Regional employment and economic growth effects of South Africa's transition to low-carbon energy supply mix

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Highlights

- The transition to low-carbon supply mix in South Africa is inevitable.
- Not all provinces will have the same labour and production impact.
- The impact depends on global coal markets too, as well as, immigration of skills.
- Need for policies to assist areas, i.e. Mpumalanga with higher negative impacts.

Abstract

This paper examines the long-run regional economic effects within South Africa of changing the electricity-generation mix towards less coal. To do so, a regional Computable General Equilibrium (CGE) model of South Africa is employed for the analysis. The overall result stemmed from all scenarios suggest that the effect of a transition to an energy supply mix with smaller share of coal generation is sensitive to other economic and policy conditions, in particular the reaction of the global coal market and hence, South Africa's coal exports. Under conditions in which surplus coal resulting from lower domestic demand cannot be readily exported, the economies of coal-producing regions in South Africa such as the Mpumalanga province are the most severely affected. The subsequent migration of semi-skilled labour from

that province to others within the country require appropriate and timeous planning by energy policymakers and urban planners.

Keywords: energy transition; South Africa; low-coal; regional effect; labour

1. Introduction

Under the 2015 Paris Agreement, the vast majority of nations agreed to act collectively against climate change. The agreement aims to limit global temperature increases by promoting sustainable means of development that would ultimately reduce harmful emissions. UNEP (2017) stated that short-term action and accelerated ambition by countries are crucial: if the emissions gap does not close by 2030, the Paris target of limiting temperature increases to well below 2 degrees Celsius (beyond pre-industrial levels) will become practically unachievable. The same report stresses the importance of transitioning away from coal as a major source of energy in order to achieve the agreed climate targets. Such an energy-mix transition, however, should be done methodically and systematically, taking into consideration possible political, socioeconomic and energy system effects.

Coal-fired power plants dominate South Africa's electricity generation. State owned enterprise and the national energy supplier, Eskom, is responsible for over 90% of the country's electricity generation and is projected to have an installed capacity of 55,116 MW in 2020 once new coal-fired plants, Kusile and Medupi, are complete. Once these projects are complete, Eskom will operate 15 coal-fired power plants, accounting for 47,318 MW or 85% of the installed capacity. South Africa's grid-based electricity generation capacity dwarfs that of any other country in Sub-Saharan Africa. Coal fired generation in South Africa's Mpumalanga province, where the majority of coal is mined, will account for 34,856 MW alone. However, South Africa's electricity generation profile has also caused it to rank as one of the largest CO_2 emitters per capita in the world. As part of its international commitments to reducing CO_2 emissions, the South African government is planning to reduce the share of coal-fired plants in electricity generation. Indeed many of the older coal-fired plants are scheduled to be decommissioned over the next two decades. At the Paris negotiations, South Africa was a strong representative of developing nations that are often worst impacted by climate change. Minister Molewa of the Department of Environmental Affairs stated: “global markets have been given a strong signal that the transition towards a low carbon economy is underway, and that carbon markets and other market-based solutions will be utilized to assist in this transition” (Department of Environmental Affairs (DEA), 2016).

Fig. 1. Eskom power stations concentration.

Source: Eskom website (www.eskom.co.za)

Within this context, the impact of transitioning to a low-coal supply mix in South Africa will differ between the various provinces of the country due not only to their socioeconomic differences but also primarily to the regional location of electricity generation. Importantly, as seen in Figure 1, the heavier concentration of coal-fired generation in the country is located in the Mpumalanga province (12 out of the 15 coal-fired power plants). These power plants have been through the years a main source of employment and income – by decommissioning them due to age or supply mix choices, the impact on the specific province would certainly be negative in the short-run, without any other interventions in place. The rest of the provinces where new power generating facilities will be located in the future might be experience positive socioeconomic consequences, by assuming the new plants are employers and income generators for the local communities. Examining the effects of the proposed generation-mix change at only a national level would ignore disparate regional outcomes that may pose serious consequences for coal-producing provinces such as Mpumalanga.

The purpose of this paper is to examine the regional economic and labour market effects in South Africa assuming a transition of the supply or generation-mix to a 50-50 scenario: 50% coal and 50% non-coal generation by 2040. The research question posed here is whether the various South African regions, represented by the nine provinces, will experience differences in the magnitude and direction of the economic impact (economic output, employment levels, trade, etc.) they will experience due to the energy supply transition to cleaner forms of energy. More particularly, these effects will be compared and contrasted, in order to create awareness of the importance of analysing at a regional disaggregated level, when planning energy policy and technology changes.

2. Brief literature review

In the literature, this transition to cleaner forms of energy has been associated with societal benefits, environmental improvement and economic development (Consoli, Martin, Marzucchi, & Vona, 2016) (Porter & van der Linde, 1995). Promoting greener forms of energy production is generally agreed to contribute to job creation by many studies (Cameron & van der Zwaan, 2015; Lehr, Nitsch, Kratzat, Lutz, & Edler, 2008) however this fact is challenged by others (Henriques, Coelho, & Cassidy, 2016; Sooriyaarachchi, Tsai, El Khatib, Farid, & Mezher, 2015). The "challengers" of the positive impact of non-fossil fuel technologies base their argument on the potential increases of electricity prices with the alternative energy generation adoption (Lesser, 2010). Lesser (2010) continues arguing that utilities globally do not criticize above-market prices from renewables because in all probability they pass the costs to the consumers. However, these higher costs lead to high "value" of job creation in the transition: "each green job created led to the loss of two jobs in the rest of the Spanish economy" or "in Germany, the cost per green job created has been estimated to be 175 000 euros1" (Lesser, 2010).

In most studies in the literature, the effects of a transition to cleaner energy generation to employment creation primarily considered direct impacts (Llera Sastresa, Uson , Bribian, & Scarpellini, 2010; Wei, Patadia, & Kammen, 2010; Simas & Pacca, 2014; Cansino, Cardenete, Gonzalez-Limon, & Roman, 2014; Sooriyaarachchi, Tsai, El Khatib, Farid, & Mezher, 2015). General equilibrium approaches however can provide with the impacts to the economy in its entirety by providing information on the indirect and induced impact on jobs (Bulavskaya & Reynes, 2017). Lehr et al. (2012) agree that only by employment of total economy models, researchers can examine the positive and negative effects in employment. Here, we define the effects as offered by IRENA (2011) and summarised by van der Zwaan, Cameron and Kober (2013).

- Direct jobs are related to core production activities; manufacturing, construction, maintenance, site development, installation and operation;
- Indirect jobs are linked with activities such as extraction and processing of raw sources, marketing, administration, consultancies and research institutions;
- Induced jobs come from activities of direct and indirect workers, shareholders whose spending of earnings can stimulate all the economic sectors of the country (they can

[1] 2009 values

be highly dependent on the cost of technologies (Mu, Cai, Evans, Wang, & Roalnd-Holst, 2018)).

Cartelle Barros et al. (2017), Simas and Pacca (2014) and Tourkolias and Mirasgedis (2011) agree with this classification of job impacts. Lesser (2010) notes that there are dangers in a pure classification of job impact. Governments nowadays especially in developing countries are marginally obsessed with the target of job creation. They focus primarily on the employment opportunities in the construction and operation phases, which can be proven myopic and in a sense, aiming at vote maximising, without honestly admitting that these jobs are not sustainable in the future. In addition, the induced effects might also be misleading if the wage level is not taken into consideration: “the more employees are paid, the more money they will have to potentially spend on goods and services” (Lesser, 2010).

A recent study by Bulavskaya and Reynes (2017) estimated the employment potential of renewable energy and heat generation in the Netherlands in around 50 000 new jobs by 2030 and a positive effect of 0.85% to the GDP of the country relative to a baseline scenario. They explained that by the nature of generation of wind and solar technologies being more capital and labour intensive than the current power generation by coal and gas. This amount of jobs might have been even higher if it was not for the negative consequence of the higher electricity prices expected mainly because of higher capital requirements of the new technologies. Pointing towards human capital, Consoli et al. (2016) raise our attention to the fact that green jobs have a high-level cognitive skills requirement, and hence require more formal training, more work experience and higher education levels.

The international transition towards adoption of cleaner energies has made the investigation of the economy-wide impact imperative. The literature argues now that such a policy change will not only affect the energy sector exclusively – that is why Computable General Equilibrium (CGE) models have become attractive in an effort to analyse the long-run economic implications of such shifts (Peace and Weant, (2008)). Within the energy and environment context, CGE models are often used to evaluate the impact of carbon tax and other fiscal policies (Sue Wing, (2006); Sue Wing, (2008)). The effect of the transition to non-fossil energy mix was evaluated recently for China by Dai et al. (2011)and Mu et al. (2018) Dai et al. (2011) assumed in their scenarios either energy efficiency improvements, an injection in the form of investment to the renewable energy sector or carbon taxes, leading to carbon intensity reductions and hence, reduction in the emissions levels. Their focus was to evaluate whether China's climate commitments can be achieved and at what "cost". Mu et al. (2018), on the other side, focused on the employment effects of the transition. The literature has evaluated, as discussed before, the job creation potential of renewable energies but in a partial equilibrium context and hence, ignored the effects to the fossil fuel industry. Mu et al. (2018) made an effort to take them into consideration: their results showed that China's effort in expanding solar and wind power can create a number of jobs but would lead to net job losses.

Appreciating the importance of sustainability, local governments are also interested in promoting economic competitiveness and ensuring a favourable trade-off between economic development and environmental protection. By investigating green job creation at a US state level, Yi (2013) was able to make some propositions regarding the regional labour market effects of such programmes. Local policies for renewable energy and energy efficiency are highly correlated with the green jobs in the specific urban areas. Also, the economic conditions and unemployment levels of the state have shown to influence the amount of green jobs to be created in the area: when the unemployment is high, it might be a sign of a constrained economy, where disposable income is low and hence, consumers do not demand clean energy products and services. High unemployment is also a signal of underutilization of production factors and hence, less energy is required for production purposes that might lead to loss of jobs. Population differentials between states play also a role in the potential of green job creation. Yi (2013) puts significant emphasis on the differences created by the labour supply: the larger the labour pool in a state, the more green jobs to be created and maintained; also, the higher the average education of the population and the specific skills in the area will influence the probability of green job creation. So, even between geographical regions or provinces as in the case of South Africa the job impact differs. Even more importantly, the national net effect of job creation is dependent on the individual regional effects.

3. Methodology, data and simulation design

3.1 Computable General Equilibrium (CGE) model

Capturing the regional impact of a reduction in the use of coal in electricity generation requires a detailed regional multi-sector model of South Africa that accounts for changes in the use of industry-specific inputs in the electricity sector and sales of coal. For this paper, we use TERM-SA, a multi-regional, comparative-static computable general equilibrium (CGE) model, based on the well-known TERM model developed at the Centre of Policy Studies (CoPS) in Melbourne, Australia. The ability of CGE models, such as TERM-SA, to recognise the many inter-linkages in the real economy, and account for price-induced behaviour and resource constraints in determining both the direct and indirect effects of a shock on the economy, has made it one of the preferred methodologies for practical policy analysis around the world.

While the complete model is too large to describe in this paper, a comprehensive description of the TERM methodology, and CoPS-style of CGE modelling in general, is contained in Horridge (2011) and Dixon et al. (2013), respectively. Country-specific versions of the TERM model exist for Australia (Horridge et al. 2005), United States (Wittwer, 2017) Brazil (Ferreira-Filho and Horridge, 2016) and China (Horridge and Wittwer, 2008), amongst others. As the theory of the TERM-SA model and data structures are well documented in these references, for this paper we provide only a general overview.

The core model equations describe the behaviour of producers, investors, households, government and exporters at a regional level. Producers in each region are assumed to minimize production costs subject to a nested constant-returns-to-scale (CRS) production technology. In this nested structure, each regional industry's inputs of primary factors are modelled as a constant elasticity of substitution (CES) aggregate of labour, capital and land inputs. Commodity-specific intermediate inputs to each regional industry are modelled as CES composites of foreign and domestic varieties of the commodity. Labour inputs used by each regional industry are distinguished by occupation, with substitution possibilities over occupation-specific labour described via CES functions specific to each regional industry. In each region, the representative households are assumed to choose composite commodities to maximise a Klein-Rubin utility function. Households and firms consume composite commodities that are assumed to be CES aggregations of domestic and imported varieties of each commodity. The allocation of investment across regional industries is guided by relative rates of return on capital. For each region-specific industry, new units of physical capital are constructed from domestic/imported composite commodities in a cost-minimising fashion, subject to CRS production technologies. Region-specific export demands for each commodity are modelled via constant elasticity demand schedules which link export volumes from each region to region-specific foreign currency export prices. Regional demands for commodities for public consumption purposes are modelled exogenously, or are linked to regional private consumption.

3.2 Dataset

The TERM-SA base year reflects 2015 data and is calibrated using various data sources. TERM-SA recognises 52 different industry and commodity groups[2], 10 occupation groups and 9 provincial regions. The regional database consists of a set of matrices, capturing the structure of the South African economy. A national database is created based on the 2015 Supply Use Tables (SUT) published as part of StatsSA (2017) following the process described in Roos (2015). This database includes a USE matrix valued at producers' price. This matrix shows the flow of commodity c, from source s to user u. Values at producers' price is the sum of the flows of commodity c, from source s to user u at basic price and the associated indirect tax. We also have a matrix capturing the trade and transport margins which facilitate the flow

[2] This version of TERM-SA identifies a single aggregated electricity industry as described in Standard Industrial Classification division 41.

of commodities to users. Value added matrices are: labour payments by industry and occupation, capital and land rentals by industry and production taxes by industry. The database is balanced in that the costs equal sales for each sector.

From the national database we create regional input-output data and inter-regional flows of commodities. Detailed regional data is typically not available in the required format for models such as TERM-SA. We use regional output shares to inform us on regional distribution of inputs and outputs. We then construct inter-regional trade matrices which show the trade of commodities between regions. Our task is made easier by assuming that industry-specific technologies are similar across regions. Given these assumptions we ensure that regional data is consistent with national data. Substitution elasticities in general were calibrated to reflect those in Bohlmann et al. (2016). A more detailed description of the regional database construction process and model is contained in Horridge et al. (2005), Horridge and Wittwer (2008) and Horridge (2011).

3.3 Simulation Design

CGE models are designed to isolate and measure the economy-wide effects of a policy change relative to a business-as-usual (BAU) baseline. Given the comparative-static nature of the model, the underlying structure of the model database serves as a proxy for the BAU baseline in this paper. We test our policy scenario – the reduction of coal in the supply mix of electricity generation – under four sets of simulation conditions or assumptions. The four simulations are all based on a standard long-run model closure[3], with minor variations between each to distinguish different possible economic conditions.

Our first simulation (SIM 1) uses a standard long-run policy closure in which a cost-neutral technological change is applied to the electricity industry so that it uses 40% less coal and

3 A CGE model includes more variables than equations. Each equation in the model determines an endogenous variable, that is, the change in a variable is determined by an equation in the model. Variables not determined by the model are set as exogenous. A closure identifies which variables are endogenous and exogenous in any given simulation. The features of a standard long-run closure in TERM are described in Horridge (2011).

7.5% more of all other inputs to make one unit of electricity. This policy shock, which aims to effectively alter the recipe of production for electricity within the context of the TERM-SA database and the proposed policy design, is common across all four simulation scenarios.[4] The policy shock replaces coal mined in Mpumalanga (and to a lesser extent Limpopo) with new non-coal electricity generation in every other region. The second simulation (SIM 2) uses the same closure as in SIM 1 but we allow the national supply of semi-skilled labour to endogenously adjust (with fixed real wages) to the shock to the input demand. This reflects the abundance of unemployed semi-skilled labour in South Africa. Our third simulation (SIM 3) replicates SIM 1, but with coal exports fixed at baseline levels. This reflects a scenario in which international climate agreements reduce the global demand for coal relative to a business-as-usual baseline and prevent the effects of reduced local demand for coal from being counteracted by increased exports. The fourth simulation (SIM 4) replicates SIM 3 but with semi-skilled labour again allowed to adjust endogenously.

Other key features of the long-run policy closure used across all simulations include: 1) all rates of return move together to keep aggregate national capital fixed to the baseline; 2) for most or all occupations, wages adjust so that national employment is fixed to the baseline; however, regions that attract more of particular occupations have to pay a higher real wage to the occupation; 3) investment in each industry and region follows the corresponding capital stock, i.e. capital growth rates are fixed; 4) government demand were fixed to the baseline; 5) exporters face fairly elastic world demand curves that are typical of small open economies; 6) nationally, nominal household consumption follows nominal GDP, whilst regionally, nominal household consumption follows the local wage bill, subject to a national constraint (these assumptions limit the movement in the national nominal balance of trade as a percentage of nominal GDP), and 7) the national consumer price index is the numeraire. Unless otherwise

4 For this paper, the focus is on the effects of a movement away from coal-fired electricity generation. Detailed analysis of the composition of non-coal generation as applied in, for example, Van Heerden et al. (2016), falls outside the scope of this paper.

stated, all policy simulation results reflect percentage change deviations in the underlying value of variables, relative to the baseline, as a result of the policy shock.

4. Empirical Results

TERM-SA allows us to analyse the economy-wide effects of the policy change on South Africa at a national and regional level. For this paper, we focus on the performance of the key macro and industry level results, as well as regional labour market outcomes. It should be noted that we do not quantify any of the expected environmental benefits of the policy shock in this paper.

Interpreting the results of a CGE simulation requires knowledge of the underlying database and an understanding of the model theory and assumptions imposed on the model. According to our recent TERM-SA database, 26% of the value of coal produced in South Africa is used by the electricity industry and 56% is exported.[5] A further 16% is used by other industries with the balance used by households. Semi-skilled labour, including plant and machine operators and trade workers make up the bulk of employment in the coal industry. Over 75% of coal in South Africa is produced within the Mpumalanga region.

[5] The core TERM-SA database reflects Rm values adapted from the 2015 Supply Use Tables published by Statistics South Africa. Use shares for coal is different when represented in volume terms instead of value terms since local use and export prices achieved by coal producers differ significantly from time to time. In terms of volume, the local electricity industry is the largest single user of locally produced coal in South Africa. These differences do not affect the computational validity of the results produced by TERM-SA.

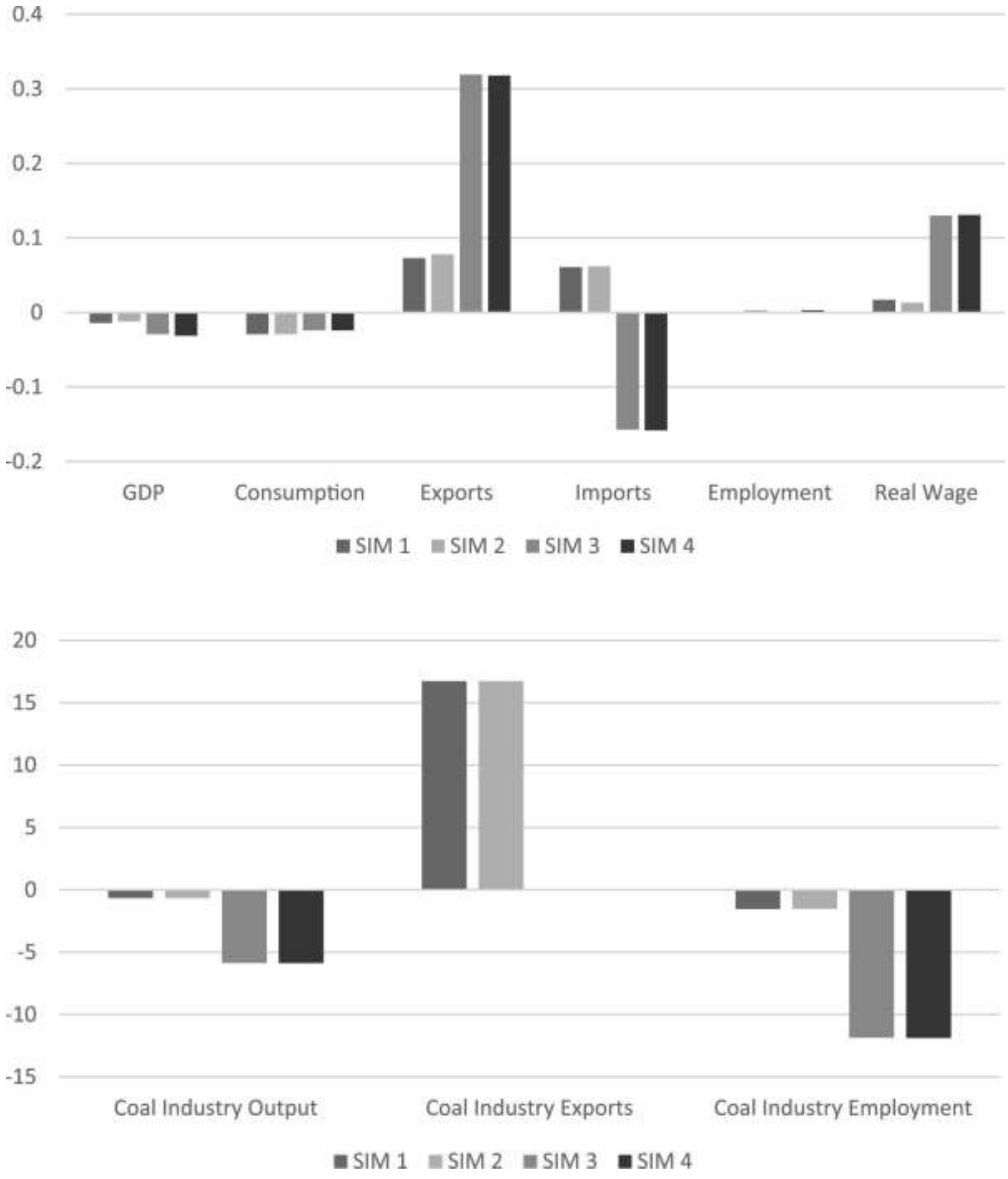

Fig. 2. National results (% change deviation from BAU).

Figure 2 shows selected results at a national level for key macro indicators (GDP, Consumption, Exports, Imports, Employment, Real Wage) and the coal industry (Coal industry output, Coal industry exports, and Coal Industry employment). Observing Figure 2, GDP and Consumption of households would be expected to be lower but marginally (between -0.014

and -0.031% for GDP and -0.024 and -0.029 for Consumption for all four scenarios) relative to the baseline case, although total exports are expected to increase by a range between 0.073 and 0.318% relative to the baseline. The impact on national employment levels is almost non-existent relative to the baseline: showing thus that an analysis focused only on the national levels would be almost misleading in not presenting potential risks when it comes to unemployment creation.

Results for SIM 1 show that coal output is expected to drop by a mere 0.67% relative to the baseline. Because we assumed that world demand for South African coal was elastic[6], the reduction in local demand due to the policy change was counteracted by a large export increase of 16.74% with only a small drop in export prices. Coal-producing regions in South Africa, in particular Mpumalanga, are therefore shielded from any major negative effect. As shown in Figures 3 and 4, regional GDP and employment effects are extremely small under SIM 1 assumptions. However, the fall in coal export prices leads to a decline in the terms of trade and so to a small drop in national GDP. Naturally, with GDP contracting relative to the baseline, most macro and industry level variables follow this trend, with the notable exception of increased exports (mainly due to the increase in coal exports).

[6] This assumption is supported by the fact that South Africa is a small open economy, and that coal is largely a homogenous product with a competitive market globally.

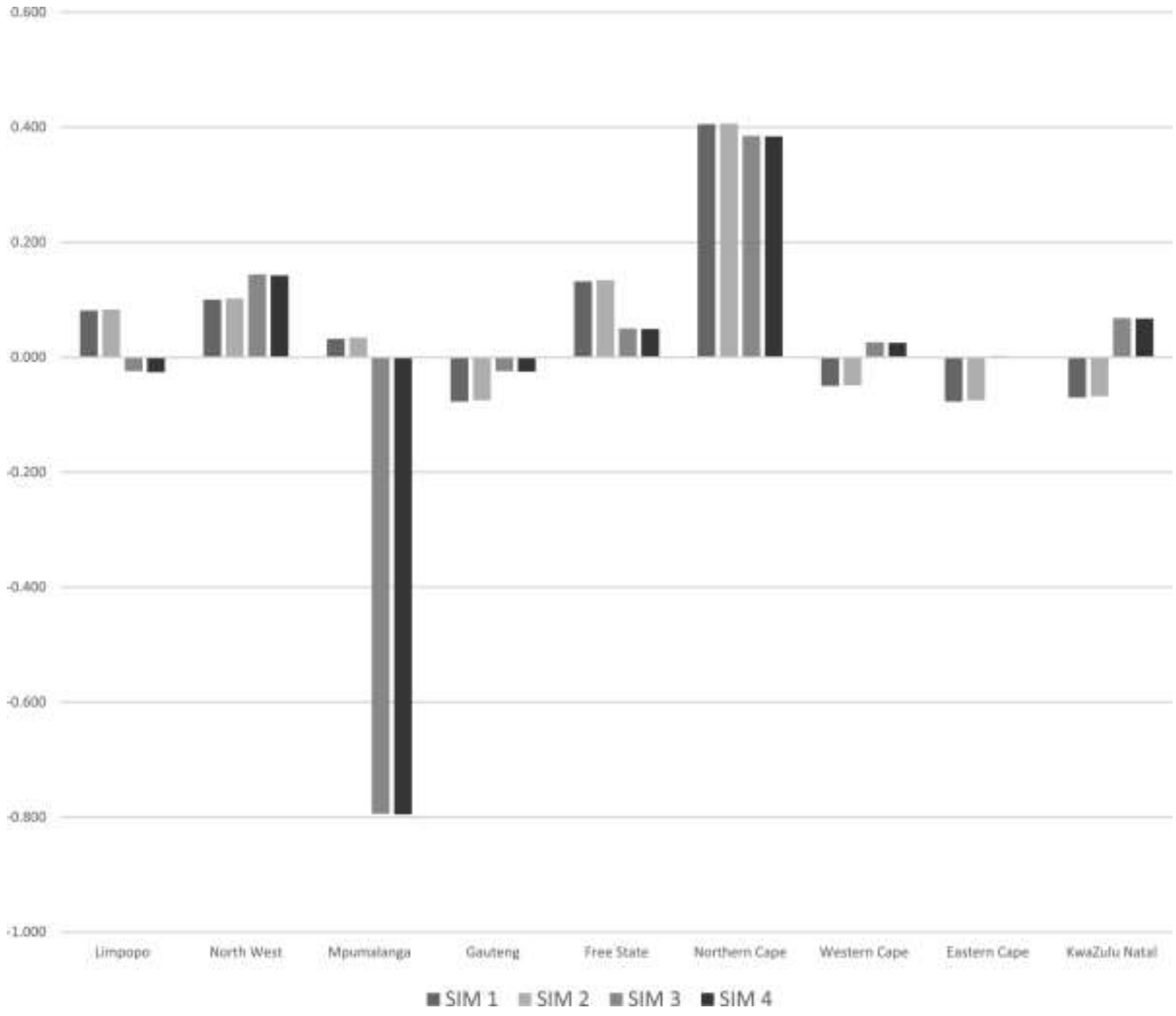

Fig. 3. Regional results GDP (% change deviation from BAU).

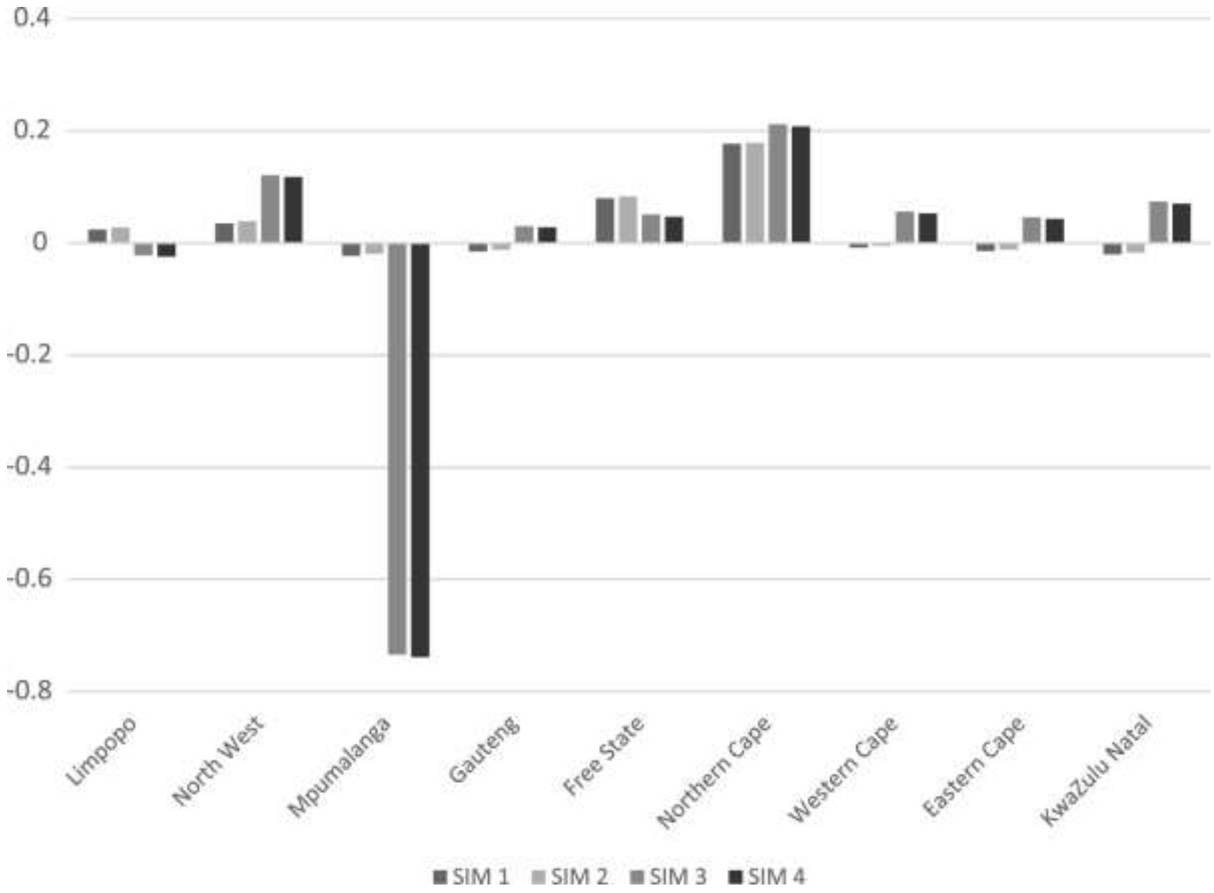

Fig. 4. Regional results Employment (% change deviation from BAU).

The overall observation concerning GDP effects is that the Mpumalanga province would be the one more hurt by the transition, especially if the coal exports are assumed to be capped (see Figure 3). On the other side, the North West and Northern Cape provinces could be considered “winners” from such a transition to low-coal supply mix, due to their capacity and resources of renewalbe energy generation facilities.

Similarly, employment trends in these provinces follow the GDP trends (Mpumalanga lower and Northe West and Northern Cape higher than the baseline level).

SIM 2 is the same as SIM 1, but with semi-skilled labour no longer fixed to the baseline. Apart from minor effects as a regional occupation level, aggregate results do not differ much between SIM 1 and SIM 2. However, it is exactly these regional effects that are of importance in this study. The difference in labour market assumptions between SIM 1 and SIM 2 allows nationwide semi-skilled employment to endogenously react in response to the policy shock. Semi-skilled labour is also able to move between regions following changes in the marginal product of labour. On average, this means lower employment in coal-producing regions such as Mpumalanga and higher employment in regions such as the Northern Cape where increased production of non-coal electricity generation is likely to occur.

The results of SIM 3 and SIM 4 highlight the importance of the assumption regarding coal exports. In these simulations, we assume that coal exports remain fixed at baseline volumes (and, by implication, that coal prices are lower).

The model implies an upwardly-sloping supply curve for coal, with domestic demand that is fairly insensitive to price. For SIM 1 and SIM2 we assumed that foreign demand curves were fairly flat. Thus coal no longer needed for power generation could simply be diverted onto the world market. For SIM 3 and SIM 4 we assume that the coal export demand schedule is vertical; so that lower domestic demand translates directly into lower coal output, and into lower coal prices (from the supply curve). The lower coal export price causes the terms of trade and GDP to decline more sharply. Our shock reduced the coal needed to make electricity by only 40% (not 100%). Hence cheaper coal means cheaper electricity, which benefits all provinces. This is one reason why non-coal-producing provinces benefit from reduced coal demand; another reason is that the reallocation of labour towards non-coal-producing provinces implies that real wages fall more in those provinces, so they become more competitive.[7]

The effects on the coal industry and the coal-producing regions are far more pronounced in SIM 3 and SIM 4. On a national level, coal output now drops by almost 6% and employment within the sector by close to 12%. Following the Paris Agreement and the general trend of countries increasingly considering non-coal sources for electricity generation, it seems unlikely

[7] In the policy run, labour or employment is fixed relative to the baseline at a national level, but allowed to move between regions in response to the policy shock. Real wages are endogenous in the policy run.

that above baseline coal exports are achievable. In this sense, we believe that SIM 3 and SIM 4 give us the best indication of the long-term effects of the policy change[8]. Whereas overall GDP, and subsequently consumption, is lower in SIM 3 and 4 relative to SIM 1 and 2, improved overall exports in SIM 3 and 4 do act as a buffer. Agriculture, mining (except coal) and manufacturing industries all see an increase in their exports due to an improvement in competitiveness as a result of the real devaluation of the local currency.

Similar to SIM 1 and SIM 2, the only difference between SIM 3 and SIM 4 is that nationwide employment of semi-skilled labour, including plant and machine operators and trade workers, is no longer fixed to the baseline, but is allowed to respond to the national wage level. This slight variation in closure conditions between SIM 3 and SIM 4 generates a small additional loss for coal-producing regions to the benefit of regions where non-coal generation may be expected to grow, such as the Northern Cape. Semi-skilled employment in Mpumalanga is hardest hit in SIM 3 and SIM 4 due to its close link with the coal industry and the restrictions placed on the trade of coal via the model closure.

Under these scenarios we notice an increase in semi-skilled employment, relative to the baseline, in all regions except the coal-producing regions of Mpumalanga and Limpopo. For Mpumalanga, semi-skilled employment drops by between 2% and 3%. Effects in Limpopo are more muted due to the smaller share of coal production in that economy. However, the labour-market assumption is less important than the assumption about coal exports. More detailed effects on various types of occupation are given in the Appendix.

5. Conclusion and Policy implications

This paper investigated the long-term regional economic effects of a change in South Africa's electricity generation-mix, in line with its international commitments to reduce CO2 emissions.

8 The alternate view might be that a reduction in foreign coal demand would occur whether or not South Africa used less coal. In this view, the additional pain in SIM 3 and 4 is really caused by the green policies of other countries.

Extensive attention was given to the impact on the economic growth and employment in the provinces of the country. To do so, the study employed a newly developed regional CGE model of South Africa that takes into consideration not only the national macroeconomic indicators but also, the specific geographical and structural characteristics of all the regions. The national results of the analysis show that GDP is expected to be lower than the BAU reference scenario, while the country's employment levels in aggregate will only have a marginal overall effect. Contrasting the national results with Mu et al. (2018) and Dai et al. (2011) that also conducted their analysis at a national level; we observe similarities in the impact on employment: although increases are expected due to the non-fossil fuel power generation expansion, the losses from the reduction in coal generation in some cases offset them. Mu et al's (2018) results of a declining employment net effect with higher renewable energy penetration in the supply mix suggest that the job creating potential through renewable energies is not unlimited and they suggest that "as renewable expansion becomes more aggressive higher subsidies will be required to offset an increasing marginal cost of generation."

The results, overall, suggest that the minimization of the negative consequences of a transition to less coal energy supply mix in the country does not only depend on the country's energy demand and supply profile as well as the economic structure, but also, the reaction to global markets, particularly that of coal. In the case, that coal exports remain the same or increase towards the country's trade partners the effects on employment and GDP growth in coal mining provinces will be constrained. However, appreciating the fact that South Africa's coal trade partners will follow similar patterns with regards to their supply mixes, we anticipated that coal exports will be restricted and not increase to cover for the lower demand for coal by the South African power generation sector. Policymakers' view of how much room there is in the current economic and policy environment to increase exports of coal from regions that will be adversely affected by the change in domestic policy is therefore important to the analysis. Concerning semi-skilled labour migration, regions close to Mpumalanga such as Gauteng and regions that will pick up the slack in the terms of non-coal electricity generation such as the Northern Cape should pay close attention to these outcomes.

Our results indicate that careful planning at a regional level is required, particularly with regard to the labour migration outcomes of a long-term transition towards low-coal electricity generation. The economic effect on coal-producing regions such as Mpumalanga is significant. Semi-skilled jobs in the coal industry such as plant and machine operators and trade workers are most vulnerable. New jobs in the non-coal electricity generation sector provide some relief on an aggregate level, but it may come at a significant adjustment cost for some communities if the transition is not managed well.

Given the environmental considerations of the policy proposal, it is important to note that the large reduction in coal use for electricity generation will help South Africa achieve its emissions targets (World Bank, 2016). The announcement of a carbon tax to be implemented from 2019 in South Africa will only serve to cement the policy direction simulated in this paper. Hence, in essence, the future path for South Africa's energy supply mix is prescribed, what is left for the policy makers is take appropriate action and look for concerted policies to lessen the negative socioeconomic impact that this transition will have to the country that already suffers from high levels of unemployment and inequalities.

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Appendix

Table A1: Regional Employment Results by Occupation (SIM 1)

EMPLOYMENT TYPE (SIM1)	Limpopo	NorthWest	Mpumalanga	Gauteng	FreeState	NorthCape	WestCape	EastCape	KZN
Legislators/Managers	0.062	0.074	0.055	-0.027	0.100	0.224	-0.024	-0.032	-0.028
Professionals	0.036	0.046	0.028	-0.028	0.072	0.171	-0.010	-0.013	-0.010
Technicians	0.047	0.043	0.059	-0.028	0.079	0.168	-0.017	-0.027	-0.020
Clerks	0.023	0.033	0.020	-0.018	0.058	0.105	-0.016	-0.014	0.002
Service Workers	0.023	0.015	0.010	-0.004	0.043	0.026	-0.023	-0.012	-0.002
Skilled Agric Workers	-0.022	0.043	-0.231	0.042	0.066	0.136	0.015	0.027	-0.026
Craft Trade Workers	-0.013	0.012	-0.130	-0.019	0.169	0.459	0.042	0.002	-0.052
Plant Machine Operators	-0.012	0.051	-0.243	0.030	0.091	0.206	0.030	0.022	-0.038
Elementary	0.026	0.026	-0.019	-0.001	0.070	0.138	-0.015	-0.013	-0.037
Domestic	0.038	0.013	0.015	-0.010	0.052	0.089	0.001	-0.023	-0.024
EMPLOYMENT TYPE (SIM2)	**Limpopo**	**NorthWest**	**Mpumalanga**	**Gauteng**	**FreeState**	**NorthCape**	**WestCape**	**EastCape**	**KZN**
Legislators/Managers	0.061	0.073	0.055	-0.027	0.100	0.223	-0.024	-0.032	-0.028
Professionals	0.036	0.045	0.028	-0.028	0.072	0.171	-0.010	-0.013	-0.010
Technicians	0.047	0.042	0.059	-0.028	0.079	0.168	-0.017	-0.027	-0.020

Clerks	0.023	0.033	0.020	-0.018	0.058	0.105	-0.016	-0.014	0.002
Service Workers	0.023	0.015	0.010	-0.004	0.043	0.025	-0.023	-0.012	-0.002
Skilled Agric Workers	-0.058	0.007	-0.266	0.007	0.030	0.100	-0.020	-0.009	-0.060
Craft Trade Workers	0.053	0.078	-0.063	0.049	0.236	0.525	0.109	0.070	0.017
Plant Machine Operators	-0.072	-0.010	-0.303	-0.030	0.031	0.145	-0.030	-0.039	-0.097
Elementary	0.026	0.025	-0.019	-0.001	0.069	0.137	-0.015	-0.013	-0.036
Domestic	0.038	0.013	0.015	-0.010	0.051	0.088	0.001	-0.023	-0.024

EMPLOYMENT TYPE (SIM3)	**Limpopo**	**NorthWest**	**Mpumalanga**	**Gauteng**	**FreeState**	**NorthCape**	**WestCape**	**EastCape**	**KZN**
Legislators/Managers	-0.002	0.082	-0.234	-0.023	0.042	0.204	0.009	0.006	0.063
Professionals	0.013	0.081	-0.286	-0.015	0.037	0.197	0.014	0.019	0.042
Technicians	0.016	0.046	-0.028	-0.030	0.010	0.143	-0.005	-0.007	0.040
Clerks	0.004	0.062	-0.215	-0.014	0.024	0.119	0.014	0.018	0.045
Service Workers	-0.020	0.007	-0.083	-0.003	-0.012	-0.004	0.006	0.006	0.041
Skilled Agric Workers	-0.095	0.358	-2.415	0.297	0.162	0.381	0.285	0.295	0.197
Craft Trade Workers	-0.068	0.244	-2.073	0.181	0.213	0.632	0.241	0.198	0.166
Plant Machine Operators	-0.100	0.381	-2.758	0.321	0.176	0.432	0.345	0.319	0.226
Elementary	-0.028	0.093	-0.640	0.042	0.031	0.143	0.044	0.036	0.067
Domestic	-0.019	0.018	-0.214	0.011	-0.006	0.067	0.009	0.001	0.038

EMPLOYMENT TYPE (SIM4)	Limpopo	NorthWest	Mpumalanga	Gauteng	FreeState	NorthCape	WestCape	EastCape	KZN
Legislators/Managers	-0.002	0.082	-0.234	-0.022	0.042	0.204	0.009	0.006	0.062
Professionals	0.013	0.081	-0.286	-0.014	0.037	0.197	0.014	0.019	0.042
Technicians	0.016	0.046	-0.028	-0.029	0.010	0.142	-0.006	-0.007	0.040
Clerks	0.004	0.062	-0.215	-0.013	0.024	0.119	0.014	0.018	0.044
Service Workers	-0.020	0.008	-0.083	-0.003	-0.013	-0.005	0.006	0.006	0.040
Skilled Agric Workers	-0.239	0.212	-2.555	0.151	0.017	0.237	0.140	0.149	0.052
Craft Trade Workers	0.002	0.314	-2.003	0.251	0.282	0.702	0.310	0.267	0.235
Plant Machine Operators	-0.240	0.241	-2.894	0.178	0.033	0.289	0.201	0.175	0.082
Elementary	-0.028	0.093	-0.640	0.041	0.031	0.144	0.044	0.035	0.067
Domestic	-0.019	0.018	-0.214	0.012	-0.007	0.067	0.009	0.001	0.038