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Quantifying Uncertainty in Baseline Projections of CO2 Emissions for South Africa

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Introduction
Framing domestic climate change policies and national positions in global climate negotiations requires the best possible information about possible future outcomes. Defining this position is made by trading-off emission reductions and economic growth. Policy makers' efforts in this regard are focused on achieving low carbon development at the lowest possible cost to the economy. This cost of mitigation is calculated as a difference in costs (defined in monetary units) between a baseline situation and a new one characterized by lower emissions, (Hourcade 1996). For most developed countries the emission reduction is calculated relative to a benchmark date in the recent past. Usually in studies of developing countries, emission reduction is calculated in terms of a percentage reduction from an emission level in a baseline trajectory at a specified future date, often several decades in the futures. The definition of a baseline trajectory is problematic:

- Uncertainty: the baseline trajectory is driven by many uncertain factors
- Definition: which existing policies and effort are to be included in the baseline?
- Mitigation and Development: for developing countries issues of poverty, inequality, and education goals need to be traded-off against mitigation goals. Are development goals and aspirations met in the baseline?

This study deals mainly with the first item: Uncertainty. A central purpose of policy research and policy analysis is to help identify the important factors and the sources of disagreement in a problem, and to help anticipate the unexpected. And yet many policy studies are carried out with very little emphasis on the underlying uncertainty that policy decisions would be sensitive to. Energy-economic and environment (E3) models are simplified representations of the complex energy-economic and environment systems that we are part of. These models are useful in that they help to organise information about the system in a systematic way. They help decision makes and stakeholders better understand the system, both in terms of how different courses of action impact on the system and help meet objectives, and how the system responds to different uncertain and uncontrollable situations. These models can be used for projecting national baselines given input assumptions and their inherent uncertainty, provided it can be quantified.

Objective
The objective of this project is to quantify the uncertainty associated with key model inputs to develop a probability distribution of baseline emissions for South Africa over the 2015-2050 period. This objective is to be met in two phases. In the first phase, the most important and uncertain input parameters were selected for uncertainty analysis, and the associated uncertainty was described. In the second phase the uncertainty in inputs is propagated via an E3 model of South Africa (South African TIMES Model - SATIM) to obtain the probability distribution for the baseline emissions of South Africa, over the period of interest.

Methodology

We stress that we are not only interested in projecting the most likely trajectories for each of these quantities over the period 2015-2050. We are also interested in assessing the uncertainty around the most likely trajectory. Projecting this far into the future is an extremely, perhaps impossibly, complex task. We use a combination of methodological approaches to do this, triangulating between these approach in an attempt to arrive at some kind of consensus projections.

The approach followed here is to assess uncertainty on a small number of key drivers influencing the energy system, and hence GHG emissions associated with it. We assess distributions over possible values that these drivers can obtain in the future, and pass these values to the E3 model. For each combination of possible inputs, the model returns outputs for quantities like GHG emissions. By submitting many possible inputs to SATIM, a range of possible outputs is obtained. This process takes the form of a Monte Carlo simulation.

Scenarios

We do this for one "no mitigation" scenario for South Africa but for two different scenarios of mitigation outside of South Africa:

1. Little/no international mitigation
2. Ambitious international mitigation

The international mitigation scenarios are made explicit because of the nature of the data we draw on for global energy commodity prices and solar technology costs.

Uncertain Key Drivers

We assess uncertainty on seven key drivers:

- Population growth
- GDP growth
- GDP distribution (tertiary vs other sectors)
- Domestic Coal Production costs (Central Basin and Waterberg)
- Overnight investment costs of Nuclear
- Overnight investment costs of Solar PV and CSP (2 global mitigation scenarios)
- International Coal, Oil and Gas prices (2 global mitigation scenarios)

The methodology used to obtain projections depends on the nature of the key driver. For international commodity prices and for technologies in which South Africa can be expected to pay global prices (i.e. nuclear, PV, and CSP), a number of detailed long-term projections are available in the literature. We essentially used these projections verbatim, without any additional input from expert elicitations. In the same vein, we used existing UN probabilistic population projections, which represent arguably the state-of-the-art in population forecasting practice.

Projections for the other key drivers (i.e. GDP growth, share of GDP claimed by the tertiary sector, domestic coal prices, domestic gas prices) are based on expert elicitations. This is largely because reliable literature sources were unavailable or the local nature of the information tipped the balance in favour of expert knowledge. Detailed semi-structured interviews were used to elicit qualitative information on possible future outcomes, followed by a quantitative assessment of ranges of possible values. We followed generally accepted best practice when assessing this information, using the protocol outlined in the next section.

In order to keep the elicitation task manageable for experts, we assessed three-point probability distributions (minimum, mode, and maximum) at three distinct points-in-time (2020, 2035, 2050). Direct elicitation of annual probabilistic projections i.e. annual probability distributions, was not considered practically feasible and in any case would be subject to overwhelming anchoring biases. Even with this highly restricted elicitation goal, interviews took between 2 and 4 hours to complete, even after some preparatory work by experts before the interviews.

Information gathered using either literature searches or expert elicitation was rarely in a form that could be directly used by the SATIM. Some "post-processing" was invariably required. Operations included interpolation between the three key time-points in the case of elicited quantities, currency standardization, and aggregation over sources.

Where available, the local interviews were supplemented with results obtained from the literature.

Results

Figure 1 shows the GDP growth and population simulations (black lines) over the modelling horizon as obtained from the experts and the UN model respectively. These same simulations are used in both scenarios. The green lines show the average, and the blue and red lines show the 80th and 95th percentiles, respectively.

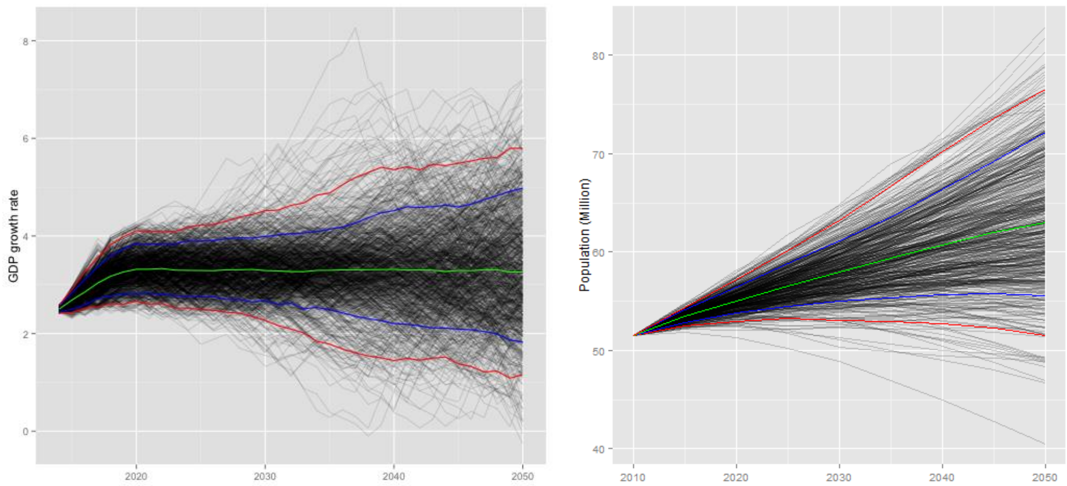

Figure 1 GDP Growth Rate (%) and Population (Million)

Figure 2 shows the coal price paid by power plants averaged over the two coal regions modelled, whose distribution is quite similar in the two international mitigation scenarios. Figure 3 shows the CSP base plant costs, showing a lower average in the "with international mitigation effort" scenario given higher levels of installation, but also higher variation, given the higher uncertainty in what these levels could be. A similar result is seen for PV (not shown here).
The result on the share of electricity generation from coal is shown in Figure 4, which, given the "no domestic mitigation effort" assumption stays relatively high in the majority of the simulations. The result on the total CO_2-equivalent emissions for the South African energy system is shown in Figure 5. In both scenarios, the CO2 emissions increase by roughly the same amount on average, with a slightly average in the "with international mitigation efforts" scenario given the slightly increased competiveness of solar technologies, amongst other effects, not shown here on the other sectors of

the energy system such as the transport and industry. In both scenarios, the variation in the results is quite staggeringly wide. The implications for mitigation policy is not totally clear at this stage. What is more certain though is that if the rest of the world makes some mitigation efforts, it is unlikely that South Africa would be allowed to continue without also making some efforts. The framework developed here needs to be extended to address the other 2 points mentioned in the introduction – to help South Africa find robust strategies to still achieve its development aspirations while still satisfying the international community.

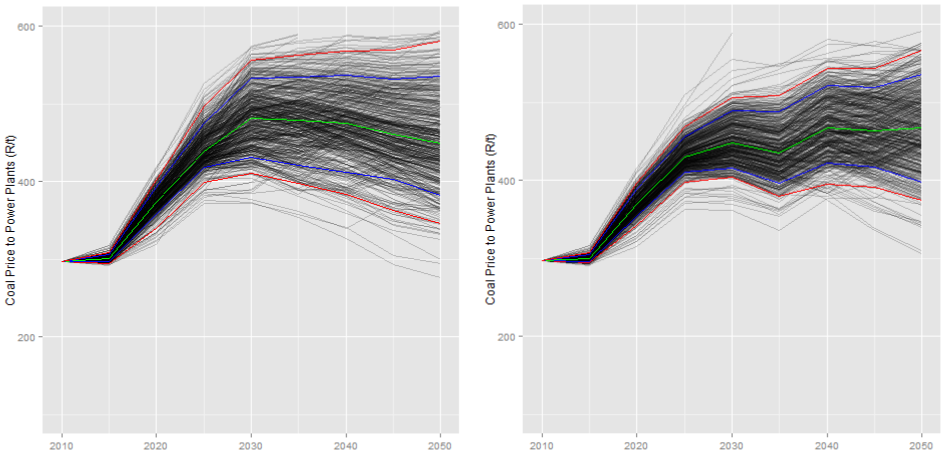

Figure 2 Average Domestic Coal Price to Power Plants without and with international mitigation efforts

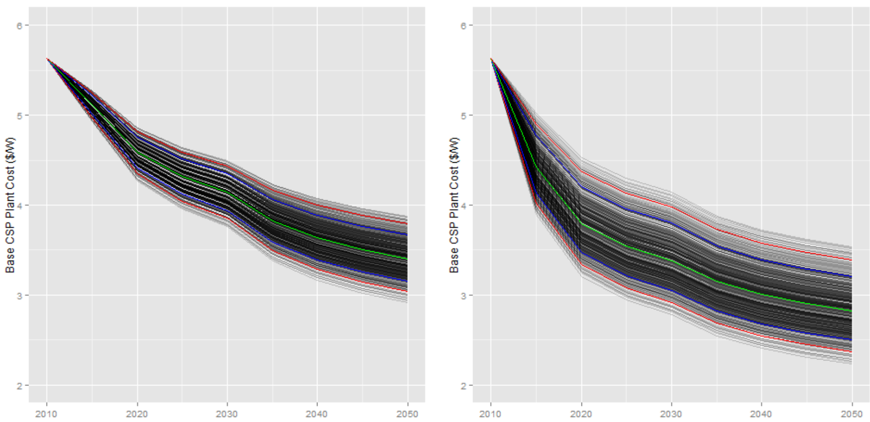

Figure 3 CSP Plant Cost without and with international mitigation efforts

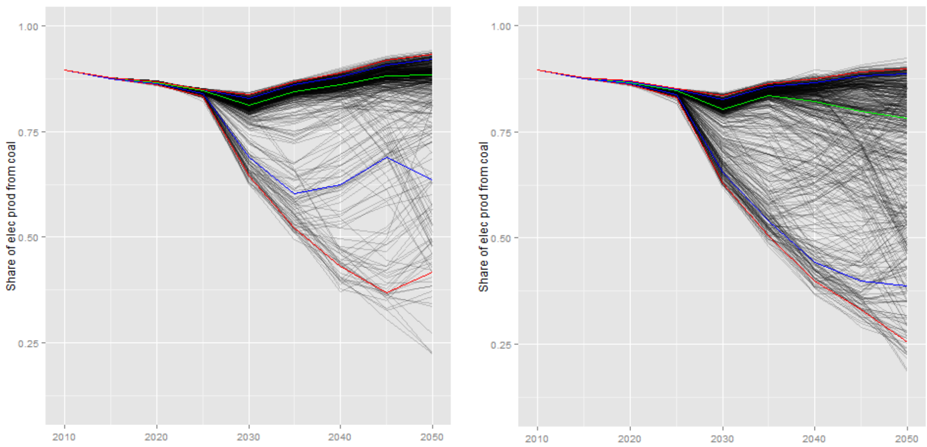

Figure 4 Share of electricity production from coal without and with international mitigation efforts

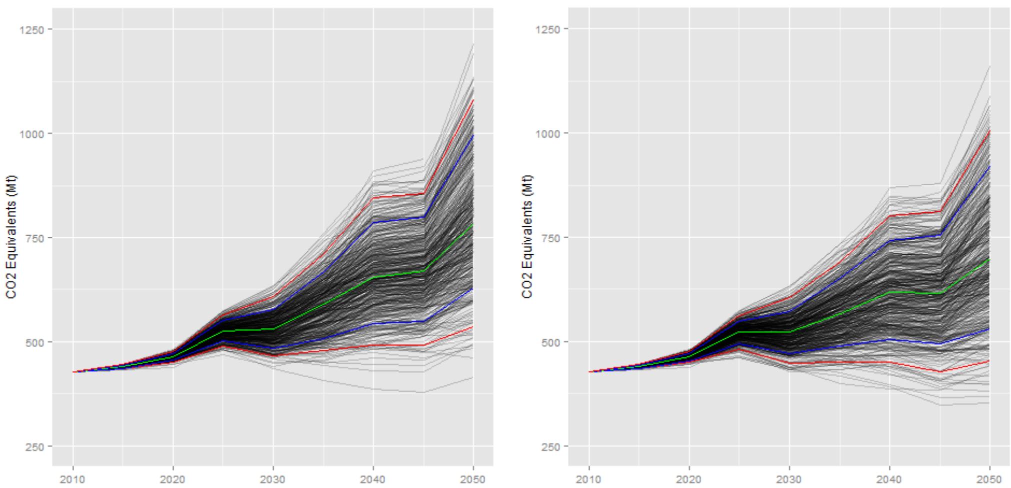

Figure 5 Total CO_2-eq emissions from the South African Energy System without and with international mitigation efforts