Greening the South Africa's economy could benefit the food sector: evidence from a carbon tax policy assessment

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Abstract

South Africa has a competitive and viable food production sector which enables the country to be a consistent net exporter of agricultural products. Lately, the business and labour organisations have raised concerns that the government's intention to implement the carbon tax policy will affect the food supply, subsequently exacerbating the unemployment and food insecurity in the country. Carbon tax is one of the policy tools to be implemented in order to reduce the growing greenhouse gas (GHG) emissions thus helping the government meets its Paris Agreement commitments. South Africa's National Treasury released a second draft of the carbon tax bill in 2017, which takes into account the concerns raised by different organisations. In this paper, we evaluate the potential impact of the carbon tax policy on agriculture, food and other sectors using a dynamic computable general equilibrium (CGE) model. The results show that the carbon tax is an effective policy tool to mitigate emissions, as they decline by 33 percent relative to the baseline by 2035. This also leads to a welfare loss of R98.326 billion as the country transforms into a green economy. The carbon-intensive sectors like transport, steel and coal-generated electricity experiences significant output decline. However, the agriculture and food sectors show improvements in terms of jobs and production when the carbon tax is implemented. The positive effects on these two sectors are greatly reduced if tax exemptions provided to the agricultural sector are removed and the tax revenue is not recycled in the form of production subsidy to industries.

Key words: CGE, carbon tax, agriculture

JEL classification: C68, H23, Q18

1. Introduction

South Africa has been consistently ranked amongst the world's top fifteen largest emitters of greenhouse gas (GHG) emissions per capita over the past decade. According to World Resources Institute (WRI 2015), the country produced a total of 524 metric ton carbon dioxide equivalent ($MtCO_2$-eq) in 2014, which is approximately 1.2 percent of the world's GHG emissions.

The country's emissions are dominated by the energy sector, that accounts for 84 percent whereas the agriculture and food sectors contribute seven percent. The country has committed to reducing its emissions through a *peak, plateau, and decline (PPD)* strategy. The strategy anticipates the emissions to reach a peak in 2025, stagnate between 2025 and 2035, and then decline post-2035. According to the Department of Environmental Affairs (DEA 2017), the strategy forms part of the Nationally Determined Contribution submitted to the United Nations Framework Convention on Climate Change (UNFCCC) in 2016 when South Africa ratified the Paris Agreement[1]. In the Paris Agreement, the country targets to reduce emissions by 42 percent below business as usual levels.

From a South African government perspective, the preferred policy instrument to reduce emissions is a carbon tax which is a market-based policy like emission trading schemes. The main difference between the carbon tax and emissions trading is that carbon tax fixes the price while the emission trading fix the quantity of emission, as such carbon tax policy provides a better signal to investors and is considered more effective in reducing emissions (DEA 2017). According to the National Treasury (NT 2013), the carbon tax is a preferred tool because it would act as an incentive for investors to make future investment decisions that promote a green economy. It also reduces market access risk that can arise if South Africa's trading partners decide to unilaterally impose a carbon consumption tax on products originating from South Africa. This risk was also noted by Arndt, Davies, Markelow, and Thurlow. (2013) who found that up to 40 percent of the country's export products would likely face taxation if markets such as the European Union (EU) adopt an emission consumption tax.

[1] Paris Agreement is a legally-binding framework for an internationally coordinated effort to tackle climate change. It was adopted on 12 December 2015 by 196 Parties of UNFCCC. Agreement entered into force on 4 November 2016

In 2015, the National Treasury released a first carbon tax draft bill for public comments. After taking into account the received public comments, the National Treasury released a second draft bill in 2017, which contained policy features such as tax exemption to agriculture and other sectors as well as tax revenue recycling options to minimize the impact on carbon-intensive sectors. NT (2017) also pronounced a carbon rate of one hundred and twenty rands per ton carbon dioxide equivalent (R120/tCO_2-eq) in the country. This paper aims to assess the potential impacts of introducing a carbon tax on the country's emissions as well as economic performance. It also evaluates the policy effects on different sectors including primary agriculture and food industries. We used a single country dynamic computable general equilibrium (CGE) model to quantify the policy effects.

2. Review of a carbon tax policy effects on the South African economy

In the past eight years, a number of researchers have assessed the implications of introducing the carbon tax on the country's economy including Van Heerden, Blignaut, Bohlmann, Cartwright, Diederich, and Mander (2016); Alton, Arndt, Davies, Hartley, Mekrelov, Thurlow, and Ubogu (2014); and Devarajan, Robinson, and Thierfelder (2011). The study by Devarajan et al. (2011), showed that the carbon tax is an effective tool to mitigate emissions but it can also lead to a significant welfare loss. In their analysis, they did not distinguish between different energy technologies which partly explain the high welfare loss they found on the economy. Alton et al. (2014), assessed the policy effects on a detailed energy sector that distinguish five electricity technologies and three petroleum liquids. They found a minimal impact on the economy which is equivalent to a 1.2 percent decline in the gross domestic product (GDP) relative to the baseline. The low welfare loss can be attributed to a relatively low tax rate of R25/tCO_2-eq that they assumed since their study was conducted prior to the NT (2017) pronouncing the R120/tCO_2-eq tax rate.

Van Heerdern et al. (2016), examined the policy impacts using the policy designs prescribed in the first draft bill released by NT in 2015. They obtain the results that indicated a significant decline in emissions and GDP, falling by 38.3 and 13.7 percent respectively relative to the baseline by 2035. Although they applied a correct carbon charge of R120/tCO_2-eq and distinguished between various energy technologies, they did not account for the expected technology improvements in the non-coal electricity sector which partly explains the high welfare loss they obtained in their study. All the existing studies in the country have assessed the potential impact of the carbon tax policy using a CGE modeling framework and focusing on energy, industrial and manufacturing sectors. There is limited focus on primary agriculture and food sectors which raises a need for a detailed assessment of these sectors. This is important because the two sectors not only ensure food security in the country but also contributes over 8 percent to total employment.

3. Need for carbon tax policy assessment on agriculture and food sectors

The existing local studies such as Van Heerden et al. (2016) and Alton et al. (2014), shared the insight of the expected policy impacts only on the aggregate food sector, leaving policymakers, industry captains, and labour formations to not fully understand the effects on individual primary agriculture and food industries. At an aggregate food sector, existing studies found that the carbon tax will have a negative but minimal impact on the food sector. This has propelled the different organisations to raised concerns over the potential impact of the carbon tax on food production. They argue that minimal policy impact on aggregate food sector will not necessarily equate to low impact on individual agriculture and food industries because the sector has a heterogeneous industry with different input and output structures thus emitting varying quantities of emissions.

Knowing the implications of the policy on individual industries will inform the policymakers to design better support mechanisms for farmers and poor households. Horowitz and Just (2013) found that in developed countries like the United States of America, policies that provide payments to farmers to take actions that mitigate emissions helps minimise the risk exposure of farmers to mitigation policies. While mitigating the growing GHG emissions in South Africa is critical but maintain a viable food supply is equally important thus raising a need to understand the potential impact of the carbon tax on different primary agriculture and food industries. According to NT (2017), the latest carbon tax bill contains policy designs that will cushion the agriculture and food industries against any severe impacts. Such a claim has not been empirically evaluated. This paper seeks to examine the expected impacts of the latest carbon tax policy bill on the primary agriculture and food sectors in particular, and the entire economy.

4. Methodology

We applied a modified version of the University of Pretoria General Equilibrium (UPGEM) model, which is a dynamic CGE model solved in GEMPACK solution software. The UPGEM is a single country CGE model for the South Africa economy. It has a similar theoretical structure to the MONASH CGE model developed by the Centre of Policy Studies (CoPS) and described by Dixon, Koopman, and Rimmer (2013) and Dixon and Rimmer (2002). The standard UPGEM is made up of a linearized system of equations describing the theory underlying the behavior of agents in the economy. GEMPACK eliminates linearization error by implementing shocks in a series of small steps and updating the database between steps. The core UPGEM model and database is discussed in Bohlmann, Van Heerden, Dixon, and Rimmer (2015), where they explain that the demand and supply equations of the model are derived from the solution to the optimisation problems. The equations underlie the behaviour of private sector agents in a conventional neo-classical micro economics. Each industry minimises cost subject to a given input prices and a constant return to scale production function. Zero pure profits are assumed for all industries. Households are designed to maximise a Klein-Rubin utility function subject to their budget constraint. Units of new industry-specific capital are constructed as cost-minimising combinations of domestic and imported commodities. The export demand for any locally produced commodity is inversely related to its foreign-currency price. Government consumption, typically set exogenously in the baseline or linked to changes in household consumption in policy simulations, and the details of taxation are also recognised in the model (Bohlmann et al. 2015 and Dixon et al. 2013).

While UPGEM and MONASH CGE are single country models, they are underpinned by same economic theories and national accounts (i.e. Input-Output Tables) as the multiregional model like the Global Trade Analysis Project (GTAP) model. However, the GTAP model is more accustomed to analysing international trade policies. To enable an environmental policy assessment as well as the detailed treatment of the agriculture, food and electricity sectors in the analysis, we make three important changes in the modeling framework as an improvement from the previous study conducted in South Africa such as Van Heerden et al. (2016).

Firstly, we construct a new detailed CGE database that disaggregated the primary agriculture, food, and electricity sectors. The primary agriculture sector is decomposed to industries namely: grains, horticulture, livestock, fisheries, and forestry. The food sector is decomposed to beverages, meat, dairy, cereals, and sugar; whereas the electricity is split into coal and non-coal electricity. The disaggregation and mapping process was informed by the emission intensity of different sectors. The emissions and energy data were based on emissions calculated by DEA (2017); and Seymore, Inglesi-Lotz, and Blignaut (2014). They calculated both the CO_2 and non-CO_2 GHG emissions based on the national energy balance and types of activity and technology used, respectively. Seymore et al. (2014) found that there is a lot of uncertainty around the non-CO_2 because their sources are diverse. The non-Co_2 emissions are modeled as being directly proportional to the output of the related industries and allowances are made for abetment of non-Co_2 emissions.

The mapping of individual food, agriculture, and electricity industries is presented in Figure 1. Following the splitting of these industries, other sectors in the UPGEM database were kept unchanged as contained in Bohlmann et al. (2015).

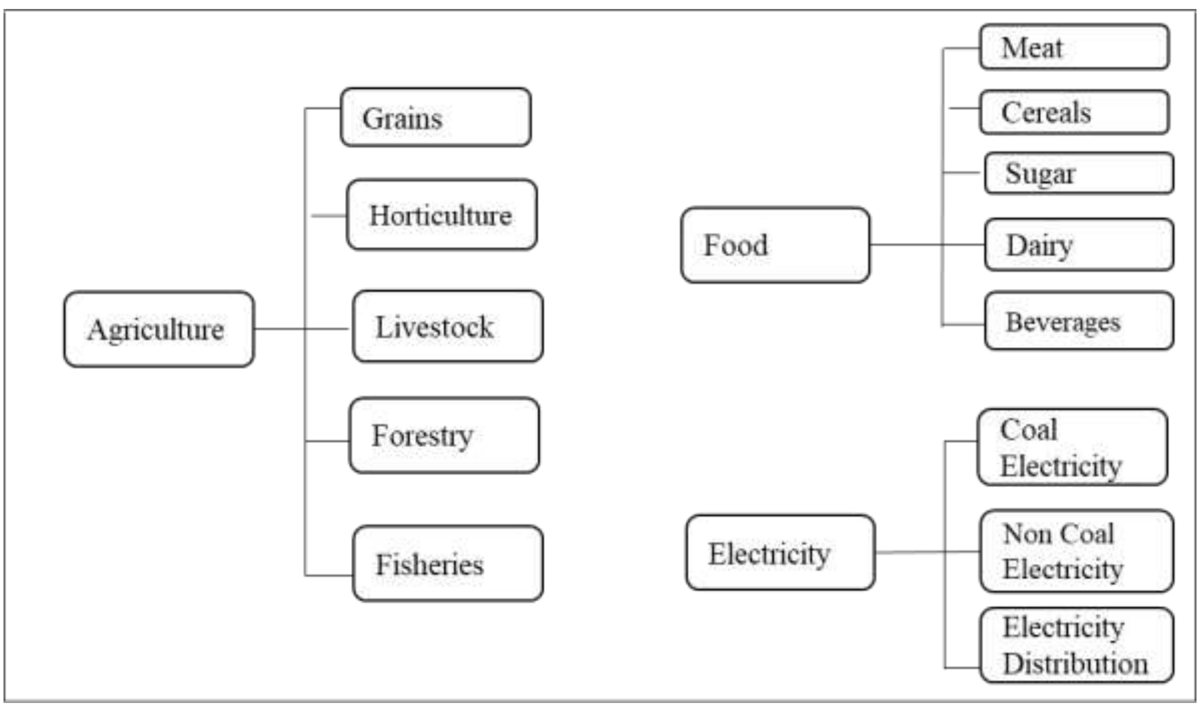

Figure 1: Industry disaggregation and mapping process

The second modification is to account for the expected technological improvements in the baseline of the non-coal generated electricity which allow for fewer emissions emitted by this industry. The allowance of technology changes is imposed exogenously in the baseline of the non-coal electricity industry based on future projections obtained from the International Energy Agency (IEA 2017). The IEA (2017) reported that renewable energy costs will decline by up to 40 percent over the next decade due to technology improvements. While this is a global projection, South Africa is assumed to be following the same trend because it is an open economy that is linked to the global economy. The assumed technology changes imply that there will be efficiency and cost competitiveness in the non-coal electricity relative to coal-electricity, even before a carbon tax policy is applied.

Thirdly, we allow environmental analysis in the UPGEM model by creating a module that is similar to the environmental analysis module for an Australian economy used in the MONASH model by Adams, Dixon, Giesecke, and Horridge (2014). The environmental module has also been applied in regional and global models like GTAP as described in Burniaux (2002) and Peters and Hertwich (2006). The additional equations created in the UPGEM model for environmental policy analysis include (i) an energy and gas emissions accounting module, which accounts explicitly for each industry recognised in the model; (ii) enable inter-fuel substitution in electricity generation; (iii) mechanism that allows for the endogenous take-up of various abatement measures in response to emission policy measures. The inter-fuel substitution between coal and non-coal electricity in the model is handled using the technology bundle approach of Hinchy and Hanlow (1996), and the modified nested production structure showing the new electricity bundle is presented in Figure 2.

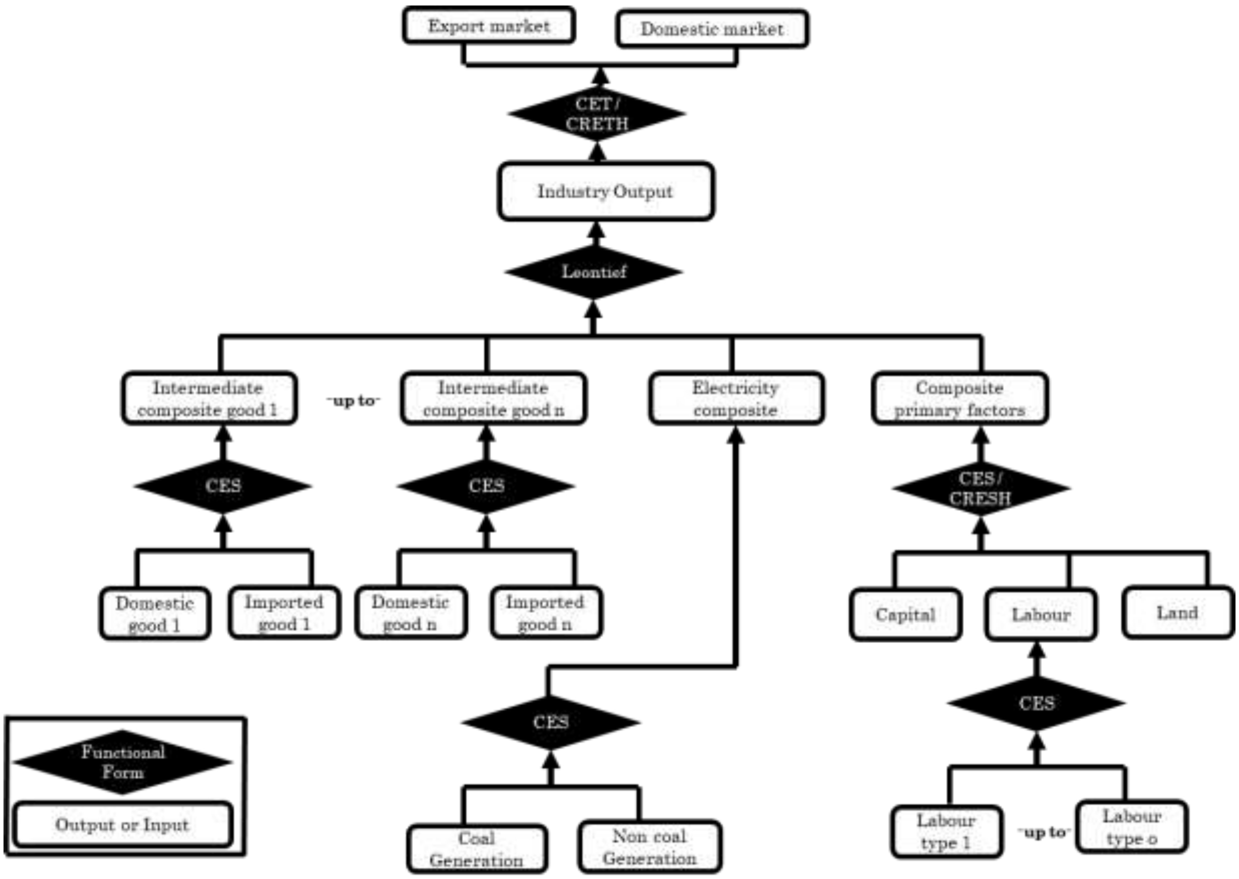

Figure 2: Modified nested production structure in the UPGEM

Source: Adapted from Bohlmann et al. (2015) and Dixon and Rimmer (2002)

Bohlmann et al. (2015) explain that, at the top level of the structure, the intermediate commodity composites and a primary-factor composite are combined using a Leontief production function. Consequently, they are all demanded by a producer in direct proportion to industry output or activity. This industry output is a composite of goods produced for export and domestic markets, which is governed by constant elasticity of transformation (CET) that determines the producers' trade-off between producing goods for export versus domestic markets. Each commodity composite is a constant elasticity of substitution (CES) function of a domestic good and its imported equivalent. This incorporates an imperfect Armington's assumption of an imperfect substitution of goods by place of production, an assumption which was first introduced by Armington (1969). The primary factor composite is a CES aggregate of composite labour, capital, and land. Composite labour demand is itself a CES aggregate of the different types of labour distinguished into eleven different occupations.

In the standard UPGEM, all industries share a common production structure presented in Figure 2, but without the separate bundle for the electricity technologies. The creation of the sub-production structure for electricity enables one to track the impact of a carbon tax in shifting the electricity demand from coal- to non-coal-generated electricity. Once the model database and model code has been altered to allow for environmental enhancement analysis, the next step was to estimate new trade elasticities for the individual agricultural and food products. As seen in Figure 2, trade elasticities, such as the Armington, play a central role in CGE models to determine the demand substitution between commodities from different sources as a result of changes in relative prices. The rationale for estimating new trade elasticities is that existing elasticities are outdated – last estimated by Gibson (2003) using data that dates back to the 1980s – which does not reflect the changes that have happened in the South African economy in the past 24 years.

Two sets of elasticities were estimated, that is the Armington elasticity and export supply elasticity using annual data from 1980 to 2017. The methods and data characteristics used to estimate trade elasticities are explained in detailed in Ntombela, Kalaba, and Bohlmann (2018). Table 1 in Appendix A presents the estimates of both the Armington and export supply elasticities. The results for the two sets of trade elasticities show that estimates for aggregate agriculture tend to be inelastic compared to estimates for an individual product, indicating a higher sensitivity of products to relative price changes. The Armington estimates were found to be closer to unity for the majority of products, suggesting that agriculture and food imports are imperfect substitutes for domestic products. The export supply elasticities for grains were found to be more elastic than for fruits and meat, implying that domestic grain production is relatively more responsive to price changes in the export markets. The long-run estimates for the two sets of elasticities were used in the modified UPGEM model to improve the functionality and accuracy of simulations. To simulate the effects of a carbon tax policy on primary agriculture, food, and other sectors, we used the policy bill released by NT (2007).

5. Description of the South African carbon tax policy

NT (2017) describe the carbon tax policy as following:

(i) The tax is levied at R120/tCO_2-eq and set to increase by 10 percent per annum over the first five years. Thereafter will increase in line with inflation.

(ii) The revenue generated from the proposed tax will be recycled via the national fiscus;

(iii) In the initial five-year window, the primary agriculture, forestry, waste handling, and land-use sectors are fully exempted;

(iv) The creation of a trade exposure allowance, which is up to 10 percent, will help protect the competitiveness of South African industries and to prevent carbon leakage problem.

(v) Trade exposed industries are those that have exports and imports combined value making up more than 40 percent of domestic output value;

(vi) The tax is effectively a fossil-fuel input tax levied on scope 1 emission, that is, emissions that result from fuel combustion, gasification, and non-energy industry process;

To determine the implications of the carbon tax on the food and other sectors, the economic data from 2011 Social Accounting Matrix (SAM) and the Supply-Use Tables (SUT) published by Statistics South Africa were entrenched with emission data from DEA (2017); and Seymore et al. (2014). The proposed carbon tax is effectively a fossil-fuel input tax, but one that is levied on industry-specific emissions such as the coal, gas, and petroleum. Since the emission and energy content of fuels vary, the tax has to be applied to fuel use. As a result, the emission and energy data need to be converted into fuels terms using industry-wide consumptions. To obtain the effective tax rate, a simple approach developed by Van Heerden et al. (2016) assist to transform the R/tCO_2-eq charge to rand per terajoule (R/TJ).

This is necessary to standardise the unit of measurement because the tax is a tax on fossil-fuel consumption, yet the tax rate in the carbon tax bill is expressed in R/tCO_2-eq. It is important to note that 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 of R120/tCO_2-eq, however, it just helps address the issue of different fuel inputs.

Table 2 contains the coefficients required to make the conversion in tax rate from R/tCO_2-eq to R/TJ, and these coefficients were estimated by Van Heerden et al. (2016). The CO_2/TJ coefficient for coal commodity is estimated at 95.60 tCO_2/TJ; for gas is estimated at 63.73 tCO_2/TJ, and for petroleum is estimated at 72.56 tCO_2/TJ. Multiplying these input fuel specific coefficients with the carbon tax rate of R120/ tCO_2-eq which is proposed in the Bill of 2017, it gives the tax rate in R/TJ as provided in the last column of Table 2. These effective tax rates still need to take into account the tax-free allowances per sector as provided in the carbon tax bill of 2017(NT 2017).

Table 2: Conversion coefficients from carbon dioxide equivalent to terajoule

Fuel type	tCO_2-eq/TJ coefficient	R/tCO_2-eq	R/TJ
Coal	95.60	120	11 472
Gas	63.73	120	7 647
Petroleum	72.56	120	8 707

Source: adapted from Van Heerden et al. (2016)

Once the tax rate is converted to R/TJ, the maximum allowances are applied and this is provided in Table 3 together with emissions as well as the sector's energy consumption levels. The emissions and energy data presented in Table 3 is derived from Seymore et al. (2014), who calculated both the CO_2 and non-CO_2 emissions per sector. The maximum allowances are derived from the carbon tax bill released by NT (2017). As indicated in Table 3, the primary agriculture has 100 percent tax-free allowances in the first five-year window of implementation. To obtain the effective tax rate, we used the information from Table 1 taking into account the maximum allowances presented in Table 3 to calculate the effective tax rate per sector in R/TJ form.

Table 3 also indicates that the majority of South Africa's emissions are from the energy sectors such as petroleum and electricity which relies on fossil fuels and coal. The leading sources of agriculture and food emissions are livestock manure and food waste. Oelofse and Nahman (2013), found that 30 percent of food is wasted per annum in South Africa which contributes to agricultural emissions. Looking at the international literature, WRI (2015) and Garnett (2011), also found that food waste contributes substantially to global agriculture and food sector's GHG emissions.

Table 3: Industry energy consumption, emissions, tax allowances, and effective tax rate

Economic Sectors	Emissions ($MtCO_2$-eq)	Energy use (TJ)	Maximum Allowance (%)	Effective tax rate (R/TJ) after accounting for allowances		
				Coal	**Gas**	**Petroleum**
Primary agriculture	5.01	72 327	100	0	0	0
Food	0.10	4 115	95	574	382	435
Chemical, steel and plastic	58.57	729 574	95	574	382	435
Coal and lignite mining	2.36	49 671	95	574	382	435
Transport services	77.21	811 860	90	1 147	765	871
Petroleum refineries	83.51	687 019	90	1 147	765	871
Other economic sectors	36.51	625 174	90	1 147	765	871
Coal electricity	296.39	2 452 146	75	2 868	1 912	2 177
Non-coal electricity	2.82	23 298	75	2 868	1 912	2 177
Electricity distribution	1.51	12 492	75	2 868	1 912	2 177
Total	**564**	**5 467 676**				

Source: own calculations based on NT 2017; Van Heerden et al. 2016; and Seymore et al. 2014.

The effective tax rates calculated and presented in Table 3 are then used as policy shocks in the model to determine the effects of introducing a carbon tax on the South African economy. The next step is to design baseline and policy scenarios that will help examine the expected impacts of the policy on the agriculture and food sectors within a broader economic context.

6. Simulation design

The proposed carbon tax has its theoretical underpinnings on the need to internalise the negative externality of emissions and thereby support a structural transition of the economy towards a more climate-resilient and less carbon-intensive economy (NT 2017; and Van Heerden et al 2016). It is important to mention that the main difference between the 2017 carbon tax Bill and the 2015 tax Bill, is that the maximum tax-free allowances across sectors have increased from an average of 70 to 95 percent. The expected effects of the carbon tax on primary agriculture, food, and other industries are tested under three sets of assumptions represented by three policy scenarios. All three policy scenarios are simulated and interpreted against the baseline, which depicts a business-as-usual scenario. This implies a normal growth in the economy without the introduction of the carbon tax. The only change made in the baseline is allowing technology improvements in the non-coal electricity industry.

(i) **Focus policy scenario:** This is the main policy scenario where the tax rate is modeled to accurately reflect the policy features proposed in the carbon tax draft bill of December 2017. One of the key assumptions shaping this policy scenario is that the tax will be introduced at R120/tCO_2-eq which then increases by 10 percent per annum in the first five years of implementation; thereafter increasing in line with the inflation rate. Moreover, the maximum tax-free allowances per sector are retained for the duration of the modeling period. The modeling period is up to 2035 to enable a longer timeframe that illustrates the carbon tax impact in the short run and long run. The tax revenue is recycled in the form of a production subsidy for all industries to reflect the proposal made by NT (2017).

(ii) **Allowances Removed policy scenario**: In this policy scenario, the carbon tax is introduced at R120/tCO_2-eq including the tax-free allowances per sector, as well as the recycling of revenue. However, after the first five years of implementation, the tax-free allowances are gradually reduced to accelerate the mitigation of emissions in the country. The reduction of tax-free allowances is maintained at 10 percent per annum up until the point where all industries are paying 100 percent tax rate.

(iii) **No Revenue Recycling policy scenario:** The tax and allowances are applied in the Focus scenario but there is no revenue recycling scheme. The second and third scenarios aim to analyse the sensitivity of the economy to a carbon tax impact if the tax revenue recycling scheme and allowance are removed. All three policy scenarios are simulated and interpreted against the baseline scenario.

(iv) **Baseline scenario**

The baseline scenario reflects a plausible evolution of the economy without the introduction of a carbon tax shock. The baseline scenario reflects the economic activities based on the available economic and emissions forecast data presented in Table 4 in Appendix B. Besides incorporating the available macroeconomic forecast data into the baseline, technology improvements are allowed in the non-coal baseline scenario.

Technology changes are exogenously imposed and free to reflect the expected innovation improvements in the non-coal industries.

The technology in non-coal electricity, especially for renewable energy like wind and solar power, has improved significantly since 2011 (the base year of this study) and is set to continue improving as the world moves away from fossil reliance towards cleaner energy sources. The IEA (2017) estimated that renewable energy cost will decline by 40 percent over the next decade largely because of technology improvements in the non-coal electricity industry. Previous studies such as Van Heerden *et al.* (2016) did not account for technology improvements in the non-coal industries which partly explains the higher welfare loss found in their results relative to the baseline.

7. Simulation results

7.1 Macroeconomic results

The first result to discuss is the impact of accounting for technology improvement in the baseline of the non-coal electricity, which is presented in Figure 2. By allowing for the technological improvements in the non-coal electricity, in line with the IEA (2017) forecasted changes, leads to relatively higher competitiveness and efficiencies in the non-coal relative to the coal electricity. Subsequently, the output of the non-coal electricity sector grows by 126 percent relative to the base year by 2035, which is higher than the growth pace observed when there is no allowance of technology changes. If no technology improvements are allowed, the non-coal electricity output increases by 79.2 percent which is inline with the GDP growth under the baseline scenario. The technology changes reduce the capital costs of establishing non-coal generation plants relative to coal generation plants, subsequently mitigating the quantity of GHG emissions emitted from the economy. This substantial growth is comparable with international expectations that forecast significant growth in the output of the non-coal electricity in the next decades.

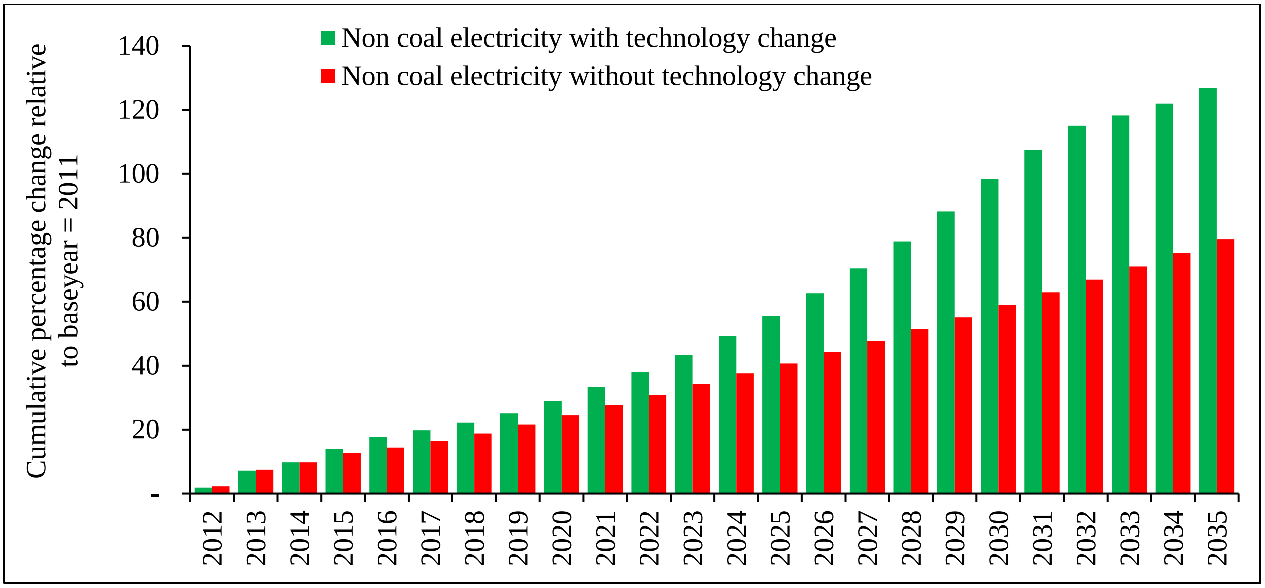

Figure 3: Expected impact of technology improvements on non-coal electricity output

The next step is to discuss the results on the macroeconomic indicators such as the GDP, aggregate employment and emissions. The implementation of a carbon charge of R120/tCO_2-eq on fuels uses leads to a substantial reduction of emissions in the country. From Figure 4, the GHG emissions decline by 32.9 percent under the Focus policy scenario which mirrors the policy designs as prescribed in the carbon tax bill of 2017. The emissions decline is lower than the 38.3 percent found by Van Herdeen et al. (2016). The main reason for this deviation is the allowance made for technological changes in the non-coal electricity sector in the baseline scenario which reduces the amount of GHG emissions the country is producing prior to introducing the carbon tax. Moreover, are the additional tax-free allowances that have been added in the latest policy bill which ease the tax burden on industries. As a result, the reduction from the baseline after introducing the carbon tax is narrowed as compared to bigger deviations found by Van Heerdeen et al. (2016).

Moreover, Figure 4 shows that the emissions can reduce to 35.1 percent and 45.4 percent relative to the baseline if the government does not recycle the tax revenue or if it removes the allowances, respectively. This suggests that more GHG emissions will be reduced if the government removes the higher tax-free allowances currently provided under the tax bill of 2017. It is important to note that the carbon tax policy alone under the current design (i.e. Focus policy scenario) is not sufficient to meet the country's emission reduction targets made in the

Paris Climate Agreement. However, the policy does make a meaningful contribution to the country's effort to reduce GHG emissions.

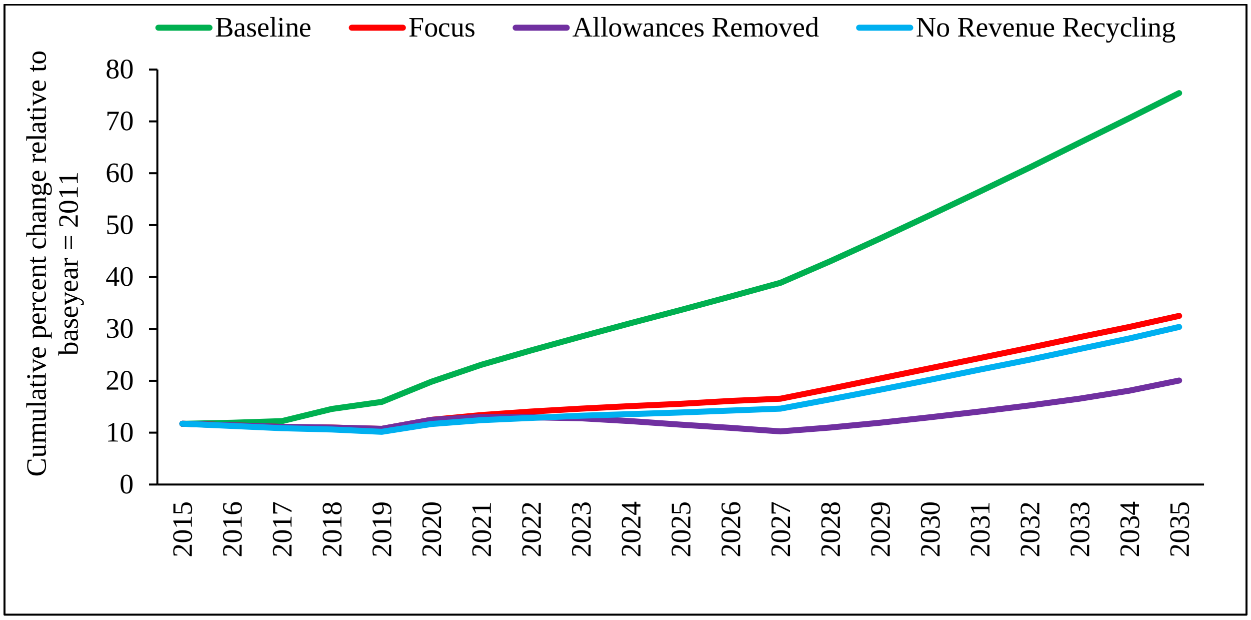

Figure 4: Expected impact of the carbon tax policy on the country's GHG emissions

The expected policy effects on the GDP growth are presented in Figure 5. The carbon tax will lead to a welfare loss, reducing the GDP by 0.91 percent (equivalent to R98.326 billion) under the Focus policy scenario relative to the baseline. When evaluating the sensitivity of different policy scenarios, it is clear that if tax-free allowances are removed at a 10 percent rate from 2021 onwards, the GDP decline by 3.84 percent relative to the baseline. But if the government withhold the recycling of the revenue back into the economy, the GDP reduce by 2.07 percent below the baseline. These results imply that the amount of the adjustment cost (i.e. welfare loss) the country will incur to transform into a low carbon economy largely depends in the manner in which government will treat the tax-free allowances as well as the recycling of the revenue back into the economy.

The results presented in Figure 1 and Figure 2 indicates that if the government removes the tax-free allowances, the emissions will reduce quicker declining to 45.4 percent by 2035 relative to the baseline. However, this policy scenario also leads to a larger impact on economic growth. The economic growth will decline by 3.87 percent relative to the baseline by 2035. This is caused by a sharper decline in investments as carbon-intensive industries like coal-generated electricity and metal and steels struggle to cope under the carbon tax policy era. The rate of unemployment will also rise due to the production constraint and deteriorating competitiveness facing the carbon-intensive industries when the carbon tax is implemented either without tax revenue recycling or without tax-free allowances provided.

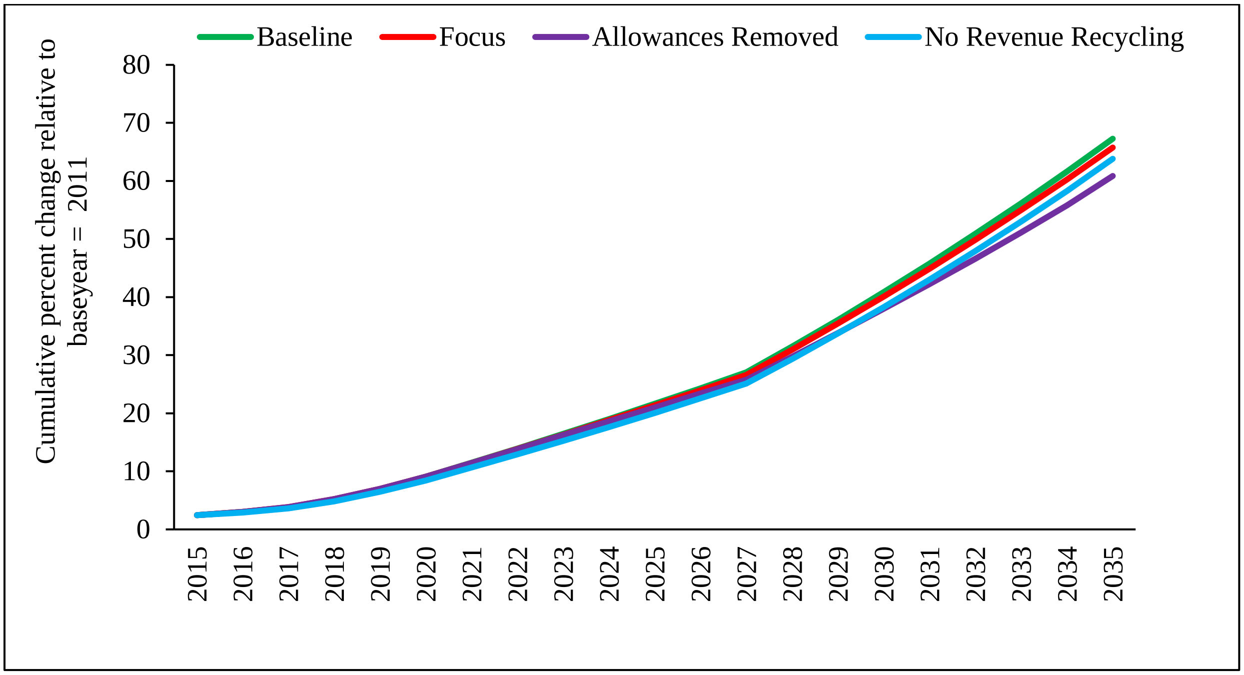

Figure 5: Expected impact of the carbon tax policy on economic (GDP) growth

The results presented in Figure 5, illustrates that the current carbon tax policy design as reflected in the Focus policy scenario will have a minimal impact on the economy whilst reducing the emissions by nearly 33 percent below the baseline by 2035. This adjustment costs to low carbon economy are lower than that found by previous studies like Van Heerden et al. (2016) and Alton et al. (2014), because of technological changes taken into account and additional tax-free allowances which were not accounted for by the previous studies. A 0.91 percentage decline in GDP relative to the baseline can be argued to be marginal adjustment costs necessary to achieve a bigger goal of preserving the environment for both current and future generations.

Arndt et al. (2013), found that green energy sectors such as the non-coal electricity in South Africa will create jobs but not at the same intensity as the fossil-related sectors like the mining and coal electricity. The expected policy impacts on aggregate employment are presented in Figure 6, and it somehwat confirms finding of Arndt et al. (2013) that greening the economy will likely lead to job losses at the national level. We found that the aggregate employment will decline by 0.62 percent relative to the baseline when carbon tax policy is implemented. This suggests that there will be employment losses when the economy transform towards less carbon-intensive industries because they create fewer job opportunities. Importantly to note is that the employment losses will be small indicating that the labour market will not be servery affected by the introduction of the carbon tax.

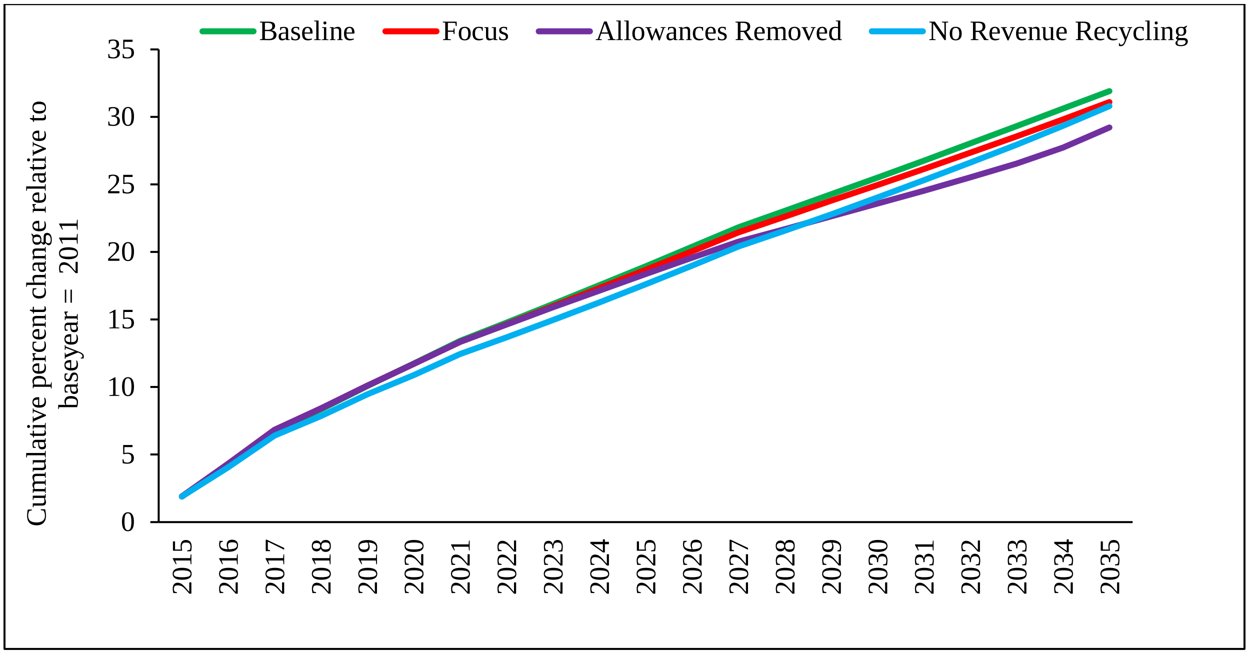

Figure 6: Expected impact of the carbon tax policy on aggregate employment

The macro results indicate that the carbon tax policy will assist in reducing the GHG emissions in the country. However, it will also lead to a minimal welfare loss driven by a decline in aggregate investments, employment and other GDP components. Despite the expected decline in the GDP, the ability of the carbon tax to reduce GHG emissions by nearly 33 percent relative to the baseline is critical in helping the country achieve its commitments under the Paris Agreement. The next section discusses the disaggregated results focusing on the effects of the carbon tax on the food, agriculture and other economic sectors.

7.2 Sectoral results

The industrial results assist in examining both the direct and indirect impacts of the carbon tax on different industries, thereby identifying the winners and losers in the economy. At a broader level, the non-coal electricity sector is the biggest winner with output growing by 224 percent above the baseline by 2035. This is driven by technological changes in renewable energy which promotes investments in the country. South Africa has an operating Independent Power Producer (IPP) program that seeks to promote investments in the renewable energy and help the country diversify it's energy sector that is currently dominated by the coal electricity. The sectoral results also indicate that the heavy emitting sectors such as the coal electricity, petroleum, metal, and steel are negatively affected losing 34 percent of output on average under the Focus scenario (Figure 7). Looking at individual primary agriculture (i.e. field crops, horticulture and livestock) and food (i.e. meat, cereals, sugar and dairy) industries, the impact is slightly positive under Focus policy scenario due to tax-free allowances provided as well as the recycling of tac revenue.

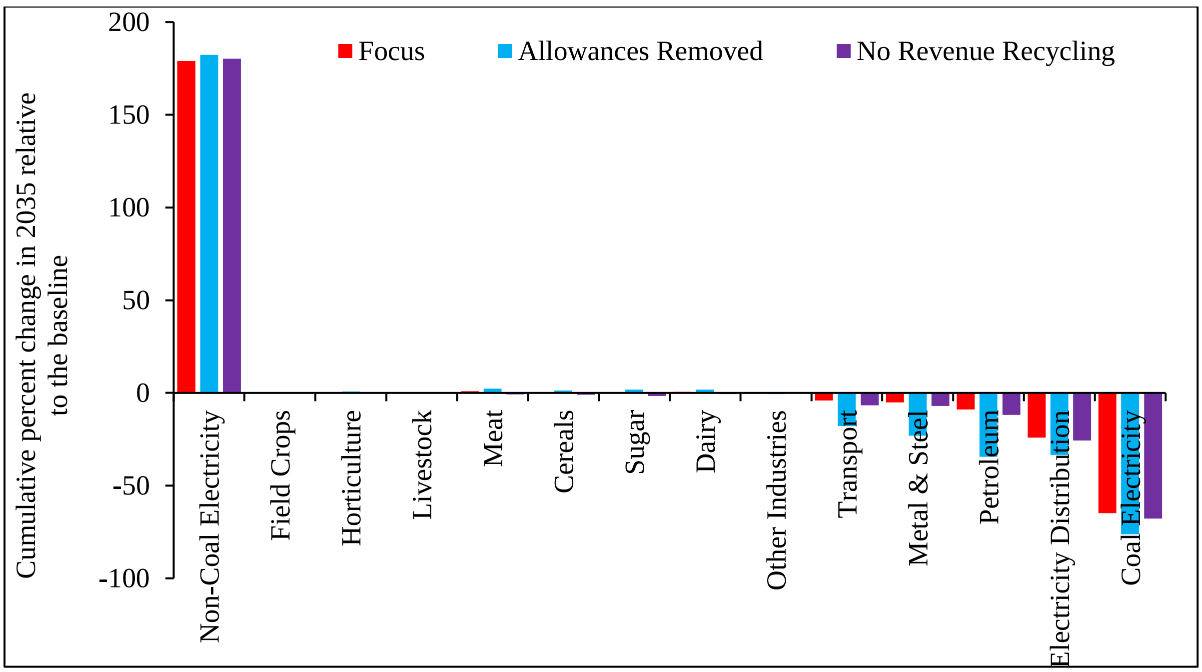

Figure 7: Expected long-term policy impact on all industries' output by 2035

It is evident that the biggest winners are those industries with low levels of GHG emissions, that is, the non-coal electricity and business industries. Furthermore, the results presented in Figure 7 clearly show that when the South African government decides to implement the carbon tax policy without tax-free allowances and a revenue recycling scheme, the impact on different industries' output would be significant and negative, with the exception of the non-coal electricity industry. If the tax-free allowances are removed, the long-run impact on the individual agricultural and food industries' output becomes negative and this negative effect persists when the revenue recycling scheme is also removed. Other industries that are expected to experience output decline relative to the baseline in the long run are the coal electricity, petroleum, steel and transport industries.

Zooming into the food sector, the results on food production shows a minimal but positive growth in all food industries relative to the baseline when the carbon tax is implemented. On average, the food sector output experiences a cumulative growth of 1.76 percent above the baseline by 2035 (Figure 8). The positive growth in the food sector can be attributed to the full tax-free allowances provided in the primary agriculture which reduces the indirect impact to the food sector under the Focus scenario. Since the food sector is heavily reliant on agricultural output, they subsequently benefit from the full-tax-free allowances granted in the primary agricultural industries.

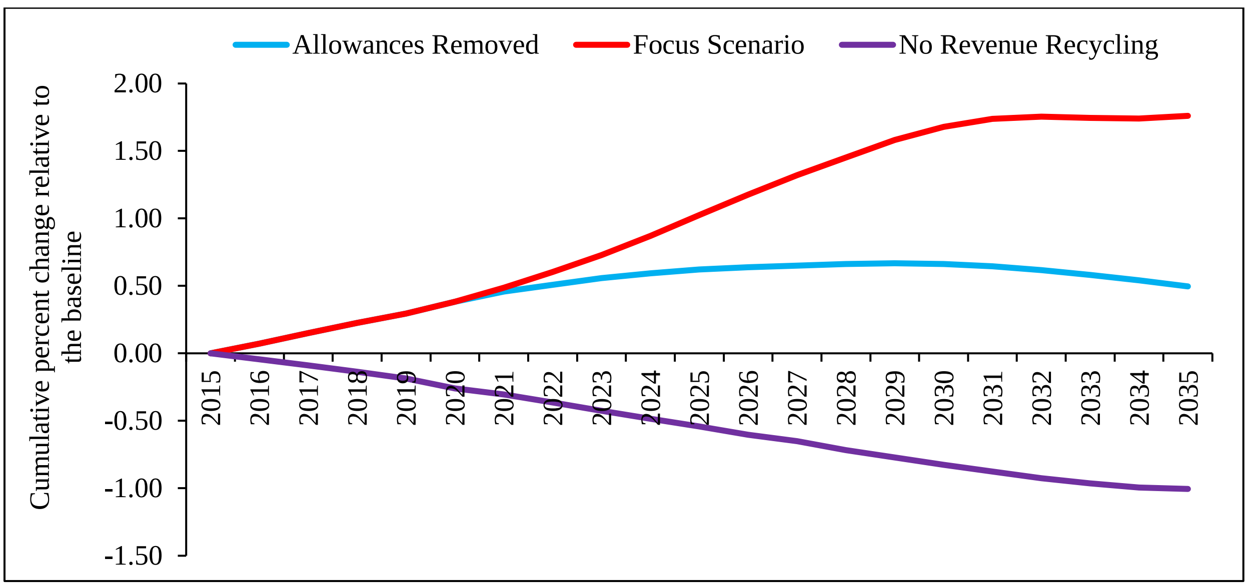

Figure 8: Expected impact of the carbon tax policy on food production in South Africa

Figure 8 also indicates that when the tax-free allowances are gradually removed, they affect the sector's ability to produce. This effect becomes severe when there is no revenue recycling in the economy as food production declines by a cumulative of 1.05 percent relative to the baseline by 2035. The results from Figure 8, suggests that the policy designs as prescribed in the latest carbon tax bill of 2017 could have positive effects on the primary agriculture and food sectors, provided the full tax-free allowances and revenue recycling schemes are maintained post the first five-year window of the policy implementation. This is contrary to the perceptions of labour and business organizations that have argued against the implementation of the carbon tax due to its likely negative effects on the food production and supply in the country.

Following the analysis of the implications of the food output, Figure 9 presents the expected effects on the food sector's employment. It is evident that the employment in the food sector will likely increase relative to the baseline. The food and primary agriculture are among the key economic sectors that are expected to experience positive growth in employment when the carbon tax is implemented. On the opposite side, the transport, coal electricity, metal, and steel sectors will experience significant losses in employment when the carbon tax is introduced across all three policy scenarios. It is worth noting that the primary agriculture and food sectors employ nearly a million people in the country. Moreover, they employ people from rural areas thus playing a critical role in alleviating poverty in rural areas.

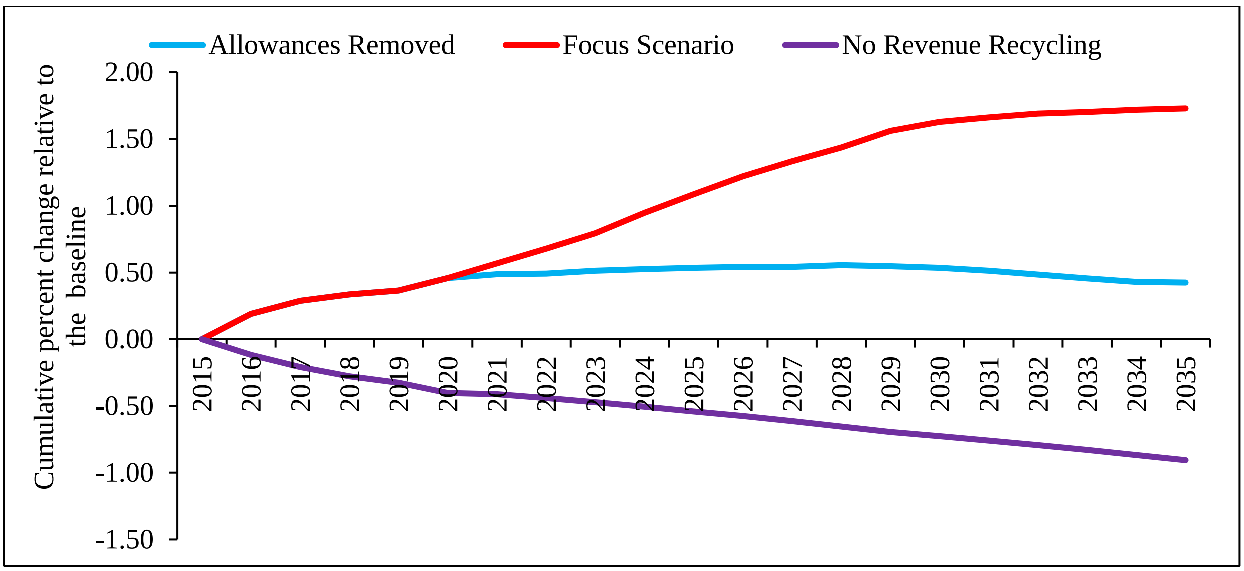

Figure 9: Expected impact of the carbon tax on food industry employment

Agriculture and food sectors are one of the key exporters in South Africa accounting nearly 10 percent to total exports. One of the key concern about the introduction of carbon tax policy was the implications on the sectors' competitiveness. To avoid affecting the competitiveness of the food sector, policymakers included a trade exposure allowance in the Bill which helps industries maintain their competitiveness in the international markets. Figure 10 indicates that the food sector will continue having a competitive edge in the global market as exports show a positive growth relative to the baseline under Focus policy scenario. At a disaggregated food sector level, the results indicate higher growth rates on food such as meat, cereals, dairy, sugar, and beverages as compared to primary agriculture. This significant growth in the food exports can be attributed to weakening consumer buying power, subsequently declining household consumption in the domestic market which avails large quantities of food for the export market. Under the Allowance Removed policy scenario, the household consumption significantly declines, hence a stronger export growth is observed under this scenario in Figure 10.

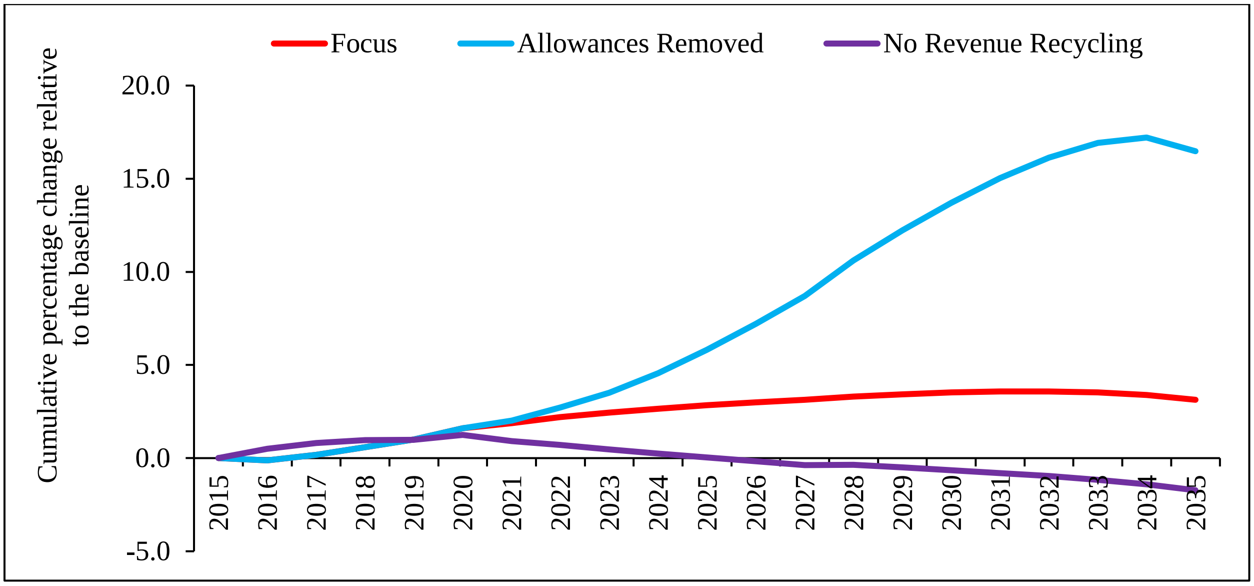

Figure 10: Expected impact of the carbon tax policy on industry exports

The sectoral results for the individual primary agriculture and food industries provide an indication that the manner in which government removes the tax-free allowance and treat the collected carbon tax revenue will determine the magnitude of the effects on the food supply in the country. For an example, the Focus policy scenario that assumes maximum tax-free exemptions and full recycling of the revenue results into output activity improvements as well as positive gains in employment. However, when exemptions are removed the negative impacts on food industries increase leading to output and employment losses. A similar negative implication is obtained when the revenue collected is not recycled.

8. Conclusion and policy recommendation

In this paper, we applied a CGE model to evaluate the expected impacts on food and agricultural sectors within a broader context of the economy. At a macro level, the results indicated that the carbon tax is an effective tool to reduce GHG emissions as it leads to large emissions reductions in the country. However, the implementation of the carbon tax also leads to a welfare loss as the country transforms into a low carbon economy. Notable, the results found in this paper appears to be much lower than the findings of the previous studies such as Van Heerden et al. (2016); and Alton et al. (2014). The deviation from previous studies can be attributed to the allowance made for technology improvement in the baseline of the non-coal electricity which reduces the emissions and attracts investments in the non-coal electricity. Moreover, the higher tax-free exemptions provided in the 2017 carbon tax bill also eases the impact on the economy which partly explains the 0.91 percent decline in the GDP relative to the baseline.

The sectoral results showed that the heavy emitting industries like coal-generated electricity, steel; metal, and petroleum will be severely affected with output declining by an average of 34 percent over the next 25 years relative to the baseline. The results on agriculture and food sectors indicate a positive benefit as output, employment and exports improve relative to the baseline when carbon tax policy is implemented. From a policy perspective, the results provide empirical evidence that agriculture and food industries could benefit from greening the economy conditional that the policymakers retain the full tax exemption in agriculture as well as recycling the revenue back into the economy. The positive assessment of the current carbon tax bill suggests that the policy makers have designed the carbon tax policy well to an extent that it partially cushions the food production system against any significant negative effects associated with the introduction of the carbon tax. Noting that the carbon tax is relatively well designed as prescribed in the carbon tax bill of 2017, it is recommended that the policy makers should retain a full tax exemption to primary agriculture beyond the first-five-year window of implementation. In addition, it is recommended that the full tax exemptions are also extended to the food sector given its importance on ensuring food security in the country. Lastly, it is recommended that policymakers develop a mechanism to reduce food waste as it is one of the primary sources of emissions emitted from the food sector.

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Appendix A

Table 1: CES Armington and CET export supply elasticities for agriculture and food products

Sub-sector	Commodities	HS code	Armington elasticity			Export supply elasticity	
			Short-run	Long-run		Short-run	Long-run
Grains	Maize	1005	0.868*** (0.221)	2.399*** (0.119)		0.491*** (0.183)	0.536*** (0.154)
	Wheat	1001	0.98*** (0.268)	1.648*** (0.151)		0.995*** (0.470)	1.707*** (0.156)
	Sorghum	1007	1.818*** (0.425)	2.171*** (0.138)		1.108*** (0.406)	1.799** (0.172)
Fruits	Apples	080810	0.506*** (0.157)	0.604** (0.1468)		0.005 (0.012)	0.013 (0.152)
	Grapes	080610	0.717*** (0.203)	0.730 (0.166)		0.139*** (0.036)	0.143 (0.153)
	Oranges	080510	0.245* (0.143)	0.252 (0.113)		0.028*** (0.099)	0.047 (0.169)
	Avocados	080440	0.270*** (0.107)	0.509* (0.138)		0.412*** (0.179)	0.685*** (0.148)
Vegetables	Potatoes	0701	0.430* (0.271)	0.522 (0.181)		0.279* (0.158)	0.360** (0.170)
	Tomatoes	0702	0.761** (0.319)	0.810** (0.329)		0.518*** (0.188)	1.064*** (0.080)
Meat	Beef	0201-2	0.911* (0.626)	1.306** (0.169)		0.497* (0.315)	0.505 (0.174)
	Poultry	0207	0.282** (0.030)	0.301 (0.173)		1.219*** (0.428)	1.657*** (0.156)
	Swine	0203	0.669* (0.512)	0.909** (0.165)		0.796** (0.664)	0.973** (0.172)
Processed	Milk	0401	0.415* (1.020)	0.506 (0.174)		0.849** (1.029)	1.213* (0.170)
	Wine	2204	1.971*** (0.176)	2.165** (0.083)		1.039*** (0.576)	1.274** (0.166)
	Sugar	1701	0.817** (0.388)	1.140*** (0.155)		0.276* (0.174)	0.334*** (0.164)
Aggregated	Agriculture		0.329*** (0.038)	0.376 (0.172)			0.450** (0.169)

Source: Ntombela et al. (2018)

Appendix B

Table 4: Macroeconomic and technology changes forecast data used to calibrate the baseline scenario

Variables	Source	Actuals							Short-medium term				Long term estimates			
		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025 -2035
Real GDP (%)	NT, 2018	3.30	2.20	2.30	1.60	1.30	0.30	1.3	0.70	1.70	2.10	2.20	2.20	2.20	2.20	2.20
Household (%)	NT, 2018	3.70	3.40	2.90	1.40	1.80	0.70	2.20	1.60	1.90	2.16	2.16	2.16	2.16	2.16	2.16
Government (%)	NT, 2018	3.60	3.40	3.30	1.90	-0.30	1.90	0.60	0.80	0.20	1.2	1.73	1.73	1.73	1.73	1.73
Investment (%)	NT, 2018	5.54	3.60	7.60	1.40	3.40	-4.10	0.40	0.90	1.50	2.10	2.73	2.73	2.73	2.73	2.73
Exports (%)	NT, 2018	3.50	0.10	4.60	2.60	2.8	1.0	-0.1	1.00	2.7	2.9	3.33	3.33	3.33	3.33	3.33
Imports (%)	NT, 2018	4.22	6.00	1.80	-0.50	5.30	-3.80	1.60	2.20	2.90	3.24	3.44	3.44	3.44	3.44	3.44
Inflation (%)	NT, 2018	5.00	5.70	5.80	6.10	4.60	6.30	5.30	4.90	5.60	5.40	5.40	5.50	5.50	5.50	5.50
Interest Rates (%)	NT, 2018	8.50	9.00	9.25	9.75	11.25	11.50	11.50	10.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50
Current Account Balance	NT, 2018	-2.20	-5.10	-5.90	-5.30	-4.60	-2.80	-2.40	-3.20	-3.70	-3.90	-3.90	-3.90	-3.90	-3.90	-3.90
Population (%)	StatsSA	1.30	1.40	1.40	1.40	1.30	1.30	1.20	1.20	1.20	1.20	1.10	1.10	1.10	1.10	1.10
Unemployment (%)	2017	24.80	24.50	24.10	24.30	25.70	26.90	27.2	27.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00
Exchange Rate (R/$)	NT, 2018	0.08	0.18	0.12	0.18	0.17	-0.07	-0.10	-0.08	0.06	-0.03	0.03	0.03	0.03	0.03	0.03

Sources: National Treasury, 2018, and Statistics South Africa, 2017