Activating the SAFRIM model in calculating the Macro-Economic impact of greenhouse gas mitigation on the South African economy

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Abstract

In building an econometric model, specifically in this case, the identification of the model framework and the specification of the equations of an INFORUM model receive ample attention in the literature and at conferences. The use of the INFORUM model for forecasting purposes is very clear. However, the identification and the discussion of how an INFORUM model is activated for macro-economic impact analysis is generally lacking. For example, if the impact of a major project, which has forward and backward linkages needs to be calculated, it is not always so clear as to how and where to stimulate the model. The objective of the paper which is to be presented at the 22nd INFORUM World Conference by the authors is to discuss how the South African INFORUM model (SAFRIM) was activated for optimizing greenhouse gas (GHG) emission mitigation options in South Africa.

Currently, the South African economy is mainly operating under the principles of a free market. It can therefore be accepted that the use of scarce resources (labour, capital, natural resources, etc.) is to a great extent applied optimally when financial and economic principles are used as the criteria for optimum growth and development. However, it is also generally accepted that the free market concept has shortcomings, specifically in terms of long-term sustainable economic growth and development as far as its ability to conserve the environment is concerned. To conserve the environment it is necessary that government intervene in certain circumstances to eliminate or reduce the negative environmental impacts of a free market economy. Unfortunately these GHG emission mitigation interventions could have major structural and accompanied price increase effects on the economy which inhibits economic growth and employment creation.

The application of the SAFRIM model is therefore, to assist the decision makers in identifying the GHG emission mitigation options which to a large extent limit the negative impacts on the economy and even in certain cases obtain a double dividend namely to limit GHG emissions but still increase the economic growth and employment in the long-term.

Keywords: *INFORUM, Greenhouse Gas Emissions, SAFRIM*

1 Introduction

The most important aspect of a macro-economic impact analysis, undoubtedly, is the construction of an appropriate model which also entails defining the basic underpinnings of the framework of the model, the estimation of the regression equations (representing important economic functions) and the setting of other coefficients and ratios that forms an intrinsic part of the model. However, an important aspect is the setting of parameters and guidelines to practically activate the model to calculate the economic impact of a specific programme or project.

The main objective of this paper is to explain how the South African INFORUM Model (SAFRIM) was used to quantify the macro-economic impact of the greenhouse gas (GHG) mitigation potential opportunities for the South African economy. It is important to compare the positive results that the various mitigation potential opportunities have on the reduction of greenhouse gas emissions but also to compare this positive reduction of gas to the cost that these reduction opportunities will have on economic growth and employment. Both the environment as well as economic development is of great importance for South Africa (National Planning Commission for 2030).

The structure of the paper is as follows:

- Description of the Case Study - South Africa's Greenhouse Gas Emissions Potential Mitigation Analysis
- Overview of the South African INFORUM model (SAFRIM)
- Activating the SAFRIM model
- Results of the Case Study
- Conclusions

2 Description of the Case Study - South Africa's Greenhouse Gas Emission Potential Analysis

The South African economy has industrialized, mainly on the basis of energy-intensive industries helped along with low-cost, coal-fired electricity generation. As a consequence, the country's absolute and per capita greenhouse gas (GHG) emissions are high in comparison to many developing countries. About 83% of South Africa's GHG emissions are derived from energy supply and consumption in comparison to an average of 49% among other developing countries.

Like many developing countries, South Africa also faces a number of social, economic and environmental challenges. Consequently, South Africa's approach (Greenhouse Gas Mitigations Potential Analysis, 2013) to mitigating climate change seeks to strike a balance that will enable the reduction of GHG emissions (voluntarily as a good global citizen), whilst maintaining economic competitiveness, realizing the developmental goals and harnessing the economic opportunities that accompany the transition to a lower carbon economy.

As a responsible global citizen and with both moral and legal obligations under the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol (Kyoto Protocol, 1997), South Africa is committed to contributing its fair share to global GHG mitigation efforts in order to keep global temperature increases below 2°C.

The overall objective of this study has been to present a set of viable options for reducing GHGs in key economic sectors. These sectors were defined as:

- Energy;
- Industry;
- Buildings;
- Mining;
- Transport;
- Waste; and
- Agriculture, Forestry and Other Land Use (AFOLU)

In the table below, a few examples are given of what the various sectors are composed of plus proposed measures:

Table 1: Examples of the composition of the sectors outlined above

Main Sector	Key Sector	Subsector	Measure
Energy	Energy	Petroleum Refining	CCS - Existing Refineries
	Energy	Petroleum Refining	Energy monitoring and management system
	Energy	Coal Mining	Coal mine methane recovery and utilisation for power and/or heat generation
	Energy	Coal Mining	Process, demand & energy management system
	Energy	Electricity and Heating	Nuclear (PWR)
	Energy	Electricity and Heating	Gas CCGT
Industry	Industry	Primary Aluminium Production	Best process selection for primary aluminium smelting
	Industry	Primary Aluminium Production	Switch to secondary production and increase recycling
	Industry	Ferroalloys Production	Implementing best available production techniques
	Industry	Ferroalloys Production	Replace submerged arc furnace semi-closed with closed type
	Industry	Iron and Steel Production	BOF Waste Heat and Gas Recovery
	Industry	Iron and Steel Production	Top Gas Pressure Recovery Turbine
	Industry	Cement Production	Improved process control
	Industry	Cement Production	Reduction of clinker content of cement products
	Industry	Lime Production	Installation of shaft preheaters
	Industry	Lime Production	Replace rotary kilns with vertical kilns or PFRK
	Industry	Chemicals Production	CCS for new ammonia production plants process emissions
	Industry	Chemicals Production	Revamp: increase capacity and energy efficiency
	Industry	Surface and Underground Mining	Use of 1st generation biodiesel (B5) for transport and handling equipment
	Industry	Surface and Underground Mining	Improve energy efficiency of mine haul and transport operations
	Industry	Pulp and Paper Production	Convert fuel from coal to biomass/residual wood waste
	Industry	Pulp and Paper Production	Application of Co-generation of Heat and Power (CHP)
	Industry	Residential	Energy efficient appliances
	Industry	Residential	Geyser Blankets
	Industry	Commercial/Institutional	Efficient Lighting
	Industry	Commercial/Institutional	Heat pumps - Existing Buildings
Transport	Transport	Road	Road - Alternative fuels - CNG
	Transport	Road	Road - Improved efficiency - Petrol ICE
	Transport	Rail	Rail - Improved efficiency - EMUs
	Transport	Rail	Rail - Improved efficiency - Diesel
	Transport	Aviation	Aviation - Biofuels
Waste	Waste	Municipal Solid Waste	Paper recycling
	Waste	Municipal Solid Waste	Energy from waste
Agriculture, Forestry and Other Land Use	AFOLU	AFOLU	Expanding plantations
	AFOLU	AFOLU	Rural tree planting (thickets)

These mitigation opportunities were defined as physical actions that can be taken to reduce or prevent GHG emissions from a given source. For example, this can constitute the implementation of technology improvements within an industrial process or individual industrial facility (e.g. replacement of an inefficient furnace).

A basket of mitigation opportunities were chosen in collaboration with the private sector in South Africa. For all the mitigation options, the financial cost impacts have been assessed against a counter-factual: the existing situation against which a new measure is compared. For example, in considering the water impact of a wind farm, what is of interest is the volume of water used by wind farms compared to the volume used by current power generation mix (primarily coal fired power) for the same level of power generated.

Note that cost was assessed on a Life Cycle Basis. This means that both capital costs associated with construction and de-commissioning (where relevant within the time period) and on-going operating costs were included.

The cost was evaluated on a Net Present Value basis; in other words with future costs discounted at a real rate of 11.3%. The macro-economic impact of the mitigation opportunities were based primarily on these cost (economic surplus) as will be explained later in the paper.

3 Overview of the South African INFORUM model (SAFRIM)

Quantifying the total macro-economic impact of the greenhouse gas mitigation measures was done by using the SAFRIM model (Mulder, 2006). The main purpose of giving an overview of the SAFRIM model is to make it possible to better explain how the model was activated.

As you all know, the INFORUM modelling system is macro-economic, dynamic and multi-sectoral of nature. It depicts the behaviour of the economy in its entirety i.e. the workings of all the major markets in their inter-related, dynamic existence are accommodated. It therefore lends itself for projecting aggregate gross domestic product (GDP) and all its components as well as the demand categories that determine GDP instantaneously and dynamically.

The system is multi-sectoral and incorporates the Input-Output (I-O) Table and national accounting matrix which also shows the magnitude and diversity of intermediate consumption within the context of the current economic structure. This allows the system to integrate intermediate input prices with the process of sectoral price formation which ultimately determine overall and final price levels in the economy. This is done through the use of behavioural equations for final demand that depend on prices and output; and functions for income that depends on production, employment and other variables.

Another important feature of this macro-economic multi-sectoral model is its bottom-up approach. In this approach, the model mimics the actual workings of the economy in that the macro-economic aggregates are built up from detailed levels at the industry or product level, rather than first being estimated at the macro-economic level and then simply “distributed” amongst sectors.

The INFORUM system is dynamic from the outset and therefore allows for projections of the economy as well as to calculate the macro-economic impact of an intervention in an economy such as a programme or new project. Therefore, macro-economic and dynamic multi-sectoral models are well suited for forecasting the baseline projection.

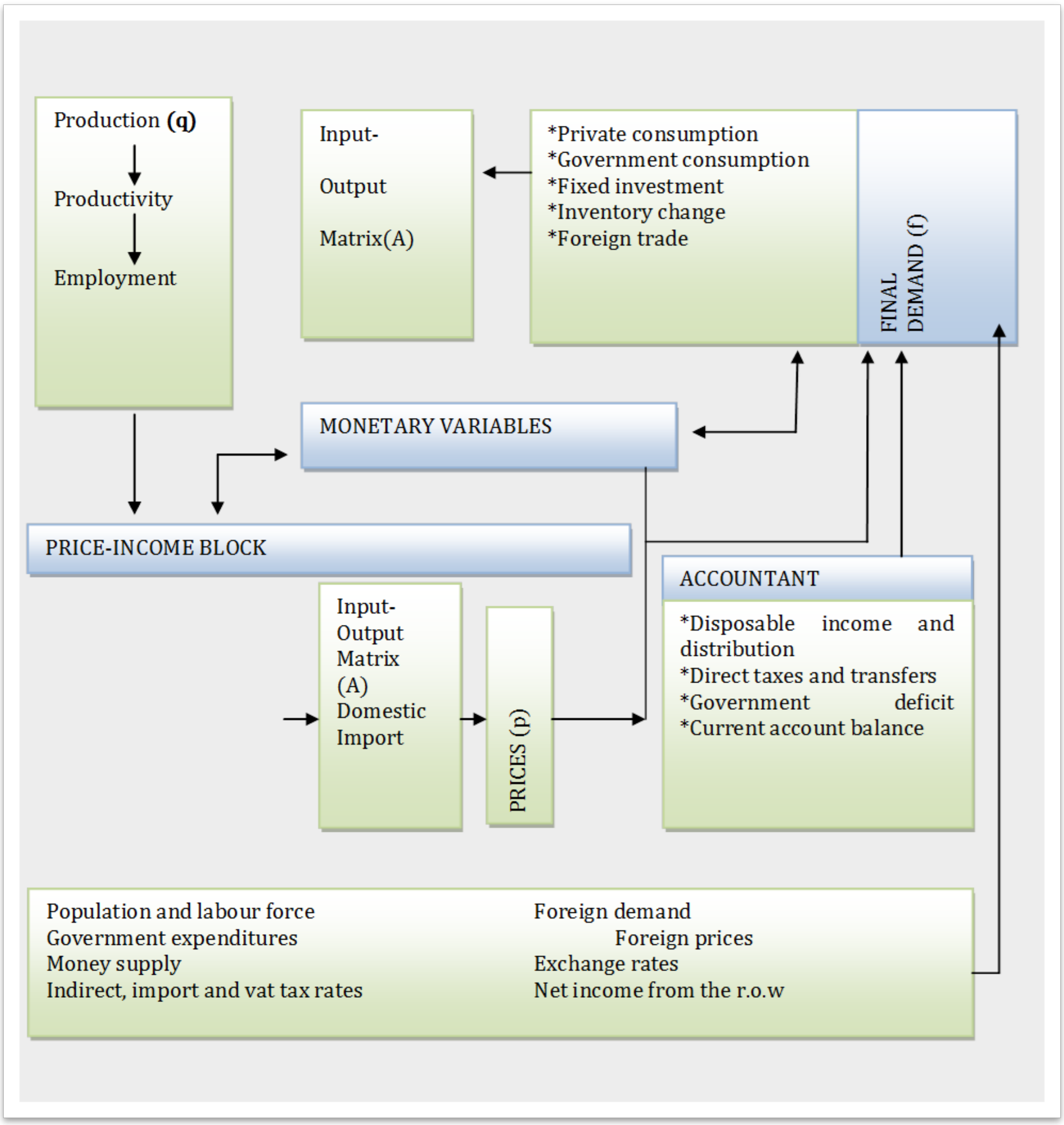
Figure 1 below depicts the dynamic and inter-related workings of SAFRIM. A description of each variable that has to be estimated is shown.

- The model “loop” begins on the production block side, where the expenditure components on GDP (supply side) are estimated in constant prices. Next, the personal savings propensity is applied to calculate what portion of total household real disposable income will be spent on consumption. From this total figure, the distribution of per-capita consumption expenditures per income group is calculated.
- Exports are usually calculated outside the model (i.e. exogenously) given the dependence of exports on international economic conditions if it used for general forecasting. However, if it is used for macro-economic impact analysis, the model is structured in such a way that exports are endogenous based on world demand as well as relative prices (South African prices relative to the prices of South Africa’s trading partners). The investment equations model the substitution (or complementarity) of capital equipment with labour and energy. The scarcity of capital is taken into account as explained above.
- Government consumption and investment expenditures are normally determined outside the model. At this point, after all the final demand categories (except for imports and inventory change) have been estimated, an input-output mathematical solution is applied to jointly and simultaneously determine output, imports and inventory change.
- The model next turns to the important job of forecasting prices at various levels. To start off, all components of value added are calculated, of which the

important one is the hourly labour compensation rate by industry, called the "wage rate". However, as indicated above, the wage rate is dependent on the availability of appropriately-skilled labour. By multiplying the wage rate with the total hours worked, total labour remuneration per industry is obtained.

- Labour remuneration is the largest component of national income, usually about 60%, and certainly has a major effect on prices. However, it is also important that the various components of capital remuneration are taken into account. Private enterprise gross profits are needed to be able to calculate a number of aggregates viz. company taxes, retained earnings and depreciation of capital assets which make up business savings, which together with personal savings impacts heavily on the savings-investment equation in the economy. Furthermore, dividends, proprietors' income, interest income and rental income generated in the private sector all ultimately contribute to personal income.
- To calculate prices, value added by industry is summed to total value added, and then passed through a product-industry bridge, to obtain value added per product. Once value added at the product level has been obtained, commodity prices are calculated. The import content of intermediate consumption is taken into account here.
- The deficit on the current account of the balance of payments before and after the implementation of the mitigation option was taken as a benchmark to ensure that the economic models adequately capture the need to borrow for and pay back the capital investments. For instance, if the deficit on the current account of the balance of payments amounts to 6% of the GDP in the base case scenario, i.e. no changes to the existing energy policies, then for controlling purposes the deficit in the current account of the balance of payments should not deviate from 6%. This was achieved by increasing or decreasing the prime interest rate.

Figure 1: Dynamic and inter-related workings of the SAFRIM Model



4 Activating the SAFRIM model

To be able to analyse the macro-economic impact of the GHG mitigation measures, it is essential that a baseline growth forecast of the South African economy should be established. The following section provides information on how a long-term (base) forecast of the South African economy was accomplished.

4.1 Forecasting the Baseline Scenario

It is important to note that the projection of the economy is done over a very long period which stretches the limits of a standard dynamically orientated econometric forecasting model. The assumptions that are usually applied to modelling, such as monetary variables (i.e. interest rates and money supply) as well as short term price fluctuations, which are normally imperative for short- and medium-term forecasting are not that significant in this case. The long-term forecast is much more driven by expected structural developments in the South African economy, specifically regarding the potential of certain sectors to be able to export over the longer-term, such as the long-term sustainable exports of iron ore, magnetite, chrome, coal, etc. It is also assumed that South Africa would play a much larger role in the African economy, and will be less dependent on its traditional trading partners, such as Europe and the United States of America. This will also change the structure of international trade, where South Africa will become more dependent on the exports of manufacturing goods and services; and less dependent on exports of primary and less processed commodities.

Specific information regarding Transnet's Capital Investment Programme over the medium to long term was also used to get an indication of the export potential of certain sectors (Transnet, 2013). However, this information emphasized that a substantial increase in harbour and railway capacity would serve as an essential prerequisite to unlock these resources.

On the other hand, the diminishing role of gold and diamonds in the future development of the economy was also taken into account. Furthermore, fundamental economic imperatives/rules were built into the forecasting scenario, which includes the following aspects:

- There should be an acceptable measure (not exceeding ±4% of the GDP) of balance on the current account of the balance of payments;
- No fundamental obstructions to obtain foreign capital;
- Positive growth of the world economy; and
- South Africa's population growth by taking into account the negative effects of HIV/Aids.

GHG emissions projections developed under this study are based on a targeted level of future economic growth based on the "moderate growth rate" defined by National Treasury and published in the 2012 draft Integrated Energy Plan

(Department of Energy, 2013). The projection of moderate growth assumes that the economy will grow steadily, with continued skills constraints and infrastructure bottlenecks in the short- to medium-term. The moderate growth scenario forecasts real growth in Gross Domestic Product (GDP growth) of 4.2% per annum over the medium-term (defined in the draft Integrated Energy Plan as 2015-2020) and 4.3% per annum over the long-term (2021-2050), according to the 2012 Medium Term Budget Policy Statement (National Treasury, 2012).

This growth rate could currently be viewed as somewhat on the high side, if structural challenges in South Africa, such as the improvement of education; poverty alleviation; and enhancement of income distribution, are taken into account. It is also important to note that the South African economy has grown since the advent of full democracy only in the order of between 3% and 3.5%, which is well below the medium growth target of ±4%. A summary of the assumptions for the medium growth scenario are depicted in the Table 2 below.

Table 2: Assumptions for the Medium Growth Scenario

	Input Variable	Parameter Value	Source and Explanation
1	**South African population**		National Development Plan 2030.
•	currently	**1.0%**	Conningarth increased the population growth to about 2% p.a. over the period.
•	long-term, declining to 0.5% by 2030	**0.5%**	
2	**South African inflation targets (SARB objectives between 3.0% and 6.0%)**	**6.0%**	Conningarth Economists.
3	**World prices/inflation**	**3.0%**	World Trade Organization (WTO) (short to medium term forecast).
4	**Final consumption expenditure by government**	**3.9%**	Conningarth Economists, underpinned by the National Development Plan, 2030. Role of government in South African economy should be in-line with economic growth.
5	**Business cycle**		Conningarth Economists.
•	2013 to 2014	**average**	
•	2015 to 2018	**above average**	
•	2021 to 2025	**below average**	
•	all other years	**average**	
6	**Exchange rate per annum (depreciation of the real effective Rand exchange rate)**	**-1.7% p.a.**	A Manual for Cost Benefit Analysis in South Africa with Specific Reference to Water Resource Development (TT305/07). This real 1.7% is over and above the purchasing power parity theory which means that the Rand will depreciate against its trading partners with this real percentage plus the difference between South African inflation and the inflation of its main trading partners.
7	**World economic growth**		OECD Economic Outlook Volume 2012/1.
•	2013	**3.3%**	
•	2014	**4.0%**	
•	2015 to 2023	**4.5%**	
•	2024 to 2052	**4.0%**	
8	**Current account of balance of payments as percentage of GDP**	**3.6%**	Conningarth Economists. Assumption is based on 10 year average of SARB bulletin. As a rule of thumb, this ratio should be in the order of net domestic investment as percentage of GDP.

4.2 Methodology to activate the model

In broad terms, the impacts of the GHG mitigation measure can be divided into so called backward linkages, forward linkages as well as balancing the economy according to certain constraints.

4.2.1 Backward Linkages

The backward linkages refer to the economic impact on other sectors of the economy if a specific sector increases its production. This may be expected to translate into a rise in the demand for raw materials, other intermediate inputs and the remuneration of labour and capital inputs.

The backward linkages originate from two main sources, namely during the construction phase of a project and when the project becomes operational. The construction phase actually entails the establishment of capital assets. For example, in order to generate electricity, a power station (a very substantial capital asset) has to be constructed, which in itself creates economic activities through, for example, additional employment opportunities. The operational impact refers to the creation of economic activities driven by the production process. For instance, to generate electricity requires the buying of raw materials such as coal and the paying of salaries and wages on an on-going basis.

Backward linkages can also change the production structure of the economy due to the implementation of a particular mitigation option, which should therefore be taken into account. For example, if renewable energy options are introduced in lieu of coal-fired power stations, the structure of the economy is altered. Such an event will reduce the need for new coal mines (or extending the life-span of existing ones) which can have a significant negative effect on employment opportunities in that sector.

A technical discussion of how the model was activated for the various backward linkages will follow now:

A. <u>Construction phase (investment impact)</u>

For the construction phase, the model was activated on the following final demand identity (constant prices).

$$fdc = pcec + invc + govc + exc - imc + fdrc + trcc + capex\_tot \qquad (1)$$

Where:

fdc = total final demand

pcec = private consumption expenditure

invc = investment (investment excluding investment in the mitigation measures)

govc = government

exc = exports

imc = imports

fdrc = residual

trcc = transfer costs

capex_tot = total net investment of the various mitigation measures

The investment related to the various GHG mitigation measures were added in the variable capex total on an annual basis over the period 2010-2050. Certain measure's investment is a net figure, for instance, electricity is needed but it can be supplied the traditional method of coal power stations or by a nuclear power station. The net investment is therefore the results of the investment of the nuclear power station minus that of the coal power station. The investment was broken down to the various assets/commodities (e.g. construction, machinery and other equipment, transport equipment, etc.) structure of each GHG mitigation measures.

B. Operational impact

The following production formula was used to activate the model for the operational impact (constant prices) on the various economic sectors.

$$outc = (!(I\text{-}AMC) * fdc) + oper\_imp \qquad (2)$$

Where:

outc = total output (production)

! (I-AMC) = inverse matrix

fdc = total final demand

oper_imp = total net operational impact of the various mitigation measures

The total net operational impact of the various mitigation measures are added to the production function that is calculated by adding it to the function outc = (!(I-AMC) * fdc). The operational impact is added on a detail sector basis per annum.

C. Changes in the production structure

The default is that the SAFRIM model applies the current structure of production in the country. However, in some cases the large scale of change associated with the mitigation measures will change the structure of production. For this study, the impact on the economy's structure was only incorporated in the case of the energy sector both because of its importance and because of the scale in the shift away from coal-based energy generation measures. These structural changes were made primarily to reduce the importance of coal mining in the South African economy as the increased role of renewables and nuclear power in future will reduce the country's dependence on coal-based power and hence the need to mine coal.

The A matrix, was adjusted on an annual basis to accommodate the changes in the production structure to take into account the influences of the various mitigation measures.

4.2.2 Forward Linkages

In this instance, the forward linkage effect refers mostly to the impact that a specific mitigation option has on the overall competitiveness of the economy. In some cases the mitigation option's effect can be counterproductive to what is currently in effect and in other cases it is more positive. This effect is largely reflected in the prices of the goods and services produced by a sector, which could have an effect on the international competitiveness of the country. Depending on the price elasticities of the demand for local products, this in turn could have an effect on local production and employment.

The model is activated by the net cost impact on a specific sector's unit production costs. It also rests on the assumptions that if a sector's product price increases/decreases because of the increase/decrease in production cost, this will decrease/increase the price competitiveness of the sector. As such the price effects are to some extent also determined by the supply-side constraints introduced in the model.

D. Price impact

The additional cost or savings brought about in the economy by the introduction of GHG mitigation measures is added into the model by increasing the value added (current prices) factor per sector where applicable. The identity below explains were it is added in the model.

$$va = lab + gos + itprd - isprd + itprs - isprs + enviro \qquad (3)$$

Where:

va = total value added
lab = compensation of employees
gos = gross operating surplus
itprd = indirect taxes on production
isprd = indirect subsidies on production
itprs = indirect taxes on products
isprs = indirect subsidies on products
enviro = additional costs or savings brought about in the economy by the introduction of GHG mitigation measures.

The next function shows how value added impacts on prices in the economy

$$uc = va/outc \qquad (4)$$

Where:

uc = value added unit cost
va = value added
outc = output/production (constant prices)

The value added unit cost is calculated by dividing value added by the output of a sector.

$$tot\_uc = impr+uc \qquad (5)$$

Where:

tot_uc = total unit cost
impr = import unit prices
uc = total value added unit cost

This is an interim step whereby the total unit cost is calculated by adding the import unit price to the unit cost.

$$ppi = (tot\_uc) * DPINV \qquad (6)$$

Where:

ppi = producer price index

tot_uc = total unit cost
DPINV = domestic price inverse

This formula is calculating the total domestic price (ppi) by multiplying the total unit cost by the domestic price inverse.

4.2.3 Balancing constraints

A technical adjustment to the model was necessary to ensure that the empirically measured impact of a mitigation option can be factually compared to a counterfactual outcome. For these purposes the deficit on the current account of balance of payments as a percentage of the country's overall economic activity (GDP), was taken as a controlling measure demonstrating the ability of the economy to financially carry the burden of a particular mitigation option. For instance, the deficit on the current account of the balance of payments amounts to 6% of the GDP in the base case scenario, i.e. no changes to the existing energy policies, then for controlling purposes the deficit in the current account of the balance of payments was constrained to 6%.

In terms of National Accounting Theory, a deficit on the current account of the balance of payments (exports less imports) must be equal to the deficit on the capital account (savings less investment). Everything being equal this implies that given the limited pool of the domestic savings, investment in some of the other projects would have to be adjusted downwards to make provision for the required investment and life cycle costs implied by the mitigation option(s). The model, simulating the workings of a market economy, will in case/cases where domestic savings are insufficient to meet the investment needs, use an increase in the real interest rate to restore equilibrium in the capital markets. The effect of this will be a decrease of overall domestic demand (therefore increasing savings and decreasing other investment (excluding investment in mitigation option in particular).

5 Results of case study

In this section the total macro-economic impact is presented. As already indicated the impact on only two macro-economic variables has been modelled. They are Gross Domestic Product (GDP) and the impact on employment. Furthermore only the dynamic impact, after taking into account the manual adjustment on the balance of payments in order to keep the economy's debt ratio at the same equilibrium point, prior to the initiation of the mitigation option, is discussed.

5.1.1 Impact on GDP

The net impact on GDP assuming 100% mitigation is achieved, (the impact of the assessment, minus the impact of the counterfactual) is given in Table 3 below.

Table 3: GDP impact analysis by sector

Average GDP Impact over the period (2010-2050)

Name	Incremental impact						Dynamic impact		Split
	Backward Linkage Impact				Forward Linkage Impact	Net Incremental Impact	Dynamic impact providing for balance of payment adjustment		
	Additional (Net) Investment Impact	Additional (Net) Operational Cost	Impact due to change in Production Structure	Total Backward Linkages	Impact due to Price Change		Impact Before Balance of Payments Adjustment	After Balance of Payments Adjustment	Final dynamic impact
Energy	23488	21461	-5493	39456	-8173	31283	31748	21745	45%
Industry	4397	787	0	5184	160	5343	5403	2371	5%
buildings	1067	1	0	1068	4350	5419	5401	5401	11%
Other Mining	2248	2545	0	4793	2813	7607	7404	7404	15%
Transport	13685	-4345	0	9313	-807	8506	8533	8533	18%
Waste	861	1807	0	2668	-888	1780	1793	1793	4%
AFOLU	155	896	0	1052	-89	963	964	964	2%
Total	**45874**	**23154**	**-5493**	**63535**	**-2634**	**60901**	**61246**	**48211**	**100%**

Note: The difference between the net incremental impact and the dynamic impact (impact before balance of payments adjustment) can be ascribed to the fact that at the dynamic impact, all the various impacts are run simultaneously in the model while the next impacts consists of the individuals impacts added together.

5.1.1.1 Discussion of GDP results

The analysis using the INFORUM model, incorporating all the mitigation measures applied on average over the programming period (the next 40 years)and taking the current year as the base year , GDP could increase by about R48 billion. This constitutes approximately 1.5% of current GDP.

In considering this 1.5% figure, the factors which influence the GDP to change both positively and negatively need to be considered. While backward-linked impacts are mostly positive (driven by capital expenditure and increased operating expenditure associated with the mitigation measures) the forward linkages often give negative GDP changes, driven by increases in relative prices.

The contribution of all the mitigation measures applied in each of the respective sectors to change in GDP is illustrated in Table 3 above.

The Energy sector makes the greatest contribution of 45% to the overall change in GDP. The mitigation options within Buildings, Mining and Transport also make significant contributions towards GDP growth.

5.1.2 Impact on Employment

The net impact (the impact of the impact assessment, less the impact of the counterfactual) on employment of the various measures is given in Table 4 below.

Table 4: Employment impact analysis - results by sector

Average Impact over the period (2010-2050), Change in Number of Jobs

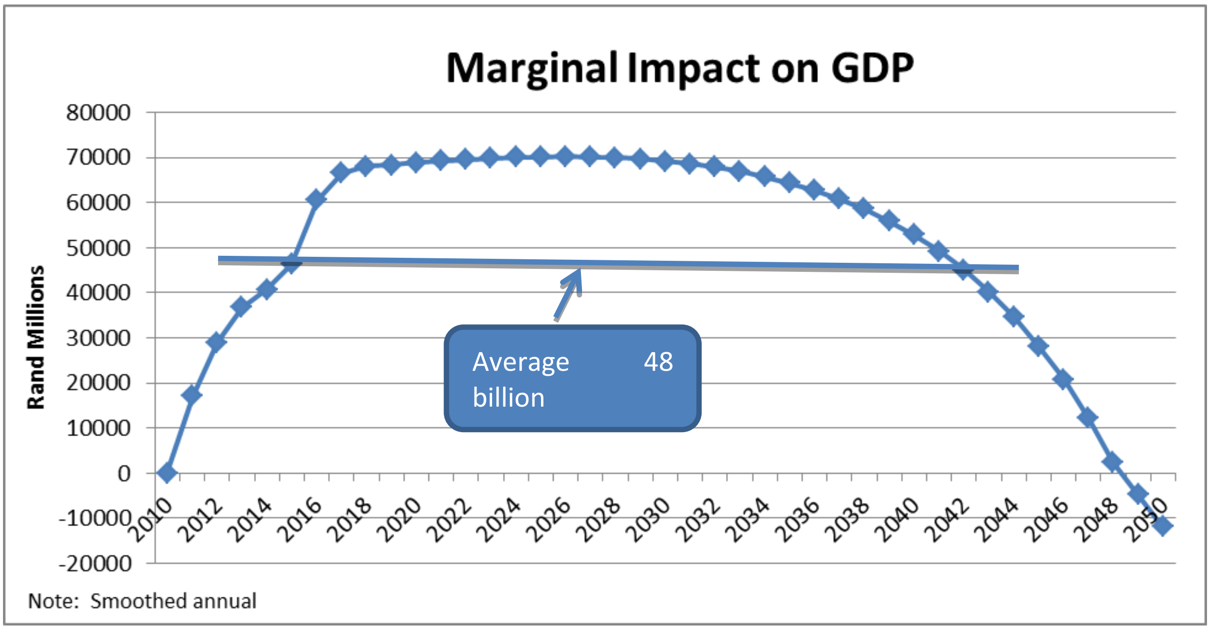
Name	Incremental impact						Dynamic impact		Split
	Backward Linkage Impact				Forward Linkage Impact	Net Incremental Impact	Dynamic impact providing for balance of payment adjustment		
	Additional (Net) Investment Impact	Additional (Net) Operational Cost	Impact due to change in Production Structure	Total Backward Linkages	Impact due to Price Change		Impact Before Balance of Payments Adjustment	After Balance of Payments Adjustment	Final dynamic impact
Energy	67243	40106	-26299	81051	-46741	34310	40510	-12468	-0.13
Industry	20271	5525	0	25797	639	26435	26760	10890	0.11
buildings	5914	7	0	5922	23863	29785	29687	29687	0.31
Other Mining	7067	3828	0	10895	14756	25651	24605	24605	0.25
Transport	46709	-12211	0	34497	-4179	30318	30455	30455	0.31
Waste	3719	4075	0	7795	-4878	2916	2983	2983	0.03
AFOLU	1371	10000	0	11371	-501	10870	10869	10869	0.11
Total	**152294**	**51332**	**-26299**	**177327**	**-17041**	**160286**	**165868**	**97020**	100%

The total impact on employment, taken directly from the INFORUM model, is 97,000 jobs based on the standard figures in the model which uses the current structure of the economy in terms of labour intensity.

5.2 Final impact on Projection over Time

The graph below plots the trend over time showing the projected marginal change in GDP in relation to the baseline figures given in Figure 2 below.

Figure 2: Marginal impact on GDP

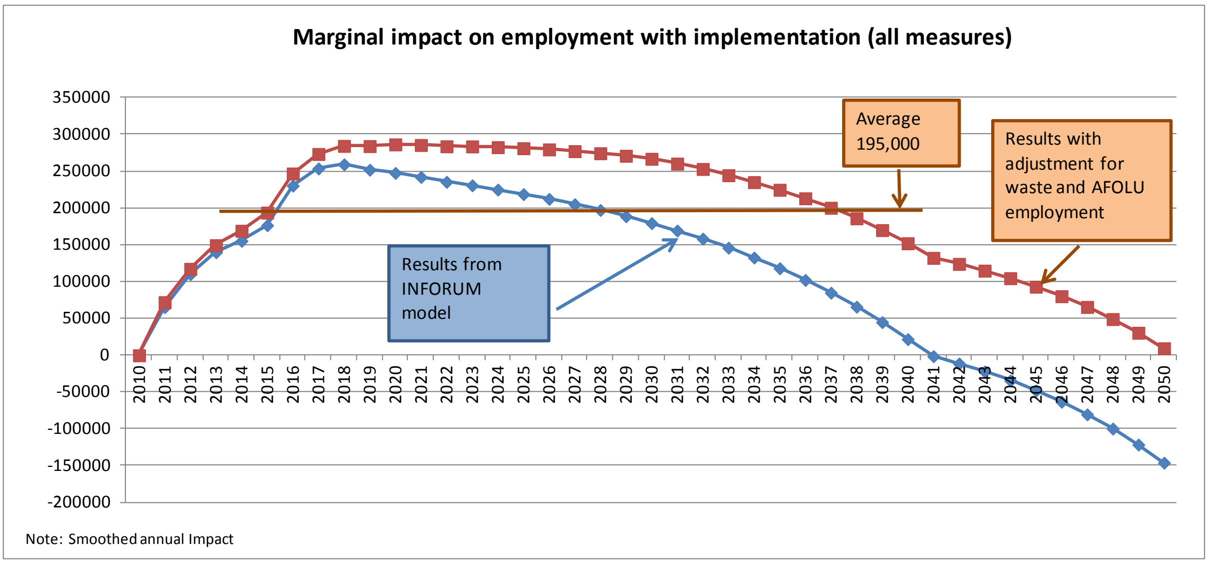


The average marginal impact on GDP over the period is R 48 million, with a peak of R 70 million in 2025. The marginal impact in 2010 is zero because no additional mitigation has been implemented yet at the beginning of the projection period.

Considering the shape of the curve, the initial incline over approximately 10 years is caused largely by the investments which are progressively implemented over this period. The decline after 2030 is related to two factors. Firstly, most of the major investments have been made and the negative impacts of relative price increases are felt. Secondly, the measures implemented in the latter years tend to be those which are economically least favourable.

Turning to employment the marginal increase in employment in relation to the reference case is shown below.

Figure 3: Marginal impact on employment, assuming all mitigation measures are applied



The overall impact on employment remains positive over the 40 year period, with an average of 195,000 additional jobs created between 2010 and 2050, assuming all technically-feasible mitigations are implemented. As with GDP, the increase in the early years is largely driven by new investments. The declining trend of the marginal impact over time is caused by for the fact that several sectoral measures with lower employment benefits are included. But, on balance over the period, employment impacts remain positive; largely because of the labour intensive outcomes of the measures in the waste and AFOLU sectors.

6 Summary and Conclusions

The main objective of this paper was to show how the macro-economic impact of a project or a programme with many facets could be quantified by the SAFRIM model. The use of the model was enhanced by making use of an actual assignment that Conningarth was part of, namely;" South African Greenhouse Gas Mitigation Potential Analysis" done for the Department of Environmental Affairs of the Republic of South Africa.

As far as the results of this Case Study are concerned, the macro-economic impacts of the foreseen mitigation measures can be summarised as follows. The increase in the GDP is in the order of 1.5% and for employment 1.2%, with the current GDP and employment as basis. For example, the 1.5% means that on average over the programming period; the GDP will be 1.5% larger than what it is currently. With all mitigation measures included, it can be concluded that it will not have a major impact on the economy. What gains there are from direct employment and backward linkages are countered by losses due to forward linkage price effects; prices typically increase with increasing costs associated with implementing most measures, without a related gain in revenue.

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