A comparative assessment of the economic benefits from shale gas extraction in the Karoo, South Africa

R. Wait & R. Rossouw

ABSTRACT

It has been said that the development of a shale gas industry could be a 'game changer' for South Africa. Proponents of shale gas tend to emphasise the benefits, whilst opponents emphasise the environmental costs. This paper is an attempt to inform the policy debate by highlighting both the potential economic benefits and environmental costs. To date, the Econometrix report (published in 2012) provides the only estimate of the economic impacts that may emanate from developing the Karoo's shale gas. The report uses a Keynesian multiplier model to estimate the impacts. The analysis performed in this paper estimates the economic impacts using a Computable General Equilibrium (CGE) modelling approach, and the results are compared to the findings of the Econometrix report. In doing so, this paper provides an expanded view of the potential economic impact. Accordingly, this paper provides a number of findings on the estimated economic impact of shale gas extraction – based on the application of an economy-wide impact modelling methodology – which should be of interest to both opponents and proponents of the shale gas industry. By including all possible results, such as a boost in public sector jobs and an analysis of the impact on consumer prices and jobs in other sectors, this paper expands the current understanding of the likely impact of shale gas extraction in the Karoo of South Africa.

Key words: shale gas extraction, economy-wide modelling, CGE, exhaustible resources, energy, macro-economy, economic development, water pollution

Mr R. Wait and Prof. R. Rossouw are both lecturers in the School of Economics, North-West University (Potchefstroom campus). E-mail: requier.wait@nwu.ac.za; riaan.rossouw@nwu.ac.za

Introduction

Companies are planning to explore and exploit the shale gas reserves of the Karoo of South Africa and, as elsewhere with shale gas projects, have encountered substantial local opposition. Various action groups and local communities have initiated lobbying and protest action. Proponents of shale gas emphasise the potential economic benefits, such as job creation and economic growth, associated with the development of this resource. Opponents emphasise the environmental risk associated with hydraulic fracturing (fracking) used to extract shale gas. The main environmental concern is water pollution, as water is a particularly scarce resource in the Karoo.

The Karoo is estimated to have 390 trillion cubic feet (Tcf) in (unproven) technically recoverable shale gas resources (EIA 2013). Vermeulen (2012) argues that further exploration is necessary to determine the true scale and commerciality of shale gas reserves. Exploration will provide a better understanding of the Karoo's geological and water configuration and the impact it will have on the fracturing process.

The uncertainties surrounding the scale of economic benefits and environmental costs make fracking a contentious issue for public policy. The South African government initially imposed a moratorium on exploration pending a review of the fracking process. This moratorium has now been partially lifted, opening the Karoo for exploration activities, but not yet fracking (DMR 2012). If the Karoo's shale gas is to be extracted, efforts will need to go beyond exploration.

Many earlier industry studies have attempted to quantify the benefits and to a lesser extent the environmental risks of shale gas extraction in the United States (US). Kinnaman (2011) provides an overview and critique of these studies. Regeneris Consulting (2011) prepared a similar industry report for Lancashire and the United Kingdom (UK). In their research note, Ames et al. (2012) conducted a cost–benefit analysis of shale gas for the US. They concluded that the economic benefits of shale gas exceed the costs.

The only recent academic work (i.e. peer-reviewed scientific publication) on this topic is the study by Weber (2012), which estimated the gains to employment, labour compensation and household income associated with escalating gas production for the states of Colorado, Texas and Wyoming in the US. The results suggest that regions with a growing gas sector experience higher growth in employment and labour income. No academic work has yet evaluated the potential economic impact of exploiting the Karoo's shale gas reserves.

Objective, problem statement and outline of the study

The objective of this paper is to evaluate the potential economic benefits and environmental costs associated with shale gas extraction. The shale gas industry is still a new phenomenon in South Africa, and the exact level of shale gas resources is still to be confirmed by further exploration. At this stage, only ex-ante predictions of economic impacts are possible. However, a report entitled 'Karoo shale gas report: A special report on economic considerations surrounding potential shale gas resources in the southern Karoo of South Africa' has been released by Econometrix (2012). This report is currently the only available estimate of the economy-wide impacts from developing the Karoo's shale gas, assuming two reserve values of 20 Tcf and 50 Tcf. It is an industry-sponsored report, which has led to criticism and doubt with respect to the results. The research question to be answered is whether shale gas development will have a significant economic impact on the South African economy as compared to the estimates of the Econometrix report.

The paper is organised as follows. The next section provides an overview of the benefits and costs of shale gas development. This is followed by a review of the economy-wide modelling methodology and the specification of the CGE model. Thereafter, the CGE-based economic impact results are presented. The summary results section compares the CGE results with those of the Econometrix report. Finally, the conclusion highlights the policy considerations critical to public discourse.

Benefits and costs of shale gas development

Arguments for developing the shale gas industry

Logic suggests that the benefits of shale gas should outweigh the costs when pursuing the development of shale gas reserves. The economic benefits of an expanding gas industry, enhanced by shale gas production, will depend on the gas/inter-industry linkages with other domains in the economy. Most notably, increased employment, income, government revenue and economic growth are expected. Furthermore, consumers can benefit from using shale gas as a source of energy (Kinnaman 2011). Such use could create a positive spill-over effect by reducing the demand for more carbon-intensive energy sources such as oil and coal. South Africa's current energy supply is highly constrained. The supply constraint, linked to rising energy prices associated with expanding generation capacity, has a negative impact on the economy. Rising energy costs further impact on the competitiveness of energy-intensive producers such as the mining and refining sectors. The presence of significant shale gas could warrant the establishment of gas turbines, which are easier to install or expand (by adding turbines). This could represent a further positive impact/spill-over for the rest of the economy. Once the appropriate infrastructure is in place, shale gas could also be used as an industrial feedstock.

Wang et al. (2011), by considering the higher power-generation efficiency of shale gas, conclude that over the long run, shale gas has a lower carbon footprint than coal. The short run carbon footprint of shale gas can be reduced to a level similar to that of coal by using existing technology to minimise methane emissions. The environmental impact could be reduced even further by storing CO_2 emissions in depleted shale gas reservoirs. In a recent study, Cohen and Winkler (2014) conclude that, regardless of the time assumptions used, shale gas produces less greenhouse gas emissions per MWh of electricity generated than coal.

However, there are opposing opinions on the use of shale gas as a cleaner 'bridge fuel' to replace coal or oil; this is clear from the debate in the literature, for example, the work of Howarth, Santoro and Ingraffea (2011, 2012) and Cathles, Brown, Taam and Hunter (2012). It must be noted that the issue of shale gas being 'cleaner than coal' does not only entail lower emissions of methane. The substitution of shale gas for coal also eliminates the other emissions associated with the combustion of coal as well as the effluents associated with coal mining. The environmental costs from shale gas are also different from the impacts of natural gas obtained from in-situ coal bed gasification (proposed for the Waterberg coal fields) or further coal mining. If shale gas developments lead to a lower domestic gas price, it will impact on the appeal of both coal bed gasification and coal.

The effects of a growing natural resource industry will vary based on the economic setting, the commodity in question and the time horizon being evaluated (Weber 2012). The impact of gas extraction can occur during two periods, namely the development stage and the production stage. The development stage entails exploration and infrastructure investments, whilst the production stage entails the production and distribution of gas. Depending on the petroleum fiscal system, revenues and taxes may accrue to the government from the early stages of exploration or only (from excise) once production has started.

Considine et al. (2009) estimated the economic impact of the Marcellus shale gas industry in Pennsylvania for 2008 and 2009. The study used an IMPLAN input–output model to estimate the multiplier impacts of shale gas extraction. The impact estimates for 2008 estimated an addition to value added of US$2.3 billion, the creation of more than 29 000 jobs and US$240 million in state and local taxes. The estimates for 2009 were US$3.8 billion for economic output, state and local taxes worth more than US$400 million and job creation in excess of 48 000. Over-optimistic assumptions of spending behaviour and drilling activity call into question these results (Kinnaman

2011). In a follow-up study, Considine et al. (2010) estimated the following economic impacts for 2009: impact on gross output of US$7.17 billion, value added of US$3.87 billion and increased employment of 44 098 jobs. The over-optimistic assumptions of the initial study are still present in the follow-up study (Kinnaman 2011). The CBER (2008) conducted a similar study of the extraction of the Fayetteville shale reserves in Arkansas. The estimated impacts for 2007 were an addition to gross output of US$2.6 billion and the creation of 9 533 jobs.

In contrast to the above-mentioned ex-ante input–output studies, Weber (2012) conducted an ex-post assessment of an expanding gas sector in Colorado, Texas and Wyoming. The study estimates income and employment impacts, and further examines the distribution of these impacts among the local population. Increased income and employment impacts do not necessarily translate into reduced poverty rates. The distributional impacts depend on the existing level of skills, the existing income distribution, the structure of the local labour market, and the size of the spill-over effects for other sectors in the economy. Weber (2012) uses OLS and IV regression analyses to evaluate economic impacts over several years. The results suggest that boom regions, with a growing gas sector, experience higher growth in employment and labour income. According to this analysis, each million dollars in gas production creates 2.35 jobs. Furthermore, Weber (2012) uses this estimate to calculate and compare employment impacts from the Marcellus shale gas production on Pennsylvania's economy. The Considine et al. (2010) employment estimate for Marcellus amounts to 44 098 and far exceeds the ex-post value of 2 183 estimated by Weber (2012) using the assumption of 2.35 jobs per million dollars of gas production. The same is true when comparing the CBER (2008) study's employment estimates of 9 533 jobs with the 1 377 jobs estimated in the ex-post analysis (Weber 2012). Although the ex-post impact results are smaller than the estimates of the input–output studies, Weber (2012) regards these impacts as modest but still significant.

An important caveat is that the input–output studies consider employment impacts created over the entire state, whilst Weber's estimates focus only on employment created in the region that produces the gas. Furthermore, the oil and gas sector uses temporary but skilled workers, who might migrate from other areas and would not be captured by the region-specific focus that is used. In addition, tax revenue could have an indirect benefit for residents if it leads to lower taxes or increased government spending on infrastructure and service delivery.

Regeneris Consulting (2011) estimated the employment impacts from shale gas extraction for Lancashire and the UK using three possible scenarios: a central case, a lower-end case and a higher-end case. The number of wells drilled and the pace with which drilling is completed are considered important determinants of the scale and nature of employment impacts. The analysis spans the period from 2013 to 2032.

Regeneris Consulting (2011) identified four key differences between the US and UK's shale gas industry. Firstly, the scale of the US's gas reserves is much greater than that of the UK. The large US reserves have attracted specialist service providers to specific shale plays, whereas the UK may not attract the supply chain to specific plays to the same extent. Secondly, there are differences in geography; US shale plays, such as Marcellus in Pennsylvania, span over rural areas with relatively small populations. For this reason, the commuting of personnel from other regions is hampered, and suppliers have to set up a local base. Furthermore, the costs of connecting to the established gas and electricity networks are much higher. Thirdly, there are differences in drilling techniques. Due to the geology, vertical and directional drilling is the norm in the UK, whereas horizontal drilling is used in the US. For this reason, there will be differences in the time-scale and costs of drilling. Finally, there is a major difference in the payment of royalties. In the US, landowners own the mineral rights to minerals underneath their land and receive royalty payments, which supplement their income. In the UK, as in South Africa, mineral rights and royalties accrue to the government and not the landowners.

The estimated employment impacts arise from three processes: the main process (drilling and fracturing), the conversion process (spending to establish infrastructure for the distribution of shale gas or electricity from shale gas) and the maintenance process (costs for the maintenance of wells) (Regeneris Consulting 2011). The central case assumes that 190 wells are drilled over a six-year period; the lower-end case assumes that 400 wells are drilled over a nine-year period, and the higher-end case assumes that 810 wells are drilled over a 16-year period. The central case estimated a peak annual employment impact of 5 600 jobs for the UK and 1 700 jobs for Lancashire. The lower-end impact estimates show an annual peak of 3 400 jobs for the UK and 560 jobs for Lancashire. The higher-end impact estimates are an annual peak of 6 550 jobs for the UK and 2 500 jobs for Lancashire.

Ames et al. (2012) conducted a rudimentary cost–benefit analysis of shale gas extraction in the US. Comparing the estimated costs and benefits, they conclude that the benefits exceed the costs to the community by 400-to-1. The benefits, in terms of consumer surplus, are estimated by using the price reduction in natural gas prices caused by the expansion of shale gas production. The environmental cost is estimated in terms of the clean-up costs of potential accidents. The result is highly dependent on the assumptions made to derive the benefits and costs. It is questionable whether these measures are an accurate reflection of all the costs and benefits arising from shale gas extraction.

The following section draws from the Econometrix (2012) report, referred to as 'the report'. The report refers to the Marcellus and Lancashire studies and identifies a number of differences that hamper comparisons with the Karoo basin. The studies of the US and UK are based on the experience of developing shale gas, whereas South Africa has no prior experience, and extraction is still to take place. The US and UK already have the necessary downstream infrastructure in place, whilst the South African gas network is fairly limited in terms of the overall energy mix. The US and UK also have access to more detailed and publicly available data and have an experienced and competitive upstream supplier base. Consumers in the US and UK are more familiar with and confident in gas than South African consumers. The Karoo basin has still to be explored, making specific estimates of production and labour requirements difficult. The report identifies five potential areas of application for natural gas in South Africa, namely, exporting gas; the use of gas as an energy source for domestic, commercial and industrial applications; power generation; creating automotive fuels; and as an energy input in the fertiliser sector. The extent to which gas is exported will influence the scale of downstream value-adding activities. The exploration phase is likely to use mostly imported capital equipment, with a shift to more local content as the process moves from exploration to production.

The report assumes shale gas production will start by 2020 and estimates the potential economic impact of developing the Karoo basin, over a 25-year period (2020–2045), using two possible scenarios. Scenario A assumes a recoverable reserve of 20 Tcf, and scenario B assumes 50 Tcf. The model is calibrated to use constant 2010 prices. Both scenarios use a wellhead gas price of US$8/mcf and apply the 2010 Rand/US Dollar exchange rate of R7.303/$ for the conversion to Rand values. Scenario A modelled a combined turnover (upstream and downstream) of R4.031 trillion, a total value added (contribution to GDP) of R2.006 trillion, a R887 billion contribution to government revenue and maximum employment creation estimated at 355 817 jobs. Scenario B modelled a combined turnover (upstream and downstream) of R9.520 trillion, a total value added (contribution to GDP) of R5.015 trillion, a R2.223 trillion contribution to government revenue and maximum employment creation estimated at 854 757 jobs. The extent to which gas is exported will have a significant effect on the estimated economic impacts. The possible impacts arising from a situation where 0% of the gas is exported, where 50% of the gas is exported, and where 100% of the gas is exported are shown in Table 1.

The impact estimates fall significantly as the share of gas exports increases (Econometrix 2012). The case where 100% of the gas is exported will still be an improvement for the country's energy trade balance over the case of not producing shale gas. The estimated economic impact will vary with changes to the assumptions

Table 1: Summary of Econometrix report impact model results

	0% gas exports		50% gas exports		100% gas exports	
Combined upstream and downstream	**Scenario A**	**Scenario B**	**Scenario A**	**Scenario B**	**Scenario A**	**Scenario B**
Project turnover (Rand million)	4 031 773	9 520 268	3 069 827	7 115 402	2 107 881	4 710 537
Project value added (Rand million)	2 006 046	5 015 116	1 587 263	3 968 158	1 168 480	2 921 200
Project government revenue (Rand million)	886 808	2 223 494	705 894	1 771 208	524 979	1 318 922
Maximum employment (Number)	355 817	854 757	258 880	612 415	161 943	370 073

Source: Econometrix (2012)

of resource size and the wellhead gas price. Fakir (2012) critiques the use of a single value wellhead price and suggests the use of a range of possible prices incorporating the unique characteristics of South Africa's current gas market. Changing cost conditions will also have a significant effect on the estimated impacts.

Unlike the US, South Africa currently has very little infrastructure to support the development of natural gas resources. Pipelines are needed to transport the gas to distribution points and consumers. In terms of exporting the gas, gas-to-liquids (GTL) plant infrastructure will be needed. Establishing this infrastructure should provide a significant injection of income and employment for the economy. However, this will be a temporary impact. Once the infrastructure is in place, there should only be minimal maintenance expenditures and limited employment impacts.

To obtain employment figures for a typical fracking well, as a means of approximating the direct employment effect of the 'fracking' activity, the authors consulted Dobie Langenkamp (2014), an oil and gas expert involved in fracking operations in Oklahoma. Langenkamp suggests that a true calculation will involve approximately 150 people for varying amounts of time, depending on the depth of the well and the size of the 'frack'. The estimates are summarised in Table 2.

The case against developing the shale gas industry

Potential negative externalities underpin the main argument against developing the shale gas industry. Such externalities typically include the deterioration of roads associated with the increased traffic of heavy trucks and equipment, conceivable health problems among the local population and environmental contamination (Weber 2012). Little (and by no means comprehensive) analysis has been undertaken in the Econometrix report quantifying the success or failure of countries or regions

Table 2: Estimates of employment per well in Oklahoma

Position	**Number of employees**
Financiers, accountants, lawyers arranging funding, preparing contracts	4
Land men, geologists, surveyors, seismic experts involved in well location	6–8
Labourers, dozer operators in location preparation	4
Drilling company – moving in , rigging up (might involve 20 trucks and drivers, dozers, mechanics, electricians)	20
Professional staff during drilling – company man, mud logger, pet. engineer	3
Mud company – mud programmer	1
Drill bit contractor	1
Special tool contractor	1–3
Drilling rig contractor with 3–4 shifts of workers (18 minimum) plus tool pushers (2)	21
Completion drilling unit	6
Production string supply	2–4
Casing crew	6
Fracking compression truck drivers and operators	20
Fracking water truck drivers	20
Fracking sand truck drivers	20
Tank site construction and hook-up	6
Road construction and maintenance crew	2
Pumper and guager	2

Source: Langenkamp (2014)

in effectively and safely managing natural gas development. Without such information, it is difficult for regulators, government officials and citizens to engage in useful discussion around natural gas development and the process of fracking (Considine et al. 2012). Whether making an allowance for regulatory changes in a province where activity is already under way, or debating whether natural gas development should be allowed, calculating methods of success is necessary for building unanimity and making thorough decisions (Considine et al. 2012).

The Econometrix report does not provide any exhaustive analysis of the potential environmental impacts (or associated costs) of shale gas extraction. The only topic of relevance covered is the implications for water resources and the associated possible constraints for the shale gas extraction activity. Although this is a major concern and also one of the most contentious aspects of fracking (especially in the dryer, semi-desert areas of South Africa, i.e. the Karoo), there are numerous other environmental factors that also need consideration. Some of these environmental issues concern air pollution (from methane emissions and production operations), land use, and fracturing fluid composition and reporting (Bluestein et al. 2012).

As regards land use, shale gas extraction results in high land occupation due to drilling pads, car parks and manoeuvring areas for trucks, equipment, gas processing and transporting facilities in addition to access roads (Lechtenböhmer et al. 2011).

However, the issue of land use by fracking is debatable when considering the relatively small area used in comparison to other forms of mining. Other possible effects include air emissions of pollutants, groundwater pollution due to unrestrained gas or fluid flows due to blowouts or spills, leaking fracturing fluid, and unrestrained waste water release (Lechtenböhmer et al. 2011). Fracturing fluids contain harmful elements, and flow-back in addition contains heavy metals and radioactive materials from the deposit (Bluestein et al. 2012).

Know-how from the US shows that many mishaps occur during extraction, which can harm the environment and be harmful to human health. The verified abuses of legal requirements amount to about 1–2 % of all drilling permits, and many of these mishaps are due to incorrect handling or leaking equipment (Lechtenböhmer et al. 2011). Contamination of groundwater by methane, which in certain extreme cases has led to the explosion of residential buildings, and potassium chloride, resulting in salinisation of drinking water, has been reported in the locality of gas wells. These negative effects multiply when shale formations are developed with a high well density of up to six well pads per square kilometre (Lechtenböhmer et al. 2011).

All these (mostly environmental) issues need to be understood and reflected on if government bodies are to positively augment current and draft regulations to safely regulate the new industry. In this regard, there are verified measures available to lessen the probable environmental effects of shale gas extraction (Lechtenböhmer et al. 2011).

Regarding the contamination of groundwater, a recent study by Davies et al. (2012) has found that the technique to extract unconventional gas can be safely implemented. According to their research, fracking has well below a 1% chance of causing unintended cracks in the ground beyond 600 metres. The study, which used data from hundreds of both natural fractures and fracking operations in Europe and the US, shows that if operations are kept at an adequate distance from aquifers, there is virtually no chance of groundwater contamination. The research also found that the chance of unintentional fractures forming 350 metres from the site was about 1%. However, in South Africa, the depths of the gas-bearing shale rock layers range between 4 000 metres and 6 000 metres (Naidoo 2012). This is much deeper than the depths at which shale gas is extracted in the US, which may reduce the risk to groundwater even further. A more recent study by the US Department of Energy at a western Pennsylvania drilling site suggests no evidence of water contamination from fracking (Begos 2013). However, Rob Jackson, a Duke University scientist, cautions that a single study does not prove water pollution can never occur, since geology and industry practices are not homogeneous (Begos 2013).

It is also important to put the threat to agriculture into context in order to establish the full value of agricultural production in the central Karoo basin, and how much of that production could feasibly be at risk if the worst-case pollution event were to arise. Accordingly, Table 3 shows the size of the agricultural sector in the Karoo relative to the region and national output, the contribution to economic growth, as well as the percentage of land used for agricultural purposes in 2012.

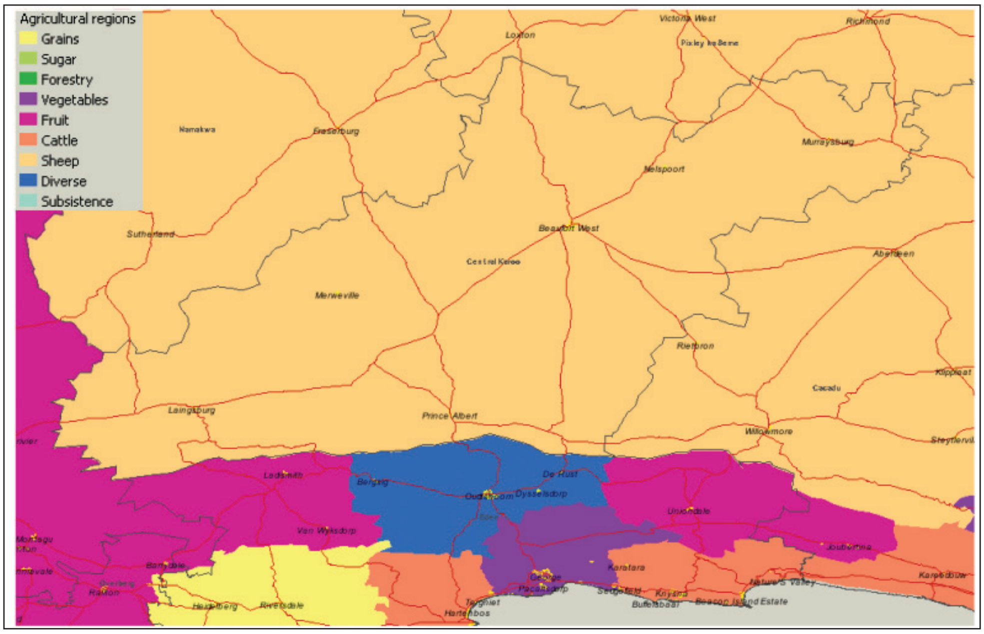
Table 3: Agriculture in the central Karoo basin, Western Cape (2012)

Category	Indicator	Value
Gross value Added (GVA)	GVA (current prices, R1 000)	R379 576
	Sector's share of regional total (%)	19.3%
	Region's share of national total (%)	0.5%
	Contribution to total economic growth (% point, constant 2005 prices)	0.1%
Land use (% of area)	Developing and commercial agriculture (i.e. farm land, potential arable, arable and grazing land)	36.3%

Source: IHS Global Insight Southern Africa, Regional eXplorer (2014)

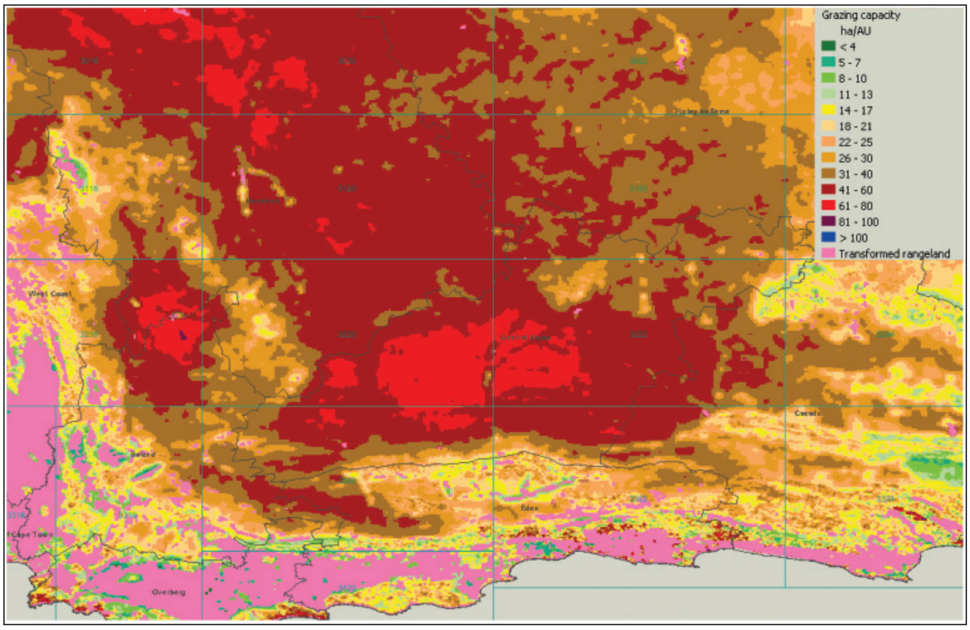
The central Karoo's agricultural sector contributed 19.3% to the region in terms of value added, and 0.5% to national value added. Moreover, the sector contributed a mere 0.1% to total economic growth in 2012. Although this contribution is relatively small, the area used for the agricultural activity is notably large (approximately 37%) and, therefore, in the event of pollution, could affect a significant number of households in the region.

Figure 1 shows that the largest proportion of the land area in the central Karoo basin is used for extensive sheep farming (represented by the light orange shaded areas in the map). Moreover, Figure 2 highlights that the predominant grazing capacity potential in the central Karoo area is very low, with a carrying capacity of between 41 and 80 hectares per animal unit (ha/AU). This illustrates the level of extensiveness of livestock production in the area. Moreover, the area has high species diversity, but of low to medium grazing quality, and is thus mainly suitable for livestock farming with conservation of the indigenous plant species (Pekeur 2012).



Source: ARC (2008)

Figure 1: Agricultural regions in the central Karoo basin, Western Cape



Note: AU = animal unit
Source: ARC (2008)

Figure 2: Grazing capacity in the central Karoo basin, Western Cape

This section attempts to stress the environment-specific risks of shale gas extraction. The level of waste products generated, the potential risk of damage to land, as well as the possible contamination of groundwater aquifers used by the agricultural sector and rural communities, are but some of the risks that have been documented. For a more complete picture, a balanced economic analysis should address the costs associated with shale gas extraction and the disposal of potentially harmful elements. If these are fully captured, then the level of negative benefits generated from shale gas extraction might be significantly higher as they will include major reductions to agricultural sector capacity from the probable scale of environmental degradation.

Perhaps the rising controversy over shale gas extraction is in part due to lax environmental impact assessments, as demonstrated by the Econometrix report.

Broader economic implications

The preceding sections discussed the different methodologies and findings of several studies, each attempting to quantify the potential impact of fracking on their respective economies. The approach used in this paper is to apply an economy-wide impact-modelling methodology in the form of a Computable General Equilibrium (CGE) model for South Africa for the shale gas question.

CGE models have been shown in past studies to be an appropriate method for modelling energy-related issues. Bhattacharyya (1996) provides a detailed overview of the application of CGE models to improve the understanding of energy policy implications in various countries over the period 1974 to 1993. Since then, many more such models have been developed and applied to topics ranging from carbon emission tax policies (e.g. Sulamaa 1995) to analysing the impact of the stimulus to energy efficiency on the economy and environment (e.g. Hanley et al. 2006).

In South Africa, CGE models have been used with increasing frequency since first applied in the country by Naudé and Brixen (1993). Energy issues have also been a major area of focus in the growing application of CGEs (see e.g. Alton et al. 2012; Devarajan et al. 2009; Altman et al. 2008; Cameron & Naudé 2008; Van Heerden et al. 2006; Van Heerden et al. 2008; and De Wet & Van Heerden 2003). Furthermore, after the 2008 energy (load-shedding) crisis, energy issues have started receiving much more focus.

Some of the qualifying factors that show CGE models to be a suitable method for the current analysis include (Arndt et al. 2008):

- CGEs simulate the working of a market economy, as well as the markets for labour, capital and commodities, thus giving a view on how changes in economic settings could be facilitated through prices and markets.

- CGEs, by their basic nature, permit consideration of new occurrences, such as fracking.
- CGEs guarantee that all economy-wide constraints are valued. For example, fracking is likely to reduce input costs, as it is a substitute for fuel imports, is expected to occupy some quantities of land, and the associated economic activities of fracking may require notable quantities of labour (i.e. the weakness of fracking is that the technology is skill- and capital-intensive and uses relatively little unskilled labour, hence the benefits to the economy will most likely flow from the up- and downstream activities linked to fracking). It is thus vital to study the balance of payments (BoP), the supply of land and the supply of labour.
- Given the level of disaggregation in CGEs, they provide a platform for investigating how dissimilar factors and networks of impact will affect the economy, how these factors and networks will interact, and which are the most important.
- CGEs offer a theoretically sound basis for welfare and distributional analysis.

According to Arndt et al. (2008), CGE models also have notable shortcomings. In an attempt to develop a complete picture of the entire economy, some detail might be lost, rendering the approach unsuitable. Likewise, some concerns can be sufficiently addressed with economic structures that are less broad, permitting the analyst to focus on analysis rather than data issues and modelling (Arndt et al. 2008).

Due to the potential scale of fracking and the expected up- and downstream implications for the economy, the CGE method was adopted.

The CGE model

A CGE model is "an economy-wide model that includes feedback between demand, income and production structure, and where all prices adjust until decisions made in production are consistent with decisions made in demand" (Dervis et al. 1985: 132). The model is applied using economy-wide consistent data on a particular economy that is captured in a Social Accounting Matrix (SAM). For this study, the most recent published SAM for South Africa (i.e. the official 1998 SAM) is used (StatsSA 2001; 2009). Although the model database is by now outdated, it still captures the inter-linkages and interaction in the local economy. Furthermore, the reaction and interaction between the economic agents (i.e. variables) in the model are far more important than the actual values. It could also be expected that the current economic structure captured in the database may well change profoundly based on a significant gas find. Other parameters used in the model, such as elasticities, are obtained from other econometric studies or by making plausible 'guesstimates' (Van Heerden et al. 2008).

The model used, in conjunction with the above database, is a South African adaptation of the Australian ORANI-G (G = generic) model termed the UPGEM, formally known as the University of Pretoria General Equilibrium Model (see Van Heerden et al. 2008). The UPGEM version used differentiates 39 sectors (including six additional agricultural and six additional energy-related sectors that were not in the original 1998 SAM – see Van Heerden et al. 2006; Van Heerden et al. 2008), 12 household types and four ethnic groups. For a more detailed discussion of the modelling approach followed in UPGEM, see Horridge (2000).

The UPGEM database captures the structure of the South African economy (shown in Table 4) and substantially influences the model results. Yet, it is also the relative change in the variables of the model that is of key importance and that should inform the decision-making process. Since shale gas extracted through fracking will most likely replace fuel imports, considerable escalations in the production of shale gas will have implications for trade. As a result, it might be expected that sectors with high trade shares (with either high export intensity or import penetration) would be relatively more affected than the non-traded sectors.

Table 4: Structure of the South African economy based on the UPGEM database (1998)

	Share of total (%)				**Export intensity (%)**	**Import penetration (%)**
	GDP	**Employment**	**Exports**	**Imports**		
Total GDP	*100*	*100*	*100*	*100*	*13.4*	*7.9*
Irrigated field	0.2	0.1	0.5	0.3	31.5	10.5
Dry field	0.7	0.2	1.7	1.0	31.8	10.6
Irrigated horticulture	0.6	0.4	1.6	0.4	36.8	5.1
Dry horticulture	0.2	0.1	0.4	0.1	36.3	5.1
Livestock	1.1	0.6	0.0	0.2	0.0	1.3
Forestry	0.3	0.4	0.1	0.7	4.9	18.1
Other agriculture	0.4	0.3	0.0	0.4	0.0	7.1
Coal	1.4	1.0	5.3	0.4	52.0	2.3
Gold	2.1	3.0	14.7	0.0	92.8	0.0
Crude, petroleum & gas	0.3	0.2	0.0	3.3	0.0	82.1
Other mining	2.2	1.8	16.0	10.3	99.3	37.7
Food	6.6	2.7	5.1	4.2	10.5	5.1
Textiles	1.7	1.6	2.0	2.0	16.4	9.7
Footwear	0.2	0.2	0.1	0.2	6.0	9.9
Chemicals & rubber	4.1	2.7	5.7	7.9	18.6	15.2

Table 4 continued

Table 4 continued

	GDP	Employ-ment	Exports	Imports	Export intensity (%)	Import penetra-tion (%)
Petroleum refineries	2.6	0.9	3.7	10.0	19.3	31.0
Other non-metal minerals	0.9	0.7	0.8	1.8	11.6	15.4
Iron & steel	1.6	0.8	9.9	12.0	85.0	60.8
Non-ferrous metal	0.9	0.3	5.6	5.7	83.6	50.0
Other metal products	1.9	1.6	1.3	3.8	9.1	15.7
Other machinery	2.4	2.0	2.1	2.6	12.0	8.7
Electricity machinery	0.9	0.5	1.0	2.6	15.1	22.6
Radio	0.5	0.4	0.9	5.6	24.7	94.6
Transport equipment	3.1	1.8	4.7	8.7	20.1	22.1
Wood, paper & pulp	3.2	1.9	4.9	6.8	20.7	17.1
Other manufacturing	1.2	1.0	2.9	1.0	32.8	6.9
Electricity	2.1	1.8	0.2	0.0	1.6	0.0
Water	0.6	0.2	0.0	0.0	0.0	0.1
Construction	5.2	3.6	0.0	0.1	0.1	0.1
Trade	10.1	11.1	0.1	0.1	0.1	0.1
Hotels	1.6	1.0	1.7	0.8	13.7	3.8
Transport services	5.5	5.5	3.4	3.1	8.3	4.6
Community services	2.8	2.7	0.6	1.2	3.2	3.6
Financial institutions	7.4	6.7	1.9	0.8	3.4	0.8
Real estate	4.4	0.8	0.0	0.1	0.1	0.2
Business activities	2.6	3.8	0.4	1.1	1.9	3.3
General government	11.7	28.0	0.0	0.0	0.0	0.0
Health services	1.8	1.6	0.1	0.0	0.6	0.1
Other service activities	3.0	6.0	0.4	0.7	1.6	1.9

Note: 'Export intensity' is the share of exports in domestic output, and 'import penetration' is the share of imports in total domestic demand.
Source: Compiled using the UPGEM database

Table 4 shows that the Crude Oil, Petroleum and Gas (CruPetGas) sector contributed 0.3% to sectoral output in 1998 (the SAM used is based on 1998 prices, but the same methodology could easily be applied to the latest figures for the industry) and ranked 35th out of the 39 sectors in the database.

According to the UPGEM database, imports of CruPetGas products were estimated to be R1 467 million. This represented around 3.3% of total imports in South Africa for the year 1998 (Table 2, column 5), which also had a positive trade balance and recorded a surplus of R12 867 million on its BoP during the same year. The surplus on the BoP corresponded to 7.1% of exports and 1.0% of GDP. The coverage ratio (ratio of total exports to total imports) is estimated to be 1.69.

Based on the UPGEM structure, producers maximise their profits under constant returns to scale, which is preceded by factors receiving income where marginal revenue equals marginal cost based on endogenous comparative prices (Van Heerden et al. 2008). Choosing between these factors is directed by a constant elasticity of substitution (CES) function.

In the model, the choice of producers to substitute between productions for either domestic of cross-border consumers is directed by a constant elasticity of transformation (CET) function. The CET encapsulates time or quality differences between the exported and domestic goods. Producers maximise profits, based on domestic and export prices, by selling in those markets with the highest potential for returns (Arndt et al. 2008).

Substitution, according to Arndt et al. (2008), for both final and intermediate usage, is also possible between imported and domestic goods via a CES Armington condition. Elasticities are different for the various sectors, with lower elasticities indicating more notable differences between domestic and imported goods.

The UPGEM applied in this paper is a basic single-period ‘static’ CGE model for South Africa (Van Heerden et al. 2008). Since fracking investment will unfold over a dozen years or more, a dynamic model would be better suited to capture the growth trajectories of such projects. Such a model was not available to the authors at the time of conducting the research, and accordingly it should be borne in mind that the model results represent a once-off effect over time and not a period-on-period change as with a dynamic model.

Scenarios: closure rules and assumptions

In the UPGEM, South Africa is assumed to be a ‘small country’ in which foreign currency import prices are determined on world markets, and prices for South African exports are likewise determined mainly on world markets. It is also necessary to specify the macro-economic setting in which the fracking activity via the CruPetGas sector is to be modelled. Results are presented for both a short- and long-run economic setting, with significant rigidities assumed to exist in the economy in the short run, and the economy adjusting fully to the shock applied in the long run.

To implement the simulation, a number of added assumptions were made that relate to the closure (i.e. the modeller's specification of the economic setting and period) of the model. In the present case, the first simulations were done using a short-run closure. This implies that the impact reflects the change over a short period (approximately two to three years) before investment can react to the changed market conditions (Bohlmann 2006). Herein, land, the rate of return on capital, employment, trade balance, technology variables and the real wage, amongst others, are exogenous. On the income-side of GDP, the real wage and capital are exogenous (and real cost of labour), and the nominal rate of return on capital is endogenous. On the expenditure-side of GDP, aggregate investment, government consumption and inventories are exogenous, while consumption and the trade balance are endogenous. These assumptions help in understanding the outcome of fracking on South Africa's consumption and competitiveness. Finally, all technological change and tax variables are exogenous.

The UPGEM differentiates between 11 labour groups, which can be classified as either skilled or unskilled. South Africa has a scarcity of skilled labour along with high levels of unemployment consisting of mainly unskilled labour. In addition, the bargaining power of trade unions means that wage flexibility is limited (Van Heerden et al. 2008). In this context, a fixed supply of skilled labour in the short run is assumed, alongside perfectly elastic unskilled labour supply at fixed post-tax real wages. In the long run, both skilled and unskilled employment is assumed to be fixed. For the model to calculate relative price changes, the nominal exchange rate is set to be the numéraire in both the short and long run (Van Heerden et al. 2008).

In terms of the long-run economic setting used for the simulations, some key features are:

- Aggregate investment moves with capital stock in the long run, whereas inventories follow industry output.
- Both government and aggregate household consumption change to ensure a fixed (balance of trade/GDP) ratio.
- Exporters face a constant elasticity of world demand, while growth in imports is driven by local demand and domestic/foreign price dependences (Van Heerden et al. 2008).

All results represent deviations from the values that the variables would have taken in the absence of the simulation shocks.

To conduct comparable analyses as in the Econometrix report, similar shocks were calculated and applied using the UPGEM. The following two scenarios were modelled:

- Scenario 1 (3 for the long run) with an assumed resource size of 20 Tcf
- Scenario 2 (4 for the long run) with an assumed resource size of 50 Tcf.

The US EIA report (EIA 2011) on shale gas resources outside of the US estimates South Africa's offshore natural gas production at 115 Bcf during 2008. This value (115 Bcf) was used to calculate the relative change in output (based on the above two resource sizes) to translate this increase in output into percentage change shocks to be applied in the UPGEM. This gave annualised percentage increases of 23.8 (20 Tcf) and 65.6 (50 Tcf) for the two scenarios respectively.

For the purposes of this study, the impacts of the potential increases in shale gas production of 23.8% and 65.6% are modelled for the extraction of crude petroleum/natural gas, and the incidental service activities sector (SIC22) denoted by the UPGEM sector 10 (CruPetGas). To apply these shocks, the 'activity level' or 'value-added variable', **x1tot**, for the CruPetGas sector (sector #10) was exogenised, and the 'all input augmenting technical change' variable, **a1tot**, for the CruPetGas sector (sector #10) was endogenised. The activity level in the CruPetGas sector was then shocked using both a short- and long-run closure to measure the resulting impact of the scenarios.

South Africa-wide macro-economic impacts

The results discussion concentrates on two variables, namely, overall economic output measured by gross domestic product (GDP), and employment. The macro-economic level impacts of the simulations are presented in Table 5. Columns 2 and 3 of the table summarise the results for the short run, while columns 4 and 5 give the results for the long run. Based on past studies, the short-run results are expected to be realised after two to three years, whereas the long-run results would only be realised after at least ten years (see e.g. Van Heerden et al. 2008; Dixon & Rimmer 2002).

Table 5: Macro-economic implications (% change)

Percentage (%) change	Short run		Long run	
	Scenario 1 Resource size of 20 Tcf	**Scenario 2 Resource size of 50 Tcf**	**Scenario 3 Resource size of 20 Tcf**	**Scenario 4 Resource size of 50 Tcf**
Gross domestic product (GDP)	0.15	0.30	0.29	0.69
Employment	0.02	0.03	0.00*	0.00*
Average real wage rate	0.10	0.18	0.65	1.52
Domestic consumption	0.11	0.19	0.28	0.65
Consumer price index	0.10	0.15	0.09	0.25
Government consumption	0.00*	0.00*	0.28	0.65
Exports (volume index FOB)	0.00	0.09	-0.04	-0.06
Export price index	0.00	-0.02	0.01	0.01
Imports (volume index CIF)	-0.36	-0.72	-0.07	-0.14
Import price index	0.00*	0.00*	0.00*	0.00*
Balance of trade (% of GDP)	0.08	0.19	0.01	0.02
Terms of trade	0.00	-0.02	0.01	0.01
Real exchange rate (depreciation/appreciation)	0.00*	0.00*	0.00*	0.00*

Note: * Exogenous by assumption

Source: UPGEM simulation results

The cause-and-effect reasoning apropos the results would be that owing to the increase in the output of the CruPetGas sector, other sectors increase sales or production output as a result of up- and downstream linkages, and consumer demand escalates due to induced employment gains. For downstream sectors such as petroleum refineries, chemicals and rubber, health services, electricity, trade and transport services, the impact is more significant than for other downstream as well as upstream sectors, with relatively larger implications for employment in these sectors (refer to Tables 6 to 9) in the short run. The service sectors are least affected by the shocks.

The macro-level results (Table 5) show that the effect of the increase in CruPetGas output on GDP is positive (between 0.15% and 0.69%) in both the short and long run. This can be ascribed to changes in domestic consumption and trade balance in the short run (given the import intensity of the South African economy), and also due to changes in investment, household and government expenditure, and the trade balance in the long run. In general, the effect across all scenarios is relatively small, with a more positive effect in the long run.

In the short-run scenarios (i.e. 1 and 2), real GDP growth increases by 0.15% and 0.30% respectively, with relatively higher levels of real GDP growth of 0.29% for scenario 1 and 0.69% for scenario 2 in the long run. These results also indicate that aggregate employment levels will increase overall by 0.02% and 0.03% respectively, mainly due to the employment gains in the CruPetGas sector (following the increase in output), as well as in the downstream sectors with strong links to the CruPetGas sector (i.e. petroleum refineries, and chemicals and rubber). The increase in activities or services (i.e. the associated economic activities of fracking, captured through the inter-linkages in the model) is shown to increase employment, particularly in the unskilled labour segments. These employment gains are substantial.

To elaborate, if results are translated in terms of GDP growth and constant 1998 GDP monetary value, scenario 1 would yield approximately R1 130.29 billion relative to 2011 real GDP (South African Reserve Bank n.d.) for South Africa, R2 253.58 billion for scenario 2, R2 165.81 billion for scenario 3 and R5 132.85 billion for scenario 4. Concerning future growth, this would infer that if South Africa targets 3% growth for a given year, the scenarios will result in the economy achieving between 3.2% and 3.3% growth in the short run, and between 3.3% and 3.7% growth in the long run. In terms of the employment (non-agricultural sector employment), this would potentially translate into 2 513 short-run employment positions gained for South Africa (StatsSA 2012) (8 379 000 x 0.03/100), and as a subset of the total employment gains, 170 unskilled employment positions.

Table 5 also shows an increase in inflation for both the short and long run (0.1, 0.15, 0.09 and 0.25% for the four scenarios). The price increase experienced in the short run is due to a change in prices resulting from a change in the import/domestic composition of household demand, and in the long run due to the increase in real wages, which forces nominal wages to increase with the same amount. Due to the relatively higher domestic prices, the foreign demand for local exports decreases in the long run by between 0.04% and 0.06%. The demand for imports has decreased relatively more in the short run than in the long run, which is due to a substitution effect resulting from the increase in output of the CruPetGas sector. Despite the decline in the domestic cost of power/electricity as a result of the new cheaper input (i.e. from shale gas), the net effect across all industries from the domestic price increase results in a decrease in aggregate export volumes in the long run. This is also directly attributable to the decrease in international competitiveness of locally produced goods and services.

In terms of the macro-level results, it can be seen that, when the shock is applied to the output of the CruPetGas sector, production volumes increase while prices need to adjust downwards to compensate. The price reduction implies an expansion of exports so that the equality between the given world prices and the marginal costs of export supplies is restored in all industries. Domestic supply will also increase as the prices of domestic products relative to the import prices drop (with import prices assumed to be constant), with a resulting drop in import volumes. Total production rises and is transmitted through the inter-industry linkages in the model. Overall domestic consumption is assumed to be fixed (but will change relative to income group level), and the resulting general domestic price increase that needs to take place to achieve equilibrium is between 0.1% and 0.15% in the short run, and between 0.09% and 0.25% in the long run. The import price index remains constant, as South Africa is assumed to be a price taker in the global market. Import volumes fall by between 0.36% and 0.72% in the short run and between 0.07% and 0.14% in the long run due to the South African economy's lower import propensity.

The impact of fracking on relative prices, discussed in the preceding paragraphs, is an important finding from the modelling results. However, it is important to realise that these price effects are mainly 'pecuniary externalities' that carry no welfare implication. Thus, the price effects arise within the market mechanism and may still result in notable damage to other consumers in the economy.

Since producers are assumed to maximise profits, employment gain is the result of increased outputs combined with sticky (and even decreasing) wage rates (average real wages assumed fixed). The employment gain in turn leads to a higher wage bill being paid to labour, with the resulting feedback of increasing household income. Similar positive results can be found for Scenario 2.

Given the macro-economic results, the impact of fracking seems to be overwhelmingly positive. However, if one delves deeper into the detailed results (at an industry/sector level), a different picture emerges. The micro/industry/sector level results for the short- and long-run scenarios modelled are captured in Tables 6 to 9.

Table 6: Sectoral results (short run) – Scenario 1

	Value added		**Exports**		**Imports**		**Employment**	
Sector % change	**Volume**	**Price**	**Volume**	**Price (LCU[a])**	**Volume**	**Price (FCU[b])***	**Volume**	**Nominal wage**
Irrigated field	0.00	-0.01	-0.03	0.01	0.00	0.00	-0.02	0.16
Dry field	0.00	-0.01	-0.03	0.01	0.00	0.00	-0.01	0.16
Irrigated horticulture	-0.02	0.03	-0.21	0.04	0.06	0.00	-0.07	0.16
Dry horticulture	-0.02	0.03	-0.21	0.04	0.06	0.00	-0.07	0.16
Livestock	0.03	0.12	-0.65	0.13	0.06	0.00	0.09	0.16
Forestry	-0.03	0.11	-0.58	0.12	0.00	0.00	-0.05	0.16
Other agriculture	0.03	0.12	-0.62	0.12	0.07	0.00	0.10	0.16
Coal	-0.05	0.03	-0.19	0.04	0.12	0.00	-0.12	0.12

Table 6 continued

Table 6 continued

Sector % change	Volume	Price	Volume	Price (LCU[a])	Volume	Price (FCU[b])*	Volume	Nominal wage
Gold	-0.17	-0.03	-0.01	0.00	0.00	0.00	-0.26	0.09
Crude, petroleum & gas	23.80	-26.36	399.02	-27.51	-29.61	0.00	-7.08	0.13
Other mining	-0.03	0.00	-0.04	0.01	-0.10	0.00	-0.08	0.13
Food	0.00	0.11	-0.63	0.13	0.29	0.00	0.01	0.17
Textiles	-0.09	0.10	-0.69	0.14	0.05	0.00	-0.10	0.14
Footwear	-0.04	0.11	-0.68	0.14	0.10	0.00	-0.07	0.15
Chemicals & rubber	0.21	-0.13	0.51	-0.10	0.03	0.00	0.37	0.20
Petroleum refineries	1.51	-1.17	5.51	-1.07	-0.22	0.00	4.91	0.20
Other non-metal minerals	-0.08	0.05	-0.27	0.05	-0.04	0.00	-0.15	0.15
Iron & steel	-0.20	0.03	-0.21	0.04	-0.08	0.00	-0.39	0.14
Non-ferrous metal	-0.08	0.01	-0.09	0.02	-0.05	0.00	-0.30	0.14
Other metal products	-0.08	0.07	-0.40	0.08	0.02	0.00	-0.11	0.14
Other machinery	-0.08	0.07	-0.40	0.08	0.04	0.00	-0.12	0.14
Electricity machinery	-0.09	0.04	-0.30	0.06	-0.02	0.00	-0.17	0.17
Radio	-0.03	0.11	-0.63	0.13	0.06	0.00	-0.04	0.22
Transport equipment	-0.07	0.08	-0.45	0.09	0.04	0.00	-0.10	0.16
Wood, paper & pulp	-0.08	0.04	-0.37	0.07	0.01	0.00	-0.17	0.15
Other manufacturing	-0.09	0.03	-0.32	0.06	0.02	0.00	-0.19	0.15
Electricity	0.02	0.15	-0.76	0.15	0.16	0.00	0.05	0.14
Water	0.02	0.18	0.00	0.00	0.19	0.00	0.10	0.16
Construction	-0.11	0.03	-0.13	0.03	0.02	0.00	-0.17	0.09
Trade	0.05	0.21	-1.07	0.22	0.21	0.00	0.08	0.21
Hotels	-0.03	0.12	-0.50	0.10	0.13	0.00	-0.10	0.23
Transport services	0.04	0.06	-0.32	0.06	0.13	0.00	0.08	0.17
Community services	0.01	0.20	-1.01	0.20	0.20	0.00	0.03	0.24
Financial institutions	0.00	0.24	-1.17	0.24	0.26	0.00	0.01	0.26
Real estate	0.00	0.30	-1.51	0.31	0.29	0.00	0.04	0.26
Business activities	-0.03	0.18	-0.88	0.18	0.19	0.00	-0.04	0.24
General government	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.23
Health services	0.08	0.19	-0.96	0.19	0.23	0.00	0.17	0.24
Other service activities	-0.05	0.19	-0.93	0.19	0.14	0.00	-0.06	0.24

Note: * Exogenous by assumption [a] Local Currency Unit (LCU) [b] Foreign Currency Unit (FCU)
Source: UPGEM simulation results

Table 7: Sectoral results (short run) – Scenario 2

	Value added		Exports		Imports		Employment	
Sector % change	**Volume**	**Price**	**Volume**	**Price (LCU)**	**Volume**	**Price (FCU)***	**Volume**	**Nominal wage**
Irrigated field	0.00	-0.02	-0.04	0.01	0.00	0.00	0.00	0.27
Dry field	0.00	-0.02	-0.04	0.01	0.00	0.00	0.00	0.27
Irrigated horticulture	-0.04	0.05	-0.34	0.07	0.10	0.00	-0.11	0.27
Dry horticulture	-0.04	0.05	-0.34	0.07	0.09	0.00	-0.11	0.27
Livestock	0.06	0.20	-1.07	0.21	0.11	0.00	0.15	0.27
Forestry	-0.04	0.18	-0.96	0.19	0.00	0.00	-0.08	0.27
Other agriculture	0.06	0.20	-1.04	0.21	0.12	0.00	0.18	0.27
Coal	-0.06	0.05	-0.29	0.06	0.22	0.00	-0.16	0.18
Gold	-0.30	-0.08	0.11	-0.02	0.00	0.00	-0.44	0.13
Crude, petroleum & gas	56.60	-47.77	2 703.31	-50.31	-58.14	0.00	-15.22	0.19
Other mining	-0.05	0.00	-0.05	0.01	-0.17	0.00	-0.12	0.19
Food	0.01	0.19	-1.03	0.21	0.48	0.00	0.01	0.28
Textiles	-0.14	0.16	-1.12	0.23	0.08	0.00	-0.16	0.22
Footwear	-0.08	0.17	-1.11	0.22	0.15	0.00	-0.13	0.23
Chemicals & rubber	0.42	-0.28	1.08	-0.22	0.04	0.00	0.74	0.33
Petroleum refineries	2.71	-2.06	9.97	-1.88	-0.40	0.00	9.25	0.33
Other non-metal minerals	-0.16	0.05	-0.30	0.06	-0.14	0.00	-0.30	0.24
Iron & steel	-0.31	0.05	-0.32	0.06	-0.15	0.00	-0.63	0.22
Non-ferrous metal	-0.14	0.00	-0.13	0.03	-0.09	0.00	-0.49	0.22
Other metal products	-0.14	0.11	-0.61	0.12	0.01	0.00	-0.21	0.22
Other machinery	-0.13	0.11	-0.61	0.12	0.05	0.00	-0.20	0.22
Electricity machinery	-0.15	0.05	-0.43	0.09	-0.06	0.00	-0.30	0.28
Radio	-0.05	0.19	-1.04	0.21	0.09	0.00	-0.07	0.37
Transport equipment	-0.10	0.13	-0.73	0.15	0.06	0.00	-0.15	0.26
Wood, paper & pulp	-0.14	0.06	-0.58	0.12	0.01	0.00	-0.27	0.24
Other manufacturing	-0.15	0.05	-0.50	0.10	0.03	0.00	-0.30	0.24
Electricity	0.03	0.24	-1.22	0.25	0.27	0.00	0.10	0.22
Water	0.03	0.30	0.00	0.00	0.31	0.00	0.16	0.26
Construction	-0.28	0.00	0.05	-0.01	-0.05	0.00	-0.46	0.12
Trade	0.09	0.37	-1.83	0.37	0.36	0.00	0.17	0.34
Hotels	-0.05	0.20	-0.83	0.17	0.21	0.00	-0.17	0.39
Transport services	0.05	0.08	-0.39	0.08	0.12	0.00	0.11	0.28
Community services	0.02	0.34	-1.69	0.34	0.35	0.00	0.05	0.40
Financial institutions	0.00	0.41	-1.97	0.40	0.43	0.00	0.01	0.45
Real estate	0.00	0.51	-2.51	0.51	0.49	0.00	0.06	0.45
Business activities	-0.06	0.29	-1.44	0.29	0.32	0.00	-0.08	0.41
General government	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.39
Health services	0.14	0.32	-1.58	0.32	0.38	0.00	0.28	0.40
Other service activities	-0.09	0.31	-1.54	0.31	0.24	0.00	-0.11	0.40

Note: * Exogenous by assumption
Source: UPGEM simulation results

Table 8: Sectoral results (long run) – Scenario 3

	Value added		Exports		Imports		Employment	
Sector % change	**Volume**	**Price**	**Volume**	**Price (LCU)**	**Volume**	**Price (FCU)***	**Volume**	**Nominal wage**
Irrigated field	0.18	-0.11	0.44	-0.09	0.02	0.00	-0.02	0.61
Dry field	0.19	-0.12	0.45	-0.09	0.02	0.00	-0.02	0.61
Irrigated horticulture	-0.07	0.09	-0.51	0.10	0.14	0.00	-0.30	0.61
Dry horticulture	-0.07	0.09	-0.51	0.10	0.14	0.00	-0.30	0.61
Livestock	0.11	0.16	-0.85	0.17	0.14	0.00	-0.05	0.61
Forestry	-0.18	0.31	-1.55	0.31	-0.11	0.00	-0.34	0.61
Other agriculture	0.10	0.12	-0.66	0.13	0.13	0.00	-0.07	0.61
Coal	-0.24	0.14	-0.73	0.15	0.41	0.00	-0.48	0.58
Gold	-1.04	0.16	-0.92	0.18	0.00	0.00	-1.19	0.54
Crude, petroleum & gas	23.80	-20.05	222.76	-20.89	-16.83	0.00	-1.10	0.59
Other mining	-0.35	0.07	-0.36	0.07	-0.36	0.00	-0.49	0.59
Food	0.05	0.20	-1.04	0.21	0.57	0.00	-0.06	0.69
Textiles	-0.22	0.30	-1.55	0.31	0.14	0.00	-0.27	0.65
Footwear	-0.19	0.30	-1.47	0.30	0.24	0.00	-0.32	0.62
Chemicals & rubber	0.41	-0.19	0.74	-0.15	0.14	0.00	0.34	0.72
Petroleum refineries	5.31	-3.84	19.79	-3.55	-0.63	0.00	5.20	0.72
Other non-metal minerals	0.01	0.19	-0.95	0.19	0.21	0.00	-0.15	0.64
Iron & steel	-0.82	0.20	-0.98	0.20	-0.03	0.00	-1.06	0.62
Non-ferrous metal	-0.72	0.16	-0.83	0.17	-0.19	0.00	-0.99	0.62
Other metal products	-0.01	0.23	-1.14	0.23	0.34	0.00	-0.15	0.62
Other machinery	-0.01	0.24	-1.19	0.24	0.44	0.00	-0.13	0.62
Electricity machinery	-0.10	0.19	-0.97	0.20	0.25	0.00	-0.27	0.66
Radio	-0.09	0.29	-1.44	0.29	0.32	0.00	-0.18	0.75
Transport equipment	-0.18	0.24	-1.18	0.24	0.29	0.00	-0.27	0.66
Wood, paper & pulp	-0.32	0.26	-1.43	0.29	0.17	0.00	-0.43	0.65
Other manufacturing	-0.44	0.25	-1.40	0.28	0.16	0.00	-0.61	0.65
Electricity	0.01	0.26	-1.28	0.26	0.24	0.00	-0.22	0.60
Water	0.10	0.20	0.00	0.00	0.30	0.00	-0.34	0.67
Construction	0.20	0.17	-0.86	0.17	0.52	0.00	0.07	0.50
Trade	0.19	0.34	-1.66	0.33	0.45	0.00	0.05	0.76
Hotels	-0.08	0.28	-1.19	0.24	0.32	0.00	-0.42	0.88
Transport services	0.39	0.04	-0.18	0.04	0.56	0.00	0.20	0.70
Community services	0.14	0.30	-1.47	0.30	0.41	0.00	0.02	0.78
Financial institutions	0.12	0.39	-1.99	0.40	0.59	0.00	0.01	0.82
Real estate	0.23	0.18	-0.89	0.18	0.36	0.00	0.01	0.82
Business activities	0.04	0.42	-2.07	0.42	0.58	0.00	-0.02	0.78
General government	0.26	0.65	0.00	0.00	0.00	0.00	0.18	0.88
Health services	0.27	0.24	-1.17	0.23	0.43	0.00	-0.04	0.73
Other service activities	-0.21	0.46	-2.27	0.46	0.34	0.00	-0.27	0.69

Note: * Exogenous by assumption
Source: UPGEM simulation results

Table 9: Sectoral results (long run) – Scenario 4

	Value added		Exports		Imports		Employment	
Sector % change	**Volume**	**Price**	**Volume**	**Price (LCU)**	**Volume**	**Price (FCU)***	**Volume**	**Nominal Wage**
Irrigated field	0.36	-0.23	0.82	-0.16	0.05	0.00	-0.13	1.44
Dry field	0.37	-0.23	0.85	-0.17	0.05	0.00	-0.12	1.44
Irrigated horticulture	-0.20	0.22	-1.30	0.26	0.34	0.00	-0.74	1.44
Dry horticulture	-0.20	0.22	-1.29	0.26	0.33	0.00	-0.74	1.44
Livestock	0.26	0.40	-2.10	0.42	0.34	0.00	-0.11	1.44
Forestry	-0.42	0.74	-3.66	0.75	-0.26	0.00	-0.80	1.44
Other agriculture	0.22	0.31	-1.68	0.34	0.30	0.00	-0.18	1.44
Coal	-0.59	0.35	-1.81	0.37	1.03	0.00	-1.16	1.36
Gold	-2.47	0.37	-2.11	0.43	0.00	0.00	-2.82	1.25
Crude, petroleum & gas	65.60	-41.83	1543.31	-43.97	-38.87	0.00	-3.77	1.39
Other mining	-0.87	0.17	-0.90	0.18	-0.88	0.00	-1.19	1.39
Food	0.11	0.49	-2.52	0.51	1.37	0.00	-0.13	1.62
Textiles	-0.52	0.72	-3.68	0.75	0.34	0.00	-0.63	1.53
Footwear	-0.45	0.71	-3.49	0.71	0.57	0.00	-0.76	1.46
Chemicals & rubber	0.88	-0.36	1.37	-0.27	0.35	0.00	0.72	1.71
Petroleum refineries	13.17	-8.46	50.35	-7.83	-1.33	0.00	12.90	1.71
Other non-metal minerals	-0.02	0.47	-2.32	0.47	0.47	0.00	-0.38	1.51
Iron & steel	-2.00	0.48	-2.36	0.48	-0.10	0.00	-2.53	1.46
Non-ferrous metal	-1.74	0.39	-1.99	0.40	-0.47	0.00	-2.36	1.46
Other metal products	-0.06	0.55	-2.73	0.55	0.80	0.00	-0.37	1.46
Other machinery	-0.03	0.58	-2.85	0.58	1.04	0.00	-0.31	1.46
Electricity machinery	-0.28	0.46	-2.37	0.48	0.59	0.00	-0.66	1.57
Radio	-0.20	0.70	-3.41	0.70	0.75	0.00	-0.42	1.77
Transport equipment	-0.43	0.57	-2.82	0.57	0.70	0.00	-0.63	1.56
Wood, paper & pulp	-0.75	0.63	-3.38	0.69	0.40	0.00	-1.01	1.53
Other manufacturing	-1.03	0.61	-3.31	0.68	0.39	0.00	-1.42	1.53
Electricity	0.02	0.61	-3.02	0.62	0.57	0.00	-0.49	1.41
Water	0.25	0.50	0.00	0.00	0.71	0.00	-0.78	1.59
Construction	0.40	0.43	-2.08	0.42	1.25	0.00	0.12	1.17
Trade	0.46	0.81	-3.94	0.81	1.07	0.00	0.13	1.81
Hotels	-0.19	0.67	-2.84	0.58	0.76	0.00	-0.99	2.09
Transport services	0.89	0.13	-0.64	0.13	1.38	0.00	0.46	1.66
Community services	0.33	0.72	-3.52	0.72	0.99	0.00	0.06	1.85
Financial institutions	0.30	0.92	-4.69	0.96	1.43	0.00	0.03	1.95
Real estate	0.55	0.45	-2.16	0.44	0.86	0.00	0.03	1.96
Business activities	0.08	1.01	-4.87	1.00	1.38	0.00	-0.06	1.86
General government	0.62	1.54	0.00	0.00	0.00	0.00	0.43	2.08
Health services	0.64	0.58	-2.84	0.58	1.05	0.00	-0.07	1.74
Other service activities	-0.50	1.10	-5.30	1.10	0.82	0.00	-0.65	1.62

Note: * Exogenous by assumption
Source: UPGEM simulation results

Tables 6 to 9 present some sectoral results. The sector-level results show that fracking will displace hardly any production from agriculture, with almost negligible declines in value added in irrigated and dry horticulture and forestry (with declines of less than 0.04% in the short run and 0.4% in the long run). Other agricultural sectors will experience an increase in value added (although still relatively small).

Gold mining value added is negatively affected (also for the other mining sectors, although to a much lesser extent) in both the short and long run (with declines of less than 3%). In South Africa, the bulk of the country's gold output is exported, with the exception of a small amount sold to the domestic jewellery industry. Accordingly, the version of the UPGEM used does not recognise that in the short term, employment in the gold industry and the amount of ore extracted is unresponsive to variations in the Rand gold price net of ore extraction and refining costs, neither does it recognise the policy of the gold industry to vary the quality of the ore extracted with the net gold price. That is, if the net price rises (falls), lower gold-yielding (higher gold-yielding) ore is mined, resulting in an approximately constant profitability of the extraction and refining process (Cameron & Naudé 2008). Therefore, there should be a negative short-run relationship between the net gold price and the output of refined gold in the model. However, this is not the case. In reality, since mining is currently constrained by unstable electricity supplies, an increase in gas production (via shale gas) would rectify this problem. This should then also have positive knock-on effects, given that the industry, in general, has positive linkages to the drilling and piping sectors.

The largest employment gains are experienced in the downstream sectors to the CruPetGas sector (i.e. in petroleum refineries), as well as in some of the sectors servicing the industry (i.e. construction and transport).

Summary results

The CGE results would suggest that fracking may provide South Africa with an opportunity to enhance economic growth and poverty reduction. However, in delving more deeply into the results, it becomes clear that large-scale growth of shale gas production unavoidably imposes adjustments on other sectors due to competition for labour. In relative terms, traditional exports shrink in both scenarios in order to make space for shale gas. Consumer prices increase slightly, and imports decrease in both scenarios. Overall, while welfare broadly increases due to enhanced purchasing power, certain households may be negatively affected due to the price and quantity adjustments associated with rapid growth in shale gas production.

The results suggest that careful attention should be paid to the labour intensity of production methods employed for fracking, since the degree of labour intensity has the potential to strongly influence the distribution of income.

Whilst CGE models are ideally suited to answer counterfactual and economy-wide questions, for example, 'What is the impact of fracking?', it is essential to recognise that these models also suffer from a number of shortcomings. Apart from some topic-specific shortcomings, two mutual faults of CGE models are that they rely on arguable assumptions, such as perfectly competitive markets and constant returns to scale, and rely heavily on the quality of data and parameter values (see Bandara 1991: 29–31).

Shortcomings specific to this study include: water usage is not captured explicitly in the model; the potential spill-overs to other exporting sectors due to the transport and other infrastructure that shale gas production will require (e.g. the potential 'crowding in') are not considered; and other methods for mitigating downside price risk for shale gas, such as the generation of electricity and identification of potential substitutes for shale gas, should be considered. However, these limitations are worst pecuniary externalities, and in CGE modelling the 'crowding in' will sooner or later lead to an adjustment in supply.

Table 10: Results comparison with the Econometrix report findings

Category	Econometrix study		CGE results			
	20 Tcf	50 Tcf	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Potential life of resource (years)	25	25	25	25	25	25
Potential contribution to GDP (%)	3.3	9.6	3.5	6.9	4.4	10.4
Potential contribution to GDP (ZAR bn)	35	90	26	52	32	77
Potential permanent employment	300 000	700 000	1 441	2 471	0	0

Source: Econometrix (2012) and UPGEM simulation results

The outcomes for GDP compare well with the outcomes obtained in the Econometrix report, but not with respect to employment, where the UPGEM results, as a result of the explicit assumptions made for both the short- and long-run simulations, show much lower employment gains than in the Econometrix report. For the Econometrix (2012) scenario A (with an assumed resource size of 20 Tcf), the outcome obtained was an average annual GDP contribution equivalent to 3.3% (equivalent to an employment level of 300 000) for employment. For scenario B (with an assumed resource size of 50 Tcf), the outcome obtained was an average annual GDP contribution equivalent to 9.6% (equivalent to an employment level of 700 000) for employment (Econometrix 2012: 67–68). Although the impact for both scenarios obtained in this analysis was relatively close to that of the Econometrix study (3.5% and 6.9% increase in real GDP for the short run, and 4.4% and 10.4% for the long run; 1 441 and 2 471 increase in employment for the short run), it should be borne in mind that this study made very different and conservative assumptions. What is interesting from the CGE analyses is that the knock-on effect of the increase in production activities in the CruPetGas sector has potentially much wider-ranging impacts across the various economic systems, as illustrated by the four scenarios modelled (scenarios 1 and 2 for the short run, and 3 and 4 for the long run).

In summary, and based on the results of both the literature review and CGE modelling exercise, the following benefits of fracking can be listed:

- Economic growth and employment
- An alternative source of energy for power generation
- A cleaner form of energy
- Possible spill-over effects in the form of reduced demand for coal and oil for electricity generation.

However, some of the costs of fracking include:

- A shift of resources from other sectors to be used as inputs for shale gas production
- The displacement of agriculture in the Karoo
- Nuisance, noise and loss of privacy to owners of property in the Karoo
- Potential irreversible damage to the natural environment.

This paper set out to address an important and relevant problem in South Africa, which is currently being debated by politicians, academia and citizens. The evidence from the modelling exercise indicates the potential for significant economic gains. These gains can only be maximised by accounting for the full extent of potential environmental costs. To achieve a net benefit, the environmental costs must be minimised by effective regulation and accountability to all stakeholders.

Conclusion

At this stage, it is only possible to conduct an ex-ante impact assessment based on estimated reserves and wellhead prices. The partial removal of the fracking moratorium should produce more detailed data on the actual reserves in the Karoo basin. Once more data are available, a comprehensive cost–benefit analysis should be conducted to compare the benefits and costs of developing this resource. In the interim, the potential negative externalities of fracking cannot be ignored, and any discussion of potential benefits must incorporate these factors.

It has been said that the development of a shale gas industry could be a 'game changer' for South Africa. However, any attempt to quantify these 'once-in-a-generation economic opportunities' should be subjected to close scrutiny by any and all interested parties. It is difficult to overcome the suspicion that privately commissioned reports make a number of systematically generous assumptions, with little consideration of the probably adverse impacts. Such an approach naturally results in an estimate of strong net benefits when the study should instead perhaps have found the opposite, given the number of uncertainties and unquantifiable negative impacts on an economy. The extent of any potential risks to the environment and the industries that rely on it, especially agriculture, cannot be ignored and need to receive as much attention as the potential economic benefits.

Finally, it is undeniable that, as both the South African population and economy continue to grow, the nation's energy demands will similarly increase. In pursuit of adequate environmentally friendly and sustainable energy sources, all benefits and costs need to be weighed and measured before any decisions can be taken. The advantages of fracking are accompanied by some very consequential disadvantages. Substantial research and debate are required to determine whether fracking is a suitable energy option for South Africa. This is a debate that is far from being decided.

Notes and acknowledgements

This article does not necessarily reflect the views of the authors' institution.

The authors would like to thank the two anonymous referees for their valuable comments. The authors also wish to thank Geoffrey Chapman for his useful comments on an earlier draft.

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