PARTNERSHIP FOR MARKET READINESS

COUNTRY PAPER | SEPTEMBER 2016

Modeling the Impact on South Africa's Economy of Introducing a Carbon Tax

PARTNERSHIP FOR MARKET READINESS

Modeling the Impact on South Africa's Economy of Introducing a Carbon Tax

WORLD BANK GROUP

Contents

Figures

Tables

Acknowledgements

The Report "Modeling the Impact on South Africa's Economy of Introducing a Carbon Tax" was commissioned by the PMR Secretariat for the National Treasury of South Africa to support the preparation of South Africa's Market Readiness Proposal.

This report was prepared by John Ward and Gaia de Battista from Vivid Economics based on the findings and outcomes of the research which had been conducted by Jan van Heerden, Heinrich Bohlmann, James Blignaut, Anton Cartwright, Myles Mander and Nicci Diederichs from FutureWorks and the University of Pretoria.

Executive Summary

This paper reviews the key findings of a modeling analysis exploring the implications of the South African carbon tax. A carbon tax, in conjunction with the recycling of revenues, has been designed by the National Treasury as one of the key mitigation instruments in helping South Africa meet its international commitments to reduce its greenhouse gas (GHG) emissions by 42 percent relative to business-as-usual by 2025 and for emissions to follow a 'peak plateau and then decline' trajectory. The carbon tax is also expected to support a structural change in the South African economy and preemptively avoid any risks to the economy that might arise from its trade partners introducing Border Carbon Adjustments. The modeling work reported in this paper differs from earlier analyses of the possible impact of a carbon tax in South Africa by more closely reflecting the actual design features of the tax proposed by the National Treasury.

The analysis suggests that the carbon tax will have a significant impact in reducing the country's emissions. The results of the simulations show that the tax policy would lead to an estimated decrease in emissions of 13 to 14.5 percent by 2025 and 26–33 percent by 2035 compared with business-as-usual. This suggests that the policy would make an important contribution towards reaching the 42 percent reduction by 2025 target,[1] but would need to be complemented by additional policies if this target is to be met. Alternatively, a higher carbon tax rate than currently envisaged could be adopted.

These emissions reductions are delivered while realising sustained growth in the economy. The carbon tax is expected to lead to a reduction in the annual average growth rate of the economy of just 0.05–0.15 percentage points compared to business-as-usual. In other words, instead of the economy growing at 3.5 percent per year, it grows at 3.3–3.4 percent per year. This means that GDP in 2035 could be between 1 and 3 percent lower than in a situation in which the carbon tax is not introduced. Sensitivity analysis shows that the carbon tax would have a similar modest impact even if the economy is expected to grow at a lower medium-term growth rate of 2.4 percent per year.

The carbon tax also has a small impact on other macroeconomic aggregates such as employment, consumption and real wages. These variables provide some proxy for the distributional impacts of the tax, which has been a key consideration in the design of the tax. In the 'focus scenario',[2] the annual growth rate in household consumption falls by just 0.23 percentage points, from 3.2 percent to 2.9 percent. Annual growth in the rate of employment falls by just 0.07 percentage points, while the growth rate in real wages falls from 0.6 to 0.4 percent per year.

1 It is important to note, however, that the baseline assumptions and model used here differ from those used in other official government analyses.

2 The study focuses on a particular tax and recycling combination which closely resembles the design proposed by the National Treasury: the tax scheme and proposed tax-free allowances are applied to all sectors and removed at a rate of 10 percentage points per annum while the recycling scheme used is an output-based rebate on all production. While the recycling scheme does not exactly mirror the recycling option proposed by the National Treasury in November 2015 release (South Africa National Treasury, 2015), it is an approach which recycles the revenues broadly across many actors in the South African economy as some elements of the proposed November 2015 recycling measures also do.

Consistent with the carbon tax's objective of promoting structural change, there are a number of important sectoral winners and losers from the tax. In 2035, the output from the nuclear generation, wind generation, hydro generation, other generation, gas generation and solar photovoltaic (PV) generation sectors is expected to be more than 200 percent greater than without a carbon tax. This reflects the basic intuition that these low—and zero-carbon sources of power become much more cost competitive with a carbon tax. At the same time, coal generation becomes much less cost-competitive and, as a result, its output is 46 percent lower in 2035 than it would be without the tax. Other sectors that see a substantial decline in output relative to the baseline include petroleum refining, other manufacturing, coke production and the electricity supply sector. It should, however, be stressed that this is a *relative* decline in output compared with the situation in which there is no carbon tax; all of these sectors are projected to grow in absolute terms between 2014 and 2035—by between 18 (coal generation) and 105 percent (other manufacturing)—even with a carbon tax.

But the vast majority of sectors are largely unaffected by the introduction of the tax. In the focus scenario in 2035, 33 of the 53 sectors modeled in the study (accounting for around 80 percent of the current output of the South African economy) would see a change in output of less than 10 percent per sector as a result of the carbon tax. These include core sectors such as financial services (output increases by 3 percent in 2035 under the carbon tax scenario relative to the baseline); metal ores (output is unchanged in the carbon tax scenario relative to the baseline); and agriculture (output increases by 2 percent in 2035 in the carbon tax scenario relative to the baseline). This reflects both the fact that carbon costs are a relatively small cost driver for many sectors of the economy, and the benefits that many sectors see as a result of the recycling of revenues.

The modeling suggests that concerns over the competitiveness impacts of the carbon tax are overstated. It suggests that exports in 2035 could be 3.5 percent higher with the introduction of the carbon tax. This reflects a combination of the benefits that some sectors get from the recycling of tax revenues, plus some sectors reorienting domestic production to international markets. Certain sectors are materially affected, however. The sectors projected to see notable declines in exports include the coke oven and iron and steel sectors, although in the latter case the sector's exports continue to grow over the period to 2035, just at a lower rate than if there were no carbon tax. The challenging export conditions for some sectors should also be seen in the context of the strong benefits for other sectors: the transport equipment, electrical machinery, and textiles and footwear sectors are all expected to see increases in the annual growth rate of exports of around 7 percent as a result of the carbon tax plus revenue recycling, leading to their exports in 2035 being around 30–40 percent higher than in the baseline.

By not phasing out the tax-free allowances built into the early phases of the carbon tax design, the carbon tax would be substantially less environmentally effective, although it would also mean that the already modest impact on the macroeconomy would be even smaller. In the focus scenario results discussed above, the tax-free thresholds in the 2016–20 period are gradually phased out from 2021. If these tax-free thresholds were to persist between 2021 and 2035 then the emission reductions delivered by the carbon tax would fall significantly: from 33 percent below the business-as-usual baseline to just 26 percent. At the same time, without the phaseout of tax-free allowances, the level of GDP in 2035 is 1 percent lower than in the baseline, compared with 3 percent in the case where the tax-free allowances are phased out.

The method of revenue recycling is also an important driver of the results. In the focus scenario, revenues are assumed to be recycled through a broad-based rebate on production for all sectors. The modeling shows that if revenues were recycled in a narrow way—in the case modeled, by providing all revenues as subsidies to the solar industry—then the abatement impact delivered by tax would be much stronger (emissions in 2035 would be 46 percent lower than the baseline, compared with 33 percent in the focus scenario). However, the impact on economic performance would be much greater (the change in annual economic growth would be 2.7 percent rather than 3.3 percent under the focus scenario). The current plans of the National Treasury for recycling revenues combine elements of broad-based recycling (a reduction in the electricity levy) with additional targeted support for certain sectors that are important for the structural transformation of the South African economy (a credit for the premium charged for renewable energy).

Introduction

Motivation for and approach to modeling the impact of a carbon tax

In 2009, at the UNFCCC Conference of the Parties (COP) in Copenhagen, South Africa made a voluntary commitment to reduce its greenhouse gas (GHG) emissions by 34 percent in 2020 and 42 percent in 2025 relative to business-as-usual. This was part of a wider commitment by South Africa to contribute to the global effort in mitigating anthropogenic climate change and to transition to a green economy. This was reaffirmed in its intended nationally determined contribution (INDC) submission to the UNFCCC, in advance of COP 21 in Paris in 2015, which envisages that emissions will peak by 2025 and plateau for approximately a decade, before beginning to decline in absolute terms from 2036 (South African Government, 2015).

The South African government has identified a carbon tax, along with recycling of the revenues raised, as a key policy instrument for contributing to the country's GHG emissions reduction goal. In May 2013 the National Treasury published its 'Carbon Tax Policy Paper: Reducing Greenhouse Gas Emissions and Facilitating the Transition to a Green Economy' (South Africa National Treasury, 2013), which outlines the proposed design for the carbon tax and various revenue recycling options. The tax is designed to provide a price signal to producers and consumers of carbon intensive products, creating an incentive to invest in cleaner technology and reduce emissions. It is also intended to facilitate a smooth transition to a low carbon economy (structural reform) in South Africa, and preempt any possible impacts on trade with countries that may implement Border Carbon Adjustments.

The design of the carbon tax is intended to balance South Africa's mitigation goals with the need to reduce poverty and maintain trade competitiveness. While providing a price signal to encourage the transition to a low-carbon economy, the proposed policy is also intended to reduce the risk of negative competitiveness implications and leakage through special provisions for sectors considered to be at risk. In addition, it is proposed that revenues raised from the tax be recycled back into the economy to help address any potential negative impacts on the welfare of poorer households.

Specifically, the key features of the proposed tax policy, as laid out in the Carbon Tax Policy Paper 2013 and subsequent documentation, are the following:

- the tax is to be levied on Scope 1 emissions—these are emissions that result from fuel combustion, gasification and nonenergy industrial processes;
- the tax will be levied at R120/tCO_2-equiv starting in 2016;
- the tax rate is set to increase by 10 percent per annum over the first five years (to reach R175.69 in 2020);
- a 60 percent basic tax-free allowance will apply to all sectors during the first five years;

- a further tax-free allowance of up to 10 percent is available to firms in 'trade-exposed' sectors;
- a further 10 percent tax-free allowance will be provided to firms in sectors where there is a structural or technical inability to make reductions (i.e. process emissions);
- firms will be able to use domestic offsets in relation to 5 or 10 percent of their gross tax liability (i.e. before the impact of exemptions);
- full exemption during the initial five-year period has been proposed for the agriculture, forestry and other land use activities as well as waste management sectors;
- a 'Z-factor' will be introduced which will reward firms that have lower emissions relative to others in the same sector, with a further tax-free allowance of up to 5 percent;
- an additional 5 percent tax-free allowance will be available to companies participating in the carbon budget process (a detailed overview of this is provided below); and
- revenue from the tax will be recycled to support the transition to a low-carbon economy and to protect poorer households and vulnerable sectors from the impact of energy price increases.

In November 2015, the media statement accompanying the Draft Carbon Bill identified more specifically how the revenue raised by the carbon tax would be recycled. It outlines the following measures (South Africa National Treasury, 2015):

- funding for the energy efficiency tax incentive already being implemented;
- a reduction in the electricity levy;
- additional tax relief for roof top (embedded) solar PV energy as already provided for the in 2015 tax legislation;
- a credit for the premium charged for renewable energy (wind, hydro and solar, as per the Integrated Resource Plan);
- additional support for free basic electricity to low-income households; and
- additional allocations for public transport.

It also confirms that measures to encourage the shift of some freight from road to rail will be supported.

Modeling the impacts of the carbon tax can aid in the decision making process by informing policy design and increase understanding of the likely implications for key stakeholders. While modeling studies examining the impact of a possible carbon tax study in South Africa have been undertaken in the past (Alton et al., 2012; Devarajan, Go, Robinson, & Thierfelder, 2009; Pauw, 2007; van Heerden et al., 2006), these have not been closely aligned with the specific design outlined in the National Treasury's 2013 paper. This study aims to address this gap by simulating the effect of the proposed tax design as accurately as possible[3] and hence provide a stronger evidence base to inform debate and discussion about the policy, especially its likely impact on macroeconomic aggregates such as GDP, consumption and exports. It can also provide insights into the advantages and disadvantages of different approaches to the detailed design of the policy, including the method of revenue recycling and the speed at which any tax-free allowances

3 It has not been possible to reflect every aspect of the proposed carbon tax design in the modeling approach, but most key design aspects are captured.

are reduced or removed. However, it should be noted that the specification of the model does not allow as wide a consideration of different revenue recycling options as have been considered in the South African policy debate.

The carbon tax is only one of a number of instruments being designed to address South Africa's emissions; in particular, the Department of Environmental Affairs (DEA) is also developing 'company level carbon budgets'. A carbon budget is envisaged to be a GHG emissions allowance (i.e. cap), against which physical emissions arising from the operations of a company during a defined time period will be tracked. This modeling exercise considers only the likely impacts of the carbon tax and does not consider the carbon budgets.[4] In the period before 2020, the carbon budget will not be a compliance instrument, while beyond 2020 the precise way in which they will operate, and their interaction with the carbon tax, is yet to be defined. As such, the modeling work does not consider what impact the carbon budgets may have on South Africa's emissions, or how the carbon tax and carbon budgets will interact.

4 Subsequent to the modelling analysis being undertaken, a decision was reached that an additional 5 percent tax-free allowance towards a company's carbon tax liability is provided to help encourage providing information to inform carbon budgets in the period up to 2020. This is not reflected in the modelling.

Methodology and Design

A number of policy and recycling scenarios were used in the modeling

The model

The study uses the University of Pretoria General Equilibrium Model (UPGEM)—a dynamic general equilibrium model of the South African economy. This model provides a quantitative description of the South African economy, and is able to account for linkages and interactions between the various sectors and agents within the economy. The standard UPGEM used in this study was slightly modified in order to be able to conduct a detailed analysis of the impact of the tax on the electricity generation mix and emissions. As a result, this model incorporates 53 industry sectors, including renewable power producers.

General equilibrium models such as UPGEM have both advantages and disadvantages in terms of analysing the impacts of policies. Models of this type work ('close') by assuming that producers minimise costs while consumers maximise utility, and that in equilibrium the markets will clear. This framework allows for an understanding of the whole economy impact of policies while accounting for interactions both between sectors, and between product markets and factor markets (so-called 'general equilibrium' impacts). As such, it provided a comprehensive methodology for undertaking economy-wide policy analysis The explicit ability to capture impacts over different time periods and to look at the results for individual sectors is also a useful feature of this modeling approach. However, due to the data requirements involved, most computable general equilibrium (CGE) models, including models like UPGEM, are not able to analyse the detailed competitive interactions that might result from a carbon tax within a particular sector or market—for example, what types of firm will be more or less affected by the carbon tax.

The modeling analysis relies on a comparison between a baseline scenario and various 'policy scenarios'. In order to measure the impacts of introducing the carbon tax on the economy, a business-as-usual, or baseline scenario is established. The baseline is then compared with the expected evolution of the economy when a particular form of carbon tax and revenue recycling scheme is introduced. The difference in the evolution of the economy between the baseline and each policy scenario is informative of the impact of different tax designs. The subsections below provide more detail on these scenarios.

Baseline scenarios

The baseline scenario is a plausible evolution of the economy without the introduction of the carbon tax, based on the currently available data; two baselines are used in the analysis to understand whether and how a change in the baseline affects the expected impact of the tax. The baselines are based on a combination of historical trends plus generally accepted macroeconomic forecasts of South Africa's economy from specialists. The main results are presented against a baseline scenario of annual GDP growth of 3.5 percent from 2016 onwards, constant inflation at 5.5 percent, and population growth of 1 percent per year. This baseline was based on GDP forecasts produced by CEPII,[5] inflation within the Treasury's target range, and steady state employment (based on information in 2014). In addition, the analysis explores how a more conservative baseline affects the expected impact of the tax. In the alternative baseline (based on more recent estimates), the economy grows at a more modest rate of 2.4 percent per year between 2018 and 2035. The population growth rate is unchanged from the original baseline of 1 percent per year. A table of assumptions used in both baselines is provided in the appendix.

The method of baseline construction means that relatively little attention should be given to what modeling analysis suggests the absolute level of emissions in the South African economy will be, with or without a carbon tax; rather, attention should focus on what *change* in emissions will result from the tax. There are two important features of both baseline scenarios.

- 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. It is also assumed that the ratio of each electricity generation technology relative to total electricity generation remain fixed in the baseline relative to 2014 values.
- Economy-wide CO_2 emissions are assumed to increase in line with GDP. This is different from other forward looking projections of emissions in South Africa without a carbon tax. For example, in the 'SO Low' scenario in the Integrated Resource Plan (IRP) Update Report (Department of Energy (South Africa), 2013), developed through a different modeling approach, emissions reductions are achieved through changing the energy mix in the electricity sector, *without* the introduction of a carbon tax. This implies that, even before considering the impact of a carbon tax, the actual generation mix and build programme could be very different than that specified in the baselines for this study. Similarly, the Department for Environmental Affairs' 'With Existing Measures' (WEM) scenario (DEA, 2014), excluding a carbon tax, identifies an emissions level of 1,000 $MTCO_2$-equiv compared with the 1,220 $MTCO_2$-equiv[6] in the main baseline scenario used in this study.

While the modeling approach adopted in this paper provides a valuable perspective that allows understanding of the impact of the tax on the overall economy in isolation, and the associated behavioural changes it may lead to, the above features mean that little attention should be given to what the modeling analysis suggests will be the absolute level of emissions in the South African economy after the introduction of the carbon tax. Any such estimates will be partly determined by expectations of what emissions will be without the carbon tax, with other modeling approaches suggesting that this could be significantly lower than the baseline used in this analysis. The focus should rather be on what the modeling analysis suggests regarding the *change* in emissions delivered by the carbon tax.

Neither baseline scenario takes into account any possible negative impacts from climate change and unabated emissions (the cost of inaction), or some of the benefits from reducing emissions that would not be realised in the baseline. In particular, the fact that air pollution (with its knock on impacts on morbidity), traffic congestion and road safety will all be worse in the baseline scenario than when a carbon tax is introduced, is not taken into account in the model.[7] As such, the policy simulation results should not be viewed as providing an assessment of the overall impact of introducing a carbon tax; it is plausible that they underestimate the benefits of this policy intervention.

5 CEPII is a French research center which produces studies, research, databases and analyses on the world economy and its evolution.

6 The alternative baseline scenario used in this modeling analysis results in emissions of 954 $MTCO_2$-equiv at 2035, which is comparable to the DEA's WEM scenario.

7 For instance, Parry, Veung, & Heine (2015) estimate that these other co-benefits alone, even before considering climate change related objectives, would justify a carbon tax in South Africa of around $10/tonne (2010 prices), equating to around R145/tonne at current exchange rates.

Policy scenario design

The modeling analysis considers multiple options of both tax and recycling policies in combination. In particular, it models four different tax designs in combination with five possible recycling schemes. These are set out below. The tax scenario and recycling mechanism are always modeled together so as to represent the complete impact of the policy package.

Tax policy scenarios

The tax policy options vary according to the speed at which the exemptions are removed and the treatment of emissions from the agriculture sector:

T1 The tax is initially modeled as closely as possible to reflect the proposed design,[8] and with the tax rate increasing by 10 percent per annum over the period 2016–21, and thereafter by the assumed inflation rate (which is 5.5 percent under the main baseline assumptions). In addition, the tax-free thresholds are held constant for the duration of the modeling period 2016–35.

T2 The carbon tax is applied as in T1, but the tax-free allowances are gradually removed at a rate of 10 percentage points per annum from 2021 onwards until all the industries are paying the full tax rate on all their emissions. The agricultural and waste sector, however, are exempt from the carbon tax at all times.

T3 The tax is applied as per T1, except for the agricultural industries where the exemption is removed at a rate of 10 percentage points per annum from 2026.

T4 This is a combination of T2 and T3: the tax is applied as per the National Treasury's 2013 Carbon Tax policy paper, and tax-free allowances are gradually removed at a rate of 10 percentage points per annum, starting in 2021, for all industries except agriculture, for which phasing out begins in 2026.

Revenue recycling schemes

The recycling of revenue from the carbon tax is an integral part of the National Treasury's proposed policy. The study considers five recycling schemes, varying from mechanisms that recycle revenues broadly across the economy, such as a reduction in VAT, to very narrow and focused recycling of revenues such as a subsidy on renewable energy production. While none of these options perfectly matches the preferred approach identified by the National Treasury in November 2015 (South Africa National Treasury, 2015), the wide spectrum of methodologies provides insights into the effect different recycling approaches might have.

R1 Recycling of tax revenues is applied through an output-based rebate on all production across all sectors; thus how much firms receive depends on their own level of production.

R2 This scenario focuses on consumers; the tax revenue is recycled through a decrease in the VAT rate on all the goods that make up household spending.

R3 This is a combination of R1 and R2.

8 Some tax relief measures included in the Carbon Tax design by the National Treasury could not be modeled in this study for technical reasons. These measures are: the proposed Z-factor-based relief of up to 5 percent, a further 5 or 10 percent allowance for the use of offsets, and a possible 5 percent allowance for firms participating in the carbon budget scheme. In addition it should be noted that process emissions are also not modeled here and thus not accounted for in the scenarios.

R4 The recycling of revenue in this scenario is through a subsidy on the production of renewable electricity generators. For modeling purposes, the subsidies are directed at the solar PV sector.

R5 The tax revenue is used to decrease the VAT rate on the four commodities that make up the largest proportion of poor households' consumption: agricultural goods, food, transport services, and beverages and tobacco.[9]

In each of these scenarios the full revenue from the tax is recycled such that the government deficit is unchanged by the introduction of the tax.

9 This is a proxy for the social grants to be given to poor households. We assume that they will spend the funds on the largest items in their consumption baskets. Some of the goods in these groups of commodities may already be VAT exempt.

Modeling Results

Interpretation of the results from running the model

Introduction

The model suggests that the policy could be effective at stemming the growth in the country's GHG emissions, and hence a useful instrument, among others, in helping the country reach its emissions reduction goals. The results of the simulations show that the tax policy would lead to an estimated decrease in emissions of 26–33 percent compared with business-as-usual by 2035. This suggests that the policy would go some way (13 to 14.5 percent) towards reaching the 42 percent reduction by the 2025 target,[10] but, unless the tax rate was increased to a rate higher than considered in this study, it would not be sufficient on its own to meet it.

It also suggests that these emissions reductions can be delivered while the country enjoys strong, sustained economic growth. The estimated effect of the carbon tax on the compound annual growth rate of GDP is a decrease from 3.49 percent per year to 3.43–3.33 percent per year over the modeling period. This is equivalent to a difference per year of between 0.5 and 0.16 percent. This means that GDP in 2035 could be between 1 and 3 percent lower compared with a situation in which the carbon tax is not introduced. The range of potential impacts arises from the differences in features such as a withdrawal rate of tax-free allowances across the different tax scenarios used in the study.

These results are consistent with the bulk of international studies reviewing the impacts on other national economies of carbon pricing with revenue recycling. Box 1 provides more detail of some of these analyses.

These—and other—results are explored further below. The following section explores some of the key results from the T2R1 scenario—referred to below as the 'focus' scenario. In this scenario the tax-free allowances, as laid out in the proposed design of the scheme, are gradually removed at a rate of 10 percentage points per annum for all sectors (except the agricultural industries), and there is a broad form of revenue recycling—a rebate to all firms proportional to their output. While this form of recycling does not mirror the currently proposed measures exactly, it shares with some of these measures a relatively broad scope, and thus is useful for the purposes of analysis. The sensitivity of results to baseline assumptions is also analysed in this section. The tax scenario sensitivity analysis section then describes how the results change depending on the choice of tax scenario; while the recycling options sensitivity analysis section explores the impact of different revenue recycling approaches. The sensitivity to baseline assumptions section considers how changes in the baseline alter the results.

10 In the model used here emissions are reduced by 13–14.5 percent compared with the baseline in 2025. It is important to note, however, that the baseline assumptions and model in this study are different from those used in other official government analyses.

BOX 1. International comparison of tax modeling results

Carbon tax modelling exercises have been carried out by various institutions and countries in order to better understand the impact of these types of policies. In most studies both tax schemes and recycling options are modelled to inform the tax design. The recycling options considered are similar to those covered in this modelling analysis: spanning VAT decreases, personal income tax reductions, and sector specific rebates.

These exercises suggest that the impact of carbon taxes (or similar environmental taxation) on GDP is largely dependent on the policy design, but is generally found to be small in either direction (Bosquet, 2000; Hoerner, 2001; Zhang & Baranzini, 2004). Meta-studies show a range of outcomes for GDP, depending on country, model used and scenarios, but results tend to be close to the baseline. In reviewing modelling analyses in European countries, Hoerner (2001) finds a GDP impact in the range of –0.5 to +0.5 percent compared with baseline in two-thirds of the studies reviewed. Similar conclusions are reached in other, more recent reviews (Barker, Qureshi, & Köhler, 2006) (Vivid Economics, 2012).

The results obtained for CO_2 emissions impacts are more varied. Hoerner shows that some studies find emissions reductions of up to 15 percent compared with baseline. However, the study also finds examples which suggest that emissions could increase in cases where revenue recycling stimulates significant additional growth that more than offsets the reductions in emissions caused by the carbon tax.

There are significantly fewer studies that examine the impact of carbon taxes on emerging market economies; however, most suggest broadly similar results. For example, studies considering carbon pricing in Indonesia (Yusuf & Resosudarmo, 2013), China (Guo, Zhang, Zheng, & Rao, 2014; Wang et al., 2009), and Brazil and Mexico (Octaviano, Paltsev, & Gurgel, 2014) conclude that carbon taxes in these countries, when combined with revenue recycling, are likely to result in small deviations from baseline GDP, although Octaviano, Paltsev, & Gurgel (2014) suggest that there could be deviations in GDP relative to the baseline of around 4–11 percent in Mexico. Some of these studies also indicate that carbon pricing coupled with revenue recycling in developing countries is not necessarily regressive (Yusuf & Resosudarmo, 2013).

Focus scenario

Overall impacts

In the focus scenario, T2R1, there is a significant reduction in emissions relative to the baseline. Emissions in 2035 are expected to be 33 percent lower in the T2R1 scenario than in the baseline, as shown in Figure 1 below. While this suggests that the carbon tax alone would not be sufficient to meet South Africa's intended 42 percent reduction versus business-as-usual by 2025—the emissions reduction relative to the baseline in this analysis is 14.5 percent in 2025[11]—it does make a marked contribution to achieving this target. This highlights the need to develop a comprehensive suite of policy measures to tackle emissions reductions and/or the need for a higher effective carbon tax rate.

At the same time, the economy continues to grow substantially over the period following the introduction of the tax: the average (compound) annual growth rate of the economy in the period to 2035 is only 0.15 percentage points lower than in the baseline scenario. The carbon tax leads to a reduction in the compound annual growth rate of GDP from 3.49 percent to 3.33 percent. This results in GDP being

11 It should be noted that the baseline used in this modeling analysis is different from that used in previous modeling where the 42 percent reduction is specified.

FIGURE 1. **In scenario T2R1, emissions in 2035 are expected to be 33 percent lower in 2035 than under the baseline assumptions**

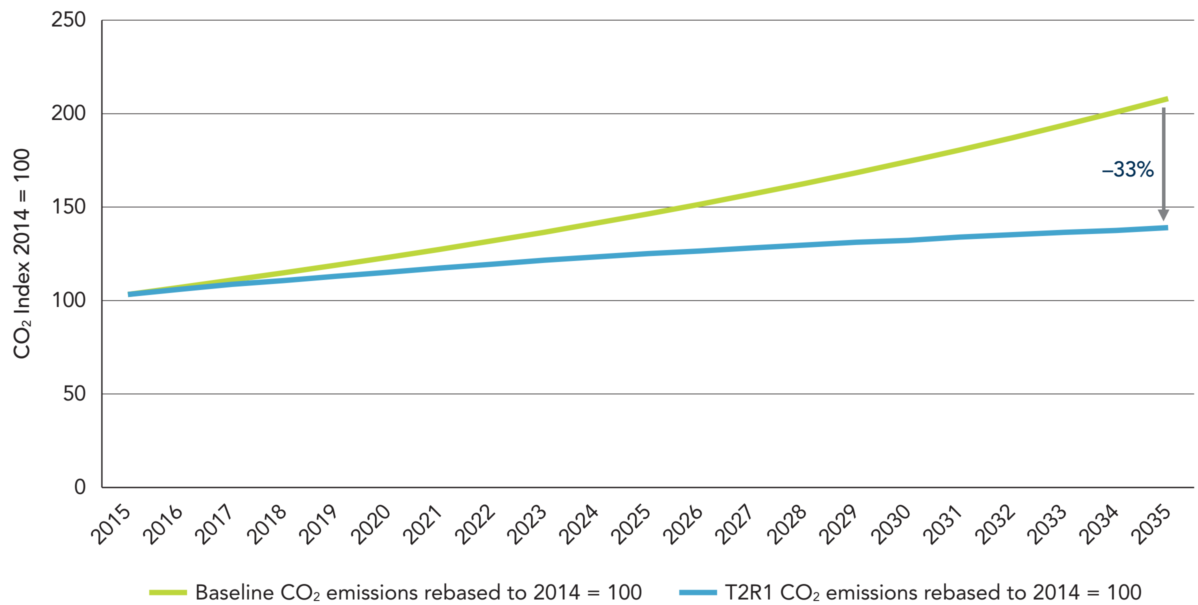
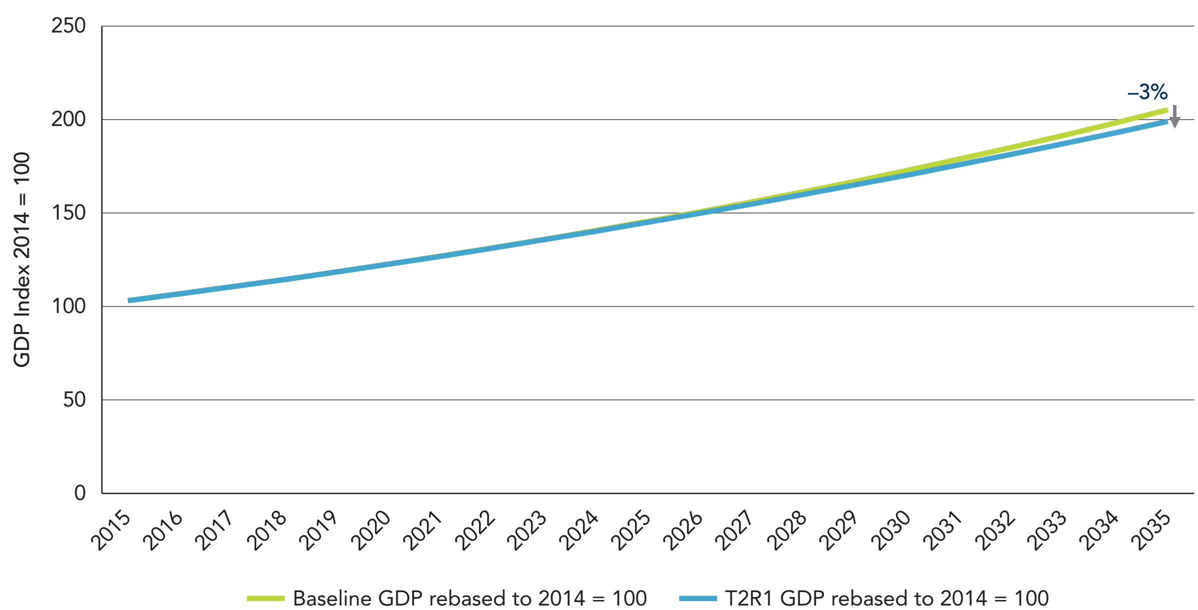


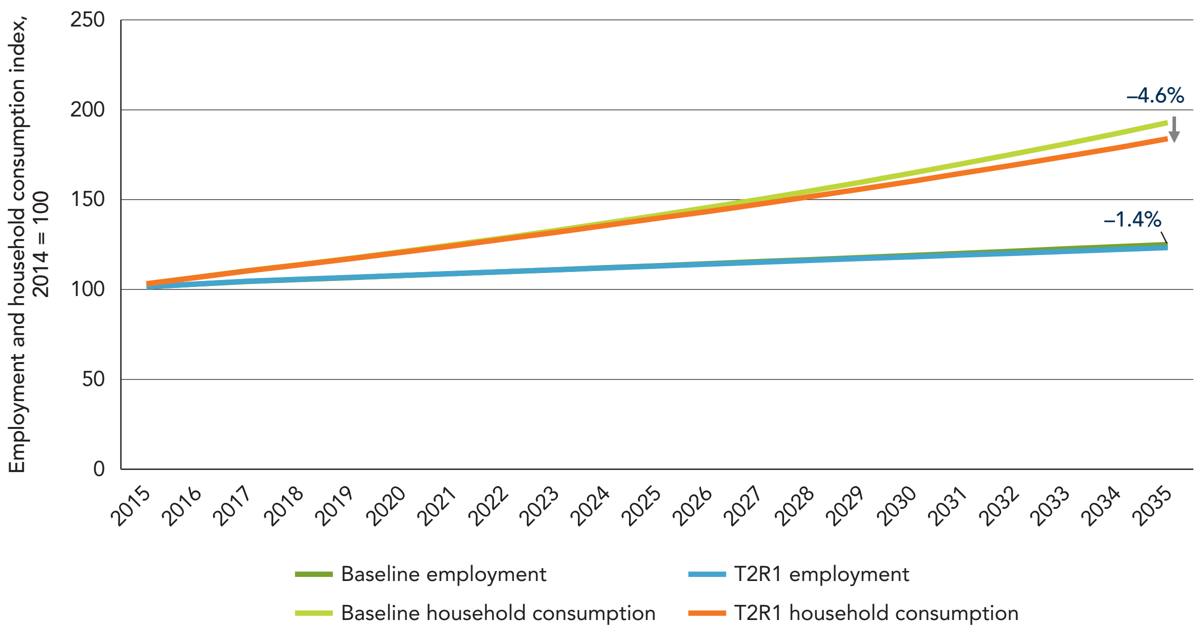
FIGURE 2. **In the context of the expected growth of the economy, the impact of the carbon tax is small (T2R1 scenario)**



3 percent lower in 2035 compared with a situation where the carbon tax is not introduced (in a context in which GDP is expected to double between 2014 and 2035).

In line with the impact on GDP, other macroeconomic aggregates are only modestly affected. Looking at household consumption and employment provides useful additional insights into the impact of the policy on welfare. In line with the small decrease in GDP level, these impacts are also small. The annual growth rate in household consumption falls by just 0.23 percentage points, from 3.2 percent to 2.9 percent. This means that the level of household consumption is 4.6 percent lower in T2R1 than in the baseline in 2035

FIGURE 3. Household consumption and employment deviations are in line with GDP impact



Note: The two employment projections overlap almost completely, with a difference of 1.4 percentage points by 2035.

(in a context in which it has grown by 93 percent over the period between 2014 and 2035 in the baseline scenario). This small decrease in household consumption relative to the baseline is driven by the decline in real wages experienced as a result of the higher consumer prices that follow the introduction of the tax (see below). As economic activity is modestly lower, employment growth also falls by 0.07 percentage points per year such that it is estimated to be just 1.4 percent lower than the baseline level in 2035. Figure 3 shows the growth paths of employment and household consumption in the focus and baseline scenarios.

Any distributional impacts arising from the tax are a key issue in the tax design, and minimising any adverse effects on the lowest-income brackets is a priority. Some insight can be provided by looking at the impact on real wages. Real wages are projected to increase by 13 percent over the period to 2035 under the baseline scenario; this translates to an average annual increase of 0.6 percent. The introduction of the tax will reduce this rate to 0.4 percent per year.

Sectoral impacts

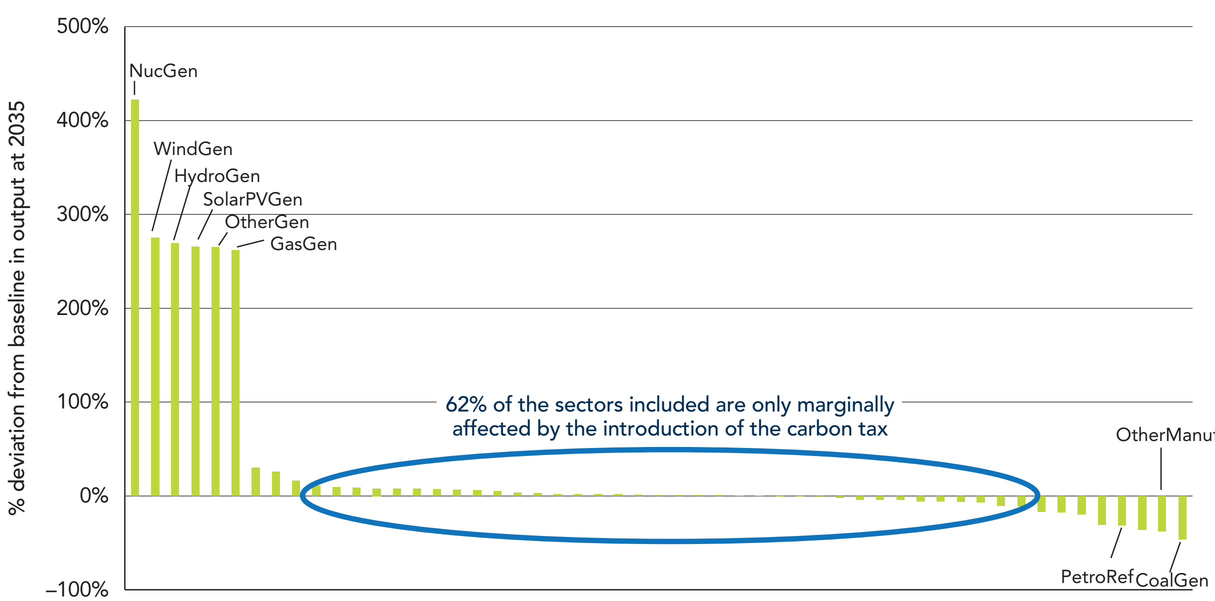
Although the modeling suggests that the overall impact of the carbon tax on the economy is small, it does also indicate that there will be some important sectoral winners and losers. This is consistent with the objective of the policy to support the structural change to the South African economy, as discussed in the introduction to this report.

Under T2R1 South Africa's lower carbon energy sector sees significant increases in output. In 2035, output from the nuclear generation, wind generation, hydro generation, other generation, gas generation and solar PV generation sectors is expected to be more than 200 percent greater than without a carbon tax. This reflects the basic intuition that these low—and zero-carbon sources of power become much more cost competitive with a carbon tax.[12] It is also predicated on all actors in the electricity generation sector responding to the carbon tax in a commercial manner, so as to reduce costs. The nonelectricity generation sector which sees the largest increases in output as a result of the carbon tax is the transport equipment sector.

At the same time, some sectors see significant declines in output compared with the baseline. Coal generation becomes much less cost competitive and as a result its output is 46 percent lower in 2035 than it would be without the tax. Other sectors that see substantial declines in output (greater than 15 percent), relative to the baseline, include petroleum refining, other manufacturing, coke production, electricity supply, iron and steel production and the transport services sector. The small decrease in output for these sectors is a result of higher costs which are at least partly passed through to prices and which, in equilibrium, lead to less production of carbon intensive goods and services and reduced demand. These price increases, especially for instance in the electricity sector, are likely to stimulate improvements in energy efficiency which would allow consumers and firms to undertake the same activities as before, while using less electricity. It should also be stressed that all of these declines reflect a *relative* decline in output compared with the situation in which there is no carbon tax; all of these eight sectors are projected to grow in absolute terms between 2014 and 2035—by between 9 (coal generation) and 82 percent (transport services)—even with a carbon tax.

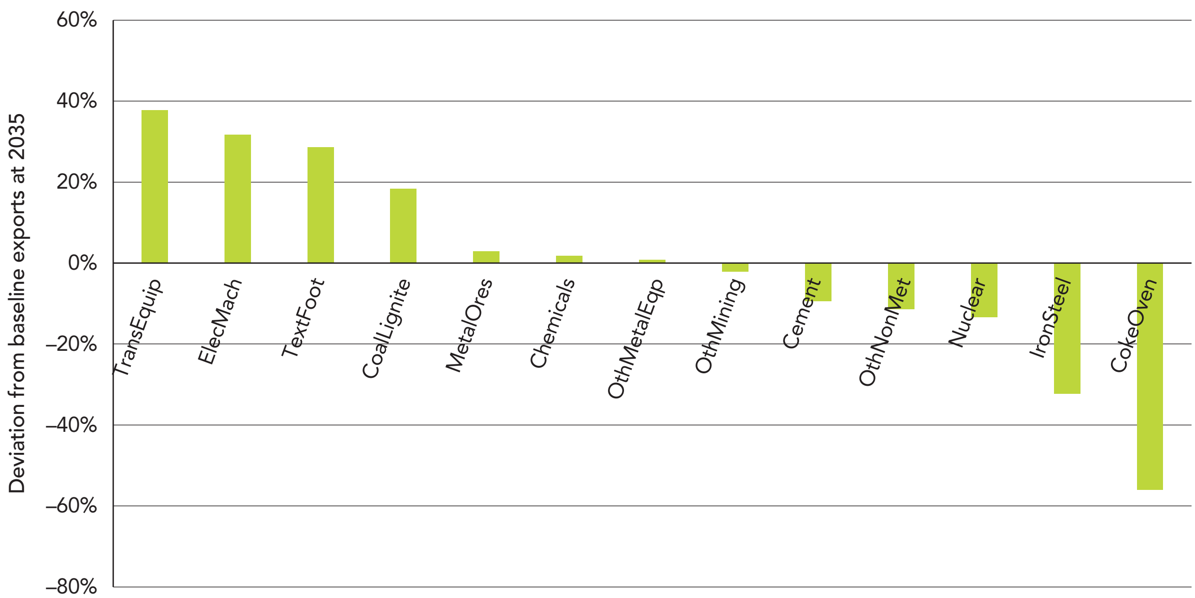
There are also a large number of sectors for which the carbon tax makes very little difference to their output. While attention inevitably focuses on sectors most significantly affected (either positively or negatively), there are a large number of sectors for which the carbon tax makes little or no difference to output level. For 33 of the 53 sectors modeled in the study, the change in output in 2035 as a result of the tax is less than 10 percent in either direction, as shown in Figure 4 below. These include core sectors such as financial services (output increases by 3 percent in 2035 relative to the baseline under the carbon tax scenario), metal

FIGURE 4. The impact of the tax, in terms of expected change in output in 2035 relative to the baseline, is small for most sectors



12 This also reflects the modeling assumption that in the baseline these sources of generation remain very low as there is assumed to be no change in the underlying costs of generation from these policies

FIGURE 5. There are as many key export sectors that see an increase in exports as a result of the carbon tax as there are sectors that suffer a decrease in exports



Note: Sectors are selected on the basis of export size as of February 2015.

ores (output is unchanged), and agriculture (output increases by 2 percent in 2035 relative to baseline). In total, the sectors that see output changes of less than 10 percent by 2035 (in either direction) account for 81 percent of South Africa's current economic output[13]. This suggests that for a large proportion of the South African economy the carbon tax is a very small driver of overall output.

A typical concern of policymakers when considering a carbon pricing instrument is that it may adversely affect the international competitiveness of the economy. Such a concern appears misplaced in this case. This has already been reflected in the carbon tax design through the additional exemptions available to firms judged to be at risk from such a threat. Overall, the modeling analysis suggests that the effect of the tax on South Africa's trade position will be limited—a small *increase* in the compound annual growth rate of exports between 2014 and 2035 from 4 percent to 4.2 percent, such that the level of exports in 2035 is 3.5 percent higher than in the baseline scenario.

However, there are likely to be stronger effects on certain sectors. Figure 6 presents the change in exports in 2035, relative to the baseline, for some of South Africa's key export sectors.[14] It shows that some of these sectors will see significant changes, *although the impacts will be both positive and negative.* The annual growth rate in exports from the coke production sector falls from 3.6 percent to –0.3 percent, and 3.3 percent to 1.4 percent for iron and steel, leading to a change in exports in 2035 of more than 50 percent relative to the baseline in the case of coke, and 30 percent for iron and steel. This is likely to be a result of the carbon tax making it more challenging for these sectors to compete internationally. It should be stressed, however, that this modeling assumes that no other jurisdictions change their climate policy settings between today and 2035, so the analysis may exaggerate the competitiveness impacts experienced by these sectors. At the same time, other export sectors will see significant increases, with the transport equipment, electrical machinery and textiles and footwear sectors all expected to see increases in the annual

13 This was calculated using sector specific output data supplied by the National Treasury.

14 These sectors were selected according to the sectors with the largest exports by value as given in the National Treasury's foreign trade performance summary for February 2015.

growth rate of exports of around 7 percent, leading to exports in 2035 being around 30–40 percent higher compared with the baseline. This may reflect a combination of the erosion of domestic sales for some of these products as well as the benefits that some sectors experience as a result of the modeled revenue recycling measures (especially textiles and footwear). As with sectoral output, there are also some important export sectors that see very little change in their export position, including 'other mining' and 'metal ores', which are expected to experience a 2 percent decrease (other mining) and a 3 percent increase (metal ores) in exports under the T2 tax scenario compared with baseline estimates.

Tax scenario sensitivity analysis

A sensitivity analysis of results to different tax policy scenarios can help inform policy design. To recap, the four tax policy scenarios are variations of the design proposed by the National Treasury in its 2013 Carbon Tax paper—specifically:

T1 The tax is initially modeled as closely as possible to reflect the proposed design and with the tax rate increasing by 10 percent per annum over the period 2016–21, and thereafter by the assumed inflation rate (in the main baseline scenario case this would be 5.5 percent). In addition, the tax-free thresholds in this scenario are held constant for the duration of the modeling period 2016–35.

T2 The carbon tax is applied as in T1, but the tax-free allowances are gradually removed at a rate of 10 percent per annum from 2021 onwards until all the industries are paying the full tax rate on all their emissions. The agricultural sector, however, is exempt from the carbon tax at all times.

T3 The tax is applied as per T1, except for the agricultural industries where the exemption is removed at a rate of 10 percent per annum starting in 2026.

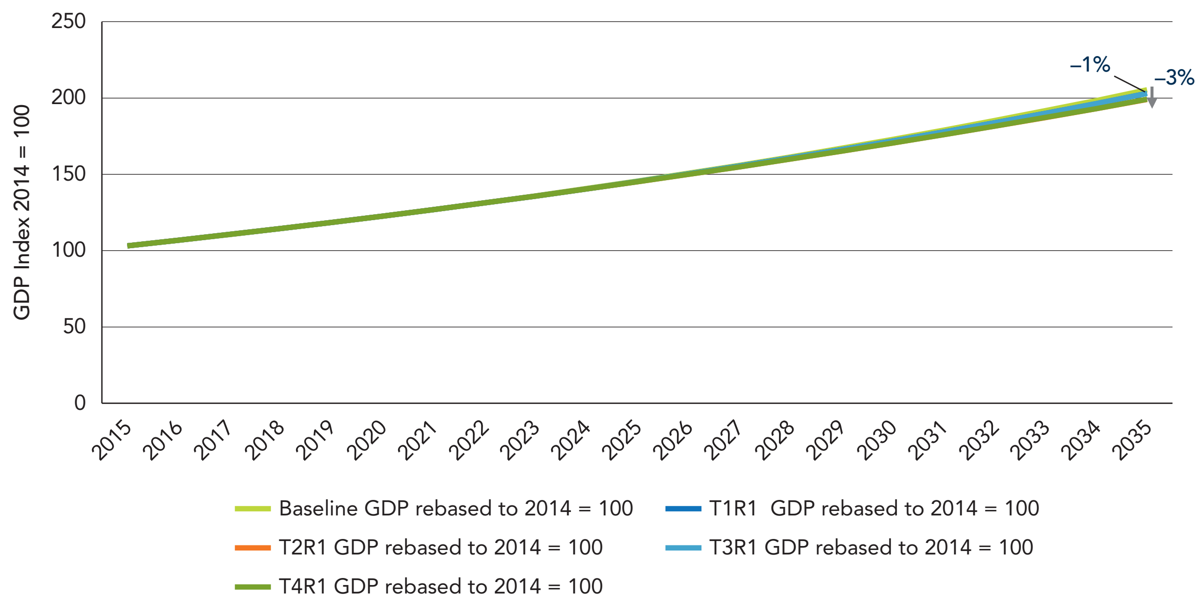
T4 This is a combination of T2 and T3: the tax is applied as per the 2013 policy paper and tax-free allowances are gradually removed at a rate of 10 percent per annum, starting in 2021, for all industries except agriculture, for which phasing out begins in 2026.

To facilitate comparison, the analysis focuses on the combination of these tax scenarios with the recycling scheme R1, which is the recycling methodology used in the focus scenario.

The slower removal of tax-free allowances significantly decreases the abatement impact of the tax. In scenarios T1 and T3 tax-free allowances are removed later compared with T2 and T4. As would be expected, this means that scenarios T1 and T3 deliver a smaller reduction in emissions than T2 and T4: a reduction of 26 percent for T1 and T3 in 2035, compared with the 33 percent reduction achieved in scenarios T2 and T4 (all relative to the baseline). A stronger price signal leads to a greater reduction in emissions. The inclusion or otherwise of the agriculture sector within the carbon tax has a negligible impact on the overall emissions reductions realised.

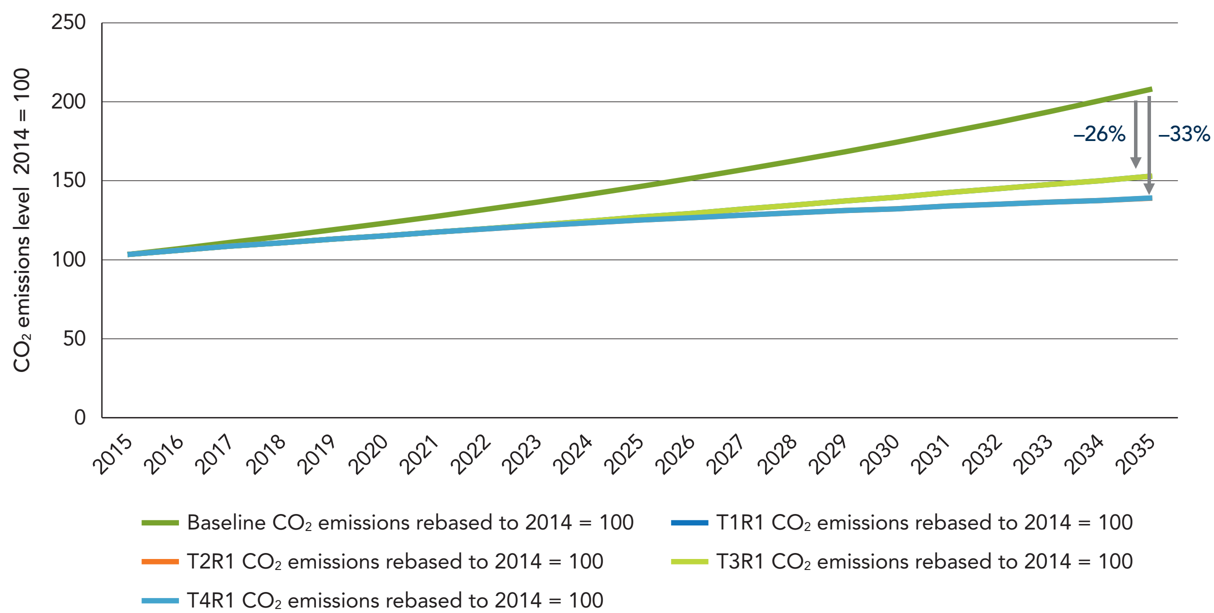
Retaining the tax-free allowances results in slightly higher GDP. Specifically, in scenarios T1 and T3, average GDP growth rate in the period up to 2035 is about 1.6 percent lower than in the baseline, compared with a 4.3 percent deviation in growth rate in scenarios T2 and T4. However, as Figure 7 illustrates, these effects are small in the context of the expected growth in the economy over the period as a whole. In addition, the negligible difference in GDP impact between scenarios T2 and T4 and between T1 and T3 indicates that the inclusion or otherwise of the agricultural sector within the carbon tax policy will have practically no impact on the overall GDP change resulting from the carbon tax.

FIGURE 6. The impact on GDP is small for all four tax scenarios



Note: T1R1 and T3R1 overlap, as do T2R1 and T4R1.

FIGURE 7. The different tax policy options give varying degrees of abatement



Note: T1R1 and T3R1 overlap, as do T2R1 and T4R1.

Although the inclusion or exclusion of the agricultural sector has little overall effect on the impact of the tax on GDP, the different tax scenarios do have a varying impact on the projected output of the sector. The overall magnitude of the impact of the tax on the sector is small, but its exact size depends on the rate and timing of removal of tax-free allowances, both from the agriculture sector itself and from other sectors. Unsurprisingly, the timing of sector specific tax-free allowances removal is the biggest driver of agricultural output change: in scenarios where agricultural exemptions are left in place for longer than for the other sectors (T2 and T4), agricultural output in 2035 is between 1.7 and 1.9 percent higher than the baseline. However, even when tax-free allowances are removed earlier (T3) or not removed for any sectors (T1), output remains 1.0 and 1.2 percent above the baseline, reflecting the benefit that the sector obtains from the increase in economic activity created by the recycling of revenues.

Recycling options sensitivity analysis

The recycling of revenues, to address welfare concerns arising from the introduction of the tax, is an integral part of the carbon tax design. The recycling scheme proposed at the time that the draft bill was published for public comment in November 2015 aims to shield those most vulnerable to the impacts of the carbon price (for instance through a reduction in the electricity levy), while further stimulating structural change in the South African economy (for example through a credit for the premium charged for renewable energy through the IPPs).

For the purposes of this modeling analysis, possible revenue recycling measures can be considered as either broad—the revenue is allocated to a wide range of producer groups and consumers—or narrow—purposefully directed towards certain producer or consumer groups. While the actual recycling measures proposed by the National Treasury contain a combination of both broad (reduction in electricity levy) and narrow (targeted support to renewable energy technologies) measures, analysing these differences helps to illustrate important distinctions and trade-offs associated with various recycling measures. To facilitate this, the analysis below focuses on the difference between R1, a broad-based recycling approach where revenues are recycled through a rebate to all sectors based on production (the size of the rebate is determined by the size of the output), and R4, a narrow-based recycling option where revenues are all recycled to the solar PV sector (this is used to represent a narrow, clean energy oriented recycling scheme). This comparison is undertaken using the tax schedule T2.

The modeling results indicate that a broader recycling scheme will have a more positive impact on South Africa's GDP than a narrower, more focused scheme. Under revenue recycling scheme R1, the compound annual growth rate of GDP falls from 3.5 percent per year under the baseline to 3.3 percent, while under the narrower recycling scheme (R4), the growth rate falls by 0.8 percentage points per year to 2.7 percent per year. This leads to GDP under the narrow recycling scheme being 15 percent lower than the baseline in 2035, compared with 3 percent under the broader recycling scheme—a difference of 12 percentage points. This result is illustrated in Figure 8 below. This effect arises because narrow recycling measures, which allocate all of the revenues to a small number of sectors, significantly distort relative prices and encourage activity that, without the subsidy, may not generate value-added[15] (GDP). By contrast, broader recycling measures better preserve relative prices across the economy and avoid this problem.

At the same time, the modeling results suggest that a broader recycling of revenues results in a smaller reduction in emissions than a narrower recycling approach focused on the renewable electricity sector alone. This confirms the intuition that focusing support on the renewable electricity sector alone will increase its competitiveness with respect to the other energy production technologies, and increase the rate of structural transformation and thus emissions reductions. By contrast, broader recycling measures lead to a reinjection of revenues into all productive sectors, including a number of heavily polluting sectors. By choosing a narrower recycling scheme aimed at renewable energy, emissions reductions in 2035 could

15 Revenue in excess of the costs of production. Each sector's gross value added (GVA) represents, broadly speaking, its contribution to GDP. These results are also driven by the assumption that the recycling of revenues to the solar industry does not result in any additional efficiency/cost improvements in this sector, due to the difficulty in calibrating the magnitude of this impact. If there were efficiency improvements within the solar sector, as seems plausible, the negative impact of this recycling approach would be smaller.

FIGURE 8. Broad revenue recycling schemes result in smaller deviations from baseline growth

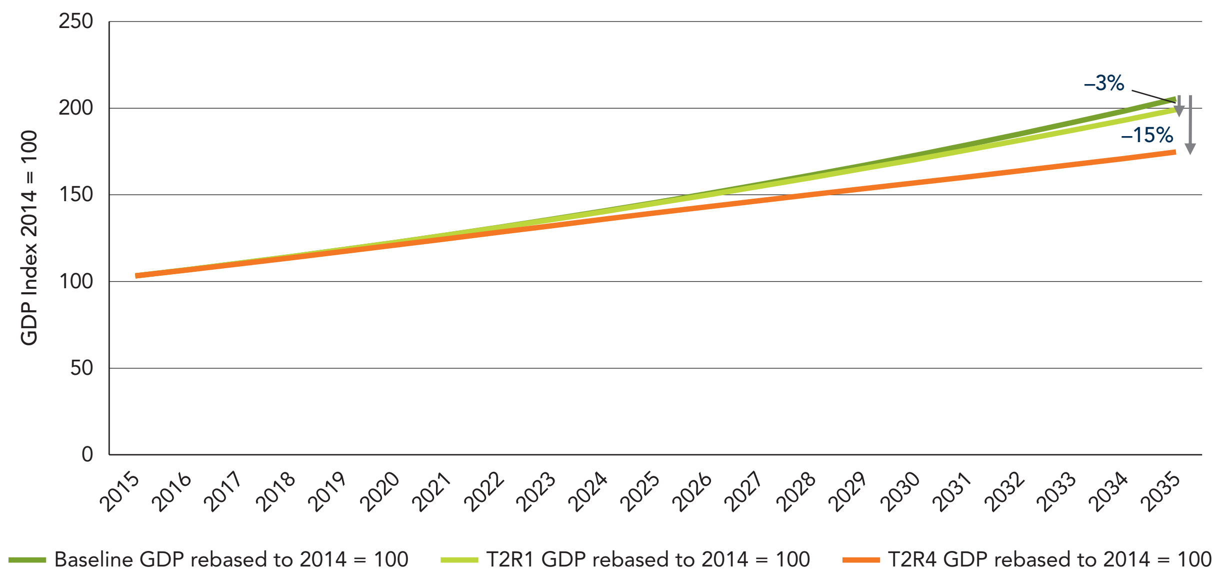
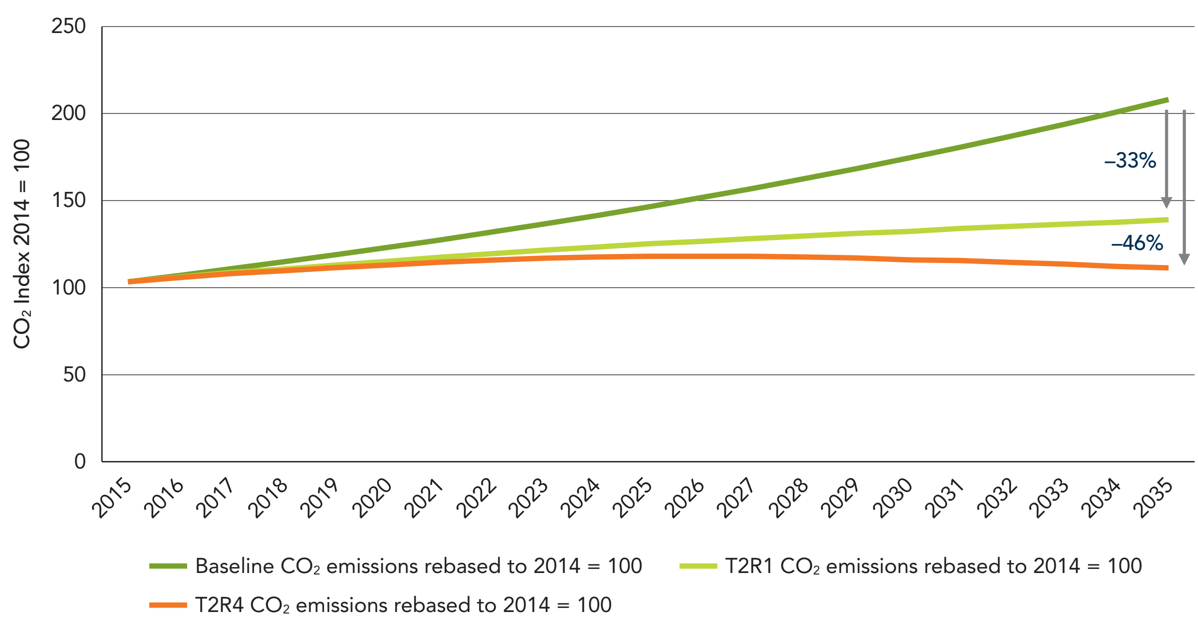


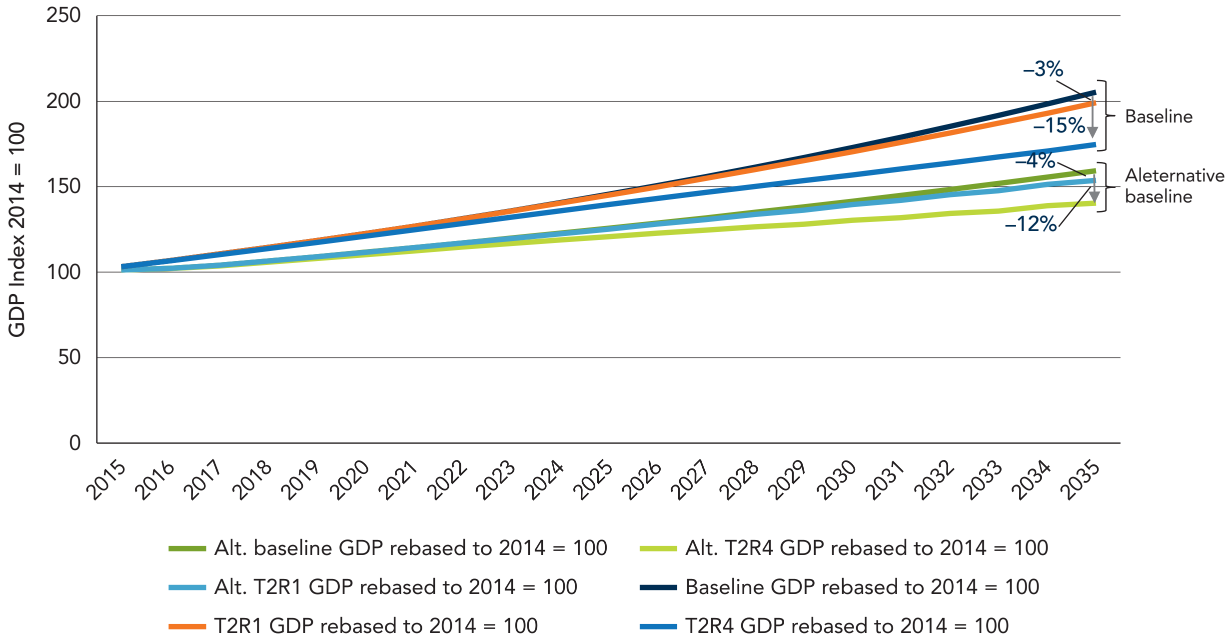
FIGURE 9. By focusing tax revenue recycling on the renewable sector emissions can be lowered further



be lowered by as much as 46 percent relative to the baseline, compared with the 33 percent reduction achieved under a broader distribution. Figure 9 illustrates this impact.

The analysis also suggests important differences between recycling measures aimed at producers compared with those focused on consumers. In general, producer focused rebates and subsidies, such as R1 and R3, tend to result in a stronger positive impact on GDP than consumer centric ones such as R2 and R5. Notably, the recycling measures proposed by the National Treasury span both consumers and producers.

FIGURE 10. The deviation from baseline for the focus scenario is still small under revised growth assumptions



Sensitivity to baseline assumptions

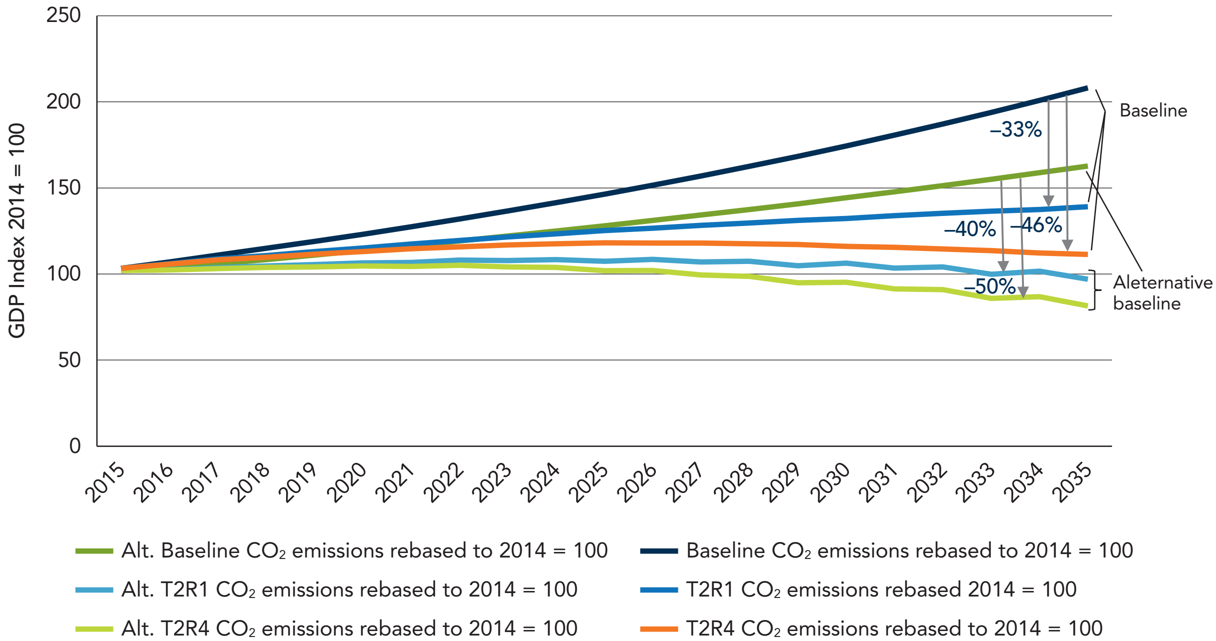
The final sensitivity analysis focuses on whether changes in the baseline assumptions lead to any significant differences in the main findings of the study. As discussed in the focus scenario section, the original baseline developed for the modeling analysis represents a relatively optimistic set of assumptions for the South African economy. The alternative baseline scenario uses more conservative projections, in line with more recent forecasts. Specifically, under this alternative baseline, economic growth slows to 0.9 percent in 2016 before increasing to 2.4 percent for the period between 2018 and 2035. This compares with the 3.5 percent growth rate for the period 2016–35 used in the results above.[16] As stressed above, the insights from the modeling analysis are provided by comparing the policy scenarios with the baseline (the deviations); this sensitivity analysis checks whether this comparison is affected by the choice of the baseline.

The results of the analysis show that changes to the baseline have very little impact on the *change* in GDP expected from the carbon tax. Figure 10 below shows the two 'families' of trajectories for GDP: the baseline, T2R1 and T2R4, with both optimistic (original) and conservative (alternative) baseline assumptions. While the level of GDP is clearly different across the two families, the impact of the carbon tax is very similar. In both families, T2R1 has a very small impact on GDP: the compound annual growth rate falls by only 0.15–0.18 percentage points per year in each family. Similarly, in each family, T2R4 has a more significant impact on GDP growth, reducing the compound annual growth rate in GDP by 0.62–0.8 percentage points.

As with GDP, the deviations from the baseline of CO_2 emissions are not significantly impacted by changes to the baseline. Under the alternative baseline, T2R1 and T2R4 result in emissions levels that are 40–50 percent lower, respectively, than the baseline in 2035, compared with 33–46 percent under the original baseline assumptions. Although the deviations are greater under the revised baseline, the relative impact of the different scenarios is very similar, as shown in Figure 11 below.

16 The appendix provides a full comparison of the differences between the baseline scenarios.

FIGURE 11. The magnitude of the reduction in emissions is similar under the revised baseline assumptions



Summary

The results of the simulation suggest that the introduction of a carbon tax will contribute significantly to South Africa's GHG emissions reduction goals. The analysis shows estimated reductions of 26–33 percent by 2035 compared with business-as-usual. This suggests that the policy will go some way towards reaching the 42 percent reduction by 2025 target,[17] but would need to be complemented by additional policies if this target is to be met. Alternatively, the carbon tax rate would have to be higher than considered in this analysis.

The economy will continue to grow whilst emissions are reduced. The modeling results estimate that a carbon tax will dampen the economy's average annual growth rate by just 0.05–0.15 percentage points. This is to say that GDP will grow at an average 3.3–3.4 percent per year instead of the 3.5 percent growth rate assumed in a scenario without a carbon tax. This reduction in the growth rate would lead to GDP in 2035 that could be between 1 and 3 percent lower than in a situation in which the carbon tax is not introduced. Sensitivity analysis carried out on the assumptions underlying the baseline case shows that the carbon tax would have a similar modest impact even if the economy is expected to grow at less than 3.5 percent per year.

Consistent with the carbon tax's objective of promoting structural change, there are a number of important sectoral winners and losers from the tax. In 2035, the output from the nuclear generation, wind generation, hydro generation, other generation, gas generation and solar photovoltaic (PV) generation sectors is expected to be more than 200 percent greater than without a carbon tax. This reflects the basic intuition that these low- and zero-carbon sources of power become much more cost-competitive with a carbon tax. At the same time, coal generation becomes much less cost competitive and, as a result, its output is 46 percent lower in 2035 than it would be without the tax. Other sectors that see a substantial decline in output relative to the baseline include petroleum refining, other manufacturing, coke production and the electricity supply sector. It should, however, be stressed that this is a *relative* decline in output compared with the situation in which there is no carbon tax; all of these sectors are projected to grow in absolute terms between 2014 and 2035—by between 18 (coal generation) and 105 (other manufacturing) percent—even with a carbon tax.

But the vast majority of sectors are largely unaffected by the introduction of the tax. In the focus scenario, in 2035, 33 of the 53 sectors modeled in the study—accounting for around 80 percent of the current output of the South African economy—would see a change in output of less than 10 percent as a result of the carbon tax. These include core sectors such as financial services (output increases by 3 percent in 2035 under the carbon tax scenario); metal ores (output is unchanged); and agriculture (output increases by 2 percent in 2035 relative to the baseline). This reflects both the fact that carbon costs are a relatively small cost driver for many sectors of the economy, and the benefits that many sectors see as a result of the recycling of revenues.

17 In the model used here emissions are reduced by 13–14.5 percent compared with the baseline in 2025. It is important to note, however, that the baseline assumptions and model used here differ from those used in other official government analyses.

The modeling suggests that concerns over the competitiveness impacts of the carbon tax are overstated. It suggests that exports in 2035 could be 3.5 percent higher with the introduction of the carbon tax. Certain sectors are materially affected, however. The sectors projected to see notable declines in exports include the coke oven and iron and steel sectors, although in the latter case the sector's exports continue to grow over the period to 2035, just at a lower rate than if there were no carbon tax. The challenging export conditions for some sectors should also be seen in the context of the strong benefits for other sectors: the transport equipment, electrical machinery, and textiles and footwear sectors are all expected to see increases in the annual growth rate of exports of around 7 percent as a result of the carbon tax plus revenue recycling, leading to their exports in 2035 being around 30–40 percent higher than in the baseline.

The magnitude of the emissions and GDP impact from the tax depends on the policy and revenue recycling scheme designs. The analysis shows that a tax policy with persistent tax-free allowances will yield substantially lower emissions reductions, but also have a slightly less negative impact on GDP growth. The type of recycling scheme applied also impacts both emissions and GDP: with broad, producer focused rebates yielding smaller GDP downside impacts but also less significant emissions reductions, whilst a narrow, clean energy focused rebate will lead to substantial decreases in emissions but a lower growth rate for the economy.

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.*

Armington, P. S. (1969). A Theory of Demand for Products Distinguished by Place of Production. *International Monetary Fund Staff Papers,* (XVI), 159–178.

Barker, T., Qureshi, M. S., & Köhler, J. (2006). The costs of greenhouse gas mitigation with induced technological change: a meta-analysis of estimates in the literature. *Tyndall Centre Working Paper,* 1–63.

Bosquet, B. (2000). Environmental tax reform: does it work? A survey of the empirical evidence. *Ecological Economics, 34,* 19–32.

DEA. (2014). *Mitigation Report: South Africa's Greenhouse Gas Mitigation Potential.* Pretoria.

Department of Energy (South Africa). (2013). *Integrated Resource Plan for Electricity (IRP) 2010–2013, Update Report 2013.*

Devarajan, S., Go, D., Robinson, S., & Thierfelder, K. (2009). *Tax Policy to Reduce Carbon Emissions in South Africa* (Policy Research Working Paper).

Dixon, P. B., & Rimmer, M. T. (2002). *Dynamic General Equilibrium Modeling for Forecasting and Policy: A Practical Guide and Documentation of MONASH.*

Dixon, P. B., & Rimmer, M. T. (2005). Mini-USAGE: reducing barriers to entry in dynamic CGE modeling. *8th Annual Conference on Global Economic Analysis Lübeck, Germany June 9–11, 2005.*

Guo, Z., Zhang, X., Zheng, Y., & Rao, R. (2014). Exploring the impacts of a carbon tax on the Chinese economy using a CGE model with a detailed disaggregation of energy sectors. *Energy Economics, 45,* 455–462. http://doi.org/10.1016/j.eneco.2014.08.016

Harrison, W. J., & Pearson, K. R. (1996). Computing Solutions for Large General Equilibrium Models Using GEMPACK. *Computational Economics,* (9), 83–127.

Hoerner, B. J. A. (2001). *Environmental Tax Reform: the European Experience.*

Octaviano, C., Paltsev, S., & Gurgel, A. C. (2014). Climate change policy in Brazil and Mexico: Results from the MIT EPPA model. *Energy Economics,* 1–15. http://doi.org/10.1016/j.eneco.2015.04.007

Parry, I. W. H., Veung, C., & Heine, D. (2015). How much carbon pricing is in countries' own interests? The critical role of co-benefits. *Climate Change Economics, 6*(4).

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

South Africa National Treasury. (2013). *Carbon tax policy paper.*

South Africa National Treasury. (2015). *Publication of the Draft Carbon Tax Bill for Public Comment.* Retrieved from http://www.treasury.gov.za/comm_media/press/2015/2015110201—Media Statement Carbon Tax Bill.pdf

South African Government. South Africa's Intended Nationally Determined Contribution (INDC) (2015).

Statistics South Africa (StatsSA). (2014). Gross domestic product Fourth quarter 2013, (May).

van Heerden, J., Gerlagh, R., Blignaut, J., Horridge, M., Hess, S., Mabugu, R., & Mabugu, M. (2006). Searching for Triple Dividends in South Africa: Fighting CO_2 Pollution and Poverty While Promoting Growth. *The Quarterly Journal of the IAEE's Energy Economics Education Foundation, 27*(2), 113–142.

Vivid Economics. (2012). Carbon taxation and fiscal consolidation: The potential of carbon pricing to reduce Europe's fiscal deficits. Report prepared for the European Climate Foundation and Green Budget Europe.

Wang, J., GE, C., Yan, G., Jiang, K., Liu, L., & Zhangfeng, D. (2009). The Design on China's Carbon Tax to Mitigate Climate Change.

Yusuf, A. A., & Resosudarmo, B. P. (2013). *On the Distributional Impact of a Carbon Tax in Developing Countries : The Case of Indonesia*.

Zhang, Z. X., & Baranzini, A. (2004). What do we know about carbon taxes? An inquiry into their impacts on competitiveness and distribution of income. *Energy Policy*, *32*(4), 507–518. http://doi.org/10.1016/S0301-4215(03)00152-6

Appendix

UPGEM

UPGEM is a recursive dynamic computable general equilibrium (CGE) model of the South African economy. It is similar to Centre of Policy Studies (CoPS)-style CGE models, such as MONASH or USAGE, which are widely used in Australia to analyse the potential impacts of changes in economic policy, especially changes in taxes, tariffs, environmental regulations and competition policy.[18] UPGEM is a flexible model that can be configured to run in either comparative static, year-on-year dynamic or long-run decomposition dynamic modes. The theoretical specification of UPGEM is based on the MONASH model of Australia described in Dixon and Rimmer (Dixon & Rimmer, 2002). A complete exposition of the model code adopted in the core UPGEM is presented in Dixon and Rimmer's 2005 paper (Dixon & Rimmer, 2005).

The version of UPGEM used in this study contains several important enhancements compared with the standard version. The motivation for these changes is to enable a more accurate and detailed analysis of the energy sector in South Africa, in particular with regard to changes in the electricity generation mix and measurement of carbon emissions in the economy. The changes made to UPGEM include: i) the inclusion of 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 GHG policy measures.

In UPGEM, emissions derived from the combustion of fuels are modeled as being directly proportional to fuel usage. No allowance is made for the type of technological innovation that would allow coal fired electricity producers to emit less GHG per tonne of coal combusted. On the other hand, it does allow for input saving technological progress.

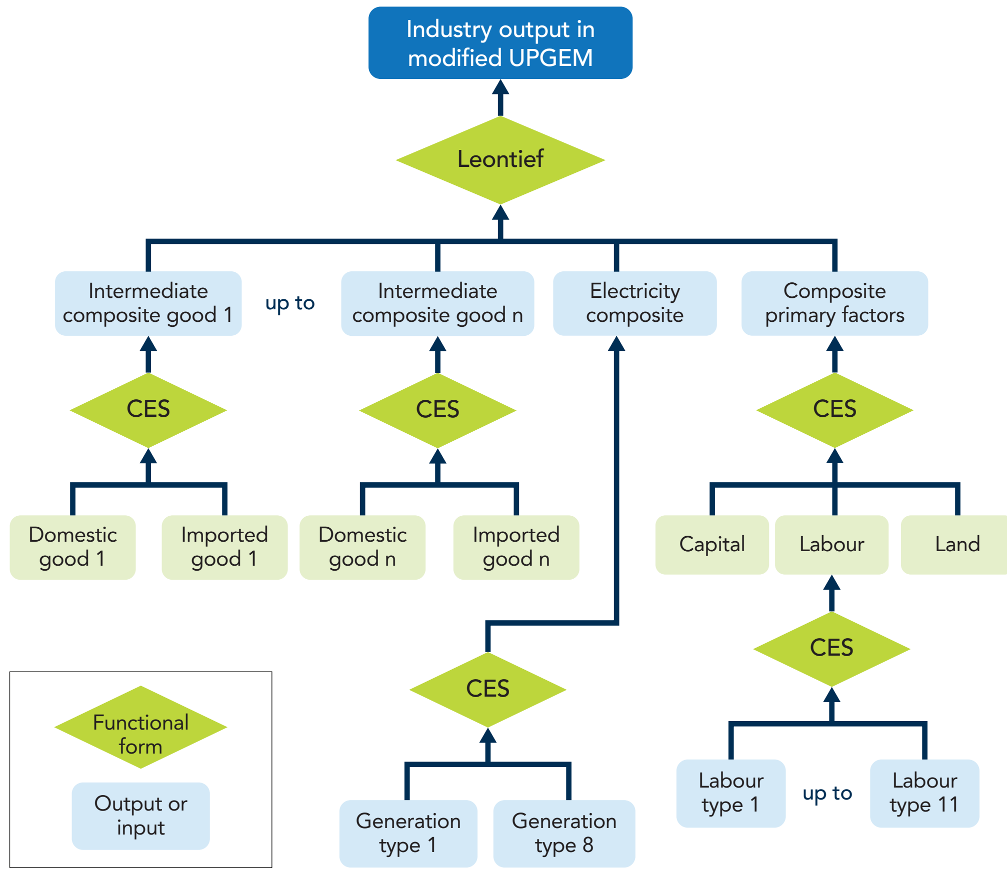
The model's base year data, or initial solution, is for 2011 and based on the supply-use tables published in Statistics South Africa (StatsSA, 2014). The UPGEM database used in this study distinguishes 45 core industries and commodities, with the electricity sector then disaggregated into eight generating sectors and one electricity distributor, to produce the final 53 sector aggregation used for this study. The database, in combination with the model's theoretical specification, describes the main inter-linkages in the South African economy. The model is implemented and solved using the GEMPACK suite of programs (Harrison & Pearson, 1996).

The core theory

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 core equations

18 These are the main uses cited by the Centre for Policy Studies available at http://www.copsmodels.com/models.htm

FIGURE A1. Nested production structure in modified UPGEM



Source: Heinrich Bohlmann, University of Pretoria

describing: the nature of markets; demands for inputs to be used in the production of commodities; household demands; demands for inputs to capital creation and the determination of investment; government demands for commodities; and foreign demand for exported goods.

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

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

The dynamic elements of UPGEM allow for intertemporal links describing: physical capital accumulation; lagged adjustment processes for labour; and government fiscal accounts. Capital accumulation is specified separately for each industry, and linked to industry specific net investment in the preceding period. Investment in each industry is positively related to its expected rate of return on capital. A similar mechanism for financial asset/liability accumulation is specified for the government's fiscal accounts. Adjustments to the national net foreign liability position of households are related to the annual investment/savings imbalance, revaluations of assets and liabilities, and remittance flows during the year. Changes in the public sector debt are related to the public sector deficit incurred during the year. In policy simulations, the labour market follows a lagged adjustment path where wage rates are allowed to respond over time to gaps between demand and supply for labour.

Model closures

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

With dynamic CoPS-style CGE models, the idea of flexible closures was fully extended with the development of four functional closure categories: long-run decomposition, historical, forecasting, and policy (Dixon & Rimmer, 2002). In dynamic CGE applications, the forecast and policy closures are the most widely used, while the baseline forecast closure is used to produce a believable business-as-usual picture of the future evolution of the economy.

The baseline forecast closure involves setting as exogenous a selection of variables such as the components of GDP, the consumer price index, or population growth, based on the availability of reliable macroeconomic forecast data, with little regard to causation. The policy closure can then be used to evaluate the impact of an exogenous shock to the economy relative to the unperturbed baseline scenario. The impact on macro variables, such as the components of GDP, is usually of particular interest to policymakers and must therefore be allowed to respond to the policy change or shock under consideration and set as endogenous again. Variables deemed to be determined independently of the policy scenario are set as exogenous, allowing no deviation between the policy and forecast simulation values for these variables. Deviations from the business-as-usual are typically reported as percentage point changes.

Baseline forecast closure

This application of the UPGEM baseline forecast uses three distinct time periods. The first is the historical period between the base year of 2011 and the present day, for which data already exists. This can inform the model in terms of what has happened over this historical period to effectively update the database. The second period is the baseline forecast period in the near term for which reliable projections exist. For UPGEM, this period usually corresponds to around 3–5 years into the future using macro forecasts from agencies such as the National Treasury or International Monetary Fund (IMF). Forecasts for the components of GDP from the income and expenditure side typically feature population growth and various macro price indices. The third period contains the long-run projections for the economy and is typically restricted to average forecast values for only a few main macro variables such as real GDP, population growth and inflation. The specific values imposed for the UPGEM baseline forecast are shown in Table 1 below.

Policy closure

The policy closure typically used for CoPS-style models such as UPGEM can be described as natural to the system of equations. That is, the variable for which the equation was written to explain is set as the endogenous variable. In this application of the UPGEM policy closure, specific changes are applied based on the design of the particular policy simulation under consideration. For example, to impose a carbon tax but hold the government's budget deficit or surplus position unchanged relative to the baseline projection requires another variable to be endogenised. The choice of endogenous variables will be dictated by the policy design. For the standard policy closure, all variables of interest are made endogenous, while variables held fixed relative to their baseline projection would typically include technical changes, positions of foreign demand curves, and various taste and preference variables.

Assumptions in the baseline scenarios

TABLE 1. The following assumptions were used in the *main* baseline scenario

Variable	2012	2013	2014	2015	2016	2017	2018–35
Data source	Historical data from South African Reserve Bank and National Treasury		National Treasury's budget review; electricity prices: Eskom's MYPD3				CEPII long-run macro forecasts; Inflation within its target range; Steady-state employment; Electricity prices and supply endogenous
GDP	2.5	1.9	1.8	3.2	3.5	3.5	3.5
Household consumption	3.5	2.7	2.2	3.2	3.5	3.5	
Investment	5.7	3.2	3.3	5.3	6.0	6.0	
Government consumption	4.2	3.4	3.2	3.3	3.2	3.2	endogenous
Exports	0.1	4.8	5.6	6.3	7.0	7.0	
Imports	6.3	7.3	5.1	6.1	7.0	7.0	
Inflation rate	5.7	5.7	6.2	5.9	5.5	5.5	5.5
Terms of trade	–2.2	0.5	0.5	0.5	0.5	0.5	0.0
Population growth	1.2	1.2	1.0	1.0	1.0	1.0	1.0
Employment	0.5	0.5	1.0	1.5	1.5	1.5	1.0
Real wage	1.5	1.0	1.0	1.0	1.0	1.0	0.5
Nominal exchange rate	–11.9	–9.0	–1.0	–1.0	–0.5	–0.5	
Electricity price	16.0	8.0	8.0	8.0	8.0	8.0	endogenous
Electricity supply	2.0	2.0	2.0	2.5	2.5	2.5	

Assumptions in the baseline scenarios

TABLE 2. The following assumptions were used in the *alternative* baseline scenario

Variable	2012	2013	2014	2015	2016	2017	2018	2019–2035
Data	Historical data from South African Reserve Bank and National Treasury		National Treasury's budget review; electricity prices: Eskom's MYPD3					CEPII long-run macro forecasts; Inflation within its target range; Steady-state employment; Electricity prices and supply endogenous
GDP	2.2	2.2	1.5	1.3.	0.9	1.7	2.4	2.4
Household consumption	3.4	2.9	1.4	1.4	0.7	1.6	2.2	
Investment	3.6	7.6	–0.4	1.1	0.3	1.4	2.7	
Government consumption	3.4	3.3	1.9	0.4	1.2	–0.2	0.2	endogenous
Exports	0.1	4.6	2	9.5	3	4.6	5.2	
Imports	6	1.8	-0.5	5.3	3.7	4.5	4.9	
Inflation rate	5.7	5.	6.	4	6.8	6.3	6	6
Terms of trade	–2.2	0.5	0.5	0.5	0.5	0.5	0.5	0.0
Population growth	1.2	1.2	1.0	1.0	1.0	1.0	1	1.0
Employment	0.5	3.1	1.	3.9	2.0	1	1.6	1
Real wage	1.5	1	—	1.	0	0	0.6	0.
Nominal exchange rate	–11.9	-	–1	—	–15.4	1.3	0.3	
Electricity price	16.0	8.0	8.0	8.0	8.0	8.0	8	endogenous
Electricity supply	2.0	2.0	2.0	2.5	2.5	2.5	2.5	

PARTNERSHIP FOR MARKET READINESS

PMR | *Supporting action for climate change mitigation*

http://www.thepmr.org
pmrsecretariat@worldbankgroup.org

WORLD BANK GROUP

2368