How Would Changes in the Electricity Generation-Mix Affect the South African Economy and Environment in the Long Run?

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** This paper represents work-in-progress, results are preliminary and subject to change **

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Abstract

South Africa is considered to be one of the most carbon-intensive countries in the world, driven by a combination of subsidized electricity prices and a coal dominated electricity generation-mix. The South African government – aware of its dual responsibility of increasing economic growth while limiting its carbon footprint – have laid out ambitious plans to achieve both these goals through its National Development Plan and Integrated Resource Plan policy documents.

In this on-going research project, we use a large-scale CGE model for South Africa that includes extensive electricity generation and carbon emissions detail to evaluate how proposed changes in the country's electricity generation-mix are expected to affect the economy and environment. The policy simulation in this paper specifically looks at the impact of a renewable energy focussed growth path for the electricity generation sector relative to a business-as-usual carbon intensive baseline. We present long-run results for key macro variables and carbon emissions with a view to informing policymakers and participants on both sides of the economic and environmental debate.

JEL codes: C68, Q43, Q55
Keywords: Electricity generation, computable general equilibrium, UPGEM

1. Introduction

Achieving or maintaining sustainable economic growth has become a global policy issue. The choice of electricity generation technologies that producers around the world choose to pursue in coming years will likely determine environmental outcomes for many decades ahead. The South African government has shown support for a low-carbon growth path, aiming to both stimulate economic activity and lower emissions in the long run. South Africa's Department of Energy (DoE) has released a number of policy documents with regard to achieving a more sustainable, clean and environmentally-friendly electricity generation profile. The most prominent of these are the Integrated Resource Plan for Electricity (DoE, 2013) and Integrated Energy Planning Report (DoE, 2012), which are periodically revised and updated. In this study, part of an on-going research project on the energy sector in South Africa, we evaluate the long-run macroeconomic and environmental impact of choosing a low-carbon and renewable energy intensive path for electricity generation relative to a business-as-usual baseline in which coal generated electricity continues to dominate. We use a computable general equilibrium (CGE) model that includes extensive electricity generation and carbon emissions detail to conduct our analysis.

2. Methodology

We use the University of Pretoria General Equilibrium Model (UPGEM)[1] to conduct our analysis of a changing electricity generation-mix on the South African economy and environment. CGE models such as UPGEM are ideally suited to providing insights into the effects of a broad range of policies and other shocks in the economy on both an industry and macro level. The general equilibrium core of UPGEM follows that of a typical CGE model and is made up of a linearized system of equations describing the theory underlying the behaviour of participants in the economy. It contains equations describing, amongst others: the nature of markets; intermediate demands for inputs to be used in the production of commodities; final demands for goods and services by households; demands for inputs to capital creation and the determination of investment; government demands for commodities; and foreign demand for exported goods. In this particular application, additional theory and data related to electricity generation and carbon emissions in South Africa are incorporated into UPGEM to enable a more accurate evaluation of the proposed policy under investigation.

3. Simulations

We run two separate simulations in order to isolate and measure the long-run impact of our renewable energy intensive growth path for electricity generation. The first establishes a business-as-usual (BAU) baseline forecast of the economy in the absence of the policy shock under investigation. The second simulation imposes the exogenous shock or policy change on the

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[1] UPGEM is based on the MONASH model described in Dixon & Rimmer (2002) and Dixon et al (2013). The MONASH model, recently renamed as the VU-National model, continues to form the basis of many single-country CGE models around the world. MONASH-style models adopted and extended the techniques first introduced in Johansen (1960) and are typically implemented and solved using the GEMPACK suite of programs described in Harrison & Pearson (1996) which combine to eliminate Johansen's linearization errors.

economy, in this case, the move towards cleaner sources of electricity generation. The forecast and policy simulations are done with different closures to the model. In the forecast closure we exogenise variables that we have forecast information for, such as real gross domestic product (GDP), and endogenise variables that are related to them, such as overall primary factor technical change (A). Shocking the model with the forecasted value of GDP would give a resulting value for A. If we would then change the closure by making GDP endogenous and A exogenous, we would get the same value for GDP by shocking the value of A by the solution value found previously. In general, therefore, we do a baseline forecast of the economy, then change the closure of the model to the policy closure that will be used later in the policy simulation, and re-generate the baseline forecast with it. We are now ready to apply any set of additional policy shocks to the exogenous variables. If we would run a policy simulation where no additional shocks are applied to the policy variables, the original baseline forecast values would be the result of the simulation. This makes it legitimate to interpret differences between results in the policy and baseline runs as the effects of the policy shocks.

To conduct our analysis in the most efficient way, taking into consideration our long-run focus, we use the decomposition closure explained in Dixon & Rimmer (2002:42-70). Our analysis is therefore comparative static. We choose to set up our long-run simulation to reflect a 24 year period – from the model's base year of 2011 to our end period of 2035.

The policy shock implemented in this paper restricts the long-run growth of traditional sources of electricity generation, including Coal, Nuclear, Hydro and Other and forces all additional electricity generation growth in the economy to come from renewable sources, including Solar PV, Solar CSP, Gas and Wind. The policy simulation results are relative to a baseline forecast scenario in which the current status quo of coal dominated electricity generation is assumed.

Baseline Forecast

We set a number of key macro variables and ratios exogenous and shock them with forecast values to reflect our best guess of how they will evolve over the 2011-2035 period, taking into consideration available historical data over the 2011-2015 period and the latest available medium and long-term forecasts (Treasury, 2015; CEPII, 2012). In some cases, exogenous variables are not shocked with any explicit value, effectively imposing a forecast of 'no change' in such variables or ratios. Exogenous variables given explicit forecast values include: GDP, employment, investment, exports, electricity supply and population growth. Implied by our baseline forecast is an electricity supply to GDP growth ratio which we set at 0.75 given a real GDP growth forecast of 120% and an electricity supply growth forecast of 90% over the cumulative 24-year forecast period. Other variables or ratios that are set as exogenous include: the capital/GDP ratio, industry rates of return on capital, relative competitiveness as measured through domestic to foreign price ratios and the growth of each electricity generator relative to overall growth in electricity supply. The last assumption ensures that the status quo of coal dominated electricity generation is maintained in the baseline.

Policy Simulation

In order to evaluate our policy simulation results responsibly, we must give careful consideration to our assumptions. For instance, no exogenous assumptions are made with regard to technical improvements or relative cost competitiveness of the different sources of electricity generation. Without such exogenous projections, the cost competitiveness of each generator is established by the base year data. Based on available data, renewable sources of electricity generation are notably more expensive than traditional sources of electricity generation. In other words, renewables require more inputs (and cost more money) to produce for a given amount of sales than traditional sources and must therefore be subsidized (even more than traditional sources) to meet our zero pure profits condition. This information is reflected in the UPGEM database. From a modelling perspective, before considering any environmental effects, our expectation would therefore be that by forcing the economy to produce electricity using a more costly technology is unlikely to yield any benefits. We present the main policy simulation results in Table 1 below.

Table 1: Selected Policy Simulation Results

Variable	**% Change**	**Comments**
Real GDP	0.19	Mainly due to building of new capital
Real GNP	–0.06	New capital mainly financed through foreign savings
Capital	0.96	Renewable sources are capital intensive
Technology	–0.16	Renewables are more costly to produce
Real Wages	–0.07	Slight drop in real wages in order to maintain baseline employment
Renewables	1650	Huge growth in output of renewable sources of electricity generation
Traditionals	–47.4	Growth in traditional sources exogenously constrained
Emissions	–21.3	Substantial fall in carbon emissions from restricting coal-fired generation

The policy shock is to restrict the growth of traditional electricity generating sources to zero relative to its 2011 base year levels. This forces massive growth in renewable sources of electricity generation. Our database indicates that renewable sources are not only relatively more expensive, but also heavily capital intensive. This implies that the economy will need a lot more capital over the 24 year simulation period. With no change in employment assumed in the long run, real wages will then be expected to fall to accommodate this structural change in the economy.

Real GDP rises on the back of increased capital in the economy. However, this is not doing much good for the economy as the additional capital has to be financed by foreign savings as we've assumed no change in our domestic savings behaviour relative to the baseline. Our increased net foreign liabilities and subsequent interest payments cause real GNP to fall slightly relative to the baseline, despite the increase in GDP. The deterioration in technology highlights the move towards, what is considered in the model, a more costly and inefficient way of generating electricity. Changing our exogenous assumptions regarding the improvement of renewable technology and cost competitiveness must still be considered. However, one the major storylines that emerges from this policy simulation is that, with renewable generators increasing their output by around 1650% relative to the baseline, CO2 emission falls by 21.3%, representing a significant portion of the desired amount of the emissions reduction target sought by policymakers.

4. Conclusion

Moving towards a cleaner, renewable focussed electricity generation-mix holds the potential of long-run GDP growth and a vastly reduced carbon emissions profile for South Africa. However, South African policymakers should beware of rising net foreign liabilities in pursuing such a capital intensive build programme, especially if renewables are expected to remain relatively expensive in future. With increased foreign investment required to pay for the additional capital, our results show that real GNP will grow at a slightly reduced rate in the long run, relative to the baseline. It should be noted that we assume no change in the interest rate on foreign debt, despite the considerable increase in debt projected in the long run. Allaying these fears is the fact that we have not assumed any changes in the cost competitiveness of renewable technologies relative to the baseline in this simulation. It is widely expected that as renewable technologies are adopted on an increasingly larger scale that significant cost benefits will emerge. Early results suggest major gains for the economy as a whole in the long run under such conditions. As may be expected, the biggest loser is the coal industry, which stagnates at current production levels as growth in new generation capacity are forced towards renewable sources. Despite the anticipated short-run adjustment costs of moving towards a low-carbon growth path, the economy stands to benefit from massive emissions savings for very little cost in the long run. The implications of such a low-carbon focussed build programme for related policies such as the proposed carbon tax are also worth noting as it would form part of the suite of policies envisaged by policymakers to reduce the country's overall emissions profile. Other scenarios are still being investigated and improvements to the modelling and simulation design process are on-going.

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