**The economic and environmental effects of a carbon tax in South Africa: a dynamic CGE modelling approach**

# Abstract

South Africa’s National Treasury released its Carbon Tax Policy Paper in May 2013 which proposed a R120/tCO2-equiv. levy on coal, gas and petroleum fuels. Here we model the possible impacts of such a tax on the South African economy using the Department of Economics, University of Pretoria’s dynamic computable general equilibrium (CGE) 53 sector model. The model shows that the carbon tax has the capacity to decrease South Africa’s Greenhouse Gas emissions by between 1,900MtCO2-equiv. and 2,300MtCO2-equiv. between 2016 and 2035. The extent of emissions reductions is most sensitive to the rate at which tax exemptions are removed. Recycling of carbon tax revenue reduces the extent of emissions reductions due to the fact that economic growth is supported. The manner in which carbon tax revenue is recycled back into the economy is therefore important in terms of the extent of emissions reductions achieved, but not as significant as the influence of different exemption schedules. The model shows the carbon tax to have a net negative impact on South Africa’s GDP relative to the baseline under all exemption regimes and all revenue recycling options assessed. The negative impact of the carbon tax on GDP is, however, greatly reduced by the manner in which the tax revenue is recycled. Recycling in the form of a production subsidy for all industries results in the lowest negative impact on GDP. This suggests that support for the economy through broad-based recycling of the tax benefits all sectors.

**JEL Codes:** C68

**Keywords:** Computable general equilibrium, UPGEM, carbon tax

# *“No one is going to win the Nobel Prize in economics for finding the solution to climate change. The economist who came up with it died a decade before the first prize was given out. Arthur C. Pigou identified the general problem and the solution – what’s by now known as “Pigouvian taxes”. The correct – the only correct – approach is to price each and every ton of carbon according to the damage it causes.*

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# Introduction

South Africa’s National Treasury released a Carbon Tax Policy Paper for public comment in May 2013 (National Treasury 2013). The paper, an update of a discussion paper released in December 2010, describes in detail one of South Africa’s efforts to respond to anthropogenic climate change and transition to a green economy. In December 2015, National Treasury published the Draft Carbon Tax Bill which represents one of the final steps before implementation of the tax. In this paper, we aim to estimate the economy-wide effects of the carbon tax, as described in National Treasury (2013; 2015).

The carbon tax aims to change the behaviour of firms, incentivising them to shift towards cleaner technology when replacing/renewing machinery, technology or processes. The carbon tax will bring the price of carbon closer to its true social cost. This Pigouvian approach is widely regarded by economists as the correct way to address the externality problem (Stern, 2008; Wagner *et al*. 2015). To ensure that South Africa transitions to a low carbon, climate resilient economy in a cost effective and economically efficient manner, it is important that the objectives of inclusive economic growth, poverty alleviation, job creation and the lowering of our Green House Gas (GHG) emissions are appropriately balanced and the trade-offs effectively managed. Hence, given the developmental challenges that South Africa has to deal with and the internationally accepted common but differentiated responsibilities and respective capabilities principle (CBDR-RC) that requires more developed countries to make a greater effort to reduce global GHG emissions, South Africa’s carbon tax should be gradually phased-in.

Various economic modelling techniques to estimate the impact of a carbon tax were previously undertaken (Van Heerden *et al.* 2006, Pauw 2007, Kearney 2008, Devarajan *et al.* 2009, Alton *et al.* 2012). The first key paper is Van Heerden *et al*. (2006), in which a triple dividend was found if environmental taxes are recycled through a reduction in food prices. This landmark study used a comparative-static CGE model of South Africa, which would later come to be known as the University of Pretoria General Equilibrium Model (UPGEM). The second key paper is Alton *et al*. (2014). In this paper, the authors use a dynamic CGE model to evaluate the introduction of a carbon tax in South Africa that would achieve national emissions reductions targets set for 2025. The authors’ main findings highlight the sensitivity of the mode for recycling carbon tax revenues to distributional outcomes, and that the tax alone, ignoring all potential benefits, reduces national welfare by only a small margin.

In our paper, we improve on the CGE approach used in Van Heerden *et al*. (2006) by using an updated and dynamic version of UPGEM with a detailed electricity generation mechanism. We also further the analysis in Alton *et al*. (2014) by basing our policy simulations on the announced carbon tax rates and exemptions schedule. In general, our analysis supports the main findings in the two aforementioned papers. Our modelling results suggest that a carbon tax with broad sector coverage implemented gradually and complemented by effective and efficient revenue recycling will contribute towards significant GHG emission reductions, and have only a marginally negative impact on economic growth over the short-term. Over medium to long term, the carbon tax will support the transition to a more sustainable low carbon economy and green jobs.

# Methodology and Database

We use a modified version of the University of Pretoria General Equilibrium Model (UPGEM) to conduct our analysis of the South African carbon tax. UPGEM is a dynamic computable general equilibrium (CGE) model of South Africa, developed by staff at the University of Pretoria in collaboration with the Centre of Policy Studies (CoPS) in Melbourne, Australia. UPGEM has been used in a variety studies over the last decade, including Van Heerden *et al.* (2006) and Bohlmann *et al*. (2015). The theoretical structure of UPGEM is similar to the MONASH model developed by CoPS and documented in Dixon & Rimmer (2002; 2005) and Dixon *et al*. (2013). The core UPGEM database is based on the 2011 supply-use (SU) tables published in StatsSA (2014). A stylised representation of the database is shown in Bohlmann *et al.* (2015). . The modified version of UPGEM used in this study distinguishes 53 industries and products. It includes a more detailed treatment of the electricity sector by allowing up to eight different technologies or types of electricity generation, as illustrated by the nested production structure in Appendix B. It furthermore allows for environmental analysis by linking UPGEM to an external emissions database and adding appropriate theoretical extensions.

Dynamic CGE models such as UPGEM are designed to quantify the effects of a policy change, or exogenous shock, to the economy, over a period of time. Given that the database and initial solution to the model are based on 2011 data, 2012 represents the first simulation year. In this analysis, our simulation period extends to 2035, allowing us to evaluate the effect of the carbon tax over a 20 year period (2016-2035) from when it was first imposed. A good way to examine the impacts of an exogenous shock is to compute the differences between a scenario in which the shock has occurred – the policy simulation – and a counterfactual scenario in which the particular shock under examination did not occur – the baseline scenario. Results are then reported as percentage change deviations over time between the first baseline simulation run and the second policy simulation run.

Following the CoPS-style of implementing a CGE model, the general equilibrium core of UPGEM is made up of a linearised system of equations describing the theory underlying the behaviour of participants in the economy. It contains equations describing, amongst others: i) the nature of markets; ii) intermediate demands for inputs to be used in the production of commodities; iii) final demands for goods and services by households; iv) demands for inputs to capital creation and the determination of investment; v) government demands for commodities; and vi) foreign demand for exported goods. The model is implemented and solved using the GEMPACK suite of programs described in Harrison & Pearson (1996) and Horridge *et al*. (2013). GEMPACK eliminates linearisation error by implementing shocks in a series of small steps and updating the database between steps.

The specification of the modified UPGEM implemented in this paper includes enhancements for environmental analysis based on the MMRF model of Australia documented in Adams *et al.* (2014). UPGEM functions in a similar fashion with the ability to activate several add-ins when required. For MMRF, these add-ins include: i) an energy and gas emissions accounting module, which accounts explicitly for each industry recognised in the model; ii) equations that allow for inter-fuel substitution in electricity generation; and iii) mechanisms that allow for the endogenous take-up of various abatement measures in response to greenhouse gas policy measures. MMRF tracks greenhouse gas emissions at a detailed level. It breaks down emissions according to emitting agent, emitting region, and emitting activity. UPGEM follows this same strategy, but excludes the regional accounting component due to data limitations.

Emissions derived from the combustion of fuels are modelled as being directly proportional to fuel usage. No allowance is made for the type of technological innovation that would allow, for example, coal-fired electricity generators to emit less greenhouse gases per tonne of coal combusted. However, the model does allow for input-saving technological progress. For example, the coal-fired electricity generators may reduce the amount of coal burnt per kilowatt-hour of output. This sort of technological progress is typically imposed exogenously. Inter-fuel substitution in electricity generation is handled using the “technology bundle” approach from Hinchy & Hanslow (1996), also used in other CGE models for energy analysis applications, such as TAIGEM[[1]](#footnote-1). Non-combustion (or activity-related) emissions are generally modelled as being directly proportional to the output of the related industries. However, in simulating the effects of a carbon tax or some other price-related penalty on emissions, allowance can be made for abatement of non-combustion emissions. The amount of abatement is directly related to the price of carbon. The add-ins to the core model described here have been included and activated in the modified UPGEM model’s theoretical structure. South African specific data underlying the add-ins were then constructed from available data sources to make these components computable.

The energy and emissions database is a critical component to the modified UPGEM. In order to measure the impact of the South African carbon tax, it is necessary for the model to have greenhouse gas emissions embedded in the database. This, in essence, implies a vector of CO2-emissions and energy consumption (in terajoule), per industrial sector. The emissions and energy data used to develop the database for the model is based on Blignaut *et al*. (2005) and Seymore *et al.* (2014). As described in these papers, a sectoral emissions and energy inventory was developed using emission factors from various South African sources, as well as UNFCCC default factors that resembled that of the South African DEA specific emission factors. It should be noted that the database contains no fugitive emissions. The source document for compiling the emissions and energy database is the 2007 energy balance of South Africa published by the Department of Energy, which has been adjusted to 2011 levels using the GDP growth rate over the period. The country-wide emissions level for 2007 was estimated as 503MtCO2-equiv., with the households’ portion being 45MtCO2-equiv. This implies industry-wide emissions of 458MtCO2-equiv., which compares favourably to the estimate of 433MtCO2-equiv. by DEA (2009) for 2000. Our estimate has been adjusted to 514MtCO2-equiv. for industries and 564MtCO2-equiv. for the country as a whole for 2011, as can be seen in Table 1. The tax is not levied directly on households, but indirectly through their consumption of commodities, hence the fact that their emissions and energy use is omitted from the database.

Table 1: Summary of emissions and energy use for 2007 and 2011.

|  |  |  |
| --- | --- | --- |
|  | **2007** | **2011** |
| **Households** | **Industry** | **Total** | **Households** | **Industry** | **Total** |
| CO2-emissions (Mil ton) | 45 | 458 | **503** | 50 | 514 | **564** |
| Energy use (TJ) |  | 6 012 316 |  |  | 6 735 434 |  |

The proposed tax is effectively a fossil fuel input tax, but levied on industry-specific CO2-emissions. Since the emissions and energy content of fuels vary, the tax has to be applied on fuel use. An emissions and energy database in terms of fuels had to be developed based on the industry-wide consumption levels. This is provided in Table 2. Note that biomass-related emissions and energy use is excluded from the database as it does not represent a fossil fuel, hence the fact that the numbers for total emissions and energy use is less than depicted in Table 1. This exclusion, together with that of households, narrows the tax base by about 15 per cent.

Table 2: Emissions (in Mil ton) and energy use (in TJ) by fuel for various years.

|  |  |  |
| --- | --- | --- |
|  | **2007** | **2011** |
| **MtCO2-equiv** | **TJ** | **MtCO2-equiv** | **TJ** |
| Coal | 336 | 3 517 949 | 377 | 1 804 330 |
| Gas[[2]](#footnote-2) | 23 | 353 767 | 25 | 2 055 578 |
| Petroleum | 73 | 1 008 948 | 82 | 1 607 768 |
| **Total** | **432** | **4 880 664** | **484** | **5 467 676** |

The disaggregated fuel use by sector is provided in Table A1 in Appendix A. In addition to the fuel use by sector, the information from Table 2 can be used to calculate the effective tax rate when incorporating the published exemption thresholds. This is since a CO2/TJ coefficient can be estimated, which is 96 tCO2/TJ for coal, 64 tCO2/TJ for gas and 73 tCO2/TJ for petroleum respectively. The proposed carbon tax rate in 2016 is R120/tCO2, which allows for calculating a R/TJ tax rate. Applying the threshold exemption percentages, excluding that of offsets, shown in Table 3, provide the effective tax rates presented in Table A1. This was done to standardise the unit of measurement and the tax base in TJ, as the tax is a tax on fossil fuel consumption, yet the tax rate is expressed in R/tCO2. The standardisation in TJ thus allows for the differences in the emission coefficients of each fuel input. This database therefore allows for sector-specific fuel consumption levels, fuel and sector-specific emission factors and intensities, and sector-specific exemption thresholds. The use of an effective tax rate does not imply a change in the tax design, which is based on applying the full marginal tax rate (R120/tCO2 increasing at 10 percent per annum for the first five years, and then linked to inflation thereafter) to the non-exempted emissions, or the balance of the tax base. It is important to note that the 2011 energy use in TJ and the 2016 effective tax rates, provided in Table A1, are exogenous variables. The tax payable in 2016 is endogenously derived by the model, by estimating a fuel use consumption level for 2016, taking into consideration the entire system-wide dynamics of the economy, model design, database, and closure rules as discussed herein.

Table 3: Proposed emissions tax free thresholds.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Sector** | **Basic tax free threshold (%)** | **Maximum additional allowance for trade exposure (%)** | **Additional allowance for process emissions (%)** | **Total (%)****(Col 5)** | **Maximum offset (%)** |
| Electricity | 60 | - | - | 60 | 10 |
| Petroleum | 60 | 10 | - | 70 | 10 |
| Iron and Steel | 60 | 10 | 10 | 80 | 5 |
| Cement | 60 | 10 | 10 | 80 | 5 |
| Glass and ceramics | 60 | 10 | 10 | 80 | 5 |
| Chemicals | 60 | 10 | 10 | 80 | 5 |
| Pulp and paper | 60 | 10 | - | 70 | 10 |
| Sugar | 60 | 10 | - | 70 | 10 |
| Agriculture, forestry and land use | 60 | - | 40 | 100 | 0 |
| Waste | 60 | - | 40 | 100 | 0 |
| Fugitive emissions from coal mining | 60 | 10 | 10 | 80 | 5 |
| Other | 60 | 10 | - | 70 | 10 |

**Source: National Treasury, 2013.**

# Simulations

As noted in the previous section, we run two separate simulations to isolate and measure the impact of the South African carbon tax. The first establishes a business-as-usual (BAU) baseline forecast of the economy in the absence of the shock under investigation. The second simulation imposes the exogenous shock on the economy, in this case, the introduction of a carbon tax. Subsequent policy scenarios, simulating two revenue recycling options, are also tested. Results quantifying the impact of the shock are typically reported as percentage changes between the values in the baseline run and the policy run for each variable, although some variables, such as changes to the budget deficit or net foreign liabilities, may be reported as ordinary changes.

The forecast and policy simulations are done with different closures to the model. In the forecast closure we exogenise variables that we have forecast information for, such as household consumption, and endogenise variables that are related to them, such as the average propensity to consume (APC). Shocking the model with the forecasted value of household consumption would give a resulting value for the APC. If we would then change the closure by making household consumption endogenous and the APC exogenous, we would get the same value for household consumption by shocking the value of the APC by the solution value found previously. Therefore, in general, we do a baseline forecast of the economy, change the closure of the model to the policy closure that will be used later in the policy simulation, and re-generate the baseline forecast with it. From there we are ready to apply any set of additional policy shocks to the exogenous variables. If we would run a policy simulation where no additional shocks are applied to the policy variables, the original baseline forecast values would be the result of the simulation. This makes it legitimate to interpret differences between results in the policy and baseline runs as the effects of the policy shocks.

## 3.1 Baseline Forecast

The baseline forecast shows the macroeconomic projections for the main components of GDP from the expenditure side based on IMF (2016), National Treasury (2016) and CEPII (2012) estimates. Baseline projections paint a business-as-usual (BAU) picture of the economy without the policy change or shock under investigation.

The BAU baseline projection allows us to run the various policy scenarios simulating the impact of the carbon tax against it and estimate the deviation from the baseline caused by the tax. From the given forecast values we find that cumulative real GDP growth of 86.5 per cent is predicted for the 24 year simulation period between 2011 and 2035, taking into consideration historical data between 2012 and 2015. This is equivalent to an average annual growth in real GDP of around 2.6 per cent over the forecast period with an average of 3 per cent forecast from 2019-2035.

Figure 1 shows the macroeconomic projections for selected macro variables generated in the baseline forecast in year-on-year percentage change terms. Figure 2 shows macroeconomic projects for GDP from the income side, specifically, in cumulative percentage change terms, relative to 2011. Apart from increases in capital and labour, real GDP growth is also generated from technical progress or productivity gains. Given the growth in capital and labour projected over the forecast period, and taking into consideration that each contributes roughly half of gross value added (GVA) at factor cost, we find that technical change improvements contributing to around 28 per cent of the projected GDP growth should be generated. We have made conservative estimates regarding employment growth. Employment is forecast to rise in line with population growth thereby leaving the unemployment rate virtually unchanged. Inflation is forecast to remain within the inflation target range, rising an average of 5.6 per cent per annum over the forecast period.

On an industry level, we find that industry output typically follows the performance of the main macro variable with which it has the closest association. Primary and secondary industries, which are export intensive such as mining and selected manufacturers, are therefore expected to perform in line with projected export growth. Similarly, the construction industry’s fortunes are closely tied to projections concerning investment growth in the baseline.

**Figure 1: Macro Forecasts for 2012-2035 (year-on-year percentage change)**

**Figure 2: Macro Forecasts for 2012-2035 (cumulative percentage change)**

For the purpose of this baseline forecast, no explicit assumptions were made regarding future improvements to efficiency and costs competitiveness of clean technologies relative to fossil fuel based sources in the electricity generation mix. We have also assumed the ratio of each electricity generation technology relative to total electricity generation to remain fixed in the baseline relative to 2014 values. Subsequently, CO2 emissions are forecast to rise in line with real GDP. This is a simple BAU baseline, designed solely to help isolate and measure the impact of the proposed carbon tax as an instrument towards achieving government’s desired generation-mix and carbon emission targets. BAU baseline assumptions can easily be tweaked to incorporate future expectations regarding cost and efficiency of different technologies, but to establish an initial benchmark, we assumed the status quo to be maintained in this particular baseline forecast simulation.

We do not consider any of the IRP Update (DoE, 2013) generation-mix options in our BAU baseline. The emissions cap targeted by policymakers, and subsequent shadow price, built into the IRP Update baseline scenarios make it difficult to assess what the impact of a carbon tax alone would be. Analysis presented in the IRP Update suggest that the carbon tax is too low to make any tangible difference to the optimal generation-mix given the emissions limit of 275MT per annum and indirect carbon price it imposes on the economy. However, that outcome is contingent on various cost competitiveness assumptions, especially regarding renewable technology, which has changed considerably since 2013. It should also be kept in mind that the IRP Update modelling was done through a suite of energy models whereas the analysis in this study is conducted with a CGE model linked to a carbon emissions database. We believe that imposing a carbon tax on the BAU baseline specified here is likely to yield the most accurate reflection of the impact of the tax on the overall economy and the behavioural changes it may lead to. However, given that the generation-mix and build programme is likely to be very different to that specified in our baseline, with or without the proposed carbon tax, results from the policy simulations should not be used to estimate the level of carbon emissions in the economy after the imposition of the tax, unless great care is taken. Instead, we advise the focus of our policy results to remain only the percentage change deviation, relative to the baseline path, caused by the carbon tax.

## 3.2 Policy Scenarios

In this section the results from the modelled impact of the proposed carbon tax on the economy of South Africa is discussed. We are interested to see what the effects of the carbon tax would be on GDP and total carbon emissions in general, but also on some specific industries that might be more vulnerable than others. The tax revenue is also recycled back into the economy in two ways such that the government budget stays constant/revenue neutral and we compare the different outcomes. Furthermore, as alternative scenarios, the proposed first five years’ tax exemptions are phased out over the forecast period and the differences between the taxes with and without exemptions are discussed. The results are reported as deviations from the baseline which was described above.

#### Design of the tax policy scenarios

South Africa’s economy has historically been and still is dependent on coal as both an important mining sub-sector and more generally as the source of domestic energy. Dependence on coal as the predominant electricity feedstock has created structural economic challenges in the desire to reduce the country’s high levels of greenhouse gas emissions (GHGs) per unit of Gross Domestic Product (GDP). To address this, and in a demonstration of climate change leadership, South Africa committed to making a fair contribution to the global effort to prevent anthropogenic climate change by curtailing its GHGs in a “peak-plateau-decline” (PPD) emissions trajectory in 2009. The voluntary PPD commitment involves a 42 per cent reduction in GHGs by 2025 relative to business-as-usual (DEA 2011a and b).

As one way of achieving the PPD targets, South Africa’s National Treasury proposed levying a carbon tax on all actual emissions so as to influence energy consumption and investment patterns (National Treasury 2013)[[3]](#footnote-3). In May 2013, National Treasury released a “Carbon Tax Policy Paper - Reducing Greenhouse Gas Emissions and Facilitating the Transition to a Green Economy”. The Carbon Tax Policy Paper described in detail the design features of the proposed tax. As a result, it was possible for the first time to model the potential impact of the carbon tax with reference to a proposed policy.

In this section we seek to contextualize the modelling work by describing the key design features of South Africa’s proposed carbon tax and how they have been captured in the modelling exercise. It is acknowledged that there are a number of previous studies on this topic as mentioned above. This study, however, draws on the published Carbon Tax Policy Paper. As such, it is able to indicate the extent of GHG emissions mitigation that is likely to be achieved by the proposed tax design, and by implication the extent to which other measures might be required to meet specific mitigation targets.

The need for a carbon tax is justified by its potential role in (i) reaching mitigation targets, (ii) assisting with structural reform, and (iii) protecting South Africa’s competitive advantage.

South Africa adopted a voluntary target of 34 per cent reduction in GHGs by 2020 (and 42 per cent by 2025) relative to business as usual, as outlined in the National Climate Change Response White Paper (DEA, 2011a). The tax serves as a price signal to carbon intensive sectors and firms within those sectors. (ERC, 2007).

The South African tax has its theoretical underpinnings in the need to internalise the negative externality of emissions and thereby supporting a structural transition of the national economy towards a more climate resilient and less carbon intensive economy. Both the National Development Plan and South Africa’s Green Economy Accord (DED, 2011) highlight that this economy will also be more labour intensive.

Lastly, it is hoped that making an “early move” (National Treasury, 2013:16) will provide a competitive advantage to South Africa in accessing new markets that may be about to implement BCAs.

Key design features of the proposed tax include:

* The tax is effectively a fossil fuel input tax levied on Scope 1 emissions – emissions that result from fuel combustion, gasification and non-energy industrial processes.
* The tax is levied at R120/tCO2-eq, with implementation proposed to commence in 2016, and is set to increase by 10 per cent per annum over the first five years (R175.69 in 2020).
* The tax is applied to the six greenhouse gases accounted for by the UNFCCC (CO2, CH4, N2O, PFCs, SF6 and HFCs) although no SF6 or HFC emissions are reported by South African firms.
* Every sector is provided with a basic exemption of 60 per cent of their emissions during the initial five years, but specific sectors may qualify for further exemptions (up to a maximum of 90 per cent) as a result of their structural or technical inability to cut emissions, Z-factor allowance as recognition for best performance of firm within the sector, trade exposure exemptions and *via* carbon offsets. The 60 per cent threshold and the exemption categories are to be reviewed after the initial 5-year phase. It should be noted that the full marginal tax of R120/tCO2-eq is levied on the non-exempted portion of the emissions.
* In the initial 5-year window it is proposed that agriculture, forestry, waste handling and land-use activities receive an additional 40 per cent exemption, thereby rendering them 100 per cent exemption from the tax. The cement, iron and steel, aluminium and glass sectors are listed as among potential sectors qualifying for a 10 per cent exemption on top of the blanket 60 per cent exemption, due to the inherent structural/ technical difficulty these sectors are expected to confront in reducing emissions.
* To protect the international competitiveness of South African industry and to prevent carbon-leakage through the relocation of firms, a further exemption of up to 10 per cent is available to “trade-exposed” sectors. Trade-intensive industries are defined as those industries in which exports and imports combined are more than 40 per cent of domestic output. In the initial 5-year window, aluminium, iron, glass, ceramics and sugar are among the sectors that might receive up to 10 per cent additional exemption in the initial period.
* Further reductions in tax exposure of either 5 per cent or 10 per cent are possible through carbon offsets, depending on the sector in which a firm operates. The details of offset arrangements are outlined in a draft offsets paper released for public comment in April 2014 (National Treasury, 2014).
* The maximum tax-free threshold (including the offsets and possible adjustments to the basic 60 per cent tax-free threshold for carbon intensity) is limited to 90 per cent, except for those sectors (forestry, agriculture, land-use and waste) that have been completely excluded during the first 5-year period.
* Revenue from the proposed tax will be recycled *via* the national fiscus. In keeping with the National Treasury’s strategy of retaining fiscal flexibility, the carbon tax policy paper does not make specific commitments with regards to how the revenue would be recycled, although it lists a number of recycling and tax shifting options. It is, however, the intention to use the revenue generated to support the structural transition towards a low carbon economy, to protect poor households from the impact of energy price increases and stimulate the green economy. It is beyond the scope of this paper to model the effects of the carbon tax on income distribution or poverty.

The proposed introduction of the carbon tax constitutes a fiscal shock, complete with relative economic “winners and losers”. Anticipating the different impacts and distributional effects is one of the outcomes of the modelling exercise and crucial to the effective implementation of the carbon tax.

#### Design of the specific tax policy shocks

All policy scenarios modelled are based on carbon taxes being imposed on all industries that use coal, gas (including both Liquefied Petroleum Gas (LPG) and natural gas) and petroleum in the production process. In 2016 the Rand per Terrajoule (R/TJ) tax rates on these fuels equivalent to a carbon tax of R120/tCO2-equiv. is R11,472/TJ on coal, R7,647/TJ on gas and R8,707/TJ on petroleum. These are the rates that apply before taking into account the various exemptions.

We firstly impose the carbon tax on greenhouse gas emissions, taking into account all the suggested exemptions as published in the 2013 Carbon Tax Policy Paper. All the industries pay the R/TJ rates on the fuel inputs as indicated above, but the tax base is reduced by the total percentage tax free thresholds (Scenario T1). The tax free thresholds are then gradually removed by 10 percentage points per annum from 2021 onwards on all industries, until all industries pay the full tax. This implies, for instance, that the petroleum industry’s tax rate would take seven years to reach the full rate (from 2021), while the cement industry take eight years, since they respectively have a 70 and 80 per cent exemption initially (Scenario T2).

For the first five years from 2016, the tax rates are increased by 10 percent per annum (as per the 2013 Carbon Tax Policy Paper), and thereafter by the assumed inflation rate, which is 5.5 percent per annum over the forecast period, in both scenarios T1 and T2.

### Comparing the effects of the different tax policy shocks

#### Impact on CO2 (without recycling)

We compare the two sets of tax policy shocks with the baseline forecast by showing the deviations from the baseline in the growth of total CO2 emissions. It is expected that the first tax scenario with the generous exemptions of Table 4 would have the smallest effects on curbing emissions, while the second scenario where all the exemptions are gradually phased out would have the biggest impact on emissions.

In Figure 3 we see exactly these anticipated results: the first set of exemptions has the smallest effect on emissions, while removing all the exemptions has a significant effect: it reduces the increase of emissions by almost 50 per cent. From these results it can be anticipated that the results of imposing the “carbon taxes” (without considering recycling) are likely to reduce CO2 emissions between 38.3 per cent if all exemptions are in place, and 50 per cent by the end of the forecast period if all exemptions are gradually phased out.

**Figure 3: Cumulative percentage change in CO2 emissions as a result of taxes on fuel inputs (deviation from baseline)**

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#### Impact on GDP (without recycling)

In Figure 4 the blue line shows that with the implementation of the carbon tax, but with the 60-100% exemptions on the various industries over the forecast period, total real GDP will decrease by 6.4 per cent, relative to the baseline, by 2035. When the exemptions on all industries are phased out from 2022 (purple line), then the total real GDP will decrease by 13.7 per cent over the forecast period, relative to the baseline.

**Figure 4: Cumulative percentage change in real GDP as a result of taxes on fuel inputs (deviation from baseline)**

#### Sectoral impact (without recycling)

In this section we compare the industry effects of the tax scenario where all the exemptions are phased out on all industries. In Figure 5 we show the respective sectoral impacts of the fuel input tax and discuss some of the results.

The biggest impact on production among the industries is on CoalGen, the industry that produces electricity from coal. This is to be expected because coal forms almost 70 per cent of the industry’s intermediate input costs and coal is taxed as one of the four fuel inputs. The next four sectors that are detrimentally impacted on are Petroleum Refineries, Coke Oven, Other Manufacturing and Iron and Steel. The first two are also quite easy to explain because they use large amounts of coal and crude gas as inputs into their production processes – Petroleum Refineries use 15.5% coal and 18.4% crude gas as intermediate inputs, and Coke Oven uses 28.7% coal and 14.1% crude gas. The reason why Iron and Steel and Other Manufacturing are amongst the biggest losers can be found in Figure 6. The carbon tax increases the costs of all industries and hence drives a wedge between South African prices and that of the rest of the world. Our industries become less competitive and lose foreign market for their outputs as they become more expensive. Figure 6 shows that exports of both industries decline by about 30 per cent over the forecast period.

**Figure 5: Industry results of the implementation of a fuel input tax in per cent change deviation from the baseline and with all the tax exemptions phased out except for the agricultural industries (policy set 2)**

**Figure 6: Cumulative percentage change in exports of Iron and Steel and Other Manufacturing (deviation from baseline)**

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### Design of the tax recycling schemes

South Africa, in line with its fiscal management policy, will not be ring-fencing the carbon tax revenue for specific projects or sectors. However, a number of recycling initiatives have been highlighted in the policy paper where the carbon tax revenue could be channelled. The modelling approach used here supports South Africa’s planned recycling strategy by identifying those sectors and socio-economic classes that are most likely to be adversely affected by the tax. The model is expected to assist decision makers in striking an appropriate balance between environmental and economic goals.

Similarly, the National Treasury is committed to using the carbon tax revenue in a manner that prevents an exacerbation of South Africa’s existing socio-economic inequality, and the model serves as a useful tool in suggesting the extent to which, and how this might be done.

In the results presented above fuel input taxes were shown as being levied on all industries when they use fuels as inputs in their production processes, but there was no recycling of the tax revenue back into the economy. This is a very unrealistic scenario, because it would not happen in reality that the government levies taxes but does not spend the revenue. The economic effects of such an unrealistic scenario is that total demand in the economy would shrink (the taxes are leakages from the economic system that are not injected back in, resulting in an increase in government surpluses), resulting in a general price decrease (deflation) and lower costs of production. Exports will usually benefit from such economic conditions. Although the revenue collected would not be earmarked for specific expenditures, it is important to choose different channels of revenue recycling in the model and study the different outcomes that the various channels would result in.

UPGEM is not a macroeconomic model with elaborate government accounts in it. The government revenue and tax system in the model is primitive, because the model specialises in determining the prices and quantities of industry production of various commodities in its quest to search for new equilibriums after certain shocks have been applied to the model. We apply the recycling of revenue through subsidies or lower taxes on industries or commodities in the model, thereby affecting the price system, rather than on higher levels of spending by the government. We model two different recycling schemes, namely by decreasing:

1. the VAT rate on industries and households, and
2. the power of the tax on intermediate sales to the green electricity generators and the electric machinery industry.

When the tax revenue is not recycled, the government runs into a large budget surplus (or a decrease in the deficit). The recycling is effected by keeping the budget surplus (or deficit) fixed at the same level as in the baseline, while allowing one of the two tax variables mentioned above to adjust accordingly.

### Comparing the effects of the two recycling schemes

#### The effects of the various recycling schemes on real GDP growth

Figure 7 shows the deviations in real GDP growth from the baseline as a result of the general tax recycling scheme. With the said fall in total demand when tax revenue is not recycled, the real GDP falls much below the baseline, as depicted in Figure 5 above. When the revenue is recycled, however, we would expect the size of the deviation from the baseline to decrease, as the recycling is stimulating some part of the economy. Figure 7 shows three lines for real GDP deviation from the baseline for the two no recycling cases and the general recycling scenario discussed above.

**Figure 7: Cumulative % change of the impact of imposing carbon taxes on the real GDP of the no-recycling scenarios compared to five recycling scenarios**

The results are largely in line with expectations. Recycling through a reduction in the general tax on production takes real GDP almost back to the baseline (brown line). GDP is effected most negatively with the introduction of a new tax without exemptions (purple line); it is effected less severely if the tax is gradually implemented (blue line), and effected the least when the revenue is recycled again.

#### The effects of the two recycling schemes on carbon emissions

In Figure 7 the effects of recycling are shown on real GDP growth, relative to the baseline. Although it is important to have a feel for the general effects of recycling schemes, we are particularly interested in this study on the “negative” effects of the recycling schemes on carbon emissions, i.e. mitigating the effect of the tax without recycling and hence suppressing the deviation in CO2 reduction from the baseline as reported on earlier. The carbon tax does very well, as seen above, to curb emissions, but when we recycle the revenue, the economy is stimulated again and production in some industries increases.

Just like the more general recycling schemes would affect GDP more than specific taxes levied on a small tax base, we would expect that they would also affect CO2 emissions more. Recycling the tax revenue to industries that generate low carbon electricity should not undo the good effects of the tax on carbon emissions, while a general stimulation of the economy should have a much larger effect. We see exactly this happening in Figure 8.

With no recycling of tax revenue, the total level of carbon emissions ends up 50.1 per cent below the baseline level, while recycling through a general tax on production decreases this effect to 40.7 per cent below base. Recycling the revenue through a subsidy on green electricity generation maintains the initial positive result by changing emissions only slightly, to 52.5 per cent below the baseline.

**Figure 8: Cumulative percentage change in carbon emissions of the no-recycling scenarios compared to three recycling scenarios (deviations from the baseline)**

#### The effects of the various recycling schemes on green electricity generation

The penultimate effect that we would like to highlight in this section is the effect of recycling tax revenue on the production levels of green, or renewable, electricity. In Figure 9 we show the increase in the level of production of Solar PV electricity above the baseline when we (i) levy a carbon tax but do not recycle the revenue (bottom line) and (ii) when we recycle the revenue through a subsidy on green electricity production. All the other recycling scenarios have very small effects on green generation – so small that the lines lie close to or on top of the no recycling line. The effects of this recycling scenario are enormous on green generation: without recycling the tax revenue Solar PV generation grows by 291 per cent above the baseline, while with the subsidy on this section of industries, the output of Solar PV grows by 376 per cent. The other green generators look very similar.

**Figure 9: The effects of recycling carbon tax revenue through a production subsidy on the production of all green electricity generators**

#### Impact of taxes on the Iron and Steel industry, with and without recycling

The last set of impacts that we would like to highlight in this section is the effect of the various recycling schemes on the Iron and Steel industry. The tax with all the exemptions phased out over the forecast period causes the industry to decline by 39.5 per cent in 2035, but if the tax revenue is recycled through a general subsidy on all production in the economy, the impact is significantly reduced to 24.2 per cent (green line in Figure 10). An insightful result is that when recycling takes place through a production subsidy on green generators, the Iron and Steel industry is still severely affected by the tax (purple line). Iron and Steel is electricity intensive and the whole sector becomes much more expensive with the implementation of the tax.

**Figure 10: Per cent change in Iron and Steel production with the fuel input tax and various recycling options (all tax exemptions in place) (deviation from baseline)**

# Conclusion and Policy Recommendations

Here we used a 53-sector dynamic computable general equilibrium (CGE) model developed by the University of Pretoria, Department of Economics to model the impacts of the national Treasury’s proposed carbon tax which equates to R120/tCO2-equiv. subject to a set of sector-specific exemptions.

Baseline emissions rise from 564MtCO2-equiv. for 2011 to 1,236MtCO2-equiv. for 2035 – an increase of 672Mt over the baseline period. Introducing the tax caused a reduction in CO2-emission growth by between 35 and 44 percent under different scenarios. These scenarios imply a cumulative reduction of between 1,900MtCO2-equiv. and 2,300MtCO2-equiv. relative to the baseline over the 2011-2035 modelling period, with the single biggest (annual) reduction of between 190 and 250MtCO2-equiv being in 2035. The planned exemptions on the carbon tax to various industries erode the positive effects on emissions significantly and we would therefore like to recommend that the government phases them out faster than planned.

All the tax and recycling scenarios, however, reduce GDP growth. The range of cumulative reduction (between 2016 and 2035) varies being between 1.5 and 6.5 percent. This range is much less than the reduction in CO2-emissions mentioned above, implying the CO2-emissions reductions effect outstrips that of the negative GDP-effect by several orders of magnitude. If the revenue is recycled through a subsidy on all industry production then the negative effects of the carbon tax on GDP growth is minimised. The more production-orientated and the broader the recycling base, the better the recycling scheme is for the economy compared to narrow and/or consumption/welfare orientated recycling schemes.

The production of fossil-fuel intensive sectors is affected most by the carbon tax, as can be expected since that is the focus, or objective, of the policy instrument. Total exports decrease as a result of the carbon tax due to a reduction in South Africa’s competitiveness, but this result does not assume adoption of carbon pricing by South Africa’s main trading partners. Iron and Steel and Other Manufacturing are the worst affected, and their exports could be lower than the baseline level by as much as 50 percent. Other traditionally export-orientated industries, such as Other Metal Equipment, are lower than the baseline level by much less (17%), while Other Mining is lower by 3 percent.

The method of recycling chosen by the government is crutial for the macroeconomic and industry results. Recycling through a subsidy on green energy (obviously) results in higher levels of energy produced through this technology, while recycling through a decrease in the general VAT rate is much better for the Iron and Steel and other export oriented industries. It makes these industries more competitive in world markets since a lower VAT rate lowers the production price indices. Our recommendation is that the government should not only try to protect certain industries through tax exemptions, but should also consider various recycling methods which might be more efficient in terms of the effects on the environment and economy.

Carbon pricing can contribute to South Africa’s efforts to reduce its anthropocentric carbon dioxide emissions, but, in and by itself, it is unlikely to be sufficient to achieve any of the stated government objectives, and/or to honour the voluntary Peak-Plateau-Decline commitments made (DEA 2011a and b). This implies that should South Africa embark on a carbon pricing strategy that it will have to adopt further measures as well to achieve such objectives. Reducing the country’s carbon footprint implies a package deal with multiple instruments.

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**APPENDIX A. Summary of the energy database used in the CGE model.**

Table A1: Energy consumption (in TJ) by fuel and effective tax rate (R/TJ) by fuel and per sector after making provision for the tax free exemption thresholds.

|  |  |  |
| --- | --- | --- |
|  | **Fuel consumption (TJ) (2011)** | **Effective tax rate (R/TJ) (2016)****(after applying the tax free thresholds)** |
| **Coal** | **Gas** | **Petroleum** | **Total** | **Coal** | **Gas** | **Petroleum** |
| **SIC1 – AGRICULTURE** |
| Agriculture | 289 | 27 027 | 36 439 | **63 755** | 0 | 0 | 0 |
| Forestry | - | 3 293 | 4 426 | **7 719** | 0 | 0 | 0 |
| Fishing | - | 354 | 499 | **853** | 0 | 0 | 0 |
| **SIC2 – MINING** |
| Coal mining | 589 | 31 070 | 18 013 | **49 671** | 2 294 | 1 529 | 1 741 |
| Metal ores extraction | 16 606 | 8 410 | 7 295 | **32 311** | 3 442 | 2 294 | 2 612 |
| Crude gas extraction | 1 186 | 1 773 | 478 | **3 436** | 3 442 | 2 294 | 2 612 |
| Other mining | 36 195 | 54 108 | 14 577 | **104 880** | 3 442 | 2 294 | 2 612 |
| Electric energy and gas | 14 737 | 6 | 327 | **15 070** | 3 442 | 2 294 | 2 612 |
| **SIC 3 – MANUFACTURING** |
| Food | 2 512 | 1 163 | 28 | **3 703** | 3 442 | 2 294 | 2 612 |
| Beverages and tobacco | 391 | 21 | - | **412** | 3 442 | 2 294 | 2 612 |
| Textiles and footwear | 1 285 | 410 | - | **1 695** | 3 442 | 2 294 | 2 612 |
| Wood and paper | 921 | 128 | 26 | **1 075** | 3 442 | 2 294 | 2 612 |
| Print and publication | 2 057 | 5 936 | 1 068 | **9 061** | 3 442 | 2 294 | 2 612 |
| Coke Oven | 62 454 | 94 566 | 1 358 | **158 378** | 3 442 | 2 294 | 2 612 |
| Petroleum refineries | 145 726 | 535 866 | 5 428 | **687 019** | 3 442 | 2 294 | 2 612 |
| Nuclear fuels | 1 299 | 22 789 | 4 806 | **28 893** | 3 442 | 2 294 | 2 612 |
| Chemical | 6 197 | 108 714 | 22 925 | **137 836** | 2 294 | 1 529 | 1 741 |
| Rubber | 928 | 213 | 965 | **2 106** | 2 294 | 1 529 | 1 741 |
| Plastic | 185 | 1 705 | 224 | **2 114** | 2 294 | 1 529 | 1 741 |
| Glass | 291 | 6 395 | - | **6 686** | 2 294 | 1 529 | 1 741 |
| Cement | 8 163 | 16 364 | 78 | **24 604** | 2 294 | 1 529 | 1 741 |
| Other non-metal | 8 843 | 18 452 | 87 | **27 383** | 2 294 | 1 529 | 1 741 |
| Iron and Steel | 131 276 | 57 824 | 108 953 | **298 053** | 2 294 | 1 529 | 1 741 |
| Other metal equipment | 9 001 | 50 119 | 13 294 | **72 414** | 3 442 | 2 294 | 2 612 |
| Electricity machinery | 128 | 102 | 2 066 | **2 297** | 3 442 | 2 294 | 2 612 |
| Radio and TV | 19 430 | 20 726 | - | **40 156** | 3 442 | 2 294 | 2 612 |
| Transport equipment | 7 | 272 | 5 | **284** | 3 442 | 2 294 | 2 612 |
| Furniture | 2 121 | 1 444 | - | **3 565** | 3 442 | 2 294 | 2 612 |
| Other manufacturing | 1 165 | 133 334 | 1 064 | **135 562** | 3 442 | 2 294 | 2 612 |
| **SIC 4 – ELECTRICITY, GAS AND WATER** |
| Coal-fired power gen | 2 412 161 | - | 39 985 | **2 452 146** | 4 589 | 3 059 | 3 483 |
| Nuclear power gen | - | - | 2 496 | **2 496** | 4 589 | 3 059 | 3 483 |
| Wind power generation | - | - | 252 | **252** | 4 589 | 3 059 | 3 483 |
| Hydro power generation | - | - | 3 505 | **3 505** | 4 589 | 3 059 | 3 483 |
| Solar PV power gen | - | - | 504 | **504** | 4 589 | 3 059 | 3 483 |
| Solar CSP power gen | - | - | 252 | **252** | 4 589 | 3 059 | 3 483 |
| Gas power generation | - | 1 168 | 504 | **1 673** | 4 589 | 3 059 | 3 483 |
| Other generation | 12 120 | - | 2 496 | **14 616** | 4 589 | 3 059 | 3 483 |
| Electricity distribution | - | - | 12 492 | **12 492** | 4 589 | 3 059 | 3 483 |
| Water | 12 710 | 48 | 388 | **13 146** | 3 442 | 2 294 | 2 612 |
| **SIC 5 CONSTRUCTION** |
| Construction | - | 6 888 | 10 509 | **17 397** | 3 442 | 2 294 | 2 612 |
| **SIC 6 WHOLESALE & RETAIL TRADE AND HOTEL & RESTAURANT SERVICES** |
| Trade | - | - | 44 780 | **44 780** | 3 442 | 2 294 | 2 612 |
| Hotel and restaurants | 3 029 | 248 | 2 804 | **6 082** | 3 442 | 2 294 | 2 612 |
| **SIC 7 TRANSPORT, STORAGE AND COMMUNICATION SERVICES** |
| Transport services | 12 110 | 17 034 | 782 716 | **811 860** | 3 442 | 2 294 | 2 612 |
| Post and Tele-communication services | 411 | 578 | 26 556 | **27 545** | 3 442 | 2 294 | 2 612 |
| **SIC 8 FINANCIAL AND BUSINESS SERVICES** |
| Financial services | - | - | 16 391 | **16 391** | 3 442 | 2 294 | 2 612 |
| Insurance services | - | - | 1 874 | **1 874** | 3 442 | 2 294 | 2 612 |
| Other financial services | - | - | 978 | **978** | 3 442 | 2 294 | 2 612 |
| Real estate | - | - | 30 498 | **30 498** | 3 442 | 2 294 | 2 612 |
| Other business services | - | - | 17 275 | **17 275** | 3 442 | 2 294 | 2 612 |
| **SIC 9 COMMUNITY, SOCIAL AND PERSONAL SERVICES** |
| General government | 6 025 | 3 067 | 12 737 | **21 828** | 3 442 | 2 294 | 2 612 |
| Education | 62 | 277 | 421 | **760** | 3 442 | 2 294 | 2 612 |
| Health | 3 109 | 13 873 | 21 013 | **37 995** | 3 442 | 2 294 | 2 612 |
| Other services | 462 | 3 916 | 5 962 | **10 340** | 3 442 | 2 294 | 2 612 |
| **Total** | **1 804 330** | **2 055 578** | **1 607 768** | **5 467 676** |  |  |  |

**Appendix B: Nested production structure in modified UPGEM**



Industry output in modified UPGEM

--up to--

Intermediate

composite good 1

Domestic good 1

Imported good 1

CES

Output or input

--up to--

Labour

type 1

Labour

type 11

Leontief

Capital

Labour

Land

Intermediate

composite good 44

Composite

primary factors

CES

Domestic good 52

Imported good 52

CES

CES

CES

Generation

type 1

Generation

type 8

Electricity composite good factors

1. Taiwan General Equilibrium Model [↑](#footnote-ref-1)
2. To represent both LPG and natural gas. [↑](#footnote-ref-2)
3. This paper was an update of a December 2010 paper on the same topic. [↑](#footnote-ref-3)