An analysis of the potential socio-economic impacts of shale gas development in South Africa

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ABSTRACT

The South African government is in the process of considering shale gas exploration applications in the Karoo basin. There are conflicting views on whether the development of the resource will be to the detriment or benefit of the South African economy. This paper makes use of a dynamic Computable General Equilibrium (CGE) model adapted for the South African energy sector to analyse the potential socio-economic impacts of the development of shale gas. Simulation results indicate potential negative impacts on GDP contribution by all the sectors simulated, except the natural gas sector and the Gas-to-Liquid petroleum sector, as well as potential negative impacts on employment. The negative impacts on growth and employment are likely to worsen poverty and inequality. Potential impacts on trade are negative as the trade deficit increases. In terms of environmental impacts, the uptake of gas would decrease CO2 emissions. All results are compared to the baseline scenario. Based on these results, it is recommended that the decision on whether the development should go ahead or not ought to take into account the potential socio-economic costs, and potential ways to hedge against them.

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GLOSSARY OF TERMS

ADB	African Development Bank
AU	African Union
Bcf	billion cubic feet
CCGT	Combined Cycle Gas Turbine
CNG	Compressed Natural Gas
CO2	carbon dioxide
CTL	Coal-to-Liquid
CGE	Computable General Equilibrium
DME	Department of Minerals and Energy
DMR	Department of Mineral Resources
DOE	Department of Energy
EIA	Energy Information Administration
e-SAGE	Energy extended South African General Equilibrium
GDP	Gross Domestic Product
GHG	Greenhouse gas
GTL	Gas-to-Liquid
IRP	Integrated Resource Plan
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
Mossgas	Mossel Bay Gas
NERSA	National Energy Regulator
NGLs	Natural Gas Liquids
NGV	Natural Gas Vehicles
NPC	National Petroleum Council
OCGT	Open Cycle Gas Turbine
PetroSA	Petroleum Oil and Gas Corporation of South Africa
PWC	Price Waterhouse Cooper
SAM	Social Accounting Matrix
SAMSA	South African Maritime Safety Authority
Stats SA	Statistics South Africa
Tcf	trillion cubic feet
US	United States of America

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Chapter One: Introduction

1.1 Background

Shale gas is a form of natural gas. According to Jacoby, O'Sullivan and Paltseva (2012), different combinations of hydrocarbons form natural gas. They further state that the resource can be found in multiple geological formations and is mostly made of methane, but it also comprises of heavier small particles such as pentane, ethane, propane, butane and many more. Various types of natural gas include wet and dry gas deposits which are separated and sold as Natural Gas Liquids (NGLs). Jacoby, et al (2012), further, state that other forms of natural gas are associated with oil production.

Natural gas resources are further categorized by their reservoir's physical and chemical geologic properties. These are known as either conventional or unconventional depending on the ease at which they can be extracted. Those that can be extracted fairly easy with standard methods are regarded as conventional resources while resources that require much more sophisticated techniques such as tight sandstones are referred to as unconventional resources. According to Jacoby et al. (2012) shale gas is an unconventional resource; and requires sophisticated techniques to extract.

An Econometrix report (2012) defines shale gas as natural gas found in shale formations of finely grained sedimentary rocks. According to the report, the gas has a wide range of industrial and commercial uses, such as electricity generation. In 2012, the Department of Mineral Resources (DMR) simply defines the resource as hydrocarbon gas extracted from unconventional reservoir rocks.

The Energy Information Administration (EIA) (2013) states that shale gas is the second largest unconventional energy resource after heavy oil. In terms of environmental conservation, the gas is said to be more environmentally friendly and, therefore, more attractive from a sustainability point of view compared to coal. This is due to its lower levels of carbon dioxide (CO_2) emission when it is burned from gas into electricity (Bai, Elgmati, Zhang and Wei, 2012).

The unconventional gas uprising, which started in the United States of America and Canada, has spread across the world to be what Albrycht (2012) refers to as a global phenomena. According to the EIA (2014), the US, China, Canada, and Argentina are, at present, the only four countries producing commercial volumes of shale gas worldwide, with the US being the dominant producer.

The EIA (2013) report estimates that South Africa's Karoo basin has 390 trillion cubic feet (tcf) of technically recoverable shale gas resources. This according to the report puts the country in the eighth position in countries endowed with these resources in the world. EIA (2015) defines technically recoverable resources as quantities of oil and natural gas that could be developed using existing technology, irrespective of oil and natural gas prices or production costs.

The DMR (2012) states that PetroSA's Mossgas project was started with a reserve of approximately one tcf only. This, according to the report was sufficient to launch the operation's GTL plant, in Mossel Bay, which provides approximately 5% of national demand for liquid fuels and creates about 1500 employment opportunities. This highlights the potential significance of shale gas exploitation for both fuel supply and job creation. However, economically recoverable reserves can only be determined through exploration. In the case of South Africa, this can be done only once the government provides the necessary go- ahead through the awarding of exploration and, later, production licenses.

Exploration licences in the country are still to be issued. As a result, the true socio-economic potential benefits and costs cannot be ascertained at this point. Using a Keynesian multiplier model, Econometrix (2012) estimates that extracting only 20 tcf to 50 tcf of the resource can be translated into 300 000 to 700 000 permanent jobs over a period of 25 years. This is one indication of the potential economic benefits that can be realised through the extraction of the resource, if found. However, Fakir (2015) states that, more research must still be done on the potential costs to the environment and society at large, in order to allow these potential economic benefits to be put into perspective.

South Africa plans to expand its electricity generation mix, as at present there is an over reliance on coal as the main source of energy. The BP Statistical Review of World Energy (2014) states that in 2013, 72% of total primary energy consumption in South Africa was

derived from coal, (22%) from oil, while the consumption of natural gas was at (3%), followed by a combination of nuclear and renewables at (3%). Similarly, the EIA (2015) states that, the country holds the ninth position, world-wide, in largest recoverable coal reserves, and holds 95% of total reserves in Africa. This according to the report has pushed the country into a leading position in the continent, in greenhouse gas emissions, responsible for 40% of total emissions in the continent, while being in the thirteenth position in the world's largest emitters. On the other hand however, Wang et al. (2011) states that shale gas has a lower carbon footprint in the long run compared to coal in power-generation.

Given these considerations, companies are planning to explore and develop shale gas reserves in South Africa. This has been met with widespread reactions from various interest groups each with varying viewpoints. The outcry is mostly against hydraulic fracturing, sometimes referred to as 'fracking', which is the primary method adopted in the exploration of shale gas. The DMR (2012) define hydraulic fracturing as the process of breaking open rocks using force applied through a fluid medium, commonly referred to as a carrier. Typical examples of the fluids used include water, liquid petroleum gas (LPG), liquid nitrogen, liquid CO_2, diesel, and other chemicals.

Wait and Rossouw (2014) state that, those in support of shale gas development stress the potential socio-economic benefits, such as the creation of employment opportunities and economic development. They also state that the resource can be used as a cleaner alternative to coal in the generation of energy and many other possible positive multiplier effects associated with the exploitation of the resource. The authors also state that those against the development of the resource on the other hand, highlight risks to the environmental associated with the hydraulic fracturing. These include the pollution of ground water, the use of scarce water resources, noise to be created by and during the movement of trucks and equipment. Other possible negative impacts according to the authors include, possible displacement of agriculture and farming in the Karoo, which is one of the main economic activities in the region and a shift of resources from other important sectors to the production of shale gas.

This, therefore, means that the successful exploitation of the resource requires a careful balancing of the issues raised by all stakeholders. The aim of such a balancing act should be to ensure that the potential socio-economic benefits exceed all the associated costs.

According to Wait and Rossouw (2014), one other major challenge associated with the development of shale gas in South Africa is a lack of existing gas infrastructure. They state that transporting the gas to various distribution points and end users requires the use of pipelines that are currently not available in the country. Plant infrastructure and GTL transformation plants will also be needed to aid the process of exporting the gas, if it is seen as a feasible option. They further state that if this infrastructure is established then significant strides can be made towards providing jobs and increasing incomes in the economy. This, however, will be a temporary impact as major infrastructural investments can be expected to be done only in the early stages of the resource development. According to the DMR (2012), this challenge can be overcome, as a demonstration of enough resources would drive the necessary investment in infrastructure.

1.2 Problem definition

The scale of South Africa's shale gas resource has the potential to cause a fundamental shift in the country's gas industry. At times, this is referred to as being a 'game changer' for the country's economy as a whole. Gas is a cleaner form of energy compared to other fossil fuels. With the country's current high carbon intensity that has been a concern for investors, the government, NGOs and the general public, the direction that South Africa is going to take next in terms of the exploration, development and general management of the resource is of great interest.

Generally speaking, the discovery of most natural resources has a significant effect on the performance of that country's economy. This is more important for those resources whose development lasts several years (non-renewable resources). Several studies worldwide have been undertaken prior, during and post the development to understand and measure the impacts of the discovery, (Jacoby et al., 2012; Ames, Corridore, Ephross, Hirs, MacAvoy & Tavelli, 2012; and Barth, 2013; etc.).

One economic theory developed to put this into perspective has been the 'natural resource curse'. The theory postulates that countries that have an abundance of natural resources experience negative economic growth in the long term. Duruigbo (2005) states that resource-rich countries, almost without exception, are faced with diverse social, economic, and political problems. There are extensive problems of extreme poverty, environmental degradation, human rights abuses, fascism and civil conflicts. Several empirical studies have

been conducted to test this theory (Sachs & Warner, 1995; Duruigbo, 2005; Barth, 2013, etc.). The general agreement amongst these authors is that in most countries, especially developing nations, this theory holds (Sachs & Warner, 1995; Duruigbo 2005; Barth 2013; etc.).

According to Duruigbo (2005), in African countries like Nigeria and Equatorial Guinea, the oil and gas sector epitomises the resource curse. The author states that vast amounts of revenues from royalties and oil exports going into government funds, make way into the private accounts of public officials and those connected to them. The author states that multinational oil companies are also major beneficiaries. The only losers as per Duruigbo (2005) are the citizens of these countries, in particular, members of oil-producing communities, who absorb the costs of the development of oil and gas without enjoying the full benefits

Looking at South Africa in particular, one can consider the mining industry as a point of reference. The city of Johannesburg, known as the 'city of gold', is a direct result of the country's gold and platinum mineral resources. Several other non-mining sectors, such as the retail and finance, have developed from the city over time. This has allowed the country to have a competitive and comparative edge in the world economies. This, however, has not been achieved without costs. There are major negative environmental and social costs that the country has had to pay — and continues to pay — because of its mining industry. A recent case in point is the Marikana tragedy in 2012 and the various environmental disasters such as the acid mine drainage issue. These are just a couple of South African cases where the development of natural resources (gold and platinum) has not led to improvements in the socio-economic conditions in the country.

In light of the above highlighted challenges and successes, this research aims to address the following questions:

- What negative impacts, if any, does shale gas have on the socio-economic status of South Africa?
- What and how are the potential impacts of shale gas development affecting:
    i) Economic growth?
    ii) Trade?
    iii) Employment?

iv) Welfare and poverty?

v) Greenhouse gas emissions?

Multiple studies have been undertaken in an attempt to analyse the benefits and the related costs of shale gas development. This is more so in the US than in any other country. Of these studies, those found to be most relevant in the context of this paper has been a 2012 report by a task team funded by a South African government ministry (referred to in here as the DMR; the report put together by Econometrix (2012); work by Wait and Rossouw (2014); and Fakir (2015).

The DMR report is a result of the work of a working group/task team on shale gas and hydraulic fracturing. The team was headed by the DMR, and made up of representatives from various departments and institutions, such as the Petroleum Agency SA (regulator of the upstream oil and gas sector in the country), the Department of Environmental Affairs, Science and Technology and Energy and Eskom, the Council for Geoscience and various water-related bodies. The aim of the working group was to assess both the positive and negative consequences of exploiting the resource by analysing the potential costs to environment envisaged from hydraulic fracturing, as well as the possible negative and positive social and economic impacts of the development of the resource. The main recommendation of the report was to allow normal exploration activities of the resource to take place, with the exclusion of hydraulic fracturing. This was to allow for an opportunity for these entities to gather the much-needed data in order to conduct better informed cost and benefit studies.

Work by Fakir (2015) also considers the potential economic (such as the Gross Domestic Product or (GDP)) and environmental costs associated with the exploitation of the resource. However, this work differs from all the other studies done in South Africa in that it attempts to link geology, technology and the financing and environmental issues that drive the extraction of shale gas. However, like the DMR (2012) report, it is mostly qualitative in nature and involves a review of existing literature on shale gas in the US while incorporating the South African situation.

Both the Econometrix (2012) report and the paper by Wait and Rossouw (2014) focused on the possible benefits that can be realised from the exploitation of the gas. The paper by Wait and. Rossouw (2014) is a comparative assessment of the Econometrix (2012) findings.

However, both studies fall short at sufficiently considering the possible negative socio-economic and environmental externalities that could be realised. Due to the methodology used, the work by Wait and Rossouw (2014) is an improved attempt at analysing the potential positive externalities compared to the Econometrix (2012). This paper, therefore, aims to build on the former, in an effort to provide a better analysis of both the potential positive and negative socio-economic impacts associated with the development of shale gas in South Africa.

1.3 Research objective

The objective of this paper is to analyse the potential socioeconomic impacts of shale gas development in South Africa. In this study, the null hypothesis is that the development of shale gas will have multiple negative socio-economic impacts in South Africa. The objective will be investigated by simulating the impact of the gas development on socio-economic factors, while paying careful attention to both the positive and negative impacts; welfare distribution implications; the impact on poverty levels; and the impact on trade. The aim, therefore, is to test the null hypothesis (H_o), stated above, in an effort to answer the research questions raised in the problem definition section.

1.4 Justification for the study

Shale gas development has the potential to have significant benefits for the South African economy in the form of increased employment opportunities and income, Econometrix (2012) and Wait and Rossouw (2014). The development of the resource in a large scale may reduce the energy deficit in the country, enabling the South African economy to realise greater growth in the future, lessen the country's carbon footprint and reduce imports of gas, oil and petroleum commodities. Consumers may also benefit from more reliable and affordable energy: but at what cost?

The South African government is optimistic that the development of the resource will provide the country with more reliable options to coal in energy generation. In an effort to contribute to the policy debate around the implications of this development for the South African economy, it is important, therefore, to highlight the main factors that require attention so as to ensure that the development takes place in the most responsible and sustainable manner possible, should it occur.

As is the case in most developing countries, issues of energy security supply are important matters for South Africa, especially in light of recent load-shedding experiences. Equally important is the financing of energy-related projects. A delicate balance is often established between the country's public funds through the fiscus; local and foreign private investments; multinational corporations' investments; development finance funding from institutions, such as the World Bank, the International Monetary Fund (IMF); and development banks like the African Development Bank, the BRICS Bank, and many more. In the case of shale gas, Fakir (2015) states that at this stage, it is not clear who is going to take on the responsibility of funding the resource's development between the public and private sector. This risks incurred in the exploration and development phases, however, are expected to be taken up by private oil and gas companies.

1.5 Structure of the study

This research paper is organised as follows: the first chapter introduces the topic being studied in order to put the research objective into context. Chapter two contains a review of existing literature on the topic. This is done, firstly, by reviewing the existing theoretical basis for the literature and then looking at empirical studies undertaken to test the theory. The methodology applied to investigate the research problem in question is covered in Chapter three. Chapter four contains a discussion of the results. The conclusion is presented in Chapter five with recommendations for future research.

Chapter Two: Literature review

This chapter aims to analyse existing literature on the study of shale gas as an extractable non-renewable natural resource and the possible socio-economic impacts that could result from its extraction. Section 2.1 focuses on the theory adopted as most relevant for most non-renewable natural resources. A review of existing literature, specific to shale gas impacts, is given in section 2.2. The main areas of focus here are economic growth, employment, poverty, trade and income distribution. Existing literature on shale gas is brought into context in section 2.3 by comparing the US current oil and gas experience with the current natural gas sector in South Africa.

2.1 Theoretical background

There are opposing findings on whether natural resources are a blessing or a curse. Several studies have analysed the link between availability of natural resource and the performance of the economy. The theoretical basis for these studies has often been the 'resource curse' theory. The key aspects of the resource curse that have been studied include negative impacts on economic growth and development as measured by GDP, occurrence of poverty, creation of greater conflicts in society and weak per capita income growth (Barth, 2013; Jacobsen & Parker 2014).

Research by Sachs and Warner (1995) found that the natural resource curse exists in countries with a large amount of natural resource wealth but growing at a slower pace compared to resource-poor countries. This has been the subject of several research papers. The general consensus seems to indicate that the resource curse holds within the US, and more so in regions where there was once a strong extractive industry, (Barth, 2013).

Closely related to the resource curse, is the 'boom-and-bust' phenomenon, where there is a rise (boom) in economic activity supported by an increase in demand and therefore, prices, of non-renewable natural resource or commodities, which is then followed by a bust, as commodity demand and prices decline. Barth (2013) states that extractive industries are notorious for their boom-and-bust phases. The author states that the negative economic impacts experienced during the declining phase may be greater than the positive economic impacts realised in the boom. Furthermore, according to Weber (2012) growth in the non-booming export sector is hindered as the costs of labour rise and the real exchange rate

appreciates, both of which lessen a country's competitiveness in the world market. This is an effect known as the 'Dutch disease'.

Models of the 'Dutch disease' suggest that resource-linked booms can discourage growth in the non-extractive industries that produce other goods, such as manufacturing and commercial agriculture. This happens as the booms increase local wages which are added input costs that cannot be passed on to foreign consumers (Corden & Neary, 1982). On the other hand, however, some models postulate that booms can encourage corresponding investments in domestic non-natural resource extractive industries and supplement growth (Duranton & Puga, 2004; Glaeser & Gottlieb, 2009).

With a slightly different viewpoint, Rosser (2005) defines the resource curse as distortions to a country's politics and economy caused by a sudden boom in the extraction of natural resources, with developing countries more affected by the curse than developed countries. The author argues that developing countries with weak institutions, corruption and financial mismanagement that are overly reliant on one resource and overvalued exchange rates are more prone to suffer from the curse of natural resource endowment. Pendleton (2005) states that it is not the availability of oil that ensures that conflicts, corruption and poverty exist in oil rich countries, but pre-existing institutional problems. This then suggests that countries' pre-existing legal, financial and political frameworks may influence the impacts realised from the extraction of natural resources. If the existing structures do not guard against the misuse of the natural resources and set the desired conduct by all parties, then the resulting impacts are most likely to be negative. Therefore, both authors suggest increased efforts to promote transparency in the resource-rich industries to deal with the associated negative impacts.

In Nigeria, Opeyemi (2012) conducted an empirical analysis of the resource curse. The author made use of purposive sampling techniques. Questionnaires were sent to main industries in the economy of Nigeria and a number of people were interviewed. The results of the regressions adopted revealed that corrupt or weak institutions, lack of technology enhancement and the Dutch disease have a direct and significant influence on the negative impacts realised in the country from the extraction of its natural resources.

In analysing the economic benefits from natural gas, Weber (2012) used an OLS and IV regression analyses to estimate the impacts of a natural gas booming sector on employment

and income for counties in Colorado, Texas, and Wyoming. The findings were that, in the short run, large-scale natural gas uptake resulted in small increases in employment and the median household income. However, it was also found that the increased income and employment effects do not inevitably translate into reduction in the levels of poverty. The welfare effects depend on pre-existing conditions such as, levels of skills, the prevailing income distribution, the structure of the domestic labour market, and the size of the spill over-effects on other industries in the economy at large.

Jacobsen and Parker (2014) studied the US oil and gas booms currently attracting labour, added capital resources, and realising increased profits for that economy to ascertain if affected communities will be faced with reduced income in the long run following the boom. The oil boom-and-bust cycles of the 1970s and 1980s were used to gain the needed insights. Annual data on drilling assisted in the identification of western boom-and-bust countries. The authors found that the communities experienced significant positive effects on employment and income during the boom. Once the boom has passed, however, they found that per capita incomes fell and unemployment compensation payments rose compared to what they would have been in the absence of the booming gas sector. Christopherson and Rightor (2011) suggest that these boom-and-bust phases can be managed by decreasing the pace and scale of development of the natural resource.

Seydlitz and Laska (1994) studied the boom-and-bust cycles of the petroleum industry in Louisiana and came to the conclusion that the improved societal welfare conditions realised during the booming periods are a short run phenomenon. The authors state that the improvements can be lost in the long run and as early as the second or third year of increased petroleum production. They then deduced that, a well-diversified economy which is not only focused on the booming petroleum sector may be needed to avert some of the losses experienced during the bust.

This, therefore, suggests that increased economic activity resulting from natural resource abundance can create short-term economic benefits, but in the long run these benefits can be dampened by long run low economic growth, unemployment and poverty. This seems to be more so in countries with weak institutions. The IMF (2014) country report indicates that South Africa is a country with fairly strong institutions however, it is still dealing with corruption-related challenges, is still dependent on one sector (mining) for most of its exports,

there are low levels of economic growth and persistent levels of poverty, inequality and unemployment. As such, the impacts of shale gas development may or may not yield desirable outcomes in South Africa.

2.2 Shale gas studies

It was known for some time that the shale deposits discovered in many parts of the US contained large quantities of natural gas. These, however, were commercially unrecoverable, but in the last decade, this has changed and the deposits have become economically feasible due to innovations in the technology applied in the development of horizontal drilling and hydraulic fracturing. According to Kellogg and Hausman (2015), although these methods have been in use for sometime, they became cost-effective only recently for large-scale gas extraction. Higher oil prices during this time were also a contributing factor to the increase in demand for gas. The outcome has been a boom in shale gas investment, laying the ground for opportunities of a natural gas revolution (Jacoby, O'Sullivan & Paltseva ,2012; Kellogg & Hausman, 2015).

According to Albrycht (2012) the successes in shale gas development originates from the Canada and the US. Pennsylvania, Texas and British Columbia are the particular areas where the resource's developmental positive impacts were first realised (Albrycht, 2012). Kellogg and Hausman (2015) state that the natural gas market in the US was approximately 50 bcf per day for the period from 1990 to 2007, mainly extracted from Louisiana, Texas and Oklahoma. This changed from 2007 to 2013. During this period, production accelerated by 25% encouraged by progression in technology. Reservoirs that have seen a lot of activity according to Pennsylvania, Kellogg and Hausman (2015) include the Barnett Shale in Texas and the Marcellus Shale.

A lot of research in the US has been done to quantify the economic benefits as well as the environmental costs of shale gas development. This has paid more attention to the economic benefits and less attention to the environmental risks. Ames et al. (2012) did a basic cost–benefit analysis of shale gas extraction. The authors found that the benefits as measured by consumer surplus exceed the costs to the community by 400-to-1. The estimation of the benefits was done using the drop in the price of natural gas as a result of increases in output, whilst the estimation of environmental costs was based on the clean-up costs of potential accidents. The environmental costs estimate was limited to reported and potential incidents of

water contamination clean-up costs. This is an inadequate estimation, as it excludes other costs such as containment costs, compensation costs, monitoring costs and latent or cumulative costs. Therefore, a more comprehensive definition of environmental costs may change the 400-to-1 ratio significantly.

Erbach (2014) considered the impacts of oil and shale gas on the US and Canadian markets and on the flows of energy, globally. It was found that persisting environmental concerns about fracking were being attended to by the oil and gas industry and regulatory bodies. It was also established that the switch from coal to gas in the production of electricity led to a drop in US greenhouse gas emissions. Erbach (2014) thus concluded that in the future, the overall impact of shale gas development on the climate would be positive if it substitutes unwanted coal and if methane emissions can be minimised. Erbach (2014) also states that the new source of energy has led to a reduction in gas prices and less energy imports. Households and industry have benefitted from the cheap gas, especially in steel production, fertilisers, plastics and basic petrochemicals. Therefore, great benefits have been obtained from shale gas development in North America and Canada, (Erbach, 2014).

In an attempt to understand how shale gas influences US energy and environmental policy, Jacoby et al. (2012) applied a Massachusetts Institute of Technology (MIT) Emissions Prediction and Policy Analysis (EPPA) model. They state that the MIT-EPPA is a CGE model that represents multiple regions and sectors of the global economy and considers both domestic and international prices of the electricity and non-electricity markets.

Jacoby et al. (2012) used two scenarios of greenhouse gas control to examine the influence of shale gas on policy decisions. The one scenario was based on mandating, through regulation, renewable power generation and discontinuing the use of coal in favour of shale gas, while the other considers using prices as tool to reach a 50% reduction in emissions. The authors found that shale gas development benefits the domestic economy and manages emissions. They, however, caution against taking shale gas as the solution to reducing emissions, saying that the technology used in the development of the resource also poses other risks that need to be considered as well, to complete the task. These risks cast doubt in the degree to which the prospects of shale gas can be realised.

Similarly, in a policy brief Tyner and Taheripour (2014) looked at the economic and environmental impacts of a concurrent increase in shale oil and gas resources; and policies aimed at reducing greenhouse gas emissions in the US. The policy brief also makes use of a CGE Global Trade Analysis Project (GTAP)[1] in its analysis. The authors found that shale oil and gas expansion has a great positive impact on the US, with an increase in the nation's welfare of over $300 billion per year relative to 2007 and an increase in GDP of about 2.2% higher each year than in 2007. In their view, if the large shale oil gains are taken as an unanticipated windfall for the economy, part of that dividend from the windfall can be used to pay for Greenhouse gas (GHG) reductions. They suggest that, the most effective way to do so is with a carbon tax. They concluded that policies that encouraged shale oil and gas development and at the same time cause considerable reduction in GHG emissions result in a considerable welfare and GDP gain for the economy.

In Indonesia, Hartono, Nurkholis and Hutagalung (2014) also analysed the economy wide impacts of expanding the supply of natural gas and lowering consumption of fuel oil through a programme of natural gas fuel replacement with the assistance of a CGE model. They found that the increasing the supply of natural gas benefited the economy of Indonesia, through national and export activities, a positive contribution to GDP, employment, government consumption and household income.

Kellogg and Hausman (2015) attempted to estimate the broad-scale welfare and distributional effects of the gas supply boom in the US. They did this by providing estimates of supply and demand elasticities, with which they projected the decline in natural gas prices associated with the increased supply of the resource. Impacts on welfare are found to be positive for four demand sectors (residential, industrial, commercial and electricity), but negative for producers, with varying degrees for each region. Kellogg and Hausman, therefore, argue that the shale gas revolution has caused improved welfare for natural gas consumers and producers of $48 billion per annum. They, however, state that additional research must still be conducted to evaluate the environmental risks of shale gas production.

[1]The GTAP is a global CGE model with 113 regions and 57 sectors, simulated with great aggregation to simplify the analysis, (Tyner & Taheripour,2014).

Unlike the US, where shale gas extraction is at fairly advanced stages, in South Africa the economic effects of shale gas extraction have not been extensively studied. This is mainly because no exploration has taken place yet.

A report by the DMR (2012) works from an assumption of 30 tcf produced, for US$ 4 per cubic feet of gas at R8 per US$ and estimates that with gross sales value of almost R1 trillion and R960 billion added to GDP, 30 more GTL plants could be established with around 48 000 more GTL plant-only related jobs over a 20 to 30 year period. Work by Fakir (2015) is similar to that of the DMR (2012) in that the methodology of his study makes use of literature reviews, conversations with experts and the analysis of technical material to unpack the socio–economics of shale gas. Unlike the DMR (2012), however, Fakir (2012) does not make any quantitative estimates of the potential socio–economic impacts of shale gas development in South Africa. The author makes use of a well-head based model[2] that can be used to compute break even costs (social, economic and environmental) using discounted cash (DCF) – flow analysis, Internal Rate of Return (IRR) and Weighted Average of Cost of Capital (WACC).

Econometrix (2012) uses a Keynesian multiplier model to estimate the economic impacts of shale gas development in the Karoo. The report finds that, in spite of the environmental, technical and commercial uncertainties, there is potential for significant economic benefits from the exploitation of the gas. Wait and Rossouw (2014) also examined the potential economic impacts of shale gas extraction in South Africa using a CGE modelling approach. Their results suggest that developing a shale gas sector could promote economic growth and reduce poverty in South Africa.

Both studies, those of Econometrix (2012) and Wait and Rossouw (2014) focused on analysing the potential economic benefits of shale gas extraction in South Africa, highlighting mainly the potential positive impacts on GDP and employment. Even though the potential social and environmental costs were considered, more so in Wait and Rossouw (2014) than in Econometrix (2012), they were mostly assessed qualitatively. This is also the case for both the (DMR, 2012) and (Fakir, 2015).

2 The model is a base economic model designed to understand break-even costs in relation to gas prices taking into account economic, environmental and social costs (Fakir, 2012).

Econometrix (2012) estimated a more significant contribution to the average annual GDP, between 3.3% and 9.6%, with between 355 817 and 854 757 more permanent job possibilities from the development of the shale gas sector. Whereas Wait and Rossouw (2014) arrived at similar estimations for GDP contributions at around 3.5% (scenario 1) and 6.9% (scenario 2) increases in average annual GDP, but much lower potential employment opportunities varying from 1 441 to 2 471. The estimates were based on 20 Tcf and 50 Tcf respectively for a 25 year-plus period.

The aim of this study is to go beyond a focus on just employment and GDP, but to consider much broader possible socio-economic impacts, such as impacts on South Africa's trade balance as a result of the potential increase in natural gas exports in relation to the suggestions of the Dutch disease. In this way, an attempt will be made to analyse the overall impacts of shale gas exploitation on other sectors of the economy and society. Possible welfare implications and impacts on poverty will also be considered.

One limitation of Wait and Rossouw's (2014) study is the use of a static CGE model. According to Thurlow (2004), in a static model, consumers and producers act inertly to prices in choosing quantities to be demanded and supplied. In this way, markets are assumed to reach equilibrium through the interface of relative prices to ensure that both the factor and goods market are at equilibrium, (Thurlow, 2004). According to Alton et al. (2012), static models permit the costless reallocation of capital across sectors. This understates the costs of adjusting to economic activities or policies and prevents sectors from investing in less energy intensive sectors when economic conditions dictate so.

To address this, this study makes use of a dynamic CGE model that caters for the rigidities, such as immobility of capital across different sectors of the economy and persistent structural unemployment and inequality problems within the South African economy resulting in cases of continuing disequilibrium in the markets. Unlike the static model, the dynamic model also accounts for knock-on-effects on the rest of the economy resulting from policy or non-policy changes. It also allows one to look at long-term impacts of these changes, such as long-run decline on economic growth from extractive activities as alluded to by the natural resource curse theory.

2.3 Discussion

Having reviewed available literature on the topic, this section brings forth a more practical discussion of the social and economic issues of shale gas. This is done by looking deeper into the impacts of the resource in the US and outlining the current natural gas industry in South Africa. This is done to bring the potential impacts of the shale industry as a whole into context.

In the US, where shale gas exploitation is at advanced stages, the industry has widespread social and economic impacts across various sectors of the economy and numerous states and districts. According to a report by Price Waterhouse Cooper (PWC) (2013), these are direct impacts resulting from the industry's employment and production activities; indirect impacts as the industry's acquires intermediate and capital goods from multiple sectors; through personal procurement by employees and producers, both within the sector; from the extra income in the sector's value chain; and from proceeds received from oil and natural gas companies (induced impacts).

2.3.1 Natural gas prices

Observations from the US

For the US economy, the uptake of shale gas has resulted in a downward effect on prices of natural gas. Fakir (2015) states that this has seen the year-on-year average Henry Hub natural gas spot price (which is used to standardise natural gas market prices in North America), falling by more than 50%, from $8.86 per million Btu (MMBtu) in 2008 to $4.00/MMBtu in 2011, with a fall of around $2.50/MMBtu on average per annum in 2012. The author also states that these are contrary to natural spot prices of natural gas in Japan, which vary from $13 to $15/MMBtu and the European prices around $9/MMBtu.

The IHS Global Insight (2011) report states that, in general, low priced gas should stimulate investment and job creation in the chemicals sector. Other manufacturing sectors should also become more profitable and competitive in relation to their international counterparts. This according to the report should enable an incremental and broad general rise in the manufacturing sector.

As per the IHS Global Insight (2011) report on the US, the instant impact of reduced gas prices is that electricity became cheaper. This is due to positive impacts on gas-fired electricity generators. The reduced gas prices trickled into the power sector and resulted in retail electricity prices averaging 10% less. The main point to note however is that gas-powered generation plants already existed in the US and were ready to receive the gas from shale gas and generate electricity immediately. This is not the case in South Africa, gas-fired plants must still be built, which will cause a delay in them being used in electricity generation and, therefore, reducing retail electricity prices.

The report further states that the cheaper gas and electricity led to a direct reduction in the cost of energy for both households and businesses. As a result, consumers enjoy increased purchasing power while the economy benefits from improved consumer and business confidence. Businesses realise increased revenues, and local manufacturers are more cost competitive internationally. Furthermore, the low gas prices also contributed to a 1.1% surge in the level of GDP by 2013, an additional 1 million more employed persons by 2014, and 809,000 more employment opportunities created by 2015.

Natural gas pricing in South Africa

In South Africa, natural gas supplied to the general market is piped gas (loosely referred to as Sasol gas) that is imported from Mozambique. Santley, Schlotterer and Bernhard (2014) state that as a result its pricing, demand and supply is determined by price charged to South Africa by Mozambique, the volumes delivered and transportation costs. They further state that the prices of the gas delivered have to be no more than $7 per MMBTU to competitive with coal as a base load option.

South Africa also produces its own natural gas, offshore, through PetroSA, in Mossel Bay. This is not sold to the general public, but instead it is used as feedstock into PetroSA's GTL refinery. Tetra 4, in Welkom in the Free State province, also has a licence to produce natural gas. Similar to the piped gas in South Africa from Mozambique, the price of this gas is regulated by the National Energy Regulator (NERSA), (PWC, 2012). NERSA regulates the maximum selling prices according to the formula stated below:

"GE = w1 CL + w2 DE + w3 EL + w4 HFO + w5 LPG"

Where:

GE = Maximum price for gas energy (ZAR/GJ) at the point of its first entry into the piped-gas transmission/distribution system;

CL = indicator of equivalent price of coal;

DE = indicator of equivalent price of diesel;

EL = indicator of equivalent price of electricity;

HFO = indicator of equivalent price of heavy fuel oil;

LPG = indicator of equivalent price of liquefied petroleum gas; and

wn = weighting of the n^{th} indicator in the basket (where, w1+w2+w3+w4+w5 =100%)

According to NERSA (2011), the formula excludes trade margins, charges on transmission, storage and levies. Instead, once the maximum gas price is determined, all these other tariffs and levies are then put together to ascertain the final amount to be charged. Steyn (2014) states that the formula uses the price of non-gas energy fuel sources as a reference that allows for the gas price to move in line with other sources of energy.

Since the natural gas sector is not well developed and is not significant in South Africa, there is no substantial competition within the sector. This can be ascribed mostly to the lack of indigenous supply and the dominance of Sasol in the domestic market. This dominant position was until recently, shielded through the Gas Act, under a ten year regulatory agreement. The agreement allowed Sasol the sole right to import natural gas from Mozambique, until March 2014, (PWC, 2012).

A report by the Ethekwini Municipality (2015) states that the agreement created a platform for Sasol to import gas and recover development costs. Now, however, all licences are subjected to the same regulatory provisions as stipulated in the Gas Act, 48 of 2001. According to Steyn (2014), based on the amount of gas use, a customer falls into one of six groups that each have their own price ceilings. Sasol is its own biggest customer, and

consumes about 60% of the gas to create fuel with its specialised gas-to-liquids technology. As a result, the operator has a lower maximum price than other customers that use less gas and fall into other groups, Steyn (2014).

Customers, therefore, can negotiate actual prices up to the maximum levels approved by NERSA. According to Ethekwini Municipality (2015), the regulator has only approved maximum prices for four traders. These are Sasol Gas Ltd — R117.69/GJ on 26 March 2013; Virtual Gas Network (VGN) — R278/GJ on 29 July 2013; Novo Energy (Pty) Ltd — R246/GJ on 9 December 2013; Spring Lights Gas — R123/GJ on 27 February 2014; and Realtile has applied for a licence to supply methane rich gas —R150/GJ — on 07 April 2014 to areas in KwaZulu-Natal. A fifth is trying to enter the market, Steyn (2014), however, states that Sasol Gas's actual average molecule price for a customer is about R42 a gigajoule, below (NERSA) R117 a gigajoule, the maximum price for gas.

When it comes to shale gas pricing in South Africa, Fakir (2015) states that LNG —or piped gas — imported from Mozambique could be used to benchmark domestic gas prices. The author also suggests that, in the early stages of establishing a market for shale gas, it maybe necessary to discount prices stimulate demand and sustain production. If the shale gas found is significant enough to produce enough to meet the needs of an export market, then the gas price would be influenced by global gas prices as well. All of this, however, remains unclear and rather abstract, as the estimated resource have not been proven yet

2.3.2 Employment

According Wait and Rossouw (2014) employment impacts of shale gas should come from three courses. The key course being drilling and fracturing (extraction); the conversion phase (infrastructural development expenditure for the distribution of shale gas or electricity from the resource) and the maintenance of resource wells. Similarly, the IHS Global Insight (2011) report also state that in many infrastructure-based commercial activities, economic contribution usually occur in two different stages. The first stage being the establishment of the needed infrastructure, at which many construction and manufacturing related job opportunities are created. This stimulates growth in indirect and induced jobs. As per the report, this is often, followed by a stability stage, where many of the newly created job opportunities fade as construction and infrastructural development stops, leaving long-term job opportunities only in the direct essential and indirect supplier sectors.

However, according to IHS Global Insight (2011), this is not necessarily the case with the shale gas sector in the US. In these states, estimates of employment distribution during a 25-year period from 2010 to 2035 are nearly equal. Showing that increased capital investment, during the infrastructure build-up phase, may continue for the entire period being forecasted, as the supply of natural gas increases to match demand.

The IHS Global Insight (2011) states that this is due mainly to employment multiplier of the shale gas sector. According to the report, this multiplier determines employment contributions to the economy through employment opportunities created indirectly and induced as the sector grows. Some sectors have greater impacts than others depending on the size of the multiplier. The larger the size of the multiplier, the bigger the knock-on effects of every dollar amount spent per sector in terms of creating additional jobs in the economy at large.

In comparison to other industrial sectors, the shale gas sector has one of the largest employment multipliers, on average. For every direct job generated by the sector, plus three more additional jobs are created in the economy through indirect and induced impacts. Because of this, the industry is considered to be ahead of sectors like finance, construction and manufacturing in job creation. This employment multiplier is caused by a number of fundamental factors that drive the sectors' indirect and induced job creation (IHS Global Insight, 2011).

First, as per the report, the shale gas industry is a capital intensive industry spending close to 50% of its turnover purchasing materials, services and other supplies from suppliers in multiple sectors like, construction, fabricated metals, technology, and chemicals, The industry also procures a wide variety of services such as, legal and financial services. However, according to IHS Global Insight (2011), it is not just the substantial spending on capital or the extensive supplier base that cause the large employment multiplier. Another and second important factor is the power of US suppliers. The US is considered to be a world leader in all aspects of the shale gas development value chain. Consequently, there is a wide pool of local suppliers in the industry's value chain. This translates into significant portions of dollars spent in the US that remains in the US economy and American jobs. This is not the case for South Africa, as a majority of the capital goods needed during initial infrastructural and construction phase will have to be imported. This will entail money going out of the country.

In addition, significant economic contributions do not end with the creation of employment opportunities within the shale gas sector and amongst its related suppliers. The jobs created are also of a very high quality. This is due to technology advancement in the sector. As a result, average wages in the shale gas sector are more than those paid in sectors like manufacturing, wholesale trade and education. Consequently, workers in this sector and its related suppliers spend more on average, causing bigger induced income impacts, (IHS Global Insight, 2011).

According to PWC (2013), total employment impacts of the US's oil and natural gas sector to the economy in 2011 amounted to 9.8 million full-time and part-time jobs created, and it was responsible for 5.6% of total US employment generation. This combines impacts as a result of both operational and capital investment. Nationally, each direct job in these sectors supported about 2.8 jobs somewhere else. Including direct, indirect, and induced impacts, the industry's overall impact on labour income was $598 billion, or 6.3% of national labour income during this period.

Fakir (2015), however, cautions against over-optimistic expectations and estimations of potential employment opportunities to be created from shale gas development in South Africa. The author states that the anticipated jobs do not speak to the country's current technological reality and advancement prospects. The shale gas sector is highly automated and mechanised, this is expected to be more so with the anticipated required improvements in fracking techniques. The author also states that available literature on the numbers of jobs to be created can be hard to compare. This is because assumptions about direct, indirect and induced employment impacts differ from one study to the next. These assumptions also influence understanding of the relevant economic multiplier models adopted in determining the job numbers. Some of these assumptions are informed by overall turnover generated and expectations of domestic expenditure, while others are not (Fakir, 2015).

Another issue to take into consideration when looking at potential impacts of shale gas development on employment in South Africa compared to the US is that prior to shale gas development, the US had a conversional oil and gas industry. For this reason, the necessary skills needed in shale gas existed and were ready to move into shale gas development. This is not the case in South Africa.

In addition, the National Petroleum Council (NPC) (2011) state that a growing local oil and gas sector may enable economic growth and employment in this sector, but this can be at the cost of growth in other sectors. This will cause job losses and value erosion from sectors providing other sources of energy, such as coal, and those supported by the coal sector, like rail.

South African natural gas employment

The South African Maritime Safety Authority (SAMSA) (2010) indicates that there are 7 500 people employed in the country's oil and gas sector, which has about R196 billion in annual turnover, with the refining segment contributing almost 99% to the total industry's revenue. Furthermore, the industry is responsible for approximately 90 000 indirect jobs in the distribution and marketing segment.

Table 1: Employment in the South African offshore oil and gas industry, 2010

	Employment	**Turnover**
Upstream	4 800	R1.2 billion
Downstream/Refining	2 700	R195.0 billion
Indirect (Support, Distribution & Marketing)	90 000	n/a
TOTAL	**97 500**	**R195.0 billion**

Source: SAMSA (2010)

2.3.3 Welfare distribution and poverty

According to a joint report by the African Development Bank (ADB) and the African Union (AU) (2015), the exploitation of oil and gas resources can enable socio-economic development by providing a platform for wealth accumulation for private individuals, both the private and public sector. This happens as the natural resources provide an opportunity for an economy to diversify away from relying on primary agricultural activities; to invest in human resources and the development of infrastructure.

The prerequisites for these as per the report, however, include good governance in the public and private sectors, appropriate fiscal regimes, effective public sector financial management and sound economic policies. This also involves converting the wealth from oil and gas development into physical and human capital, sustained economic growth, and poverty alleviation. This, then, suggests that South Africa should get its house in order first, if the

potential wealth to be created from shale gas is to be used for the greater benefit of society at large.

Fakir (2015) suggests that in South Africa this can be done by learning from the Norwegian and Chilean models based on designing fiscal policy to enable optimal collection of royalties, fees, levies and taxes. This should allow the government to build new human and physical capital stock and expertise from the depleting resource. Other countries have considered establishing 'stability funds' to smooth the effects of commodity price fluctuations due to boom-or-bust phases. These funds should then act as needed cushions for managing currency risk and for managing the booms-and busts-periods associated with the extractive industries, (Fakir, 2015).

The ADB and the AU (2015) state that countries like Norway and the Gulf (Middle Eastern) have utilised the wealth created form natural resources to facilitate economic development and eradicate poverty by channelling fiscal revenues levied from the extraction of the resources towards pro-poor investments through stability funds. This has been accomplished through taxing the development of natural resources and concentrating the tax revenue on poverty-reducing initiatives. This, according to the report, includes setting aside part of the fiscal proceeds for the upliftment of marginalised groups, especially those who reside near the extractive activities or oil and gas producing communities. In this way, wealth redistribution programmes may act as the necessary tool to minimise any negative socio-economic impacts associated with the development of natural resources, particularly in communities where the development is taking place.

According to Fakir (2015) in the post-1994 period, South Africa moved from lower middle-income to upper-middle-income status due to substantial growth in per capita income. In 1994, the average annual income per person was around R12 281. This grew up to on an annual average of R62 676 by 2013, which works out to, a compounded annual increase of 8.9% per annum. The author states that on the other hand however, the country is ranked as one of the highest in the world when it comes to inequality in the distribution of the wealth acquired, with persistent unemployment challenges for the last two decades. The mining industry has perpetuated this situation, but if wealth from shale gas development is managed differently, the opposite results are possible.

Wait and Rossouw (2014) state that the development of shale gas may afford the country an opportunity to change its stubborn structural problems through increased economic growth and reduced poverty levels. However, large-scale shale gas development brings about adjustment challenges for other sectors in the economy as they compete for labour. This is because traditional exports can be expected to shrink with the uptake of shale gas. Prices paid by consumers can be expected to increase slightly as well, while imports decrease. Overall welfare may increase, mostly because of improved purchasing power. Certain households may suffer because of price and quantity adjustments associated with rapid development of the resource. Wait and Rossouw (2014) then suggest that it may be necessary to consider carefully, the labour intensity of production techniques used in the development of the resource, since the degree of labour intensity has the potential to strongly influence the distribution of income. However, given that the industry is by its nature very capital intensive, this should prove to be a big challenge.

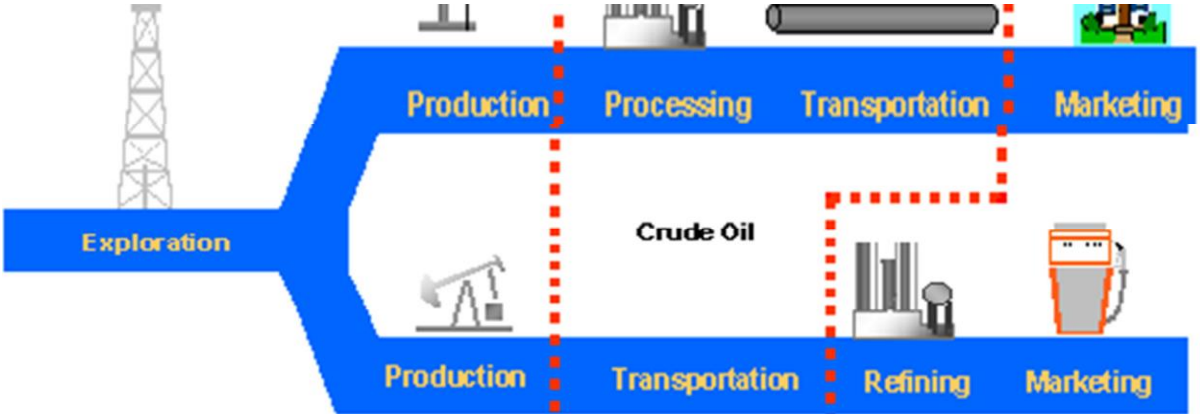
2.3.4 Economic growth

The PWC (2013) report indicates that any dollar of shale gas revenue generated leads to direct and indirect effects on value added (GDP). GDP is taken as the broadest measure of domestic value added from all goods and services, produced and supplied. GDP is therefore used as a measure of the economy's performance, (PWC, 2013). According to IHS Global Insight (2011) the contribution of shale gas to GDP in the US was more than $76 billion in 2010. This according to the report had increased further in 2011, as measured the industry's total impact on GDP of $1.2 trillion, which was 8% of the national total.

In terms of the potential impacts of shale gas development on economic growth in South Africa, Fakir (2015) states that this will be informed by the size of the resource, its economic viability and the pace of its development. Moreover, an availability of gas domestically would eliminate the need for foreign fuels. This should be beneficial for the country's trade balance and GDP. However, the extent of economic value to be created is subject to the amount of domestic value created through beneficiation. Therefore, the higher the levels of beneficiation, the more direct, indirect and induced jobs will be created, (Fakir, 2015).

2.3.5 Sectoral impacts

Figure 1: Typical oil and gas value chain



Source: SAMSA (2010)

The diagram above illustrates a typical oil and gas sector value chain. The structure of the sector is divided into three main categories, the upstream, midstream and downstream. All these categories cut across various sectors of the economy. For this reason, any activity in the oil and gas sector affects multiple sectors.

The upstream segment is dominated by exploration and production activities. According to Wait and Rossouw (2014), in the case of shale gas in South Africa, the capital and equipment to be used during the exploration phase is most likely to be imported with more materials being procured locally in the later stages of production as the economy adjust to the needs of the booming gas sector. This may be so because, the industry is highly specialised and concentrated on very few international players. South Africa has not yet developed the necessary expertise to compete with these suppliers, as the industry is very small and only accounts for less than 3% of total economic activity in the country, as per the (Ethekwini Municipality, 2015).

Midstream starts as the gas leaves the treatment plant and extends to end users (retail or downstream). It entails processing, transportation via pipeline network and storage. Once natural gas has been processed, it needs to be distributed to a location for consumption. This is done at the downstream category. The Ethekwini Municipality (2015) states that gas can be routed to market via different storage and transportation methods (ships, rail and trucks.).The report further states that the transportation of natural gas by virtual pipelines such as by road, rail and sea can be more economical than using pipelines. Given South Africa's limited

infrastructure, particularly in areas of low demand, pipelines may not be viable. In this case then, different technologies can be used to overcome pipeline constraints. These, as per the Ethekwini Municipality (2015), include Compressed Natural Gas (CNG) as the infrastructure to compress the gas is significantly cheaper than that of Liquefied Natural Gas (LNG). However, the final decision on the option to be chosen in South Africa will be informed by a combination of reserves found and distance to the final market (Ethekwini Municipality2015).

According to the Ethekwini Municipality (2015), Sasol Gas already has a couple of distribution pipelines from Secunda that connect Pretoria, Johannesburg, and Sasolburg, as well as a distribution network that links off the Transnet gas transmission pipeline to customers in KwaZulu-Natal.

Table 2: The Direct, Indirect, and Induced Impact of the Oil and Natural Gas Industry to the US Economy, 2011

Sector Description	Employment	Labor Income ($ million)	Value Added ($ million)
Direct Impact of the Oil and Natural Gas Industry	2,590,700	$203,591	$551,018
Indirect and Induced Impact on Other Industries	7 ,242,600	$394,024	$658,372
Operational Impact	5,854,500	$311,777	$522,535
Agriculture	84,700	$2,591	$3,978
Mining	13,700	$1,064	$2,749
Utilities	24,600	$3,256	$12,950
Construction	430,000	$23,762	$25,822
Manufacturing	380,200	$26,826	$46,883
Wholesale and retail trade	777,600		$54,430
Transportation and warehousing	228,900	$11,869	$16,159
Information	101,700	$10,432	$20,710
Finance, insurance, real estate, rental and leasing	721,200	$37, 435	$144,867
Services	2,829,100	$142,602	$172, 764
Other	262,7 00	$18,7 61	$21,221
Capital Investment Impact	**1,388,100**	**$82,247**	**$135837**
Agriculture	17,400	$592	$876
Mining	3,700	$282	$699
Utilities	4,000	$525	$2,165
Construction	20,900	$1,170	$1,390
Manufacturing	221,800	$17,941	$28,886
Wholesale and retail trade	218,000	$11,497	$19,450
Transportation and warehousing	57,600	$3,073	$4,342
Information	35,200	$3,810	$7,950
Finance, insurance, real estate, rental and leasing	155,000	$8,091	$26,553
Services	640,500	$34,270	$42,575
Other	13,900	$997	$953
Total Economic Impact	**9,833,200**	**$597,615**	**$1,209,389**

Source: PWC (2013)

Table 2 shows direct, indirect and induced impacts of the US's oil and gas operational and capital investments. According to PWC (2013), operational impacts result from the procurement of intermediate inputs, wages paid to labour and returns to investors, while capital investment impacts result from infrastructural investments at national level. The economic impacts portrayed in the table are limited to the industry's backward linkages with its suppliers and exclude forward linkages with its consumers. As can be seen from the table, investment in oil and gas has an impact on multiple sectors in the economy directly and indirectly. The biggest impact in terms of value added and employment created is on the services industry.

Table 3: Direct impact of the oil and natural gas industry on the US economy by subsector (2011)

Table 3 Direct Impact of the Oil and Natural Gas Industry in the US Economy by subsector, 2011

Sub-Sector Description	Employment Amount	Labour Income $ Millions
Oil and gas extraction (including NGL extraction)	7 83,800	61,454
Drilling oil and gas wells	97 ,400	9,040
Support activities for oil and gas operations	269,300	22,27 1
Natural gas distribution (private)	112,300	15,599
Natural gas distribution (public)	6,500	356
Oil and gas pipeline and related structures construc	112,500	9,443
Petroleum refineries	7 2,500	20,596
Asphalt paving, roofing, and saturated materials ma	24,200	4,225
Petroleum lubricating oil and grease manufacturing	10,200	1,899
Petroleum and petroleum products merchant whol	95,900	7 ,558
Gasoline stations	87 9,400	30,650
Fuel dealers	83,200	1,840
Pipeline transportation	43,500	18,660
Total Oil and Natural Gas Industry	**2,590,7 00**	**$203,591**

Source: PWC (2013)

Table 3 displays direct impacts of investing in the oil and gas industry on its subsectors. The biggest impact in terms of employment numbers is on the gasoline stations, followed by the extraction subsector. Whereas the biggest impact in terms of value added is on the extraction of resources followed by the petroleum refineries subsector.

Wait and Rossouw (2014) state that shale gas development in South Africa will increase output in the natural gas sector. This should cause other industries to expand production as well, due to upstream and downstream linkages. Consumer demand should rise because of

induced employment gains. Industries with high trade shares, these being either high export intensity or import penetration, such as, gold mining, other mining, coal, iron and steel, non-ferrous metal, petroleum refineries, may also be expected to realise greater impacts compared to non-traded industries, (Wait and Rossouw, 2014). This should occur because some of these industries such as coal, will compete with the shale gas sector directly for the energy market, while others can be expected to provide the inputs required to expand the sector.

2.3.5 (a) Industrial Sector/ Manufacturing Sector

Krupnick, Wang & Wang (2013) states that industrial sectors, manufacturing in particular, stand a chance to be one of the main sectors to benefit from the development of shale gas. These benefits can come about in two ways. First, these sectors stand a chance to increase their sales volume due to increased demand for manufacturing and construction materials. Second, the cheaper gas price should decrease production costs in the petrochemical industry. Some of these costs saving benefits should ultimately be passed down further in the value chain, to downstream industries such as plastic and rubber, (Krupnick, Wang & Wang, 2013).

The IHS Global Insight (2011) report states that in the US, the rise in construction activity and lower gas prices following the development of shale gas should stimulate the auto manufacturing sector and in turn revitalise the steel industry. This should come about as a result of increased demand for steel pipes used in production, drilling, distribution and transportation. Krupnick et al., (2013) however, states that these manufacturing projects require large amounts of upfront investments that take at least five years to generate positive cash flows. For this reason, the returns on investment in this sector are vulnerable to changes in gas prices.

According to the Department of Minerals and Energy (DME) (2005), the South African economy is a very energy intensive economy. This is due to two main factors. The first one relates to the type of dominant activities in the economy, these being, mining, metal smelting, minerals processing and synfuel production, which are fundamentally massive users of energy. The report further state that the country has extremely deep gold mines that have low concentrations of ore and therefore, require much more energy for the extraction of each ounce of gold.

The second factor relates to the method used to convert coal into liquid fuels. The DME (2005) states that this process also uses a lot of electricity. As an example the DME (2005) states that aluminium smelters in South Africa utilise substantial amounts of energy to produce aluminium. This however, can be expected to change when Sasol switches to natural gas instead of coal as feedstock for chemical production at Sasolburg, enabling the production process to be more cost, and energy effective, (DME, 2005). The domestic production of natural gas from shale should therefore have a significant impact on the country's most industrial sector like, mining and manufacturing.

2.3.5 (b) Transport sector

According to Krupnick et al (2013), oil can be substituted for natural gas in three ways in the transport sector. First, through a GTL conversion process, the resource can be transformed into liquid fuels, like, ethanol, methanol and diesel. With minor modification, the liquid derived from these fuels can be burned in engines that generate motive power. Secondly, light and medium - duty vehicles can switch from using petrol or diesel to CNG. These Natural Gas Vehicles (NGVs) can also use both, CNG or gasoline. Thirdly, natural gas can be cooled and condensed into Liquefied Natural Gas (LNG) for use in heavy-duty vehicles like trucks in the place of diesel.

PWC (2012) states that there is not much natural gas-related economic activity in South Africa in the transport sector. Fuels used in the transport sector represent a large portion of the economy's imports, (DOE, 2005). If this were to change due to shale gas availability, PWC (2012) indicates that the payback period for purchasing NGVs shortens as oil prices increase. But these vehicles require large investment in networks of refuelling stations and pipelines. One benefit of having NGVs, however, is that gas emits less emissions when it is burnt, compared to oil which improves local air quality, (PWC, 2012).

2.3.5 (c) Electricity sector

According to Krupnick et al. (2013), in the long run, and once the needed infrastructure is in place, cheaper natural gas from shale is expected to encourage power plant operators to switch from using other sources of fuels like, coal to natural gas. This should raise the percentage of natural gas in the energy generation mix. Furthermore, all other things remaining unchanged, lower prices of natural gas should reduce total electricity prices and, thus stimulate demand for electricity. Business investment decision can also be altered

towards building new gas powered power plants and retiring old plants, running on alternative fuels. Over the short term, however, power plant operators can take advantage of the lower gas prices by changing capacity factors of different generating units to enable them to use natural gas. They can also run natural gas–powered generators more often, (Krupnick et al., 2013).

Krupnick et al. (2013) states that in the US about 30 GW of coal-fired plants will be closed down by 2016. This accounts for roughly 10% of the total coal generation capacity. The author also states that, the annual share of coal generation dropped from 48.2% to 42.3%, from 2008 to 2011. While the percentage of power generated from of natural gas rose from 21.4% to 24.8%, and the percentage contribution of renewable rose from 9.2% to 12.7%. This provides an indication of the potential direction in power generation in South Africa as well, should shale gas development be successful.

Besides the shale gas uptake, Krupnick et al. (2013) states that the closer of coal-fired power plants could also be influenced by stricter air-quality regulation targeted towards the industry. These have forced many coal power producers to make a choice between investing in environmental control facilities, if they want to stay in business or, investing in new, cleaner gas-fired plants. The latter decision has become more attractive due to the low price of gas, although historical gas price volatility dampens the increased interest, (Krupnick et al., 2013).

According to the IHS Global Insight report (2011), natural gas-fired plants require less capital injection, can be built more quickly, and have fewer carbon emissions than coal-fired plants. South Africa, on the other hand, is a developing economy with a substantial industrial base, which is highly dependent on power. This energy intensive economy relies mainly on local coal from the country's coal reserves, (DOE, 2005). This then means that the availability of shale gas could potentially cause a switch from less coal to more natural gas in the country's energy generation. The country has already recognised a need to have more natural gas in its energy mix as demonstrated in the DOE's Updated Integrated Resource Plan (IRP) (2013) for electricity.

The Ethekwini Municipality (2015) states that the biggest driver for increased gas usage in South Africa will be feedstock for electricity generation and this is being driven by a government commitment to reduce greenhouse gas emissions. Natural gas is also expected to play a significant part in the generation of electricity energy mix new build over the next 15

years up to 2030. The government is focusing on increased power generation in the form of committed, and new build power stations from 2010 to 2030, and part of that new build includes natural gas power stations in the form of Combined Cycle Gas Turbines (CCGT) and the conversion of Combined Cycle Gas Turbines (OCGT) from using expensive diesel to cleaner and cheaper gas as feedstock.

2.3.6 Household energy use

Households use energy for heating, cooling, cooking and for most electricity run household appliances. Changes in the relative prices of coal-based energy could cause switching to natural gas-based energy sources in the long-run once as the prices of these can be expected to drop due to increased supply of shale gas. PWC (2012) states that this switching can be expected with changes in relative prices of fuel like, oil as well.

PWC (2012) also states that gas–fired boilers used by households have less carbon emissions than most alternative fuels. This then means that there is potential to improve the efficiency of boilers by retiring old stock with the development of shale gas. The construction of gas distribution networks however, is necessary to bring end users closer to the supply. According to the DOE (2005), the residential sector in South Africa accounts for 16.4% of final demand for energy. Most of this is biomass used in rural areas. The report also state that middle- and high- income households are also increasing their quantity of energy used.

2.3.7 Trade balance

According to IHS Global Insight (2011) looking at the US's chemicals manufacturing sector as an example, when gas prices were higher than oil, the sector's competitive advantage declined significantly. However, with the shale gas revolution experienced around 2006, the trade balance of the chemicals sector, for instance, moved towards a net export position. This, according to the report, could not have been realised without the low-priced natural gas.

South Africa imports most of the fuel used in the transportation sector. The country also imports most of the natural gas commercially available for use. The availability of shale gas in the country is then likely to replace both these fuel and the natural gas imports. This will have implications for the country's trade balance. Wait and Rossouw (2014) state that this maybe more for sectors with high import and export volumes. The necessary policy measures

will then have to be put in place to ensure that implications of the Dutch disease effect in these industries are minimised.

For instance, Fakir (2012) states that if huge amounts of capital for infrastructure and storage are required for shale gas development resulting in lags in the development of a local gas market, then, the producers of the resource will be prompted to export it. In the event that significant reserves are confirmed, foreign currency will flow into the country, strengthening the rand and potentially destroying other local exports and jobs. According to Wait and Rossouw (2014), the question of how much gas gets exported will also depend on the scale of beneficiation.

2.4 Potential demand of shale gas in South Africa

Wait and Rossouw (2014) states that there are various ways in which the potential supply of natural gas from shale gas development can be utilised in South Africa. The authors state that the gas can be exported; it can be used to generate electricity for industrial, domestic and commercial use; it can be applied in locomotive fuels; and be used as an energy input in fertiliser. According to the PWC (2012) report, currently, natural gas in the country is used mainly in the GTL and chemicals sectors, dominated mainly by PetroSA, Sasol and some industrial users. DME (2005) states that these industrial users include, metals processing, ferrous and non-ferrous, pulp and paper, petrochemical and the mining sector. With the mining industry consuming about 47% of total demand from end users.

The PWC (2012) report further states that the main barrier to entry and increasing demand in natural the gas sector, currently, is the unavailability of a wide transmission and distribution network. DOE's updated IRP (2013) makes provision for gas-fired CCGT power generation for 2028 to 2030. In the absence of indigenous gas plays, the country is left to depend on imported LNG for the gas-fired power generation anticipated in the IRP, (PWC, 2012).

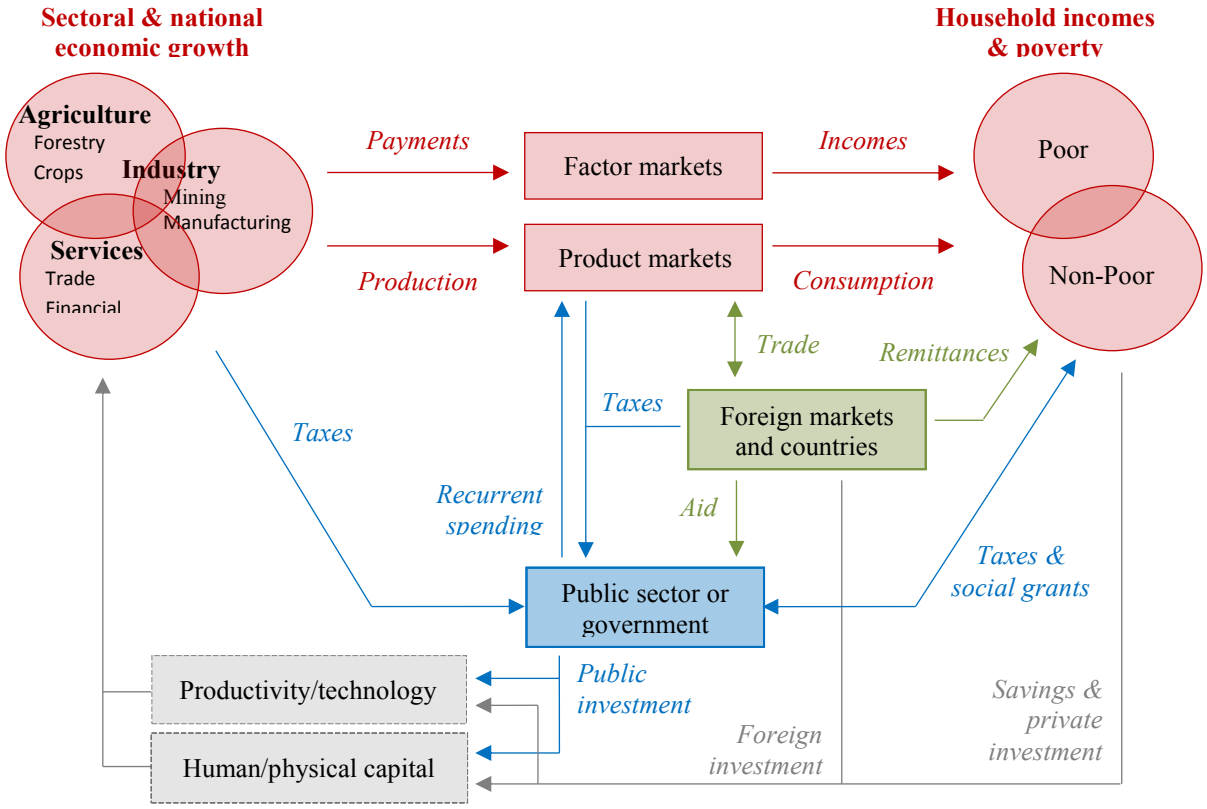
Chapter Three: Methodology

The major impacts of shale gas development can be realised during two main phases, namely the developmental phase and the production phase. The development phase includes exploration and infrastructural development, whilst the production phase involves the production and distribution of the resource. These phases cut across various sectors in the economy with different impacts. It is then essential to try to understand the potential economy-wide impacts of shale gas development using an economy-wide model such as a CGE.

An economy-wide model looks at the impacts of policy changes for the whole economy with several interacting sectors, Parappurathu (2004). While in partial equilibrium model for instance, effects of policy changes are examined only in the markets or sectors that are directly affected. This therefore means that, partial equilibrium models assume that what happens on the one sector being analysed has no effect on other sectors. In general equilibrium models, however, activity in one sector has direct and indirect impacts on every other sector and therefore models all sectors simultaneously.

CGE models provide a framework, consistent with economic theory to analyse welfare and distributional impacts of policy changes and ensure that constraints of the entire economy are considered and accounted for, in the framework, (Arndt, Benfica, Tarp, Thurlow and Uaiene, 2008). The authors further state that in such models, economic decision-making is a result of decentralised optimisation by producers and consumers within a comprehensible economy-wide framework. Therefore, inflexibilities of institutions and imperfection in markets are captured by the imposing, (exogenously) the immobility in sectoral capital stocks, labour market separation, and home consumption. This according to the authors allows this type of modelling to be applied more realistically to developing economies. Figure 2, below, illustrates the conceptual framework of the production and consumption backward and forward linkages imitated by such a model.

Figure 2: Economy wide conceptual framework



Source: Alton, Arndt, Davies, Hartley, Makrelov, Thurlow, & Ubogu (2012) (adopted for the e-SAGE)

As can be seen in figure 2, interactions between producers and households occur in both product and factor markets. Production-side linkages are determined by the technologies used by sectors, including the number or skill levels of its workers. Backward and forward production linkages are caused by producers' demand for intermediate inputs, (Alton, Arndt, Davies, Hartley, Makrelov, Thurlow and Ubogu, 2012). For instance, when agricultural production expands it demands additional inputs from other sectors, such as machinery from the manufacturing sectors and transport services. This, therefore, encourages economic activity and employment in those other sectors as well. Figure 2, therefore, portrays the working of an economy in which the interaction of producers in different sectors (agriculture, services and industry), households (urban and rural), government and the rest of the world, is interceded through prices and markets

In this study, a dynamic CGE model for South Africa, extended for the energy sector (e-SAGE) is used to simulate the possible impacts of shale gas development in the country. According to Dervis, de Melo and Robinson (1982), a CGE model is an economy-wide model that links demand, production and income structures. In the model, prices adjust until demand equals supply. Thurlow (2004) states that the dynamic model is different from the static model in that, capital accumulation and allocation is specified within the model, thus allowing for the immobility of capital across sectors and capital investment in one period to be related to investment from previous periods.

The dynamic model for South Africa, therefore, is solved as successive equilibriums, with each equilibrium representing a single year. It then produces a projected growth path expected for the economy. Policy and non-policy changes or simulations, can then be expressed by exogenously changing applicable parameters, after which, a new series of equilibriums is computed. The results found then allow for an interpretation of the deviations between the policy, or simulation-influenced growth path, and the projected growth paths, as the economy-wide impacts of the simulated policy change, (Thurlow, 2004).

A static CGE model assumes that producers and consumers react passively to prices in determining their demand and supply schedules, thus allowing markets to clear through the interaction of relative prices, (Thurlow, 2004). Static models also assume that consumers' demands are derived from a one-period utility function. Alton et.al, (2012) explain this as meaning that household savings in such a model are not endogenously determined using an inter-temporal utility function, and so it does not smooth consumption over time. Therefore, since capital accumulation cannot be defined inter-temporally, the dynamics in the SAGE model is defined as a recursive process. This means that the model can be separated into 'within-period' and 'between-period' components, (Alton et al., 2012).

Both internationally and locally, the application of CGE models has ranged from energy policy implications, carbon emission tax policies, energy efficiency, economic and environmental policy implications. International studies include Bhattacharyya (1996), Jacoby, et al. (2012), Tyner and Taheripour (2014), Hartono, Nurkholis and Hutagalung (2014), and Arndt et al (2008). South African studies comprise of, Alton et al. (2012), Wait and Rossouw (2014), Merven et al. (2014), to name a few energy related analyses.

Wait and Rossouw (2014) state that CGE models have a proven track record in modelling energy-related subjects. According to Thurlow (2004), these models allow for an interpretation of impacts of policy changes on the entire economy, including their simultaneous impacts on measures like employment, production, inequality and poverty. This, as per the author, makes CGE models to be preferred over partial equilibrium models. Thurlow (2004) state that the other reason for the preference of CGE models over partial equilibrium models is their ability to include parallel impacts of policy changes.

Similarly, Arndt, et al. (2008) state that CGE models explain how variations in economic conditions, both desirable and undesirable, can be corrected for by market price adjustments. The authors state that, CGE models by their nature, allow for consideration of new occurrences, such as unconventional gas. According to Wait and Rossouw (2014), shale gas exploitation is one such phenomenon. Arndt, et al. (2008) states that, one way to think of a CGE model, is to consider a laboratory that allows for quantitative assessment of different simulations and their impacts on the economy. This laboratory breaks these impacts down into fine detail for each sector and institution.

However, CGE models are not without limitations. Arndt, et al. (2008) analyses these shortcomings in detail. They state that the economy-wide approach imbedded in the model is not suited for the analysis of all issues, as some important detail might be lost due to the simplifying assumptions adopted. Therefore, Arndt, et al. (2008), state that some issues do not require the wide and sophisticated nature of CGE modelling, allowing analysts to focus on examining the impacts of the issues being studied, instead of spending too much time on methodological concerns.

According to Mervin et al. (2014) CGE models can be aggregated models and in order to capture the complexity of the electricity sector for instance, (including all the technologies, demand and supply constraints) it is best to couple the model with a bottom up energy model such as the South African TIMES Model (SATIM). This has not been done in this study because the e- SAGE model is sufficient for what needs to be considered.

Another drawback of this type of method according to Thurlow (2004) is that, the models used are highly theoretical, which often requires some level of generalisation about reality. This therefore makes it crucial to understand the true characteristics of the economy being

modelled and the limitations of the model in order to ensure that these are accounted when structuring the simulations to be carried out. In addition, Caetano and Thurlow (2014) state that for the results to be credible, careful attention needs to be paid to the accuracy of the data and assumptions adopted during model calibration.

In the case of shale gas however, Wait and Rossouw (2014) state that the use of an economy-wide model is necessary because of the potential scale of the resource development and its implication from upstream to downstream sectors of the oil and gas industry. The model also captures all the economy-wide knock-on, production and consumption effects between producers and consumers. This according to Alton et al. (2012) enables a measurement and assessment of all the impacts of shale gas development in the economy. For all these reasons therefore, a CGE method has been adopted in this study. The closure assumptions assumed are South African- specific to account for the gap between general economic theory and the country's reality in order to ensure that the model is closely aligned with South Africa's economy.

3.1 Model calibration and data sources

According to Wait and Rossouw (2014), the CGE model needs to be calibrated using economic data for a particular economy as captured in a Social Accounting Matrix (SAM). Calibration is defined by Alton et al. (2012), as the process of assigning values to the model's theoretical parameters and variables using observed country data. The SAM thus, represents all economic transactions that takes place domestically within the economy, (Wait and Rossouw, 2014).

Hartono, Nurkholis and Hutagalung (2014) describe a SAM as a data source made of double entries of economic transactions between all agents in the economy. They state that it consists of shaped partition matrix. The economic agents in the SAM as per Hartono et al. (2014) include, sectors in the production block; institutions like firms, government and households; and factor producing sectors. The authors provide two reasons why a SAM is an appropriate database for the CGE model. First, within each single period, a SAM consist of a summary of all economic transactions in the economy. This is comparable to the CGE's annual periods of equilibrium computed. Second, a SAM contains a record of the socio-economic structures of an economy. In this way it is also able to capture poverty and income distribution indicators, similar to a CGE model.

Alton et al. (2012) state that all linkages in the form of incomes and payments between economic agents (consumers, producers, government and the rest of the world) over a single-year period, are captured in a SAM. They further state that, similar to any other double entry systems, the inflows and outflows are represented in rows and columns, respectively. Understandably, the rows and columns totals must be equal. This means that a payment in one account equates to an income in another. In this way, the SAM provides the base-year equilibrium state required in the CGE model.

The three main data sources for constructing a SAM cited by Alton et al. (2012) are the national supply-use table produced by Statistics South Africa, national accounts produced by the South African Reserve Bank, the labour force survey and the national representative household income and expenditure survey.

According to Alton et al. (2012), demand in the SAM is estimated using the technical coefficients in the supply-use table based on value added by sectors or GDP. They state that investment and government demand is disaggregated across products. The national accounts contain information on the composition of GDP at factor cost and, or market prices. The labour force survey on the other hand, is used to segment markets for labour according different income and education groups. While the income and expenditure surveys reflect the distribution of factor incomes across different household groups and the expenditure patterns of households. The data from the surveys and the shocks put into the models are therefore the main determinants of differential income and distributional effects across household groups in the model, (Alton et al., 2012).

3.2 Estimation procedure (behavioural elasticities and other external data)

While SAM provides an understanding of the institutional and sectoral structure of the economy, while capturing the existing inter-linkages and interaction, it does not however, explain the behavioural characteristics of economic agents, nor does it explain the dynamic process updating of the CGE model across time. For this, additional sources from existing literature are utilised, (Thurlow, 2004). Alton et al. (2012) state that these behavioral elasticities, for instance, are needed to explain trade, production and consumption functions.

Wait and Rossouw (2014) state that it could also be expected that the current economic structure of the South African economy captured in the SAM may change significantly depending on how much shale gas is found and produced. Their study made use of other econometric studies and plausible 'guesstimates'. The e-SAGE model by Alton et al. (2012), utilised in this research, also makes use of econometrically estimated income, production and trade elasticities.

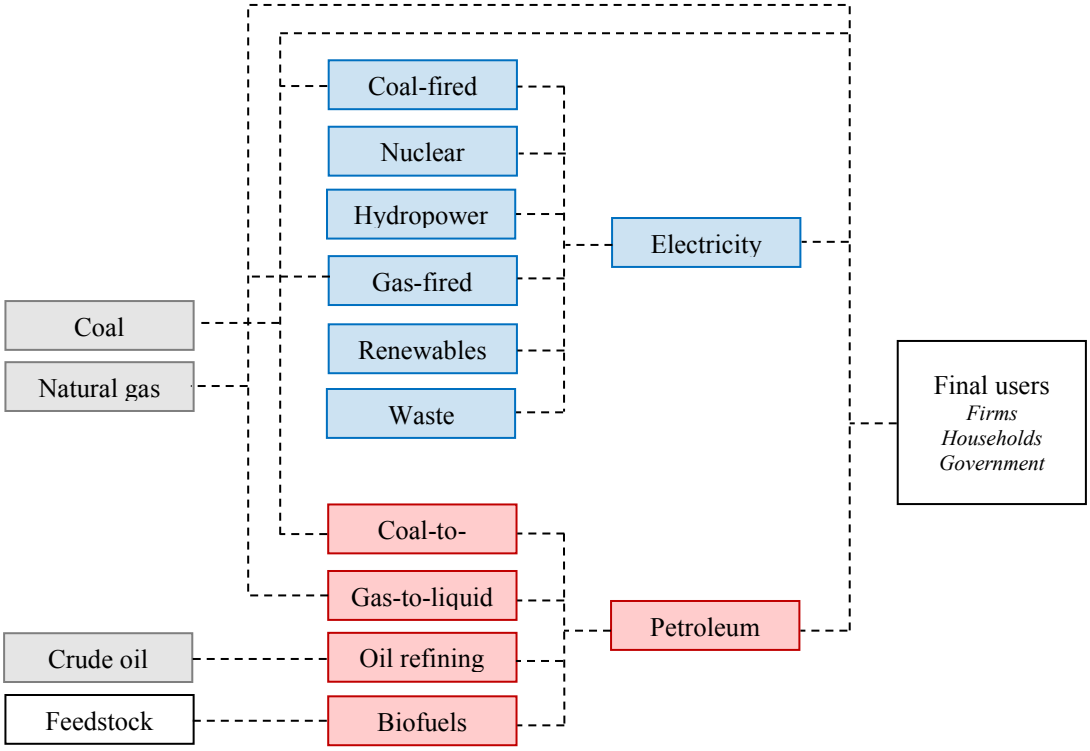
3.3 Analysis

3.3.1 Background

To carry out the analysis, the Energy Extended South African General Equilibrium (e-SAGE) model is used. The e-SAGE model is a dynamic recursive CGE model developed by National Treasury, and the United Nations University-World Institute for Development Economics Research (UNU-WIDER), (Alton et al., 2012). It mimics the functioning of the South African economy and uses the country's 2005 SAM as data input.

Alton et al. (2012) extended the South African General Equilibrium (SAGE) model in two areas to reflect the structure and workings of the country's energy sector. First, they disaggregated the energy sector by the three primary fossil fuels used in the sector: coal, crude oil and natural gas. This is done to track the flow of primary fuels from their raw form to the transformation subsectors (petroleum and electricity), and then their subsequent distribution to final energy users. The authors disaggregate the electricity and petroleum sectors as shown in figure 3 below:

Figure 3: Structure of the energy sector in the e-SAGE model



Source: Alton et al. (2012)

The above figure shows the important production and consumption linkages between industries and households in the energy sector. It shows that the end use of natural gas can come from either electricity via gas–fired power plants or petroleum through the Gas-to-Liquid (GTL) transformation process.

Secondly, the authors extend the SAGE model to allow non-energy producers to respond to changing energy prices by investing in more or less energy-intensive capital and production technologies. This then enables firms to adapt to higher energy prices by investing in lower energy-intensive technologies, and vice-versa, when energy prices are lower (Alton et al.,2012). This is the main feature of this dynamic model. Each sector's ability to respond to changes in energy prices depends on its share of new investment in the sector's total capital stock, i.e. capital stock intensity ratios.

The main objective behind the use of the model is to test the null hypothesis postulating that the development of shale gas will have various negative socio-economic impacts for South Africa such as long run negative economic growth, reduced employment, increased poverty,

trade balance problems. This is based on research findings from studies done in other countries both developed and still developing. The aim is to see if the implications of the hypothesis hold for the South African economy. Thus, an attempt is made to analyse the potential socio- economic impacts of shale gas development in South Africa, focusing mainly on economic variables such as GDP, employment, exports and imports of natural gas, oil and petroleum, welfare implication, poverty and so on. Scenario simulations based on various production levels will be used to analyse the impact on these indicators.

Given that the South African economy is currently not producing any shale gas, the e-SAGE model does not have a shale gas sector. It does, however, have a natural gas sector that represents Mossgas produced by PetroSA from the offshore F-A field and South Coast Complex fields and sent to the GTL facility in Mossel Bay via an offshore pipeline, (EIA, 2015). For this analysis, the existing output of natural gas has been increased and allowed to replace coal in the sectors that utilise both coal and natural gas as inputs to simulate a shale gas sector. It has been assumed that the shale gas sector will use the same inputs as the existing natural gas sector.

However, the potential shale gas availability is said to be in the Karoo region, which is onshore. This research then assumes that the production of shale gas will be simulated as an increase in the current natural gas production. This requires a postulation that there are no material differences between offshore and onshore natural gas production. Both offshore and onshore production technologies are, therefore, assumed to be the same. Output in the natural gas sector is thus increased by different production levels. The impacts of the increase on various socio- economic variables are then analysed under the results section below.

To a certain extent, this is similar to the approach taken by (Wait and Rossouw, 2014). Like the e-SAGE model used here, the UPGEM model applied by the authors also did not have an existing shale gas sector to be used to apply the shocks. They therefore shocked the UPGEM's crude, petroleum and natural gas and the incidental service activities sector (SIC22) denoted by the model's sector 10 (CruPetGas). The authors therefore modelled the potential increase in shale gas production using the model's existing CrudPetGas sector. In this paper, the potential impacts of shale gas production are modelled using the e-SAGE natural gas sector.

3.3.2 Specifications of the baseline

The e-SAGE captures the structure of the South African economy as shown in table 4 below.

Table 4 (a): Sectors, commodities and factors in the 2005 social accounting matrix

Sectors and commodities					
1	Agriculture	17	Printing and publishing	33	Furniture
2	Biomass feedstock	18	Petroleum products	34	Other manufacturing
3	Forestry	19	Basic chemicals	35	Recycling
4	Fisheries	20	Other chemicals	36	Electricity
5	Coal mining	21	Rubber products	37	Water distribution
6	Crude oil	22	Plastic products	38	Construction
7	Natural gas mining	23	Glass products	39	Trade services
8	Other mining	24	Non-metals	40	Hotels and catering
9	Food processing	25	Iron and steel	41	Transport services
10	Beverages and tobacco	26	Nonferrous metals	42	Communication
11	Textiles	27	Metal products	43	Financial services
12	Clothing	28	Machinery	44	Business services
13	Leather products	29	Electrical machinery	45	Government services
14	Footwear	30	Scientific equipment	46	Other services
15	Wood products	31	Vehicles		
16	Paper	32	Other transport equipment		
Factors					
1	Primary-educated labour (grade 1-7)	3	Secondary-educated labour (grade 11-12)	5	Capital
2	Middle-educated labour (grade 8-10)	4	Tertiary-educated labour (incl. certificates and diplomas)	6	Crop land

Source: Alton et al. (2012)

As shown in the above table, the structure of the South African economy in the e-SAGE consists of 46 sectors and 6 factors of production. The model is calibrated to the base year reflected in the SAM. It is then run forward over time to create a baseline growth path. The baseline scenario in the model is determined by the annual growth in factor supplies and productivity (Alton et al., 2012). The authors make various assumptions about the structure of the South African economy based on historical observations from existing literature. These are specified under section 3.3.3 below.

Table 4 (b) Base year structure: Production and trade shares and intensities

	GDP share %	Productior share %	Employ. share %	Export share %	Export intensity %	Import share %	Import intensity %
TOTAL GDP at factor cost	**100.00**	**100.00**	**100.00**	**100.00**	**9.57**	**100.00**	**12.34**
AGRICULTURE	**2.61**	**2.36**	**3.93**	**2.65**	**10.46**	**1.36**	**7.14**
of which: Biomass feedstock	0.00	0.00	0.00				
INDUSTRY	**30.46**	**43.17**	**27.62**	**82.98**	**18.08**	**82.65**	**22.17**
Mining	7.30	5.11	7.52	27.90	55.78	10.94	35.27
of which: Coal mining	1.11	0.88	1.39	2.41	28.99	0.06	1.06
of which: Crude oil						9.49	100.00
of which: Natural gas mining	0.06	0.04	0.05			0.11	26.71
Manufacturing	18.22	32.07	15.48	54.28	15.18	71.09	24.02
of which: Petroleum refining	1.48	2.53	0.15	6.01	25.99	1.90	10.70
Crude oil based petrol	1.10	2.02	0.12				
Coal to liquid petrol	0.37	0.49	0.03				
Gas to liquid petrol	0.01	0.02	0.00				
Biofuels	0.00	0.00	0.00				
Other industry	4.94	5.99	4.63	0.81	1.48	0.62	1.17
of which: Electricity	2.19	1.51	0.99	0.81	5.85	0.62	4.76
Coal-fired	1.36	1.40	0.89				
Nuclear	0.30	0.08	0.06				
Hydropower	0.02	0.01	0.01				
Renewables (solar/wind)	0.48	0.01	0.02				
Waste	0.00	0.00	0.00				
Gas	0.04	0.01	0.00				
SERVICES	**66.94**	**54.47**	**68.45**	**14.38**	**2.80**	**15.99**	**3.37**

Source: e-SAGE output

3.3.3 Closures and assumptions

The adopted closures are relevant for the South African economy as informed by Thurlow (2004) and Alton et al. (2012). They are as follows:

- Factors of production: To reflect the high levels of structural unemployment that exist amongst low-skilled workers, the supply of primary educated and uneducated workers is assumed to have upward-sloping supply curves. Skilled labour is assumed to be fully employed and mobile, growing annually at 2% for secondary-educated workers and 1.5% for tertiary-educated workers. Capital and land are assumed to be fully employed and activity specific.
- Savings and investment: A savings-driven investment closure is adopted, where domestic savings are fixed and investment is allowed to adjust with policy and

economic changes in the economy. This is informed by existing literature on savings and investment in South Africa.

- Government: Government savings are taken as fixed, and a uniform direct tax rate is assumed. This is informed by the assumption that taxes are politically motivated decisions and therefore made in isolation of changes in policy or the economic environment.
- Current account: Given that exchange rates are flexible in South Africa, the current account closure adopted is one that allows for flexible exchange rates with fixed foreign savings.

In order to carry out the simulations, one additional assumption had to be made about the stock of capital in the natural gas sector. Capital is assumed to be exogenously determined, allowing increases in capital stock to increase investment in the sector and therefore increase production to the necessary levels.

3.3.4 Limitations

The following are the main limitations of the study:

1. It is assumed that the electricity sector follows through with investments that are defined in the IRP and there is some reduction in Coal-to-Liquid (CTL) generation plants that is replaced by GTL production. This assumption may limit the absorption of shale gas into the South African economy. By changing this and allowing an increased use of gas for electricity production, there may be higher penetration of gas in South Africa.

2. Households cannot use the cheap gas from shale in the model. This is because household use of natural gas in South Africa was almost non-existent, as informed by the 2005 SAM used in the model's base year. For this reason,

3. The necessary linkages between the natural gas sector and households are not available. Tracing these and incorporating them into the model would allow for a better estimation of the potential impacts of shale gas development on welfare.

3.3.5 Simulations/ Scenarios

According to EIA (2013), estimated technically recoverable shale gas resources in South Africa are around 390 tcf. Studies done in South Africa have been based on a potential development of around 20 tcf to 50 tcf. This is quite a large amount compared to the current amount of less than 1 tcf of natural gas produced in the country and available in the model to simulate the increase in supply. In selecting the tcf to be modelled, this study had to be mindful of these issues. For this reason, the amount of natural gas supply had to be increased by the amounts stipulated below in order to draw a picture that is as close to the potential reality as possible but still not too far from what has been done already.

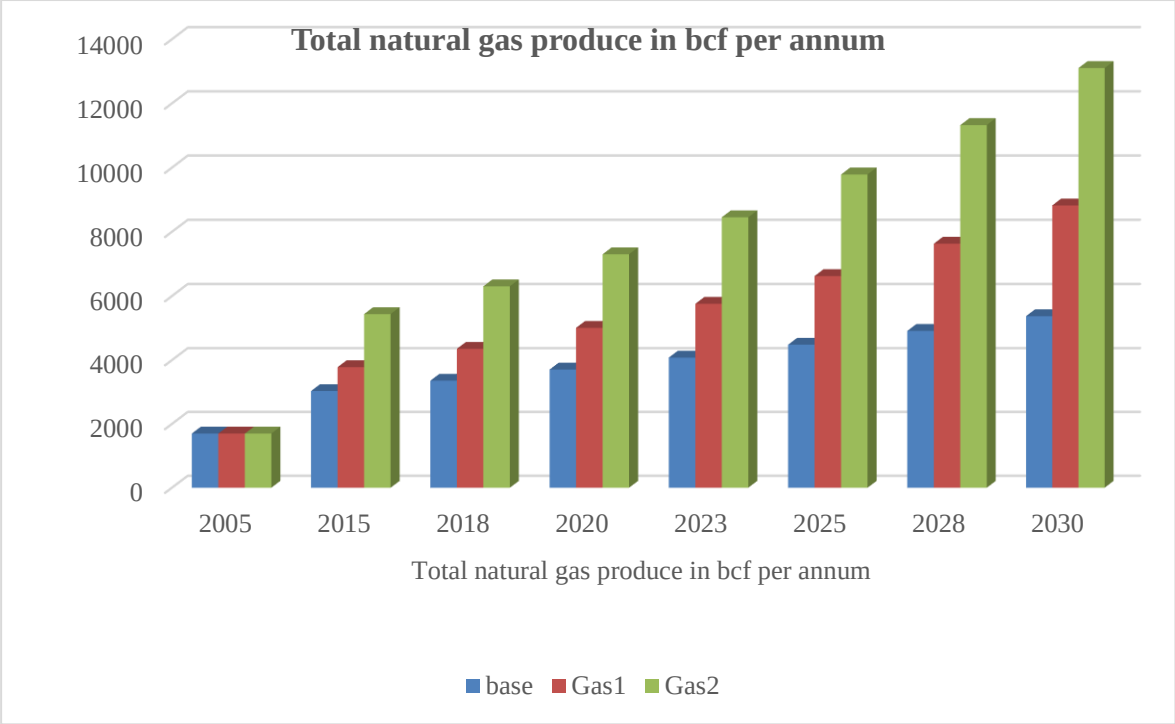
The following two comparable scenarios were modelled, as illustrated in figures 4 (a) and (b).

- Scenario 1(Gas 1) models a small increase in the quantity of natural gas and a slight penetration into the economy. Natural gas produced in this period increases up to 9 tcf. This is equivalent to a 9% average annual increase in production from the baseline. The decrease in coal production as a result of the increase in the quantity of natural gas supply goes up to 344 (1000 mt), i.e. 3% on average per annum relative to the base.
- Scenario 2 (Gas 2) models a bigger increase in the quantity of natural gas and higher levels of penetration into the economy. Natural gas produced in this period increases up to 13 tcf. This is equivalent to an 11% average annual increase in production from the baseline. The decrease in coal production goes up to 310 (1000 mt), i.e. 2.9% on average per annum relative to the base.

There are two levers used in the scenarios; one is to increase the actual supply of labour and the other to increase the demand. For the supply, the supply of capital is fixed for the natural gas (angas/ activity natural gas), thus ensuring that there is growth in the natural gas sector. To create the demand, the input coefficients for sectors that use both natural gas and coal are changed to simulate a transition in these sectors from gas to coal.

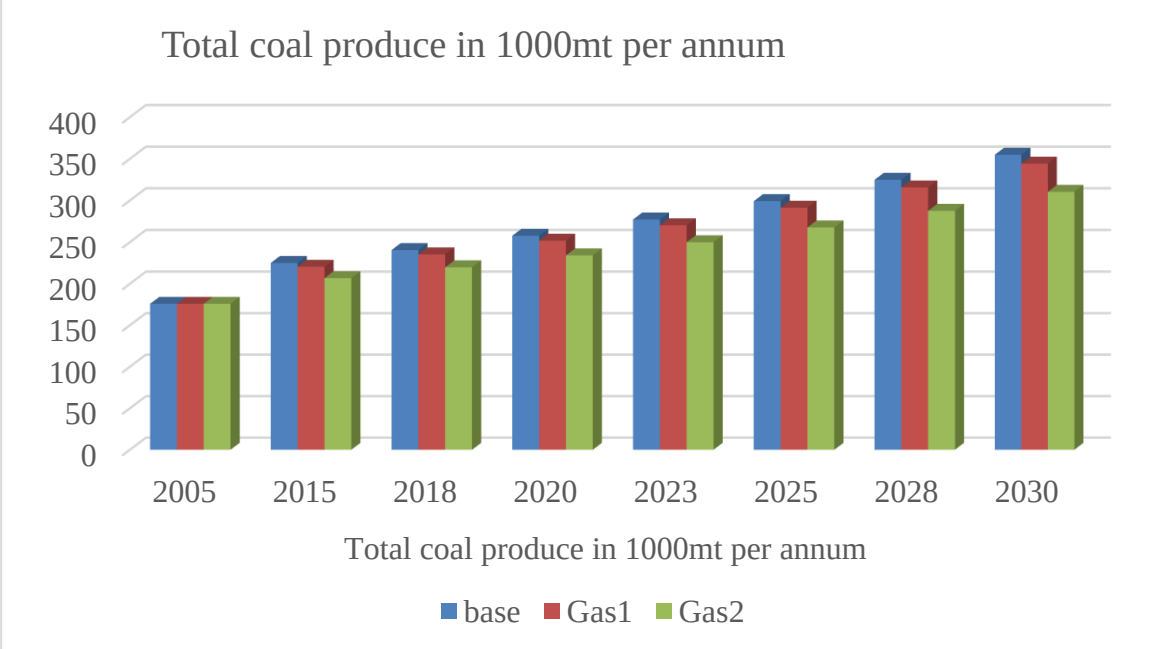
The exact sectors affected by the switch from coal to natural gas are shown in table 5 in Appendix 1. These are the sectors that make use of both coal and natural gas as their inputs. As can be seen from the table, sectors with the biggest transition as measured by the input coefficients are, Water distribution (5%), the paper sector (4%), non-metals (3%), iron and steel(2%), other mining(2%) and textiles (1%), respectively.

Figure 4 (a): Quantity of natural gas produced in bcf (2015 to 2035)



Source: e-SAGE output

Figure 4 (b): Quantity of coal produced in 1000mt (2015-2035)



Source: e-SAGE output

Interestingly, the model could not run when natural gas production is increased to utilise extremely high volumes of natural gas such as, 50 tcf as done by Econometrix (2012); and Wait and Rossouw (2014). This is because there is already a shortage of skilled labour and capital in the economy as per the closure assumptions adopted. Therefore, without a significant increase in skilled labour supply, a significant investment in education and training and an increase in the capital available to the economy, it is unlikely that the South African economy will be able to undergo a structural shift of that magnitude, at least not over the period modelled.

Chapter four: Results

4.1 Baseline scenario

At first the base is run with no development of the shale gas sector. The quantity of both capital and natural gas output without shale gas is calculated and found to be increasing at around 6% on average per annum, for both variables. In the absence of the shale gas scenarios both the capital used in production of natural gas and the natural gas output increases at around 6% on average per annum. Therefore, in the base scenario, capital growth is kept fixed at 6%.

In the baseline, a moderate GDP growth rate of 2.29%, average annual at market prices between 2015 to 2030 that is consistent with the growth rate estimated by the Energy Research Centre (2015), a growth in total labour supplied of 1.23% per year and a growth in exports of 2.49% per annum, while imports increase by 2.47% per annum.

4.2 Potential socio-economic impacts

This section analyses the results from a simulated increase in the supply of natural gas as a result of shale gas production on selected socio-economic indicators. All results presented below represent deviations from the values the variables would have taken in the absence of shale gas, i.e. the baseline.

4.2.1 Potential impacts on GDP

Table 6 (a): Annual GDP growth rates by sector (2015-2030)

	Initial share %	Average annual growth rate (%) Baseline scenario	Deviation from baseline (%-point Gas1	Gas2
TOTAL GDP at factor cost	**100.00**	**2.29**	**0.00**	**-0.07**
AGRICULTURE	**2.71**	**2.20**	**0.00**	**-0.09**
of which: Biomass feedstock	0.00	2.46	-0.02	-0.16
INDUSTRY	**30.36**	**2.37**	**0.00**	**-0.07**
Mining	7.60	2.37	0.01	-0.07
of which: Coal mining	1.30	1.58	-0.03	-0.18
of which: Natural gas mining	0.05	1.80	1.49	1.44
Manufacturing	18.25	2.36	0.00	-0.07
of which: Petroleum refining	1.61	2.12	0.01	-0.07
Crude oil based petrol	1.21	2.03	-0.02	-0.11
Coal to liquid petrol	0.39	2.38	-0.03	-0.19
Gas to liquid petrol	0.02	1.20	2.52	3.54
Biofuels	0.00	2.46	-0.02	-0.16
Other industry	4.51	2.40	0.00	-0.06
of which: Electricity	1.91	1.52		
Coal-fired	1.74	0.73		
Nuclear	0.12	2.26		
Hydropower	0.02	1.47		
Renewables (solar/wind)	0.02	2.75		
Waste	0.00	-0.02		
Gas	0.00	2.66		
SERVICES	**66.92**	**2.26**	**0.00**	**-0.07**

Source: e-SAGE output

Tables 6 (a)[3] and (b) show the impact of an increase in the output of natural gas on average annual GDP growth over the 15 year period, as a deviation from the baseline scenario. There is no deviation in total GDP from the base in scenario 1. In scenario 2, total GDP decreases by 0.07% on average per annum relative to the base scenario. This can be taken as one indication of the potential negative impacts on growth in the long run, caused by natural resource extraction, as alluded to by the natural resource curse theory.

Both tables show that the contribution to GDP by the natural gas sector increases by 1.49% in scenario 1 and 1.44% in scenario 2 on average per annum relative to the base. This is in line with expectations and can be ascribed to the increase in output, and then, investor confidence in the sector. These in turn attract more investment into the industry and therefore allow it to realise greater growth. The huge contributions by the sector to GDP in both scenarios are also realistic given that in the initial case the sector is very small in terms of contribution to GDP.

[3]A more detailed breakdown per sector can be found in table 6(b), Appendix 1

The average annual contribution to GDP by the natural gas sector is smaller in scenario 2 compared to scenario 1, due to the assumptions made about the limited supply of skilled labour and capital, and because of the limit placed on the amount of natural gas that can be used by the GTL sector.

The replacement of coal by natural gas entails a movement of both capital and human resources from the production of coal and other sectors to the natural gas sector. The natural gas sector mostly employs skilled labour. Given that both capital and skilled labour have been assumed to be fully employed and mobile, as the contribution of natural gas to GDP increases, the contribution by the coal sector and other sectors should then decrease. In these scenarios, the annual contribution to GDP by the coal mining sector decreases by 0.03% in scenario 1 and 0.19% in scenario 2 compared to the base scenario. The increase in the output of natural gas will lower prices in the natural gas sector, while increasing prices in the coal mining sector as can be seen in Table 7 (a) and (b). This will then make natural gas a more attractive alternative form of energy compared to coal.

Table 7 (a): Annual price growth rates by commodity (2015 to 2030)

	Average annual growth rate (%)		
	Baseline scenario	Deviation from baseline (%-point	
		Gas1	Gas2
ALL COMMODITIES	**0.22**	**0.00**	**-0.03**
AGRICULTURE	**-0.04**	**0.00**	**0.01**
of which: Biomass feedstock	0.08	0.00	-0.01
INDUSTRY	**0.50**	**-0.01**	**-0.06**
Mining	0.42	-0.07	-0.17
of which: Coal mining	0.01	0.00	0.01
of which: Crude oil	0.15	0.00	-0.01
of which: Natural gas mining	0.27	-0.78	-0.30
Manufacturing	0.10	0.00	-0.01
of which: Petroleum refining	-0.14	0.00	0.03
Other industry	2.31	0.00	-0.18
of which: Electricity	5.96	0.00	-0.40
SERVICES	**-0.04**	**0.00**	**0.01**
of which: Transport	-0.07	0.00	0.01

Source: e-SAGE output

Due to inter-sectoral linkages between economic sectors, contribution to GDP by other sectors changes as well. Annual contributions by sectors such as manufacturing, services and the other industrial sectors, for instance, remain the same as the baseline in scenario 1 and

decrease by 0.07% and 0.06% respectively, in scenario 2 compared to the base (table 6(b)). This implies that if the increase in the quantity of natural gas supply is too high, as is the case in scenario 2, too many resources in the economy will be shifted from other more profitable sectors into the natural gas sector, causing the sector to grow more than the other sectors.

The agricultural (fisheries and biomass feedstock) sector experiences negative per annum growth even for very small increases in the amount of natural gas as is the case in scenario 1. In the case of biomass feedstock in particular, this can be taken as a reflection of the penetration of natural gas in the economy as the availability of cheaper natural gas can replace biomass feedstock used to produce fuels. Gas to liquid petrol is the only sector other than the natural gas sector that makes positive contributions to GDP per annum as a result of the increase in natural gas supply. The average annual contributions are around 2.52% and 3.54% for both scenario 1 and 2 respectively relative to the base. This is to be expected, since more GTL plants will be needed to process higher levels of natural gas.

4.2.2 Potential impacts on trade

Table 8(a)[4] and (b) (in Appendix 1) show the average annual percentage growth in exports over the period. For all commodities, this remains the same as the baseline scenario growth in scenario 1 but declines by up to 0.09% on average per year compared to the base in scenario 2. This highlights a potential problem for South Africa's trade account balance.

There is no change in the exports of natural gas. This is because there are no exports of natural gas in the base year. The other sectors follow the same declining trend as that observed for GDP contributions except for the coal mining and agricultural sector. For these sectors, exports decrease even for small amounts of increase in natural gas as is the case in scenario 1 compared to the base, but exports in other sectors such as the manufacturing and service industries fall only for very large increase in natural gas, scenario 2. Coal mining exports, in particular, can be expected to fall due to declines in output in the sector as natural gas replaces coal.

The results of the simulations are in line with the Dutch disease theory, in which a growing extraction industry, in this case shale gas, causes an increase in production costs in the non-extraction sectors, such as manufacturing and agriculture, as a result of intense competition

[4]A more detailed breakdown can be found in table 8(b), Appendix 1

for labour as productive resources shift towards the booming gas sector. The resultant higher labour costs reduce growth in these sectors, while growth in the booming sector is accelerated. The growth in the shale gas sector will attract foreign savings. Increased foreign currency inflows will appreciate the value of the South African rand in relation to other foreign currencies, which then reduces demand for the country's exports, (Weber, 2012).

Large increases in the quantity of natural gas supply (as in scenario 2) have a positive impact only in the exports of electricity. Exports in this sector grow by up to 0.11% on average per annum compared to the base. This implies growth in the exports of electricity from gas to power related activities due to cheaper gas.

Table 8(a): Annual export growth by sector (2015 to 2030)

	Initial share %	Average annual growth rate (%)		
		Baseline scenario	Deviation from baseline (%-point	
			Gas1	Gas2
ALL COMMODITIES	**100.00**	**2.49**	**0.00**	**-0.09**
AGRICULTURE	**2.70**	**2.86**	**-0.01**	**-0.13**
of which: Biomass feedstock	0.00	0.00		
INDUSTRY	**82.66**	**2.38**	**0.00**	**-0.08**
Mining	26.48	2.47	-0.01	-0.12
of which: Coal mining	2.08	1.60	-0.03	-0.18
of which: Natural gas mining	0.00	0.00		
Manufacturing	55.36	2.37	0.00	-0.06
of which: Petroleum refining	5.59	2.20	0.00	-0.10
Other industry	0.83	-0.39	0.00	0.11
of which: Electricity	0.83	-0.39	0.00	0.11
SERVICES	**14.63**	**2.96**	**0.00**	**-0.15**

Source: e-SAGE output

As the quantity of natural gas supply increases, imports of both coal and crude oil fall by an annual average of 0.03% and 0.17% for coal, and 0.02% and 0.11% for crude oil, relative to the base scenario. This can be seen as an indication that the increase in the supply of natural gas locally allows the country to demand less imports of both resources. There are also fewer natural gas imports in both scenarios, with an increase in the quantity of natural gas produced domestically. However, imports of natural gas fall more within scenario 1 than they do within scenario 2, with an increased production of natural gas by 2.86% and 0.24%, respectively. This is because in scenario 2, more gas is needed locally than what can be produced under this scenario, due to the assumed capital and labour constraints, and also because more imported gas will be needed as a buffer, due to the natural gas penetration rates assumed.

Even though, as seen in table 13 below, the real exchange rate appreciates, causing an increase in export prices and a decline in exports, thus indicating a potential for the realisation of the Dutch disease effect for the South African economy, the rising export prices and declining import prices do not translate into increased imports. This can be attributed to the overall decline in all economic activities as reflected by declining annual contributions to GDP by most sectors, indicative of a shrinking economy, which will then afford fewer imports. As can be seen in table 9(a)[5] and (b), import growth rates for all commodities stay the same as the base in scenario 1, and then decline by up to 0.08% on average per annum compared to the base in scenario 2.

Table 9 (a): Average annual import growth rates by sector (2015-2030)

	Initial share %	Average annual growth rate (%)		
		Baseline scenario	Deviation from baseline (%-point	
			Gas1	Gas2
ALL COMMODITIES	**100.00**	**2.47**	**0.00**	**-0.08**
AGRICULTURE	**1.18**	**1.49**	**0.00**	**-0.04**
of which: Biomass feedstock	0.00	0.00		
INDUSTRY	**82.18**	**2.56**	**0.00**	**-0.09**
Mining	10.13	2.12	-0.05	-0.11
of which: Coal mining	0.05	1.50	-0.03	-0.17
of which: Natural gas mining	0.25	2.72	-2.86	-0.24
Manufacturing	71.42	2.61	0.00	-0.09
of which: Petroleum refining	1.66	1.91	0.00	-0.05
Other industry	0.64	3.12	0.00	-0.12
of which: Electricity	0.64	3.12	0.00	-0.12
SERVICES	**16.64**	**2.06**	**0.00**	**-0.04**

Source: e-SAGE output

4.2.3 Potential impacts on employment

The potential positive impacts to be realised by the natural gas sector, as reflected by positive contributions to GDP and falling imports, will be to the disadvantage of other sectors in the economy that compete with this sector for resources. This is because substantial capital and labour resources will move from these sectors to the increasingly productive natural gas sector and supporting industries, such as the GTL sector. As a result, any employment opportunities that might be created will move from other sectors of the economy to the natural gas sector.

[5]A more detailed breakdown can be found in table 9 (b), Appendix 1

Table 10 in Appendix 1 shows the exact sectors where the jobs will be created and lost for each skill category of labour. As expected, the two sectors with the biggest movements is the coal mining sector and the natural gas sector. Coal mining experiences job losses of unskilled labour due to declining output, while skilled labour lost in the sector relocates to the growing natural gas sector. The natural gas sector creates jobs across all skills levels, but more so in the skilled levels due to the increase in output in the sector. The table also indicates that jobs will also be lost in sectors like transport, food, beverages and tobacco and created by very small margins in all the other sectors across all skills levels.

The overall average annual unemployment rate for unskilled labour will be 27% for both scenario 1 and 2 relative to the base scenario by 2030. This is above the current 25% estimated by Stats SA (2016), but in line with expectations, given the decline on the average annual GDP and exports over the period modelled. It is also an indication that the exploitation of shale gas under the current economic constraints may not be a blessing for the South African economy, as reflected by the potential impacts on unemployment.

4.2.4 Potential impacts on welfare and poverty

Table 11: Annual change in average income (2015-2030)

	Initial value	Total change for the simulation period (%)		
		Baseline scenario	Deviation from baseline (%-poin	
			Gas1	Gas2
LABOR (mil of workers)	**85 794**	**1.39**	**0.00**	**-0.11**
Primary (g1-7)	41 967	1.03	0.00	-0.08
Junior secondary (g8-10)	61 728	1.05	0.00	-0.08
Senior secondary (g11-12)	106 322	1.82	0.00	-0.13
Tertiary	178 192	1.62	0.00	-0.12

Source: e-SAGE output

Table 12: Household per capita consumption growth (2015-2030)

	Initial value (rands)	Total change for the simulation period (%) Baseline scenario	Deviation from baseline (%-point Gas1	Gas2
ALL HOUSEHOLDS	**31 924**	**1.87**	**0.00**	**-0.07**
Poor households	11 565	2.00	0.00	-0.09
Percentile 1-10	5 864	2.05	0.00	-0.10
Percentile 11-20	9 990	2.01	0.00	-0.09
Percentile 21-30	12 028	2.00	0.00	-0.09
Percentile 31-40	13 711	2.01	0.00	-0.09
Percentile 41-50	16 231	1.97	0.00	-0.09
Non-poor households	52 285	1.85	0.00	-0.07
Percentile 51-60	18 460	1.93	0.00	-0.08
Percentile 61-70	22 067	1.90	0.00	-0.08
Percentile 71-80	30 348	1.90	0.00	-0.08
Percentile 81-90	56 906	1.90	0.00	-0.08
Percentile 91-100	133 699	1.79	0.00	-0.06
Percentile 91-96	83 331	1.92	0.00	-0.08
Percentile 97	96 770	1.89	0.00	-0.08
Percentile 98	115 230	1.88	0.00	-0.08
Percentile 99	142 615	1.78	0.00	-0.06
Percentile 100	230 547	1.66	0.00	-0.04

Source: e-SAGE output

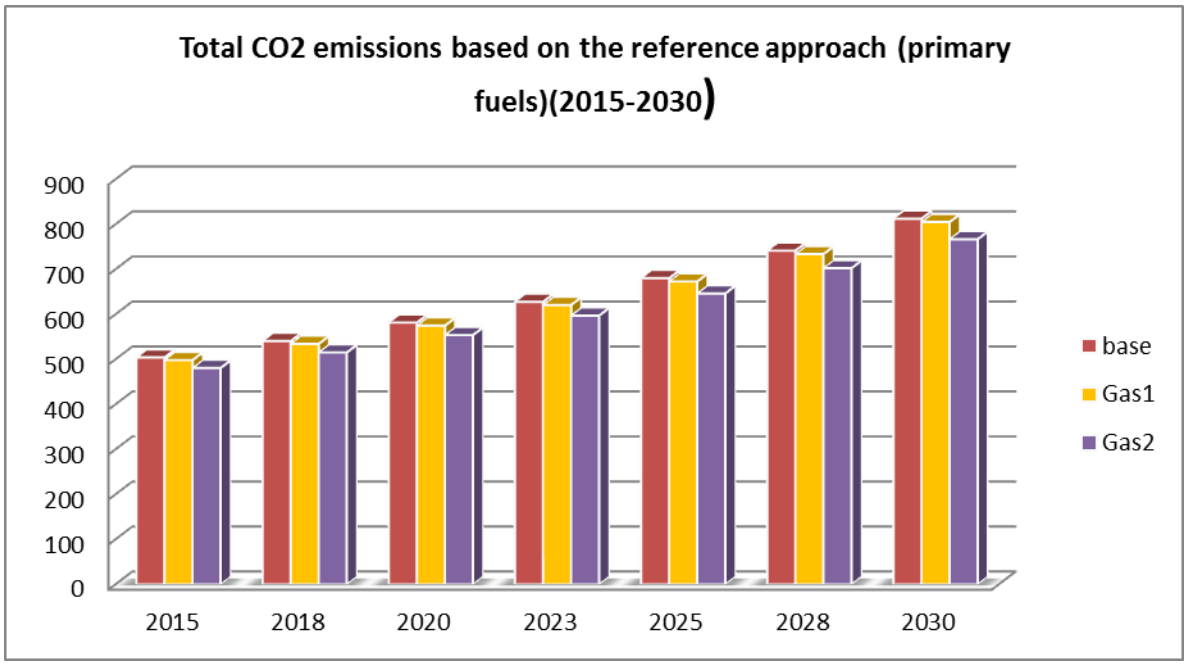
In terms of welfare and poverty, tables 11 and 12 can be used to infer the potential impacts. Table 11 indicates that the increase in natural gas simulated in scenario 1 will not cause any deviations in income on average per annum, relative to the base scenario for all skills levels. For larger increases as simulated in scenario 2, however, the potential impacts are negative when compared to the base scenario. This potential impact will be more for skilled labour than unskilled labour. The potential decline in income across all skills levels can be attributed to the potential slowdown in the economy caused by the expansion of the natural gas sector and poses a huge challenge for poverty alleviation.

Table 12 shows what could potentially happen to the growth in household consumption per capita on average per annum over the 15-year period. Similar to table 11, growth in household consumption remains the same as the baseline scenario, in scenario 1, while in scenario 2 there is negative growth for all households on average per annum compared to the baseline. The reduction in household consumption per capita is more so for poor household compared to non-poor household showing that even though the income of the middle and high class may decrease more than that of the poor, their income will still be able to consume more on average per annum. This indicates that the potential negative impacts of shale gas

development on income during the simulated period will be felt more by the poor compared to the non-poor. This could possibly push the poor further into poverty than could have been the case in the absence of the development of the resource and widening the inequality gap further. It should be noted, however, that, this situation may be different if the model allowed households to use the low-priced gas, thus increasing welfare.

4.2.5 Potential impacts on emissions

Figure 6: Total CO2 emissions based on the reference approach (primary fuels)



Source: e-SAGE output

As recorded by Mervin, et al. (2014), South Africa has made a voluntary commitment in international climate negotiations to reduce national emissions to 34% below business as usual levels by 2020 and 42% by 2025. Figure 6 shows that the development of shale gas in the country could contribute towards reaching these targets. Total CO_2 emissions from primary fuels (coal, crude oil and natural gas) are lower for both scenario 1 and 2 relative to the base. As can be seen from the above graph, the reduction is greater for larger increases in natural gas (scenario 2), with more petroleum and coal substituted with gas. Table 14 in Appendix 1 shows that this works out to a ratio of 1% and 5% to baseline emissions from primary fuels by 2020 and 2025 respectively.

4.3 Discussion

Table 13: Selected Macroeconomic indicators (2015-2030)

Indicator	Initial %	Average annual growth rate (%) Baseline scenario	Deviation from baseline (%-point) Gas 1	Gas 2
Total GDP at Market prices	100.0	2.29	0.00	-0.07
Exports	24.6	2.49	0.00	-0.09
Imports	-26.8	2.47	0.00	-0.08
Real exchange rate	92.4	1.87	-0.07	-0.16
Investment share of GDP (%)	18.2	6.28	0.01	-0.13
Private savings	15.0	6.63	0.01	-0.17
Foreign savings	3.2	-0.35	0.00	0.04
Trade deficit	8.8	1.15	0.00	0.03

Source: e-SAGE output

Based on the results of the modelling, it appears that the development of shale gas in South Africa will not mirror the US experience. This is understandable, given that the two countries are not similar. The US has a developed economy with an advanced manufacturing sector and an already existing gas infrastructure to develop shale gas. The US also does not have a shortage of resources in the form of capital and skilled labour needed for shale gas to the extent that South Africa does.

Consequently, even though the development of shale gas lowers prices of natural gas and electricity in both countries and creates more jobs in the natural gas sector, manufacturing, construction and chemicals, the impacts of the lower gas prices are not the same. For instance, table 13 shows that the overall impact on GDP on average per annum relative to the base is negative (scenario 2). Potential contribution to the GDP per annum over the period by the chemical and manufacturing industry will decrease in South Africa, unlike in the US, which experiences positive contributions from these sectors due to already existing industries that are available and able to support the booming shale gas sector.

For large increases in the output of shale gas, as seen in scenario 2, both exports and imports fall. The fall in the exports is in line with Wait and Rossouw's (2014) insights on declining traditional exports in order to make space for shale gas. The fall in exports from sectors such as manufacturing and service is contrary to the US experience and can be attributed to the country's level of development, particularly in these sectors compared to South Africa.

Even though both exports and imports fall, the potential decline on exports is bigger than the decline in imports. In scenario 2, this is 0.09% and 0.08%, respectively, on average per year compared to the base scenario. As a result, the trade deficit will grow by 0.03% per annum on average compared to the base (scenario 2). This can be attributed to a potentially stronger rand as a result of increased foreign inflows being attracted by the booming shale gas sector, and is in line with the predictions of the natural resource curse on developing economies, such as South Africa and should be cause for concern for policy makers in the country.

Unskilled labour from sectors competing with shale gas, such as coal, is most likely to be displaced, while employment opportunities are most likely to be created for skilled labour in the non-metals, metal products, machinery, construction, hotels and catering, communication, vehicles, manufacturing and services sectors. If purchasing power is used as a measure of poverty and welfare or wealth distribution and change in average income and household per capita consumption growth, it appears that the gap between poor and the rich would either remain the same or be widened. This is because the income of the poor and their consumption per capita fall by a bigger percentage compared to the rich. However, on the positive side, the uptake of shale gas as an alternative to coal would reduce CO_2 emissions in South Africa.

The main findings of this study, therefore, are that one positive impact that can come out from shale gas development under the current socio-economic conditions in the country is a possible reduction of CO_2 emissions. If the needed prior capital and skills investment is not made, employment opportunities will be created in the shale gas and related sectors, but other sectors will shed jobs as the economy shrinks. The poor will remain poor while the rich will get richer. This situation may be worsened by the rising trade deficit and the subsequent fall in GDP.

Chapter five: Conclusion

The economic literature reviewed suggests that there is a negative relationship between the availability of natural resources and socio-economic development of resource-rich countries. This is said to be more prominent in developing economies (such as South Africa) than in developed ones like the US. The former battle with low levels of economic growth, extreme poverty, environmental degradation, weak per capita income growth, declining exports in the non-resource extracting sectors such as manufacturing and agriculture, while the opposite is generally the case for the latter.

The e-SAGE model has been used to analyse potential socio-economic impacts of possible shale gas development in South Africa. The supply of natural gas is increased when simulating a shale gas sector, and allowed to replace coal in the sectors that use both coal and natural gas. This is done by increasing the supply of natural gas by 9 tcf in the first scenario (Gas 1) and 13 tcf in the second (Gas 2), where there is much more natural gas available and an even bigger replacement of coal by natural gas. The scenarios are informed by the assumptions made for a typical South African economy (closure assumptions) and existing literature on shale gas. The results are compared to the baseline scenario of no shale gas development.

Fakir (2015) states the impacts of exploiting shale gas on development in South Africa will depend on the size of the resource, the value of the resource and the pace of resource extraction. The results of this study are in line with this view and highlight two main factors. First, the South African economy will not be able to sustain high levels of increases in the supply of natural gas over a 15-year period given the current structural constraints that exist.

Policy makers may find it worthwhile to find ways to increase the quantity and quality of skilled labour needed by the sector first, before large-scale shale gas production takes place. Investment through training and education in the necessary skills development initiatives is critical. This can be done through training and education in shale gas-specific fields such as engineering, geology, environmental management, finance, economics as well as technology, research and development.

Second, substantial capital injection in the natural gas sector without taking away resources from other sectors will be needed to extract the large estimated natural gas resources. Policy and investment decisions need to be tailored towards making sure that increased infrastructural investment, including investment in machinery and equipment, is also one of the prerequisites for shale gas development,. Thus increased investment into the country's manufacturing sector (petroleum refining, chemicals, metals, non-metallic minerals, machinery, vehicle and transportation, and construction) will have to be made to ensure that these sectors will be able to support the growing shale gas sector and still be able to survive).

The results of the simulations done indicate that the resource curse may be experienced with the development of shale gas in South Africa. Most sectors will experience negative growth as measured by annual contributions to GDP, household income and consumption may fall across all income groups, agricultural and manufacturing exports will decrease as well, due to resource constraints. The only environmental factor considered is CO_2 emissions and it was found that these will fall, similar to what has been found for the US.

Based on these results, the hypothesis made that shale gas development will have negative impact on socio economic development of South Africa cannot be rejected. This is similar to what was found by Weber (2012) in Colorado, Texas, and Wyoming. Where the author found that in these states in the long run, increased income and employment impacts from shale gas development do not convert into reduced poverty and that distributional impacts depend on pre-existing level of skills, income distribution, the structure of the local labour market, and the size of the spill-over effects for other sectors in the economy. Apart from this, most studies from the US have found mostly positive impacts from shale gas development in terms of contribution to GDP, employment, exports, CO_2 emission reduction and welfare (Erbach (2014), Tyner and Taheripour (2014), Kellogg and Hausman (2015), IHS Global Insight (2011), PWC (2013), etc.).

The results of this study are contrary to what has been found for South Africa by the Department of Mineral Resources (DMR) (2012), Econometrix (2012) and Wait and Rossouw (2014) in terms of potential impacts of shale gas development on GDP and employment. All these studies found that the potential impacts will be positive for both indicators. It should be noted, however, that these studies did not factor in the shift of the already limited capital and skilled labour resources from other sectors into shale gas through a dynamic economy-wide modelling exercise. The simple multiplier model used in the

Econometrix (2012) report also does not take into account economy-wide impacts of shale gas development as done by the dynamic model used in this study. While the static CGE model applied by Wait and Rossouw (2014) does not fully capture the structural problems that exist in the South African economy and the economy-wide knock-on effects of policy and non-policy changes.

Recommendation for future research

1. The greatest opposition to the development of shale gas is centred on environmental concerns. Future research should quantify these and incorporate them into an economic model to have a better understanding of the potential socio-economic impacts of the development of the resource. This is, however, more accurately done once exploration has taken place and the potential shale gas becomes proven reserves.

2. The following assumptions should be relaxed and the model developed further:

   The inability of households to demand and use shale gas to have a better estimate of the potential change in welfare as a result of shale gas development.

   Demand for shale gas in the GTL industry should be allowed to increase further, allowing more GTL plants to be built and thus increasing the industry's contribution to GDP further. However, this would be a challenging exercise, given the economy's capital and labour constraints.

   Building an onshore gas sector into the e-SAGE model with the appropriate production and consumption linkages therefore, should, be a meaningful contribution to the understanding of the potential impacts of shale gas development in South Africa.

3. Future development finance studies could look at various financing options available to fund shale gas projects to understand if they would be better financed with public funds or by the private sector in order to maximise the potential benefits and minimise the potential costs associated with the development of the resource. It is clear that South Africa does not have the necessary infrastructure needed to develop shale gas of the estimated resource size. Future research could also look at whether the government ought to build the needed infrastructure and have the private sector use it at a cost or if

the necessary infrastructure investment should be done by the private sector. Studies that could assist the government in deciding which part of the shale gas development value chain it should participate in, how, or if it should participate at all, should also be interesting to see in the future.

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APPENDICES

Appendix 1

Table 5: Sectors affected by the switch from coal to natural gas

Sectors	Input coefficients	
	Coal	Natural gas
Other mining	-0.01656	0.01656452
Food processing	-0.00295	0.00295088
Beverages and tobacco	-0.00173	0.00173136
Textiles	-0.00757	0.0075705
Clothing	-0.00165	0.0016496
Leather products	-0.00154	0.00153535
Footwear	-0.00016	0.00016111
Wood products	-0.00396	0.00395677
Paper	-0.03732	0.0373178
Printing and publishing	-0.00054	0.00053884
Basic chemicals	-0.0026	0.00259844
Other chemicals	-0.00137	0.00137201
Rubber products	-0.00392	0.0039174
Plastic products	-0.00046	0.00046433
Glass products	-0.00197	0.00196597
Non-metals	-0.02725	0.02724747
Iron and steel	-0.02013	0.02012724
Nonferrous metals	-0.00039	0.00039109
Metal products	-0.00078	0.00077729
Machinery	-0.00035	0.00035371
Electrical machinery	-0.00037	0.00037147
Scientific equipment	-0.00014	0.00014157
Vehicles	-1.9E-05	1.9403E-05
Other transport equipmer	-0.00033	0.00033199
Furniture	-0.00137	0.00136502
Other manufacturing	-0.00089	0.00089446
Recycling	-1.9E-06	1.9379E-06
Water distribution	-0.04737	0.04737301
Trade services	-0.00065	0.00064853
Hotels and catering	-0.00209	0.00209486
Communication	-0.00039	0.00039079
Business services	-0.00088	0.00087785
Government services	-0.00059	0.00058832
Other services	-0.00279	0.00279484

Table 6 (b): Annual GDP growth rates by sector (2015 to 2030)

	Initial share %	Average annual growth rate (%) Baseline scenario	Deviation from baseline (%-point) Gas1	Gas2
TOTAL GDP at factor cost	**100.00**	**2.29**	**0.00**	**-0.07**
AGRICULTURE	**2.71**	**2.20**	**0.00**	**-0.09**
Crops	2.20	2.14	0.00	-0.08
Biomass feedstock	0.00	2.46	-0.02	-0.16
Forestry	0.43	2.39	0.00	-0.09
Fisheries	0.09	2.49	-0.01	-0.15
INDUSTRY	**30.36**	**2.37**	**0.00**	**-0.07**
Mining	7.60	2.37	0.01	-0.07
Coal mining	1.30	1.58	-0.03	-0.18
Crude oil	0.00	0.00		
Natural gas mining	0.05	1.80	1.49	1.44
Other mining	6.26	2.50	-0.01	-0.10
Manufacturing	18.25	2.36	0.00	-0.07
Food processing	3.20	2.05	0.00	-0.09
Food processing	1.97	1.95	0.00	-0.07
Beverages and tobacco	1.23	2.20	0.00	-0.11
Textiles and clothing	0.77	2.38	0.00	-0.07
Textiles	0.29	2.30	0.00	-0.06
Clothing	0.30	2.38	0.00	-0.08
Leather products	0.08	2.65	0.00	-0.09
Footwear	0.09	2.41	0.00	-0.08
Wood and paper	1.66	2.37	0.00	-0.07
Wood products	0.47	2.43	0.00	-0.08
Paper	0.70	2.38	0.00	-0.08
Printing and publishing	0.49	2.30	0.00	-0.07
Petroleum refining	1.61	2.12	0.01	-0.07
Crude oil based petrol	1.21	2.03	-0.02	-0.11
Coal to liquid petrol	0.39	2.38	-0.03	-0.19
Gas to liquid petrol	0.02	1.20	2.52	3.54
Biofuels	0.00	2.46	-0.02	-0.16
Chemicals	2.95	1.88	0.00	-0.03
Basic chemicals	0.87	1.22	0.00	0.04
Other chemicals	1.26	2.02	0.00	-0.04
Rubber products	0.19	2.11	0.00	-0.04
Plastic products	0.64	2.34	0.00	-0.07
Nonmetallic minerals	0.72	2.75	0.00	-0.09
Glass products	0.15	2.18	0.00	-0.06
Non-metals	0.57	2.88	0.00	-0.10
Metals	2.93	2.45	0.00	-0.06

Source: e-SAGE output

Table 7 (b): Annual price growth rates by commodity (2015 to 2030)

	Average annual growth rate (%)		
	Baseline scenario	Deviation from baseline (%-point)	
		Gas1	Gas2
ALL COMMODITIES	**0.22**	**0.00**	**-0.03**
AGRICULTURE	**-0.04**	**0.00**	**0.01**
Crops	0.00	0.00	0.00
Biomass feedstock	0.08	0.00	-0.01
Forestry	-0.27	0.00	0.05
Fisheries	-0.10	0.00	0.02
INDUSTRY	**0.50**	**-0.01**	**-0.06**
Mining	0.42	-0.07	-0.17
Coal mining	0.01	0.00	0.01
Crude oil	0.15	0.00	-0.01
Natural gas mining	0.27	-0.78	-0.30
Other mining	0.09	0.00	0.02
Manufacturing	0.10	0.00	-0.01
Food processing	-0.05	0.00	0.00
Food processing	0.00	0.00	-0.01
Beverages and tobacco	-0.19	0.00	0.02
Textiles and clothing	0.05	0.00	-0.01
Textiles	0.11	0.00	-0.02
Clothing	0.03	0.00	-0.01
Leather products	-0.06	0.00	0.01
Footwear	0.04	0.00	0.00
Wood and paper	-0.01	0.00	-0.01
Wood products	-0.03	0.00	0.00
Paper	0.00	0.00	0.00
Printing and publishing	0.00	0.00	-0.02
Petroleum refining	-0.14	0.00	0.03
Chemicals	0.42	0.00	-0.05
Basic chemicals	0.83	0.00	-0.09
Other chemicals	0.28	0.00	-0.04
Rubber products	0.26	0.00	-0.04
Plastic products	0.23	0.00	-0.03
Nonmetallic minerals	0.05	0.00	0.00
Glass products	0.36	0.00	-0.04
Non-metals	-0.01	0.00	0.01
Metals	0.38	0.00	-0.04
Iron and steel	0.49	0.00	-0.04
Nonferrous metals	0.53	0.00	-0.05
Metal products	0.21	0.00	-0.03
Machinery	0.10	0.00	-0.01
Machinery	0.11	0.00	-0.01
Electrical machinery	0.11	0.00	-0.01
Scientific equipment	0.07	0.00	-0.01
Vehicles and transport equip.	0.06	0.00	-0.01
Vehicles	0.05	0.00	-0.01
Other transport equipment	0.14	0.00	-0.02
Other manufacturing	-0.06	0.00	0.01
Furniture	0.05	0.00	-0.02
Other manufacturing	-0.21	0.00	0.05

Source: e-SAGE output

Table 8(b): Annual exports growth by sector (2015 to 2030)

	Initial share %	Average annual growth rate (%)		
		Baseline scenario	Deviation from baseline (%-point)	
			Gas1	Gas2
ALL COMMODITIES	**100.00**	**2.49**	**0.00**	**-0.09**
AGRICULTURE	**2.70**	**2.86**	**-0.01**	**-0.13**
Crops	2.54	2.80	-0.01	-0.12
Biomass feedstock	0.00	0.00		
Forestry	0.00	0.00		
Fisheries	0.16	3.68	-0.02	-0.29
INDUSTRY	**82.66**	**2.38**	**0.00**	**-0.08**
Mining	26.48	2.47	-0.01	-0.12
Coal mining	2.08	1.60	-0.03	-0.18
Crude oil	0.00	0.00		
Natural gas mining	0.00	0.00		
Other mining	24.40	2.53	-0.01	-0.12
Manufacturing	55.36	2.37	0.00	-0.06
Food processing	3.62	2.66	-0.01	-0.15
Food processing	2.14	2.12	0.00	-0.08
Beverages and tobacco	1.48	3.33	-0.01	-0.22
Textiles and clothing	0.98	2.78	0.00	-0.07
Textiles	0.53	2.41	0.00	-0.02
Clothing	0.24	3.00	0.00	-0.10
Leather products	0.19	3.39	-0.01	-0.15
Footwear	0.03	3.05	0.00	-0.11
Wood and paper	2.41	2.82	0.00	-0.09
Wood products	0.77	2.60	0.00	-0.08
Paper	1.37	2.91	0.00	-0.11
Printing and publishing	0.27	2.99	0.00	-0.05
Petroleum refining	5.59	2.20	0.00	-0.10
Crude oil based petrol	0.00	0.00		
Coal to liquid petrol	0.00	0.00		
Gas to liquid petrol	0.00	0.00		
Biofuels	0.00	0.00		
Chemicals	6.79	0.66	0.00	0.11
Basic chemicals	4.06	-0.32	0.00	0.22
Other chemicals	1.94	1.70	0.00	0.02
Rubber products	0.44	1.82	0.00	0.02
Plastic products	0.36	2.18	0.00	-0.01
Nonmetallic minerals	0.64	2.83	0.00	-0.10
Glass products	0.14	1.99	0.00	-0.03
Non-metals	0.50	3.04	0.00	-0.12
Metals	17.20	2.13	0.00	-0.03
Iron and steel	9.34	2.27	0.00	-0.04
Nonferrous metals	6.40	1.85	0.00	-0.01
Metal products	1.46	2.44	0.00	-0.03
Machinery	7.21	3.03	0.00	-0.09
Machinery	5.27	3.03	0.00	-0.08
Electrical machinery	0.76	2.91	0.00	-0.08
Scientific equipment	1.18	3.08	0.00	-0.10
Vehicles and transport equip.	7.73	2.96	0.00	-0.08
Vehicles	6.59	2.98	0.00	-0.09
Other transport equipment	1.14	2.83	0.00	-0.03
Other manufacturing	3.19	2.81	-0.01	-0.12
Furniture	0.86	2.86	0.00	-0.04

Source: e-SAGE output

Table 9 (b): Annual import growth rates by sector (2015 to 2030)

	Initial share %	Average annual growth rate (%) Baseline scenario	Deviation from baseline (%-point) Gas1	Gas2
ALL COMMODITIES	**100.00**	**2.47**	**0.00**	**-0.08**
AGRICULTURE	**1.18**	**1.49**	**0.00**	**-0.04**
Crops	1.18	1.49	0.00	-0.04
Biomass feedstock	0.00	0.00		
Forestry	0.00	0.00		
Fisheries	0.00	0.00		
INDUSTRY	**82.18**	**2.56**	**0.00**	**-0.09**
Mining	10.13	2.12	-0.05	-0.11
Coal mining	0.05	1.50	-0.03	-0.17
Crude oil	8.49	2.06	-0.02	-0.11
Natural gas mining	0.25	2.72	-2.86	-0.24
Other mining	1.34	2.40	0.00	-0.03
Manufacturing	71.42	2.61	0.00	-0.09
Food processing	3.19	1.79	0.00	-0.06
Food processing	2.75	1.85	0.00	-0.07
Beverages and tobacco	0.44	1.37	0.00	-0.01
Textiles and clothing	5.71	1.99	0.00	-0.07
Textiles	1.19	2.35	0.00	-0.11
Clothing	3.14	1.87	0.00	-0.06
Leather products	0.26	1.93	0.00	-0.03
Footwear	1.12	1.96	0.00	-0.06
Wood and paper	1.79	2.09	0.00	-0.07
Wood products	0.46	2.29	0.00	-0.07
Paper	0.88	2.01	0.00	-0.06
Printing and publishing	0.44	2.04	0.00	-0.10
Petroleum refining	1.66	1.91	0.00	-0.05
Crude oil based petrol	0.00	0.00		
Coal to liquid petrol	0.00	0.00		
Gas to liquid petrol	0.00	0.00		
Biofuels	0.00	0.00		
Chemicals	8.36	2.78	0.00	-0.15
Basic chemicals	2.92	3.32	0.00	-0.20
Other chemicals	4.05	2.42	0.00	-0.11
Rubber products	0.81	2.53	0.00	-0.12
Plastic products	0.58	2.65	0.00	-0.12
Nonmetallic minerals	1.12	2.70	0.00	-0.08
Glass products	0.27	2.41	0.00	-0.09
Non-metals	0.85	2.79	0.00	-0.08
Metals	3.22	2.95	0.00	-0.11
Iron and steel	0.81	3.11	0.00	-0.11
Nonferrous metals	1.10	2.96	0.00	-0.11
Metal products	1.31	2.84	0.00	-0.12
Machinery	26.72	2.86	0.00	-0.09
Machinery	15.30	2.99	0.00	-0.10
Electrical machinery	2.28	2.87	0.00	-0.09
Scientific equipment	9.13	2.64	0.00	-0.08
Vehicles and transport equip.	17.87	2.55	0.00	-0.08
Vehicles	15.11	2.48	0.00	-0.07
Other transport equipment	2.76	2.93	0.00	-0.11
Other manufacturing	1.79	2.02	0.00	-0.05
Furniture	0.57	2.26	0.00	-0.09
Other manufacturing	1.07	1.82	0.00	-0.02

Source: e-SAGE output

Table 10: Potential sectorial movement of jobs

Sectors	Skills level	base	Deviation from base Gas1	Gas2
aagri	flab-m	1.013946	1.063161	1.228884
aagri	flab-p	1.074295	1.13386	1.326229
aagri	flab-s	3.571452	3.619641	3.78591
aagri	flnd	5	5	5.000001
abchm	flab-m	6.137063	6.161342	6.233179
abchm	flab-p	6.200473	6.235608	6.335336
abchm	flab-s	8.824278	8.846786	8.916612
abchm	flab-t	8.91317	8.933134	8.992882
abevt	flab-m	-0.80787	-0.76927	-0.64219
abevt	flab-p	-0.7486	-0.69985	-0.54665
abevt	flab-s	1.703515	1.740861	1.867572
abevt	flab-t	1.78659	1.821572	1.938905
abiom	flab-m	0.964499	0.975299	1.085785
abiom	flab-p	1.024819	1.045937	1.182992
abiom	flab-s	3.520754	3.529557	3.639196
abiom	flab-t	3.605313	3.611687	3.711771
absrv	flab-m	3.945594	3.974277	4.042088
absrv	flab-p	4.007695	4.047013	4.142139
absrv	flab-s	6.577325	6.604396	6.670175
absrv	flab-t	6.664381	6.688965	6.744872
aclth	flab-m	2.543028	2.570984	2.65061
aclth	flab-p	2.604291	2.642738	2.749322
aclth	flab-s	5.139248	5.165606	5.243548
aclth	flab-t	5.22513	5.249033	5.317246
acoal	flab-m	-2.45902	-6.26277	-16.8551
acoal	flab-p	-2.40074	-6.1972	-16.7751
acoal	flab-s	0.01056	-3.89161	-14.7549
acoal	flab-t	0.092252	-3.81536	-14.6952
acomm	flab-m	3.733667	3.767321	3.85131
acomm	flab-p	3.795642	3.839912	3.951177
acomm	flab-s	6.360033	6.392205	6.474578
acomm	flab-t	6.446912	6.476606	6.549138
acons	flab-m	6.125755	6.236399	6.528798
acons	flab-p	6.189159	6.310717	6.631239
acons	flab-s	8.812684	8.923741	9.219698
acons	flab-t	8.901566	9.01015	9.29618
aemch	flab-m	3.860304	3.926023	4.105471

aemch	flab-p	3.922355	3.998725	4.205582
aemch	flab-s	6.489876	6.554922	6.735159
aemch	flab-t	6.576861	6.639452	6.809901
afish	flab-m	0.591399	0.653153	0.884587
afish	flab-p	0.651497	0.723566	0.981601
afish	flab-s	3.138208	3.199262	3.432916
afish	flab-t	3.222455	3.28113	3.505346
afood	flab-m	0.281523	0.284913	0.271556
afood	flab-p	0.341436	0.355068	0.36798
afood	flab-s	2.820486	2.821707	2.8044
afood	flab-t	2.904474	2.903276	2.87639
afoot	flab-m	2.726306	2.759651	2.877962
afoot	flab-p	2.787679	2.831537	2.976893
afoot	flab-s	5.327166	5.359045	5.476643
afoot	flab-t	5.413201	5.442627	5.550505
afore	flab-m	2.153886	2.243252	2.34664
afore	flab-p	2.214917	2.314777	2.44506
afore	flab-s	4.740254	4.829583	4.9319
afore	flab-t	4.825809	4.912745	5.005379
afsrv	flab-m	3.092185	3.109775	3.167667
afsrv	flab-p	3.153777	3.181906	3.266876
afsrv	flab-s	5.70231	5.718026	5.773666
afsrv	flab-t	5.788651	5.801892	5.847735
afurn	flab-m	3.366369	3.424002	3.623822
afurn	flab-p	3.428125	3.496353	3.72347
afurn	flab-s	5.983435	6.040202	6.241343
afurn	flab-t	6.070006	6.124323	6.31574
aglas	flab-m	3.591922	3.608348	3.658682
aglas	flab-p	3.653812	3.680828	3.758363
aglas	flab-s	6.214699	6.229211	6.277084
aglas	flab-t	6.301459	6.313483	6.351506
agsrv	flab-m	1.177501	1.183086	1.198951
agsrv	flab-p	1.237948	1.253869	1.296267
agsrv	flab-s	3.739148	3.7426	3.75522
agsrv	flab-t	3.823886	3.824899	3.827876
ahotl	flab-m	4.04331	4.083717	4.225621
ahotl	flab-p	4.105469	4.15653	4.325848
ahotl	flab-s	6.677515	6.716605	6.858344
ahotl	flab-t	6.764653	6.801263	6.933172
airon	flab-m	4.527353	4.659343	4.868698
airon	flab-p	4.589802	4.732558	4.969543
airon	flab-s	7.173813	7.306792	7.517665
airon	flab-t	7.261356	7.391918	7.592955

aleat	flab-m	2.698958	2.773386	3.021912
aleat	flab-p	2.760315	2.845281	3.120981
aleat	flab-s	5.299127	5.373128	5.624229
aleat	flab-t	5.385139	5.45672	5.698194
amach	flab-m	3.084558	3.174004	3.42177
amach	flab-p	3.146145	3.24618	3.521224
amach	flab-s	5.694489	5.78388	6.034188
amach	flab-t	5.780824	5.867798	6.108439
ametp	flab-m	2.683493	2.737799	2.8781
ametp	flab-p	2.744841	2.80967	2.977031
ametp	flab-s	5.28327	5.336641	5.476785
ametp	flab-t	5.369269	5.420205	5.550646
anfrm	flab-m	3.471397	3.52522	3.72658
anfrm	flab-p	3.533215	3.597642	3.826327
anfrm	flab-s	6.091123	6.143981	6.346698
anfrm	flab-t	6.177782	6.228185	6.421168
angas	flab-m	35.49999	70.70966	178.2159
angas	flab-p	35.58095	70.82908	178.4834
angas	flab-s	38.93063	75.0279	185.2436
angas	flab-t	39.04411	75.16675	185.4433
anmet	flab-m	6.685521	6.831836	7.168828
anmet	flab-p	6.749259	6.906571	7.271885
anmet	flab-s	9.386622	9.53424	9.875896
anmet	flab-t	9.475973	9.621133	9.952838
aochm	flab-m	2.366452	2.388465	2.439903
aochm	flab-p	2.42761	2.460091	2.538412
aochm	flab-s	4.958202	4.97847	5.027519
aochm	flab-t	5.043935	5.061749	5.101065
aoman	flab-m	0.922655	0.962694	1.105218
aoman	flab-p	0.98295	1.033323	1.202445
aoman	flab-s	3.47785	3.516633	3.65912
aoman	flab-t	3.562374	3.598752	3.731709
aomin	flab-m	1.743859	1.812067	1.987163
aomin	flab-p	1.804645	1.883291	2.085238
aomin	flab-s	4.319846	4.387492	4.563343
aomin	flab-t	4.405058	4.470302	4.636565
aosrv	flab-m	2.921789	2.954366	3.031366
aosrv	flab-p	2.983278	3.026388	3.130445
aosrv	flab-s	5.527599	5.558686	5.633922
aosrv	flab-t	5.613797	5.642425	5.707894
apapr	flab-m	2.323175	2.433752	2.464464
apapr	flab-p	2.384307	2.50541	2.562997
apapr	flab-s	4.913829	5.024903	5.0527

apapr	flab-t	4.999526	5.108219	5.126264
aplas	flab-m	1.862479	1.894671	1.984483
aplas	flab-p	1.923335	1.965952	2.082554
aplas	flab-s	4.441469	4.472186	4.560594
aplas	flab-t	4.52678	4.555063	4.633814
aprnt	flab-m	2.166157	2.191481	2.252317
aprnt	flab-p	2.227195	2.262969	2.350646
aprnt	flab-s	4.752836	4.776503	4.835194
aprnt	flab-t	4.838401	4.859622	4.908606
arcyc	flab-m	2.996819	3.087692	3.339073
arcyc	flab-p	3.058354	3.159808	3.438447
arcyc	flab-s	5.604529	5.695385	5.949401
arcyc	flab-t	5.69079	5.779233	6.023594
arubb	flab-m	1.99849	2.01738	2.060725
arubb	flab-p	2.059428	2.088747	2.15887
arubb	flab-s	4.580924	4.597998	4.638763
arubb	flab-t	4.666349	4.680976	4.712037
asequ	flab-m	3.035832	3.118084	3.380994
asequ	flab-p	3.09739	3.190221	3.480408
asequ	flab-s	5.644529	5.726546	5.992381
asequ	flab-t	5.730823	5.810419	6.066603
atequ	flab-m	2.038918	2.146981	2.499735
atequ	flab-p	2.09988	2.218439	2.598302
atequ	flab-s	4.622375	4.730878	5.088862
atequ	flab-t	4.707834	4.813961	5.162452
atext	flab-m	2.909591	2.967114	3.092092
atext	flab-p	2.971074	3.039145	3.191228
atext	flab-s	5.515092	5.571756	5.696182
atext	flab-t	5.601281	5.655506	5.770196
atrad	flab-m	1.970022	1.994622	2.046762
atrad	flab-p	2.030943	2.065973	2.144893
atrad	flab-s	4.551735	4.574664	4.624447
atrad	flab-t	4.637136	4.657623	4.697711
atran	flab-m	2.485747	2.469757	2.414707
atran	flab-p	2.546976	2.54144	2.513192
atran	flab-s	5.080517	5.061818	5.001687
atran	flab-t	5.166351	5.145163	5.075215
avehi	flab-m	3.211902	3.283529	3.503331
avehi	flab-p	3.273565	3.355782	3.602863
avehi	flab-s	5.825057	5.896175	6.117808
avehi	flab-t	5.911499	5.980183	6.192118
awatr	flab-m	2.069288	2.132135	2.003804
awatr	flab-p	2.130269	2.203583	2.101894

awatr	flab-s	4.653515	4.715656	4.580404
awatr	flab-t	4.738999	4.798727	4.653637
awood	flab-m	2.607149	2.658746	2.80622
awood	flab-p	2.668451	2.730562	2.905082
awood	flab-s	5.204993	5.255588	5.403089
awood	flab-t	5.290928	5.339087	5.476899

Table 14: Total CO2 emissions by primary fuels based on the reference approach (Ratio to baseline emissions (2015 to 2030)

	Deviation from base	
Period	Gas 1	Gas 2
2015	-1%	-5%
2018	-1%	-5%
2020	-1%	-5%
2023	-1%	-5%
2025	-1%	-5%
2028	-1%	-5%
2030	-1%	-6%