, for instance in education and training of employees and workseekers. To estimate what costs this would bring we estimated the costs of one million additional students enrolled in high schools relative to the constant enrolment numbers of the LEP demography scenario, starting in 2015. We arrive at an estimated total additional investment in education of 7.5 million $ZAR_{05}$ per year (Schers et al, 2015). This amounts to about 10% of the 2035 proceeds of the 100 $ZAR_{05}/tCO_2$ tax, and equals 2.5% of government expenditure on final consumption and administration in our BY data (305 billion $ZAR_{05}$). In reality such an investment would not be monotonously aimed at one type of education, and would rather be directed at all levels and types of education, including technical and professional colleges and vocational training. Under a Constant Educational Attainment (CEA) approach for skill definition, this increased spending would translate into a downward shift of skill segmentation thresholds. Under the Constant Share of Labour Force (CSLF) definition of skills of RP and carbon tax scenarios we assume that such spending is done well and positively impacts annual growth of productivity of all four primary factors equally.

As the gain in productivity is hypothetical we perform a sensitivity analysis to explore what minimum productivity improvement is needed for RVAT+, which thus diverts 10% of carbon tax proceeds into public ependiture, to equal GDP growth and environmental benefits of RVAT at a Ctax of 100 $ZAR_{05}/tCO_2$, which recycles all carbon tax proceeds into sales tax reduction. This minimum productivity improvement turns out to be a modest 1% annual productivity increase (Schers et al, 2015). We view this as a confirmation that education and training expenses are a relevant option for carbon tax recycling, as any productivity improvement higher than the 1% threshold thus defined is bound to induce activity growth (GDP) above that of RVAT. But, contrary to expectations, overall unemployment does not decrease compared to RVAT (see Table 22 in Appendix 5). Differentiated by level of skill changes in employment differ, with high skill unemployment decreasing and low skill unemployment increasing. This follows from our nested-CES structure and the combination with growth in capital productivity which is advantageous for high skill labour.

# 5 Discussion and sensitivity analysis

## 5.1 General discussion

A limitation to our analysis is that we, of course, only tested a certain set of policies, and for instance did not test the impact of reducing taxes on capital, or sales tax reductions differentiated by type of product. Also, like with any model, the way the model has been constructed and our assumptions influence outcomes. In our case this is the assumption about the wage curve and the use of consumer price indexation that leads to a sales tax reduction being the most beneficial, as it leads to moderation in wage growth. Other possible criticism of our scenarios is that we did not assume socio-economic benefits of increased public spending (REXP scenario) or of a lump-sum transfer (RSUM) on productivity (e.g. from better public care or a reduction in crime).[13]

In the case of investment in skills through education or training our assumed link between investment and productivity is purely hypothetical. More specific research in this field should be consulted to find out what type of interventions lead to productivity improvements. It also points to the need to better understand the role of technological change for skill of labour and vice versa. In our sensitivity analysis (see below) we also show that there is a need to design interventions

[13] Although questioned, such benefits are supported by e.g. the evaluation of a basic income trial in Namibia by Haarmann et al. (2009), as well as by an evaluation of the Mincome project by Forget (2011).

regarding education and training of the lower skilled segments of the labour market in such a way that their skills become more compatible with technological development.

## 5.2 Sensitivity analysis of reference projection parameterisation

We performed a sensitivity analysis on the parameterisation of the RP around different groups of parameters (for details see Schers *et al.* (2015)). Firstly, we analysed what happens if the main drivers of economic growth (export volume trend, and labour and capital productivity growth) have 50% faster growth rates, and what if they grow 50% slower. This leads to very significant changes in growth of real GDP. Secondly, we analysed a more rigid and a more flexible wage curve. A rigid wage to unemployment response (or vice versa) turns out to be positive for economic growth. This is explained from more moderate real wage demands with decreasing unemployment, especially for medium and high skill labour, which keeps costs and prices low and favours domestic output. Thirdly, we analysed a more responsive and a less responsive demand for labour, by respectively having higher and lower elasticities of substition between capital and the different labour factors by skill: Labour *demand* rigidity has little effect on economic growth, but an interesting impact on employment by skill: Lower elasticities benefit medium and low skill labour, as they become more complementary to capital (and its aggregate factor with high-skill labour). Finally, for international trade we analysed the case of a 3 times higher price elasticity of both exports and imports. This leads to significantly more economic growth compared to RP. For a 3 times lower price elasticity has strongly negative consequences for growth. This might be an obvious result in regard of the fact that our RP requires a reduction of (domestic) international purchasing power of the South African Rand compared to foreign currencies (or vice versa the other way round).

## 5.3 Use of BU model, and comparability of scenarios

Introducing BU model insights in a CGE-style model like IMACLIM-SA raises methodological questions (Ghersi and Hourcade, 2006). The main condition for consistent linking of two models is the convergence (to some extent) of trajectories they have in common, *i.e.* trajectories of energy supply and demand, of energy prices, and of energy-related investment (both on the supply and end-use sides). In theory at least, it is possible to control the consistency between these trajectories by coupling the BU and the CGE models in one consolidated simulation architecture—so-called 'hard coupling'—, or by performing manual iteration of model runs—'soft coupling'. However, coupling tends to be time and resource demanding, and generally results in models that are analytically less flexible.[14] Moreover, even convergence itself, e.g. of prices and investments, does not guarantee that the BU model generates unbiased behaviour for the CGE model. In fact, because most BU models (including SATIM) assume a social planner minimizing the overall costs of the energy system over the entire time-horizon explored. Therefore, BU model results are likely to diverge from aggregated energy-related decisions made by many economic agents in reality which CGEs try to capture.

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[14] A possible alternative to the method we used to link SATIM and IMACLIM-SA is to develop 'reduced forms' of SATIM model output, in which price-and-demand-response behaviour of the BU model are synthesized on the basis of a large number of scenario runs to create a 'space' of possible future production technologies (vectors of primary and secondary factor intensities) for a sector in the CGE model (Ghersi and Hourcade, 2006). The advantage of this procedure is that the BU model is not needed to run the model, as it is encapsulated into the 'reduced form' function—making the resulting model easier to use. Exploration of this 'space' of BU model response can also help to identify sets of parameters that are critical for model response, resulting in a multi-parameter 'reduced form'. Issues of consistency between trajectories, however, still remain with this method.

Still, a comparison is needed to understand what impact differences will have, given the different architectures of both models. A comparison of price and demand trajectories and other central assumptions in SATIM versus the 2005 - 2035 change in IMACLIM-SA showed that there are some similarities, but also some strong differences between the runs of the two models (see the discussion and Tables 17 and 18 in Appendix 3). More than the absolute price levels, which are a question of calibration, it is relative price changes that matter for the projection, for which reason the tables in the annex show price changes compared to the price index for physical capital. Our conclusion is that despite the differences in the trajectories of parameters and variables of the two models, we judge the use of technical coefficients from SATIM for our IMACLIM-SA projections to be appropriate as the main divergences found can be assumed to cancel each other.

## 5.4 Comparison of model outcome with other analyses

The present study is closest to Alton *et al.* (2012), who find that a carbon tax of Rand 210/t$CO_2$ leads in 2025 to an approximately -42% decrease in GHG emissions relative to BAU—*i.e.*, consistent with South Africa objectives—, and with GDP loss in 2025 between 0.68% and 1.23% relative to BAU, depending on recycling option. Thus, Alton *et al.* also find that the South African economy is very responsive to seemingly modest rates of a carbon tax, notably because of low starting point prices of energy (as also outlined *e.g.* in Pauw (2007), Table 6 p.35). On the other hand, they find a narrower range of impacts of a carbon tax on GDP than our own findings, all the more so that in their study GDP is growing at 3.9% *per annum* over 2010-2025 (against 3.4% *per annum* over the 2005-2035 period in our RP).[15] This may be due to the fact that their recycling schemes all include a tax on imports and a rebate on exports on top of the domestic carbon tax.

Another interesting point of comparison is with van Heerden *et al.* (2006). They also obtain strong impacts of limited carbon taxes on South African emissions. Particulary, they find a strong triple dividend—*i.e.*, an increase in GDP and reduction in poverty and $CO_2$ emissions with a carbon tax relative to baseline—when recycling carbon tax revenues in food tax breaks. The mechanism, they contend, is that "*when energy is complementary to capital* [as they assume]*, and when tax revenue recycling can be used to increase* [infinitely supplied] *unskilled labour demand* [as the food tax break does by increasing demand for agricultural products and thus for agricultural, mostly low-skilled labour]*, a double dividend may materialize in South Africa as in the model of Bovenberg and van der Ploeg (1996; 1998)*." We do not test a similar recycling mechanism, but the results would likely be different because in our model energy and the capital-labour aggregate can be substitutes. Furthermore, our wage curve limits the increase in demand for unskilled labour.

Turning to the numerous studies on other countries, we emphasize that our findings echo the IPCC synthesis of the institution's 2001 report (IPCC, 2001): Any given economy's most efficient recycling option is that of reducing its most distortionary pre-existing tax. Faced with the South African economic and social context, IMACLIM-SA purposely lends great importance to imperfect segmented labour markets where wages cannot freely adjust to absorb labour supply because they are also required to preserve purchasing power. It is a consequence of this central second-best feature of our model that the most efficient recycling option turns out to be that which best preserves purchasing power, namely reduction of a sales tax.

[15] We find GDP losses for a $ZAR_{05}$ 300/t$CO_2$ tax in the RVAT scenario around 3%, or approximately one year of GDP growth, relative to RP in 2035, and higher (-10% and -16%) for other scenarios.

# 6 Conclusion

In this paper we analyse how climate mitigation interacts with economic growth and unemployement reduction in South Africa under various scenarios for recycling therevenues of a carbon tax. We find that at a relatively low tax level (100 $ZAR_{05}/tCO_2$) South Africa's economic perspectives in terms of GDP and employment are better to those without carbon taxation provided that tax revenues reduce sales taxes. A sales tax reduction leads to economic benefits through moderating wage increases, assuming that wages follow consumer price indexation. Other recycling schemes do not yield such a double dividend. However, a higher level of a carbon tax (300 $ZAR_{2005}/tCO_2$ or higher) is needed to achieve South Africa's INDCs. At this higher carbon tax level, recycling tax proceeds through sales tax reduction remains the best option from the point of view of economic growth and unemployment reduction. At both the lower and higher tax level, we find that per capita lump-sum transfers of carbon tax proceeds to households reduces inequalities relative to BAU, while other recycling schemes slightly increase inequalities.

We also tested the possibility of using a part of carbon tax proceeds to invest in education and training with the goal of improving productivity. In our model such an investment, of 7.5 million $ZAR_{05}$ annually, or 10% of carbon tax proceeds of a tax of 100 $ZAR_{05}/tCO_2$, would only need to improve productivity growth for all factors of production at a rate of 1% per year to lead to a higher GDP per capita than when recycling all proceeds into a reduction of sales taxes. The downside is that the overall productivity increase in this scenario would increase inequality between high skill and low skill labour.

Methodologically, modeling supply and demand of labour by level of skill in a CGE-style model turned out to be a complicated questionwhich requires careful consideration. Aspects that need to be considered are how one defines a skill: is it a characteristic of the job (as being part of production) or as a characteristic of the worker. This definition question then also has implications for assumptions about the development of labour productivity. Another aspect to consider is what assumptions to make about the dynamics over time of technological change in production, of products and of consumer preferences. In other words: is there an underlying mechanisms that makes production more high skill intensive over time, and do consumer preferences automatically develop into the direction of more complex or high tech products?

As a policy recommendation we think it is worth to recycle carbon tax revenues into investment in education and training, but that it is needed to look at how to improve complementarity of low and medium skill labour with technological development. For future research and model improvement we are thinking about studying the impacts of differenciating productivity improvements between sectors, and to test different hypotheses about international trade and prices, as well as about household saving behaviour and government and international finance. Furthermore, we want to improve the integration of technical coefficients and constraints (limits) estimated on the basis of bottom-up model scenarios, either by expanding this to other sectors, like transport, or by trying to reach a better convergence between SATIM and the IMACLIM-SA model, for instance via soft-coupling.

# 7 References


Alton, T., Arndt C., Davies R., Hartley F., Makrelov K., Thurlow J., Ubogu D. 2012. *The Economic Implications of Introducing carbon taxes in South Africa*. WIDER Working Paper N..2012/46.

____________. 2014. Introducing carbon taxes in South Africa. *Applied Energy* (116):344-354.

Banerjee, A., S. Galiani, J. Levinsohn and I. Woolard. 2006. "Why Has Unemployment Risen in the New South Africa?" Harvard University Center for International Development Working Paper #134.

Bol, T. 2015. Has education become more positional? Educational expansion and labour market outcomes, 1985-2007. Acta Sociologica. doi: 10.1177/0001699315570918

Daniels, R.C. 2007. Skills Shortages in South Africa: A Literature Review. DPRU Working Paper 07/121. University of Cape Town.

Devarajan, S., D. S. Go, S. Robinson, K. Thierfelder. 2011. *Tax Policy to Reduce Carbon Emissions in South Africa*. Policy Research Working Paper 4933. Washington DC: World Bank.

____________. 2011. Tax Policy to Reduce Carbon Emissions in a Distorted Economy: Illustrations from a South Africa CGE Model. *The B.E. Journal of Economic Analysis and Policy* **11**(1):Art.13.

De Franclieu, L.. 2014. Exploring socio-economic scenarios for South Africa 2005-2035. *Rapport de PIL*. CIRED, Ecole des Ponts/ParisTech, Champs-sur-Marne.

DoE (South Africa Department of Energy). 2009a. Energy Balances, 2005. Department of Energy, Republic of South Africa, Pretoria. Accessed at: http://www.energy.gov.za/files/media/media_energy_balances.html.

____________. 2009b. Digest of South African Energy Statistics 2009. Directorate: Energy Information Management, Department of Energy, Republic of South Africa, Pretoria.

____________. 2011. IRP 2011. Pretoria

____________. 2013. Integrated Resource Plan for Electricity (IRP) 2010-2030 Update Report 2013. Department of Energy, Republic of South Africa, Pretoria, 21 November 2013

ERC (Energy Research Center). 2013. Assumptions and Methodologies in the South African TIMES (SATIM) Energy Model. Version 2.1, 2013/04/08. Systems Analysis & Planning Group, Energy Research Centre, University of Cape Town, Cape Town.

ESKOM. 2005. Tariffs and Charges. Effective from 1 January 2005 – 31 March 2006. ESKOM, Johannesburg. Available at: http://www.eskom.co.za/c/article/141/tariff-history/.

Forget, E.. 2011. The Town with No Poverty: Using Health Administration Data to Revisit Outcomes of a Canadian Guaranteed Annual Income Field Experiment. University of Manitoba. available at http://public.econ.duke.edu/~erw/197/forget-cea%20%282%29.pdf (accessed Sept. 2015)

Haarmann, C., D. Haarmann, H. Jauch, H. Shindondola-Mote, N. Nattrass, I. van Niekerk, M. Samson. 2009. Making the difference! The BIG in Namibia: Basic Income Grant Pilot Project Assessment Report. Basic Income Grant Coalition. Windhoek, April 2009. available at: http://www.bignam.org/Publications/BIG_Assessment_report_08b.pdf (accessed Sept. 2015)

Heerden, Van, J., R. Gerlagh, J. Blignaut, M. Horridge, S. Hess, F. Mabugu and M. Mabugu. 2006. Searching for Triple Dividends in South Africa: Fighting $CO_2$ pollution and poverty while promoting growth. *The Energy Journal* 27(2): 113-141.

Ghersi, F., Hourcade, J.-C., 2006. Macroeconomic Consistency issues in E3 Modelling: The Continued Fable of the Elephant and the Rabbit. Energy Journal, Special Issue No.2: 39–62.

Grigoli, F., 2014. A Hybrid Approach to Estimating the Efficiency of Public Spending on Education in Emerging and Developing Economies. IMF working paper 14/19.

IEA (International Energy Agency). 2012. Energy statistics of non-OECD countries – 2012 edition. International Energy Agency/OECD, Paris.

K.C., S., M. Potancokova, R. Bauer, A. Goujon, and E. Striesnig. 2013. Summary of Data, Assumptions and Methods for New Wittgenstein Centre for Demography and Global Human Capital (WIC) Population Projections by Age, Sex and Level of Education for 195 Countries to 2100. International Institute for Applied Systems Analysis (IIASA), Laxenburg.

Krusell, P., L.E. Ohanian, J.-V. Rios-Rull, G.L. Violante. 2000. Capital-Skill Complementarity and Inequality: A Macroeconomic Analysis, Econometrica 68(5):1029–1053

NERSA (National Energy Regulator of South Africa). 2009. Aggregated (average) piped-gas prices per province for the various categories of customers – 2007 Calendar year. Piped-Gas Subcommittee 18 June 2009. Energy regulator of South Africa, Pretoria.

Pauw De, K. 2007. *Economy-wide Modeling: An input into the Long Term Mitigation Scenarios process*, LTMS Input Report 4, Energy Research Centre, Cape Town, October.

RSA (Republic of South Africa). 2011. National Climate Change Response White Paper. Pretoria

____________. 2015. Draft Carbon Tax Bill. Minster of Finance, Pretoria

SAPIA (South African Petroleum Industry Association). 2013. Industry overview – Old fuel prices. Petroleum products prices in cents per litre 2006-2013. Sandton. Available at: http://www.sapia.co.za/industry-overview/old_price.html.

SARB (South African Reserve Bank). 2007. Quarterly Bulletin March 2007. Statistical Tables: National Accounts, Pretoria.

____________. 2012. Integrated Economic Accounts. presentation for the "Regional Seminar on developing a program for the implementation of the 2008 SNA and supporting statistics in Southern Africa (17-19 October 2012, Pretoria, South Africa)".

Schers, J., F. Ghersi, F. Lecocq, F. Grazi (ed). 2015. Green Growth and its Implications for Public Policy – The Case of South Africa. *Etudes de l'AFD*, no.4. Agence Française de Développement (AFD). Paris, December 2015.

StatsSA (Statistics South Africa). 2008. Labour Force Survey. Historical Revision March Series 2001-2007. Statistics South Africa, Pretoria.

____________. 2010a. Final Supply and Use Table, 2005. Report No: 04-04-01 (2005) (plus tables). Pretoria. available at: http://www.statssa.gov.za/publications/statsdownload.asp?PPN=Report-04-04-01&SCH=4764.

____________. 2010b. Final Social Accounting Matrix, 2005 (Updated Version). Report No: 04-03-02 (2005) (plus tables). Statistics South Africa, Pretoria. available at: http://www.statssa.gov.za/publications/statsdownload.asp?PPN=Report-04-03-02&SCH=4432

____________. 2012. Financial Statistics of consolidated general government 2010/2011. Annex B: Statistical Tables. Statistics South Africa, Pretoria.

____________. 2013. Mid-year population estimates, 2013. Statistical release P0302. Statistics South Africa, Pretoria.

____________. 2015. Quarterly Labour Force Survey, Q4-2014. Pretoria.

UNFCCC (United Nations Framework Convention on Climate Change). 2015. *South Africa's Intended Nationally Determined Contribution (INDC)*. UNFCC, Bonn. Available at (accessed Dec. 2015): http://www4.unfccc.int/submissions/INDC/Published%20Documents/South%20Africa/1/South%20Africa.pdf

UN (United Nations). 2013. World Population Prospects: the 2012 revision. United Nations, New York.

Van der Werf. 2008. Production functions for climate policy modeling: An empirical analysis, Energy Economics, 30:2964–2979

# Appendices

## Appendix 1: Calibration data and other parameter values

**Table 7 Nested-CES production function elasticities of IMACLIM-SA sectors**

| Sector* | KLE to Mat | KL to E | KL23 to L1 | KL3 to L2 | K to L3 |
|---|---|---|---|---|---|
| **COA** | 0.1 | 0.25 | 4 | 1.5 | 0.1 |
| **GAS** | 0.1 | 0.25 | 4 | 1.5 | 0.1 |
| **REF** | 0.1 | 0.2 | 4 | 1.5 | 0.1 |
| **ELC** | 0.1 | 0.2 | 4 | 1.5 | 0.1 |
| **EIN** | 0.1 | 0.25 | 4 | 1.5 | 0.1 |
| **MAN** | 0.1 | 0.64 | 4 | 1.5 | 0.1 |
| **LSS** | 0.1 | 0.64 | 4 | 1.5 | 0.1 |
| **HSS** | 0.1 | 0.99 | 4 | 1.5 | 0.1 |
| **TRA** | 0.1 | 0.18 | 4 | 1.5 | 0.1 |

* We report no estimates for the OIL sector, whose output is systematically projected nil in 2035.

**Table 8 Assumed nested-CES household consumption elasticities of IMACLIM-SA**

| Household class | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 |
|---|---|---|---|---|---|
| Elasticity of substitution of EAG, COMP in U | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Elasticity of substitution of ELC, REF in EAG | 0.5 | 0.4 | 0.3 | 0.2 | 0.1 |
| Elasticity of substitution of EIN, MAN, LSS, HSS, TRA in COMP | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |

**Table 9 Terms-of-trade elasticities of exports and imports of IMACLIM-SA**

| Sector | COA | OIL | GAS | REF | ELC | EIN | MAN | LSS | HSS | TRA |
|---|---|---|---|---|---|---|---|---|---|---|
| $\sigma_{Mp}$ | 0.50 | 0.10 | 0.50 | 0.75 | 0.25 | 1.00 | 1.00 | 0.10 | 0.75 | 0.10 |
| $\sigma_{Xp}$ | 1.00 | 0.10 | 0.10 | 0.75 | 0.10 | 1.00 | 1.00 | 0.10 | 0.75 | 0.10 |

$\sigma_{Mp}$ is elasticity to terms-of-trade of share of imports in total resource (volume), $\sigma_{Xp}$ is the elasticity to terms-of-trade of sheer exports.

**Table 10 Population by educational attainment and IMACLIM-SA skill, 2005**[16]

| Age group | Educational category | Population | Active population | Inactive population |
|---|---|---|---|---|
| **0-14** | - | 15 465 | - | - |
| **15-64** | No education | 1 953 | 4 691 (low skill job types) | 3 058 |
| | Primary education | 6 726 | | |
| | Lower secondary education | 12 106 | 10 386 (medium skill job types) | 5 774 |
| | Upper secondary education | 8 396 | | |
| | Post-secondary education | 910 | 5 036 (high skill job types) | 1 146 |
| **65+** | - | 2 084 | - | - |
| **Total** | - | **47 640** | **20 113** | **9 978** |

Source: *Authors' calculation and assumptions, based on data from SAM 2005 (StatsSA, 2010b) and QLFS Sept 2005 (StatsSA, 2008)*

**Table 11 Population by educational attainment in 2035 for the Low Educational Progress (LEP) scenario**

| Age group | Educational category | Population |
|---|---|---|
| **0-14** | - | 14 407 |
| **15-64** | No education | 287 |
| | Primary education | 3 764 |
| | Lower secondary education | 15 075 |
| | Upper secondary education | 18 989 |
| | Post-secondary education | 2 241 |
| **65+** | - | 4 765 |
| **Total** | - | **59 528** |

*Source: Assumptions using UN population prospects (UN, 2013) disaggregated by educational class and projections of educational attainment levels from K.C. et al (2013), from de Franclieu (2014)*

[16] This table aligns educational attainment and skill for the sake of data calibration only. It thus disregards the possibility of people with higher education occupying low-skill jobs—and indeed vice-versa.

**Table 12 Assumed BY (2005) population, actives, employed, unemployed and wages by skill and class***

| | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 | All classes |
|---|---|---|---|---|---|---|
| Total population | 4 950 | 9 316 | 9 378 | 14 964 | 9 033 | **47 640** |
| Pensioned / 65+ | 123 | 463 | 634 | 738 | 125 | **2 084** |
| Of working age / 15-64 | 2 609 | 4 335 | 4 639 | 10 315 | 8 192 | **30 091** |
| Children / <15 | 2 217 | 4 518 | 4 105 | 3 910 | 715 | **15 465** |
| Employed | 349 | 1 227 | 1 723 | 4 022 | 4 995 | **12 315** |
| Unemployed | 874 | 1 295 | 1 276 | 2 913 | 1 440 | **7 798** |
| Active, at working age | 1 223 | 2 522 | 2 999 | 6 935 | 6 435 | **20 113** |
| Share of working age active | 47% | 58% | 65% | 67% | 79% | **67%** |
| Unemployment | 71% | 51% | 43% | 42% | 22% | **38.8%** |
| Inactive, at working age | 1 386 | 1 814 | 1 640 | 3 381 | 1 758 | **9 978** |
| Working, skill 3 | - | - | 100 | 900 | 2 702 | **3 702** |
| Working, skill 2 | 50 | 100 | 780 | 2 722 | 2 193 | **5 845** |
| Working, skill 1 | 299 | 1 127 | 842 | 400 | 100 | **2 768** |
| Unemployed, skill 3 | - | - | 75 | 550 | 709 | **1 334** |
| Unemployed, skill 2 | 120 | 246 | 1 116 | 2 333 | 726 | **4 541** |
| Unemployed, skill 1 | 754 | 1 049 | 85 | 30 | 5 | **1 922** |
| Unemployment rate, skill 3 | 0% | 0% | 43% | 38% | 21% | **26%** |
| Unemployment rate, skill 2 | 71% | 71% | 59% | 46% | 25% | **44%** |
| Unemployment rate, skill 1 | 72% | 48% | 9% | 7% | 5% | **41%** |
| Total wages, skill 3 (mn ZAR) | - | - | 1 470 | 27 155 | 302 426 | **331 052** |
| Total wages, skill 2 (mn ZAR) | 230 | 684 | 9 840 | 63 361 | 145 228 | **219 343** |
| Total wages, skill 1 (mn ZAR) | 919 | 6 914 | 7 509 | 7 509 | 6 436 | **29 287** |
| Avg wage, skill 3 (kZAR/p/yr) | - | - | 15 | 30 | 112 | **89** |
| Avg wage, skill 2 (kZAR/p/yr) | 5 | 7 | 13 | 23 | 66 | **38** |
| Avg wage, skill 1 (kZAR/p/yr) | 3 | 6 | 9 | 19 | 64 | **11** |

* Skill 3 = high skill, skill 2 = medium skill, skill 1 = low skill. Class 1 is the lowest expenditure class in BY data, and class 5 the highest.
Source: Authors' own calculations and assumptions and data based on various sources

**Table 13 RP demography and distribution of actives by skill level and household class for 2035***

| | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 | All classes |
|---|---|---|---|---|---|---|
| **Total population** | 5 846 | 11 081 | 11 496 | 19 165 | 11 940 | **59 528** |
| **Pensioned / 65+** | 281 | 1 058 | 1 451 | 1 689 | 287 | **4 765** |
| **Of working age / 15-64** | 3 500 | 5 814 | 6 221 | 13 834 | 10 987 | **40 356** |
| **Children / <15** | 2 066 | 4 209 | 3 824 | 3 642 | 666 | **14 407** |
| **Active, at working age** | 1 640 | 3 382 | 4 022 | 9 300 | 8 630 | **26 974** |
| **Share of working age active** | 47% | 58% | 65% | 67% | 79% | **67%** |
| **Inactive, at working age** | 1 859 | 2 432 | 2 199 | 4 534 | 2 357 | **13 382** |
| **Active, skill 3** | - | - | 235 | 1 945 | 4 575 | **6 754** |
| **Active, skill 2** | 228 | 465 | 2 543 | 6 779 | 3 915 | **13 929** |
| **Active, skill 1** | 1 412 | 2 917 | 1 244 | 577 | 141 | **6 291** |

* Skill 3 = high skill, skill 2 = medium, skill 1 = low; Similarly class 1 is the lowest expenditure class in BY data, and class 5 the highest.
Source: Authors' own calculations and assumptions and data based on various other sources

# Appendix 2: Details of results and sensitivity analysis

**Table 14 Active population by skill level in 2005 and 2035, CEA approach**

| (millions of persons) | 2005 | 2035 |
|---|---|---|
| **Low skill level actives** | 4.7 | 2.2 |
| **Medium skill level actives** | 10.4 | 15.6 |
| **High skill level actives** | 5.0 | 10.8 |
| **Total active population**[17] | 20.1 | 28.5 |

*Source: For 2005, author's estimations on the basis of StatsSA (2008). For 2035, author's assumptions using UN population scenario (Reference) disaggregated by educational class and projections of educational attainment levels from K.C.* et al. *(2013).*

[17] We recall that we use a broad definition of unemployment and therefore also of active population by extending them to "discouraged jobseekers".

**Table 15** **Distribution of active population across household classes by level of skill for BY (2005) and projections (2035)**

| | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 |
|---|---|---|---|---|---|
| Low skill workers | 22% | 46% | 20% | 9% | 2% |
| Medium skill workers | 2% | 3% | 18% | 49% | 28% |
| High skill workers | 0% | 0% | 3% | 29% | 68% |

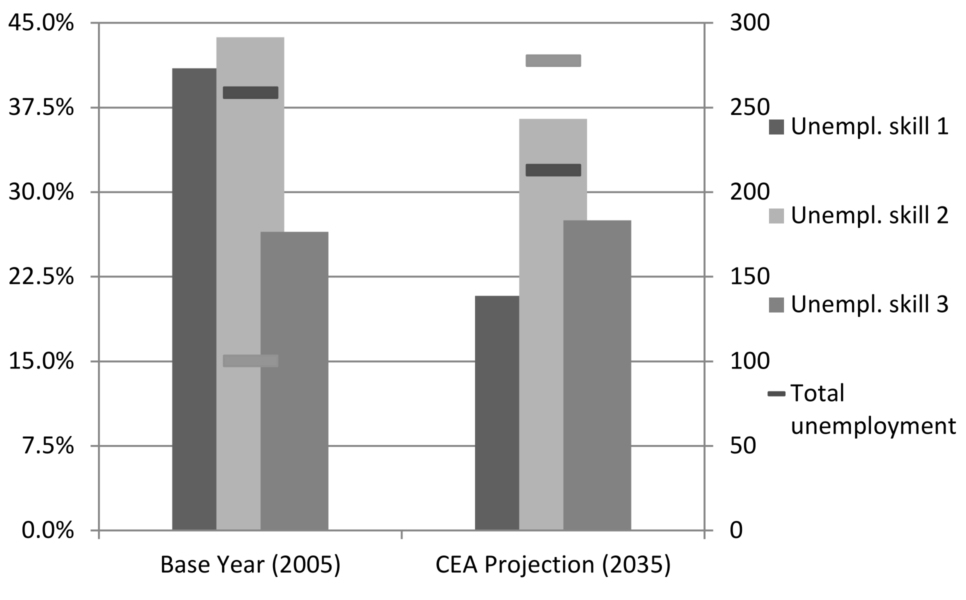
*Note. Due to rounding up lines may not sum up to 100%.*
*Source: Data from Statistics South Africa and author's assumptions*

**Table 16** **Share of skills in labour content of BY (2005) household consumption by class**

| | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 |
|---|---|---|---|---|---|
| Low skill labour | 28% | 26% | 25% | 25% | 22% |
| Medium skill labour | 49% | 50% | 50% | 50% | 47% |
| High skill labour | 23% | 24% | 25% | 26% | 31% |

*Reading note: the 2005 consumption of class 1 mobilises labour that is for 28% low skill labour, for 49% medium skill labour, etc. Source: Authors' computation on base year calibration data*

**Figure 5** **Growth and unemployment projections under constant educational attainment (CEA) definition of skills**



# Appendix 3: Comparison of SATIM and IMACLIM-SA trajectories

Our comparison of price and demand trajectories and other central assumptions in SATIM versus the 2005 - 2035 change in IMACLIM-SA shows that there are some similarities, but also a few strong differences between the runs of the two models. BY to 2035 changes for energy prices and total electricity production and other relevant parameters for electricity production and demand are shown in Table 17 and Table 18. More than the absolute price levels, which are a question of calibration, it is relative price changes that matter for the projection, for which reason the tables in the annex show price changes compared to the price index for physical capital ($p_K$ in IMACLIM notations). The comparison concerns a full SATIM run that models all energy use of South Africa (and not only electricity) and includes the "IRP updated" investment plan for electricity production (DoE, 2013). Furthermore, a comparison is made between SATIM runs with as only difference a carbon tax of 100 and 300 $ZAR_{10}/tCO_2$ and the RVAT scenarios with a 100 and 300 $ZAR_{05}/tCO_2$ carbon tax level. We observe the following divergences in the development of prices and other parameters/variables between SATIM and IMACLIM-SA runs:

- In SATIM without a carbon tax the price of coal goes up vs. the unit cost of physical capital whereas this doesn't happen in the IMACLIM-SA runs. The rise in costs in SATIM is linked to a shift from cheap to more expensive coal (due to extraction and transport costs); this does not appear in the technical coefficients of IMACLIM-SA, which evolve as functions of relative prices according to their CES specifications.
- With a carbon tax, the relative price increase of coal (compared to pK) is higher in IMACLIM-SA than in the SATIM runs. This can partly be related to the higher BY coal price in SATIM, which is a question of calibration (due to differences in the assumed heating value of coal).
- Differences in trajectories of prices of gas and diesel/refined fuels for electricity production are not very important because of the minor role these fuels play in SATIM and consequently in IMACLIM-SA. Again, SATIM price developments seem more realistic as they capture price expectations of natural gas imports from neighbouring countries and as LNG, whereas in IMACLIM-SA the GAS sector comprises cheap but unsuitable for electricity production coke-oven and gasworks gas, which go to industry.
- Whereas SATIM assumes electricity produced by neighbouring countries to remain relatively constant in price (compared to pK), in IMACLIM-SA imported electricity increases in price due to the reduction in international purchasing power of the South African Rand that follows from our scenarios.
- Overall, the quantity of imports is underestimated in IMACLIM-SA. This adds to an already lower amount of electricity made available in South Africa in IMACLIM-SA compared to SATIM, where it follows endogenously on the basis of exogenously determined useful energy demand linked to assumptions about development GDP and household income (ERC, 2013). This might indicate that the price elasticity of electricity consumption is too high in IMACLIM-SA, though in the end such a judgement be made based on a comparison with SATIM outcomes at the level of intermediate consumption (and sectors) and final consumption.
- The international price of crude oil is another point of divergence. In IMACLIM-SA it rises strongly due to the reduced international purchasing power effect. This is a difference of perspective on the development of the South African economy. Crude oil is not of direct importance for electricity production, but in the long run it could lead to more substitution of electricity to refined fuels (or CTL fuels). The latter effect is not captured, because of the

Leontief CES between energy products for intermediate consumption, but the “end-point” of this comparison, electricity production, was already considered to possibly have been underestimated in IMACLIM-SA.

- Finally, SATIM does not assume a divergence between unit costs of capital or labour costs, whereas in IMACLIM-SA unit labour costs go up because of decreasing unemployment.

For the estimation of technical coefficients, the underestimation of the coal price in IMACLIM-SA compared to the engineering-based estimations incorporated in SATIM would, in a CES setting have led to higher energy intensity versus capital intensity in the RP, whereas with a carbon tax in a “CES case” this would then probably have been reversed too strongly by the too high relative cost increases of coal consumption. In both cases the use of technical coefficients seems justified and rather compensates for shortcomings in IMACLIM-SA more than that it means combining incompatible economic futures.

More problematic might be the divergence in the international price of crude oil between the two models. This would rather be a problem for total electricity demand and production than for the values of the technical coefficients. It would be logical to expect that under such a macro-economic development industry would show a shift to electricity and coal and coal-related fuels (CTL within refined fuels), whereas also households would abandon refined fuels faster, and possibly electrified transport would increase too. We have not estimated the order of magnitude of such possible shifts (or in other words: the equivalent price elasticity between oil/refined fuels and coal/CTL and electricity). It could be interesting to see what consequences for electricity use such oil price increases would have under the partial equilibrium settings of SATIM. One possible consequence, a higher demand of electricity, could change the technical coefficients depending on the load curve. If higher demand would lead to a relatively higher peak capacity generation requirement, then this would increase the capital intensity of electricity production. If higher demand means a more even distribution in time, then the contrary would be true.

**Table 17 Parameters and variables of the SATIM runs used to derive technical coefficients for the ELC sector in IMACLIM-SA**

| Run/item | Start year | Start value | 2035 value | 2035 *vs.* start year | Relative to $p_K$ | 2035 value | 2035 *vs.* start year | Relative to $p_K$ | 2035 value | 2035 *vs.* start year | Relative to $p_K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***SATIM run*** | – | – | ———*No carbon tax*——— | | | —*Carbon tax 100 $ZAR_{10}/tCO_2$*— | | | —*Carbon tax 300 $ZAR_{10}/tCO_2$*— | | |
| **Energy prices*** | | | | | | | | | | | |
| Coal in electricity** | 2006 | 8.5 | 12.9 | 1.5 | +53% | 24.0 | 2.8 | +183% | 49.5 | 5.9 | +486% |
| Gas in electricity | 2010 | 38.7 | 85.8 | 2.2 | +122% | 89.6 | 2.3 | +132% | 73.8 | 1.9 | +91% |
| Diesel in electricity | 2010 | 82.9 | 114.1 | 1.4 | +38% | 119.2 | 1.4 | +44% | 129.4 | 1.6 | +56% |
| Imported electricity | 2020 | 21.1 | 21.1 | 1.0 | id. | 21.1 | 1.0 | id. | 21.1 | 1.0 | id. |
| International oil | 2006 | 67.1 | 102.1 | 1.5 | +52% | 102.1 | 1.5 | +52% | 102.1 | 1.5 | +52% |
| **Exogenous parameters** | | | | | | | | | | | |
| Capital cost ($p_K$) index | 2006 | 100 | 100 | 1.0 | id. | 100 | 1.0 | id | 100 | 1.0 | id. |
| Labour cost index | 2006 | 100 | 100 | 1.0 | id. | 100 | 1.0 | Id | 100 | 1.0 | id. |
| Materials cost index | 2006 | 100 | 100 | 1.0 | id. | 100 | 1.0 | Id | 100 | 1.0 | id. |
| GDP index°° | 2006 | 100 | 312 | 3.1 | - | 312 | 3.1 | - | 312 | 3.1 | - |
| **Outcomes** | | | | | | | | | | | |
| Electricity cost | 2006 | 97.8 | 110.2 | 1.1 | +13% | 131.4 | 1.3 | +34% | 154.2 | 1.6 | +58% |
| Electric output(PJ) | 2006 | 904 | 1 791 | 2.0 | - | 1 731 | 1.9 | - | 1 690 | 1.9 | - |
| Electricity imported (PJ) | 2006 | 24 | 185 | 7.7 | - | 186 | 7.7 | - | 186 | 7.7 | - |
| Coal in electricity (PJ) | 2006 | 2 608 | 4 377 | 1.7 | - | 3 269 | 1.3 | - | 1 911 | 0.7 | - |
| Diesel/Gas in elec. (PJ) | 2006 | 16 | 21 | 1.3 | - | 21 | 1.3 | - | 21 | 1.3 | - |

Notes: ° Conversion factor 1 $ZAR_{05}$ = 1.45 $ZAR_{10}$. °° ERC documentation gives GDP growth rates by 5 year period, on this basis we estimated an overall GDP growth for 2006-2035; * Energy prices by fuel are set exogenously, but prices here are weighted average values for given categories of fuels, and weighing is endogenous; ** Note on coal price: by proxy of CLE, as CLD is negligibly small and has approximately the same development.

**Table 18 Variables of selected IMACLIM-SA runs for comparison to parameters and variables from SATIM runs**

| Run/item | Start year | Start value | 2035 value | 2035 vs. start year | Relative to $p_K$ | 2035 value | 2035 vs. start year | Relative to $p_K$ | 2035 value | 2035 vs. start year | Relative to $p_K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *IMACLIM run* | | | *RP* | *RP* | *RP* | *Ctax 100 $ZAR_{05}/tCO_2$ + R2* | | | *Ctax 300 $ZAR_{05}/tCO_2$ + R2* | | |
| **Energy prices (endogenous)** | | | | | | | | | (Coal, Gas, and Refined fuel incl. $CO_2$ tax) | | |
| Coal in electricity* | 2005 | 5.7 | 8.0 | 1.4 | -9% | 29.1 | 5.1 | +244% | 70.6 | 12.3 | +711% |
| Gas in electricity | 2005 | 44.1 | 78.4 | 1.8 | +15% | 107.6 | 2.4 | +65% | 163.4 | 3.7 | +144% |
| Refined fuels in electricity | 2005 | 84.0 | 198.2 | 2.4 | +53% | 211.1 | 2.5 | +70% | 234.3 | 2.8 | +84% |
| Imported electricity | 2005 | 38.8 | 126.0 | 3.2 | +110% | 120.8 | 3.1 | +111% | 112.5 | 2.9 | +91% |
| International oil | 2005 | 57.1 | 185.2 | 3.2 | +110% | 177.6 | 3.1 | +111% | 165.4 | 2.9 | +91% |
| **Other variables (endogenous)** | | | | | | | | | | | |
| Capital cost $p_K$ | 2005 | 1128.7 | 1739.0 | 1.5 | id. | 1666.8 | 1.5 | id. | 1712.3 | 1.5 | id. |
| Labour cost | 2005 | 156.3 | 286.0 | 1.8 | +19% | 290.5 | 1.9 | +26% | 279.8 | 1.8 | +18% |
| Materials cost | 2005 | 1049.4 | 1545.2 | 1.5 | -4% | 1575.9 | 1.5 | +2% | 1553.0 | 1.5 | -2% |
| GDP index | 2005 | 100 | 270 | 2.7 | - | 273 | 2.7 | - | 261 | 2.6 | - |
| Electricity cost | 2005 | 58.4 | 95.6 | 1.6 | +6% | 130.1 | 2.2 | +51% | 153.0 | 2.6 | +73% |
| Electricity output (PJ) | 2005 | 844 | 1 717 | 2.0 | - | 1 560 | 1.8 | - | 1 382 | 1.6 | - |
| Electricity imported (PJ) | 2005 | 2 | 4 | 1.7 | - | 4 | 1.7 | - | 3 | 1.6 | - |
| **Variables following from tech coef.** | | | | | | | | | | | |
| Cons of COA by ELC (PJ) | 2005 | 2 541 | 4 374 | 1.7 | - | 3 071 | 1.2 | - | 1 630 | 0.6 | - |
| Cons of REF&GAS by ELC (PJ) | 2005 | 1 | 6 | 7.3 | - | 5 | 6.6 | - | 5 | 5.9 | - |

# Appendix 4: BY calibration hybrid I-O table and current integrated economic accounts

**Table 19 Final hybrid I-O table for Base Year 2005**

| Unit: milion ZAR 2005 | | Intermediate consumption (IC) | | | | | | | | | | Subtotals | Final consumption (FC) | | | Exports | ***Total uses*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (orange is date from "Energy bills") | | COA | OIL | GAS | REF | ELC | EIN | MAN | LSS | HSS | TRA | | C | G | I | | |
| IC | COAL MINING | - | - | 954 | 2 750 | 9 082 | 883 | 952 | 24 | 267 | - | 14 911 | 102 | - | - | 23 517 | ***38 530*** |
| | OIL | - | - | - | 37 168 | - | - | - | - | - | - | 37 168 | - | - | - | - | ***37 168*** |
| | GAS | - | - | - | 3 312 | - | 4 137 | 449 | 158 | 70 | - | 8 126 | - | - | - | - | ***8 126*** |
| | REFINERIES | - | - | - | - | 116 | 5 154 | 401 | 8 571 | 1 944 | 64 551 | 80 738 | 48 955 | - | - | 16 716 | ***146 409*** |
| | ELECTRICITY | 513 | - | - | 1 112 | - | 14 596 | 3 439 | 3 841 | 5 885 | 748 | 30 133 | 17 885 | - | - | 3 392 | ***51 411*** |
| | ENERGY INTENSIVE INDUSTRIES & MINING | 1 471 | - | 2 951 | 10 022 | 597 | 100 723 | 98 473 | 58 879 | 35 556 | 4 980 | 313 652 | 43 366 | - | 8 200 | 176 486 | ***541 705*** |
| | MANUFACTURING | 2 465 | - | 97 | 2 275 | 6 823 | 32 190 | 183 952 | 93 482 | 91 227 | 12 063 | 424 574 | 384 016 | - | 162 545 | 117 523 | ***1 088 657*** |
| | LOW SKILLED SECTORS | 968 | - | 126 | 2 944 | 210 | 20 019 | 87 546 | 20 827 | 60 021 | 18 112 | 210 773 | 126 587 | - | 99 143 | 39 270 | ***475 774*** |
| | HIGH SKILLED SERVICES | 2 230 | - | 94 | 3 719 | 4 284 | 34 671 | 55 927 | 133 937 | 327 922 | 31 269 | 594 052 | 322 201 | 305 732 | 12 241 | 45 213 | ***1 279 439*** |
| | TRANSPORT SERVICES | 9 675 | - | 77 | 1 668 | 1 261 | 27 853 | 20 357 | 30 705 | 33 263 | 8 023 | 132 883 | 47 662 | - | - | 32 434 | ***212 980*** |
| Subtotals | | 17 322 | - | 4 298 | 64 969 | 22 372 | 240 227 | 451 496 | 350 425 | 556 155 | 139 747 | **1 847 011** | 990 776 | 305 732 | 282 129 | 454 551 | **3 880 199** |
| VA | Net salary | 5 867 | - | 206 | 3 869 | 8 976 | 51 538 | 63 052 | 113 722 | 304 485 | 27 966 | 579 681 | | | | | |
| | Soc. Contributions | 105 | - | 4 | 70 | 161 | 904 | 1 105 | 2 005 | 5 355 | 495 | 10 204 | | | | | |
| | Pension contributions | 1 224 | - | 43 | 822 | 1 862 | 9 386 | 11 407 | 21 357 | 56 190 | 5 360 | 107 651 | | | | | |
| | CFC | 1 573 | - | 140 | 1 775 | 14 790 | 16 459 | 18 723 | 22 401 | 100 031 | 9 900 | 185 793 | | | | | |
| | Tax on production | 373 | - | - | -312 | 19 | 1 672 | 991 | 5 245 | 18 877 | 1 633 | 28 498 | | | | | |
| | NOS (excl T prod) | 7 833 | - | 837 | 4 176 | 1 172 | 73 663 | 61 989 | 125 787 | 187 599 | 26 425 | 489 481 | | | | | |
| Subtotal domestic production | | *34 298* | - | *5 528* | *75 368* | *49 353* | *393 849* | *608 763* | *640 942* | *1 228 692* | *211 525* | **3 248 318** | | | | | |
| Imports | | 749 | 37 168 | 2 595 | 9 304 | 85 | 57 223 | 252 798 | 43 478 | 21 840 | 36 627 | 461 865 | | | | | |
| Margins | Commerce | 2 506 | - | 2 | 35 831 | 6 | 58 507 | 135 934 | -233 393 | 608 | - | -0 | | | | | |
| | Transport | 367 | - | 0 | 5 250 | 1 | 8 573 | 19 919 | - | 89 | -34 200 | -0 | | | | | |
| Specific margins of sales to sectors ... | COAL MINING | - | - | - | - | -149 | - | - | - | - | - | -149 | | | | | |
| | OIL | - | - | - | - | - | - | - | - | - | - | - | | | | | |
| | GAS | -742 | - | - | - | - | - | - | - | - | - | -742 | | | | | |
| | REFINERIES | -2 139 | - | -22 | - | -487 | - | - | - | - | - | -2 649 | | | | | |
| | ELECTRICITY | -7 066 | - | - | -4 | - | - | - | - | - | - | -7 070 | | | | | |
| | ENERGY INTENSIVE INDUSTRIES AND MINING | -687 | - | -28 | 339 | -5 292 | - | - | - | - | - | -5 668 | | | | | |
| | MANUFACTURING | -740 | - | -3 | -16 | -847 | - | - | - | - | - | -1 606 | | | | | |
| | LOW SKILLED SECTORS | -19 | - | 13 | -455 | 590 | - | - | - | - | - | 129 | | | | | |
| | HIGH SKILLED SERVICES | -208 | - | 41 | -350 | 952 | - | - | - | - | - | 435 | | | | | |
| | TRANSPORT SERVICES | - | - | - | -1 213 | 30 | - | - | - | - | - | -1 183 | | | | | |
| Specific margins of sales to FC and of exports | SCC | -80 | - | - | 2 592 | 4 668 | - | - | - | - | - | 7 181 | | | | | |
| | SG | - | - | - | - | - | - | - | - | - | - | - | | | | | |
| | SI | - | - | - | - | - | - | - | - | - | - | - | | | | | |
| | SX | 11 681 | - | - | -894 | 535 | - | - | - | - | - | 11 322 | | | | | |
| Product Taxes and Subsidies | VAT | - | - | - | - | 2 196 | 6 333 | 67 121 | 27 721 | 78 618 | 5 853 | 187 843 | | | | | |
| | Fuel levy IC | - | - | - | 24 221 | - | - | - | - | - | - | 24 221 | | | | | |
| | Fuel levy FC | - | - | - | 14 687 | - | - | - | - | - | - | 14 687 | | | | | |
| | Other taxes & sub. | 611 | - | 1 | -18 252 | -230 | 17 220 | 4 121 | -2 975 | -50 407 | -6 826 | -56 736 | | | | | |
| ***TOTAL RESOURCES*** | | ***38 530*** | ***37 168*** | ***8 126*** | ***146 409*** | ***51 411*** | ***541 705*** | ***1 088 657*** | ***475 774*** | ***1 279 439*** | ***212 980*** | 3 880 199 | | | | | |

*Source: Authors' own calculations and assumptions and data based on SAM 2005, SU 2005, energy balances, energy use and price data from various sources.*

## Table 20 Quantities of uses and resources at base year 2005

| (orange is date from "Energy bill | | Intermediate consumption (IC) | | | | | | | | | | Subtotals | Final consumption (FC) | | | Exports | *Total uses* | Domestic production | *Imports* | *Total uses* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Unit | | COA | OIL | GAS | REF | ELC | EIN | MAN | LSS | HSS | TRA | Totals IC | C | G | I | X | | | | |
| PJ | COAL MINING | - | - | 665 | 1 310 | 4 374 | 656 | 520 | 10 | 113 | - | 7 646 | - | - | - | 7 192 | 14 837 | 14 741 | 96 | 14 837 |
| PJ | OIL | - | - | - | 1 108 | - | - | - | - | - | - | 1 108 | - | - | - | - | 1 108 | - | 1 108 | 1 108 |
| PJ | GAS | - | - | - | 129 | 5 | 251 | 20 | 5 | 1 | - | 411 | - | - | - | - | 411 | 308 | 102 | 411 |
| PJ | REFINERIES | - | - | - | - | 1 | 87 | 6 | 92 | 24 | 819 | 1 027 | 443 | - | - | 279 | 1 750 | 1 660 | 89 | 1 750 |
| PJ | ELECTRICITY | 26 | - | - | 47 | - | 908 | 144 | 83 | 128 | 23 | 1 359 | 280 | - | - | 82 | 1 721 | 1 717 | 4 | 1 721 |
| units | ENERGY INTENS | 3 | - | 6 | 14 | 1 | 221 | 179 | 90 | 59 | 8 | 581 | 55 | - | 8 | 547 | 1 192 | 1 125 | 66 | 1 192 |
| units | MANUFACTURII | 5 | - | 0 | 3 | 13 | 72 | 340 | 146 | 154 | 19 | 752 | 444 | - | 169 | 318 | 1 683 | 1 442 | 241 | 1 683 |
| units | LOW SKILLED S | 3 | - | 0 | 8 | 1 | 81 | 294 | 59 | 184 | 51 | 681 | 389 | - | 187 | 103 | 1 360 | 1 281 | 79 | 1 360 |
| units | HIGH SKILLED S | 5 | - | 0 | 7 | 10 | 96 | 128 | 259 | 687 | 59 | 1 251 | 651 | 620 | 16 | 147 | 2 684 | 2 661 | 23 | 2 684 |
| units | TRANSPORT SE | 26 | - | 0 | 3 | 3 | 89 | 54 | 69 | 81 | *18* | *343* | 67 | - | - | 62 | 472 | 407 | 65 | 472 |

*Note: energy volumes figure in PJ thanks to the hybridising process. / Source: Authors' own calculations and data based on (for energy) energy balances and various other sources.*

## Table 21 Integrated economic accounts for economic agents and households by class for the Base Year (2005)*

| Item | Var/Par | Firms | Government | Households | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 | Rest o/t World |
|---|---|---|---|---|---|---|---|---|---|---|
| Trade Balance | BAL | | | | | | | | | 7 314 |
| Sales tax | *part of FISC* | | 187 843 | | | | | | | |
| Fuel levy | *part of FISC* | | 38 908 | | | | | | | |
| Other product taxes or subsidies | *part of FISC* | | -56 736 | | | | | | | |
| Net wage revenue | RL | | | 579 681 | 1 148 | 7 598 | 18 820 | 98 025 | 454 090 | - |
| Social contributions | *part of FISC* | | 10 204 | | | | unknown by class | | | |
| Pension contributions | *part of FISC* | 107 651 | | | 1 944 | 8 788 | 14 643 | 30 227 | 52 049 | |
| Gross Operating Surpluss | GOS | 500 576 | 30 471 | 172 724 | 316 | 2 204 | 5 553 | 29 197 | 135 455 | - |
| Taxes or subsidies on production | *part of FISC* | -28 498 | 28 498 | | | | | | | |
| Returns on financial capital/Interest | RK | -159 308 | -46 498 | 177 097 | 27 | 395 | 805 | 4 497 | 171 373 | 28 709 |
| Unemployment benefits | RU | | -5 000 | 5 000 | 30 | 57 | 162 | 1 920 | 2 831 | |
| Pension benefits | RP | -50 620 | | 50 620 | 1 341 | 6 549 | 11 445 | 21 219 | 10 066 | |
| Other social benefits | RAS | | -56 330 | 56 330 | 3 784 | 7 693 | 7 815 | 12 999 | 24 039 | |
| Subtotal: Social security & pensions | RS | -50 620 | -61 330 | 111 950 | 5 156 | 14 299 | 19 422 | 36 137 | 36 937 | - |
| Other transfers | AT | 16 195 | -54 735 | 17 904 | 2 481 | 11 819 | 8 080 | -8 198 | 3 723 | 20 635 |
| **GDI before taxation (HHs)** | **GDIAI** | | | **1 059 357** | **9 128** | **36 314** | **52 679** | **159 658** | **801 578** | |
| Subtotal other taxes, except ICRP | FISC | 79 153 | 208 717 | | | | | | | - |
| Income, Revenue & Patrimony taxes | ICRP | -98 779 | 223 292 | -124 513 | 80 | 461 | 943 | 13 752 | 109 277 | - |
| Pension funds build-up | TotgrowPF | -57 031 | | 57 031 | 603 | 2 239 | 3 199 | 9 008 | 41 983 | - |
| **Gross Disposable Income** | **GDI** | **230 187** | **299 917** | **991 875** | **9 651** | **38 092** | **54 934** | **154 914** | **734 284** | **56 658** |
| Consumption | CONS | | -305 732 | -990 776 | 9 600 | 38 017 | 54 900 | 154 678 | 733 580 | - |
| Savings | S | | | 1 099 | 52 | 75 | 34 | 235 | 703 | - |
| Average saving rate | tauS | | | 0.11% | 0.53% | 0.20% | 0.06% | 0.15% | 0.10% | |
| Gross Fixed Capital Formation | GFCF | 240 925 | 25 702 | 15 502 | 150 | 595 | 858 | 2 419 | 11 480 | - |
| **Auto-financing capacity** | **AFC** | **-10 738** | **-31 517** | **-14 403** | **-98** | **-520** | **-824** | **-2 184** | **-10 777** | **56 658** |
| **Net debt** | **D** | **1 975 370** | **938 238** | **-2 483 608** | **-380** | **-5 534** | **-11 291** | **-63 069** | **-2 403 334** | **-430 000** |
| *Effective interest rate/rate of returns* | *tau_i* | *8.1%* | *5.0%* | *7.1%* | *7.1%* | *7.1%* | *7.1%* | *7.1%* | *7.1%* | *6.7%* |

** Note: Shaded areas are parts of other items; Distributions by household class are assumed / Source: Authors' own calculations and assumptions and data based on or from various sources.*

# Appendix 5: Overview of all scenario runs: key settings and outcomes

**Table 22 Main settings and key outcomes for RP and all policy scenarios***

| Scenario runs | RP (CSLF) | Ct100 RDEF | Ct100 RVAT | Ct100 RREV | Ct100 REXP | Ct100 RSUM | Ct100 RVAT+1% | Ct300 RVAT | Ct300 REXP | Ct300 RSUM |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Settings*** | | | | | | | | | | |
| Calibration year | 2005 | 2005 | 2005 | 2005 | 2005 | 2005 | 2005 | 2005 | 2005 | 2005 |
| Projection year | 2035 | 2035 | 2035 | 2035 | 2035 | 2035 | 2035 | 2035 | 2035 | 2035 |
| Carbon tax in $ZAR_{05}/tCO_2$ | 0 | 100 | 100 | 100 | 100 | 100 | 100 | 300 | 300 | 300 |
| Investment in educ & training | No | No | No | No | No | No | Yes | No | No | No |
| Annual K productivity gain | +2.0% | +2.0% | +2.0% | +2.0% | +2.0% | +2.0% | +2.02% | +2.0% | +2.0% | +2.0% |
| Annual L productivity gain | +1.0% | +1.00% | +1.00% | +1.00% | +1.00% | +1.00% | +1.01% | +1.00% | +1.00% | +1.00% |
| IRP scenario (SATIM) | IRPupdated | IRPupCT100 | IRPupCT100 | IRPupCT100 | IRPupCT100 | IRPupCT100 | IRPupCT100 | IRPupCT300 | IRPupCT300 | IRPupCT300 |
| ***Results*** | | | | | | | | | | |
| $CO_2$ emissions (Mt CO2) | 801 | 604 | 644 | 610 | 615 | 610 | 644 | 467 | 434 | 428 |
| Average annual growth rate, GDP | +3.36% | +3.11% | +3.40% | +3.12% | +3.18% | +3.11% | +3.40% | +3.25% | +2.94% | +2.80% |
| Real GDP (2035 *vs.* BY) | +170% | +150% | +173% | +151% | +156% | +151% | +173% | +161% | +139% | +129% |
| Real GDP *per capita* (2035 *vs.* BY) | +116% | +100% | +118% | +101% | +105% | +101% | +118% | +109% | +91% | +83% |
| Real wage (2035 *vs.* BY) | +36.8% | +33.1% | +41.7% | +34.4% | +38.1% | +34.2% | +41.8% | +40.8% | +35.7% | +31.2% |
| Trade balance-to-GDP ratio (2035) | +5.9% | +7.4% | +3.7% | +6.1% | +3.8% | +6.1% | +3.7% | +3.8% | +3.8% | +6.3% |
| Company net debt/GDP | 79% | 82% | 76% | 80% | 76% | 81% | 76% | 76% | 78% | 84% |
| Public net debt/GDP | 116% | -6% | 72% | 118% | 72% | 118% | 72% | 72% | 73% | 122% |
| HH net debt (savings)/GDP | -83% | -86% | -81% | -85% | -81% | -85% | -80% | -81% | -82% | -87% |
| Net debt of ROW (fin assets)/GDP | -111% | 10% | -67% | -113% | -68% | -114% | -67% | -68% | -69% | -118% |
| Corporate income and revenue tax | 23.9% | 23.9% | 23.9% | 21.6% | 23.9% | 24.7% | 23.9% | 23.9% | 23.9% | 25.7% |
| GOS/GDP | 42.5% | 42.2% | 43.6% | 41.9% | 41.0% | 41.9% | 43.4% | 44.0% | 40.3% | 41.2% |
| GFCF/GDP | 13.4% | 13.5% | 13.2% | 13.3% | 13.0% | 13.4% | 13.2% | 13.3% | 13.0% | 13.3% |
| Share of VA in output | 40.3% | 39.8% | 40.1% | 40.1% | 40.8% | 40.0% | 40.1% | 39.6% | 40.7% | 39.7% |
| Gross wages in VA | 53.2% | 52.6% | 53.6% | 52.9% | 53.8% | 52.9% | 53.7% | 53.2% | 53.6% | 52.4% |
| TY in VA | 2.0% | 2.0% | 2.0% | 2.0% | 2.1% | 2.0% | 2.0% | 2.1% | 2.1% | 2.0% |
| Share of K in VA | 44.8% | 45.4% | 44.3% | 45.0% | 44.1% | 45.1% | 44.3% | 44.7% | 44.4% | 45.5% |
| Share of NOS in VA | 34.2% | 34.5% | 34.3% | 34.3% | 33.7% | 34.4% | 34.3% | 34.6% | 33.7% | 34.5% |
| Share of CFC in VA | 10.6% | 10.8% | 10.0% | 10.7% | 10.4% | 10.7% | 10.0% | 10.1% | 10.6% | 11.0% |
| Unemployment (broad) | 28.7% | 32.6% | 25.1% | 31.4% | 28.0% | 31.6% | 25.3% | 26.2% | 30.7% | 35.6% |
| Of high skill labour | 9.6% | 12.3% | 7.1% | 11.3% | 8.9% | 11.5% | 7.1% | 7.5% | 10.4% | 14.3% |
| Of medium skill labour | 32.2% | 36.3% | 28.6% | 35.1% | 31.7% | 35.3% | 28.8% | 29.8% | 34.6% | 39.4% |
| Of low skill labour | 41.4% | 46.2% | 36.8% | 44.8% | 40.4% | 45.2% | 37.1% | 38.3% | 43.8% | 50.1% |