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PROVIDE PROJECT

The Provincial Decision-making Enabling Project

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A Computable General Equilibrium (CGE) Analysis of the Impact of an Oil Price Increase in South Africa

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PROVIDE PROJECT

The Provincial Decision-making Enabling Project

Overview

The Provincial Decision-Making Enabling (PROVIDE) Project aims to facilitate policy design by supplying policymakers with provincial and national level quantitative policy information. The project entails the development of a series of databases (in the format of Social Accounting Matrices) for use in Computable General Equilibrium models.

The National and Provincial Departments of Agriculture are the stakeholders and funders of the PROVIDE Project. The research team is located at Elsenburg in the Western Cape.

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A Computable General Equilibrium (CGE) Analysis of the Impact of an Oil Price Increase in South Africa[1]

Abstract

Following recent international oil price increases, there has been considerable interest in how this external factor can affect the South African economy. This paper reports results from a computable general equilibrium (CGE) analysis of an increase (up to 30 per cent) in international oil prices. Background information is provided, which puts the magnitude of the price variations in historical context. We describe the procedure used to adjust the social accounting matrix (SAM), which is used to calibrate the model, to account explicitly for crude oil. Then, the effects of the crude oil price increase are traced through the economy, from markets, industries through to factors, households and the government. Predictably, the shock hurts the economy: a 20 per cent increase results in a drop in GDP of 1 per cent. It is found that the major impact is to be found in the petroleum industry itself, whereas the effects on liquid fuel dependent industries such as transport is not as large as may be supposed. In agriculture, it is found that the depreciating currency has a positive effect, offsetting most of the negative effects of higher petroleum prices, particularly in export-oriented areas. In a long-term scenario, capital and skilled labour becomes mobile, and the results suggest that such reallocation may not be to the overall advantage of the economy.

[1] The main authors of the paper are Scott McDonald and Melt van Schoor.

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Executive Summary

Recently, oil prices have risen sharply and have reached record levels in some cases, generating concern over the adverse economic effects this could have in oil-importing countries. While industrialised countries are not expected to be affected severely, concern remains regarding the effects on developing countries, which are often highly oil-dependent. South Africa, with a partly developed economy, imports large quantities of crude oil, but also has large coal reserves and a unique highly developed synthetic fuel industry, suggesting a detailed general equilibrium analysis could be particularly useful.

South Africa is dependent on crude oil for 17% of its needs (by raw energy measure), but following the transformation of gas and coal into liquid fuels, the use of liquid fuels account for 29.2% of final energy use. The PROVIDE social accounting matrix (SAM) for South Africa for 2000, which is used as a basis in this study, was extended to account explicitly for the role crude oil and petroleum play in the South African economy. The SAM includes detail on agricultural and food production.

In this paper, we analyse some of the effects that a permanent increase in international oil prices could have on the South African economy using the PROVIDE Computable General Equilibrium (CGE) model, calibrated with the SAM mentioned above. The primary experiment seeks to gauge the effects of a 20% oil price increase under the assumption that government expenditure adjusts to maintain the ratio of government to total expenditure in the economy, over either the short term (where capital and skilled labour cannot relocate between sectors) or the long term (taking into account the effects on investment patterns).

The primary effect of the increase in international markets from the South African perspective is the rise in the price of imported crude oil, which translates fairly directly into a rise in the price of petroleum products. This in turn affects industries that are relatively petroleum-dependent negatively, for example plastics, chemicals, transport and some agricultural sectors. At the same time, the higher payments for oil translate into pressure on the current account, which causes a mild currency depreciation of 0.64%. Export industries benefit, and there is an overall decline in economic activity, which reduces income and output for most industries.

Tracing the price effects of crude oil along the production chain, we find that if crude oil prices increase by 20% (internationally), the domestic price of petroleum increases by 8.5% (relative to a constant CPI) because the price of its intermediate inputs has increased by 10.4%. Prices of energy-intensive commodities such as plastics (1.3%), chemicals (1.3%) and transport (0.4%) increase, but the effects are smaller than may be supposed, reflecting the fact that petroleum represents a relatively

small share of costs for most industries. For example, in the transport sector, fuel constitutes only 11.2% of the industry's costs.

In agriculture, aggregate intermediate input costs increase between 0.2% and 0.9%, depending on the particular region's dependence on crude oil. Free state agriculture has the largest cost increase (0.9%) followed by North West (0.6%), Mpumalanga (0.6%), Limpopo (0.5%) and Gauteng (0.4%). Prices are otherwise affected by the exchange rate and the fact that real consumer incomes have decreased.

Total income (measured by value added) generated in the economy declines by 1%. The petroleum industry, which generates a sizeable share thereof, is hardest hit by the crude oil price increase (income in this industry decreases by 19%), and therefore also accounts for the largest share (22%) of the effect on national income. The effect on income earned in agriculture is very small, mainly because the negative effect of the cost increase is mostly balanced by the positive effect of a weakened exchange rate: overall, there is a slight decline (0.1%) in value added in agriculture across South Africa, reflecting mostly lowered returns to factors. Most of the loss in national income, however, stems from the negative effects in the service sectors, where exports are not an offsetting factor, and lowered aggregate demand has relatively strong negative effects. The mining sectors (which includes the synthetic fuels industry and the small domestic crude oil industry) enjoy a net benefit overall.

From the perspectives of factors, the total income also decreases by 1%. This can be decomposed into the effect on unskilled labour (-0.6% on income-weighted average), skilled labour (-0.9%) and capital's (-1.1%) incomes. Capital is particularly hurt because of its importance in the petroleum industry. The income decline for skilled labour and capital manifests as lowered returns, while in the case of unskilled labour it translates into higher unemployment. These differences are also reflected in household incomes – rural households have a slightly smaller decline in incomes than their urban counterparts (-0.76% versus -0.83%), and less affluent households tend to be slightly less adversely affected.

We repeat the experiment using alternative closure assumptions, namely we allow capital and skilled labour mobility in the model, as might be expected over the longer term as agents change their investment behaviour. It emerges that the overall negative economic effects are worsened slightly: GDP (by value added) declines by 1.1% rather than the 1%. Interestingly, the effect is largely driven by a reallocation of investment towards gold, basic chemicals, iron and steel and non-ferrous metals, all of which have a strong export component. This, along with reduced crude oil imports, causes a partial reversal of the exchange rate depreciation, which contributes towards the worsening of the economy.

International crude oil prices are not necessarily determined exogenously or independent from other international prices. The same forces driving crude oil price increases may also bring about benefits to the South African economy in the form of higher prices for export goods. Two further experiments are conducted, which characterise the effects of a general rise in prices of energy (coal, petroleum, electricity) and energy-intensive commodities (particularly iron and steel and gold) along with the crude oil price increase internationally. Since many of these are important export commodities in South Africa, the impact on the economy improves in terms of total income: in one scenario of price changes the decline in GDP is only 0.2%. However, in all of the experiments, the negative effect of the increase in crude oil prices still dominates.

1. Introduction

Since the oil shocks of the 1970s and early 1980s and associated recessions in the U.S. and other economies in the world, many economists have regarded international crude oil prices as a critical exogenous variable influencing economic performance. Recently, oil prices have risen sharply and have reached record levels in some cases, generating concern over the adverse economic effects this could have. The dramatic changes are well illustrated by considering widely reported prices of the international benchmark Brent crude. In February 1999, nominal prices were at a 25-year low of under $10 per barrel. After a recovery, prices stabilised somewhat, fluctuating around the $20 to $30 range. Coinciding with the beginning of the 2003 Iraq war, a sustained increasing trend set in that ultimately resulted in record prices of over $55 in October 2004. Considerable uncertainty remains over the future of oil prices, with many believing a downward correction to be in order, but few have strong opinions on when and where it may settle for the next few years.

Despite the apparent magnitude of the current "oil shock", it is not expected to be harshly recessionary or inflationary in industrialised countries. In the first instance, these countries are far less oil-dependent than they were in the 1970s and 1980s. Secondly, when inflation is brought into account, the recent price rises are not as high as they might seem. One report suggests that oil prices approaching $164 a barrel would be required today to equal the effects of the 1980 oil shock (Steidtmann 2004). In simulations done by the International Energy Agency (IEA) (International Energy Agency 2004), it is found that the likely effects of a sustained $10 rise in oil prices for the world economy are significant but not catastrophic – a reduction in world GDP of 0.5% in the first year with the effect weakening over time. Nevertheless, the effects on oil-import-dependent economies – economies that strongly depend on oil and where domestic oil is not available – can be quite strong. As a matter of fact, the IEA's report singles out Sub-Saharan African oil-importing countries as particularly susceptible with economic activity declining by 3% of GDP[2]. On average, these countries spent 14% of their GDP on oil imports in 2000; hence increases in oil prices can have dire consequences for them.

South Africa is fortunate in that it has a relatively developed economy and also a diversified energy sector with a sophisticated, if hitherto expensive, synthetics fuel industry. This, in addition to the exploitation of three small oilfields off the south coast, can be expected to alleviate the effects of the current high oil prices. However, key sectors of South Africa's economy are relatively energy-intensive (if not necessarily oil-intensive), suggesting a general rise in energy prices could have substantial effects, at least in these sectors.

[2] A crucial assumption in their report is that dollar exchange rates remain unchanged.

In this paper, we analyse some of the effects that a permanent increase in international oil prices could have using the PROVIDE Computable General Equilibrium (CGE) model. It is possible to analyse either the effects of an oil price increase in isolation, or in the context of a more realistic scenario of effects across different sectors on world markets.

We therefore progressively introduce assumptions on the likely outcomes in the external sector in an attempt to capture global second-round effects on the South African economy. For example we can assume an increase in non-oil energy related commodities and products. One such product – coal – is a major export product in South Africa; hence a price increase for coal would have a positive, offsetting effect while at the same time contributing further to higher energy costs to the extent that higher international coal prices lead to higher domestic prices.

This CGE model does not include a financial sector; therefore the analysis is purely based on real-economy effects. Furthermore, all prices are relative to a chosen *numeraire*, the consumer price index (CPI), so that price inflation cannot occur. Given that an important part of the impact of oil shocks in the past has been associated with inflation[3] (whether directly or as a result of misguided monetary policy), care should be taken to contextualise the results appropriately. The petroleum sector in South Africa is modelled as a competitive sector where prices are determined by the forces of supply and demand rather than being administered centrally by government.

The remainder of this paper is organised as follows. The next section provides background information on the role of oil and energy in the South African economy. Section 3 introduces the CGE model while section 4 discusses the data used and details certain adjustments that were needed to account for crude oil. Likely effects are anticipated based on structural information contained in the Social Accounting Matrix (SAM). We then proceed to detail our experiments, closure rules and model results in sections 5 though 8 and in the final section make some concluding comments and advance some ideas for future research.

2. Energy and Crude Oil in South Africa

2.1. Overview

South Africa’s economy is relatively energy-intensive, with resource-based industries such as mining (especially gold mining), chemicals and iron and steel[4] being particularly heavy users of energy (Department of Minerals and Energy, Eskom and Energy Research Institute University of Cape Town 2002). Additionally, transport in South Africa is an important cost element, considering the

[3] See Barsky and Kilian (2004).

[4] Iron and steel alone account for 12.2% of total final energy demand in South Africa.

bulky nature of key products (such as coal, iron ore, agricultural inputs, agricultural produce and iron and steel) and distances involved for transporting both products and people. The availability of cheap electricity in South Africa over many years may have contributed to energy intensive secondary industries being established and to a lack of investment in energy conservation measures within industries and residential areas alike[5].

At the same time, there are factors that will reduce energy intensity over the long term. First, there is greater awareness of the need to conserve energy both because of scarcity and to reduce pollution. Second, there is also the expectation that energy prices will increase in the future as stocks of energy commodities in the world decrease while at the same time demand from large newly industrialising countries increases. And third, South Africa is undergoing a natural process of economic maturation whereby dependence on energy intensive heavy manufacturing industries has declined relative to light industry and services.

The majority of "raw" energy in South Africa – 71% by energy measure[6] – is supplied from coal, which is available abundantly and cheaply (Department of Minerals and Energy, Eskom and Energy Research Institute University of Cape Town 2002). Crude oil accounts for a further 17% of raw energy supply. Most crude oil is imported, with the small South African oilfields off the South coast producing around 3.5% of domestic crude requirements (in 2000, the year for our benchmark data), with the potential for a modest increase over the medium term.

The final use of petroleum products is much larger that this suggests, which is due to transformation of coal and gas into petroleum in the synthetic fuels industry. In all, oil products account for 29.2% of final energy use (by energy measure). Coal-based petroleum accounts for 22% of the total petroleum production and gas-based petroleum (from the Mossgas facility) account for a further 7%, so that 29% of petroleum output is from synthetic sources (Department of Minerals and Energy, Eskom and Energy Research Institute University of Cape Town 2002).

South Africa's unique and highly developed synthetic fuel industry has been viewed as an expensive strategic and political exercise to gain greater self-sufficiency during the period of international isolation in the apartheid years[7]. However, in the light of high crude oil prices, these industries have gained profitability and it is reasonable to expect that the existence of the industry will be able to cushion the domestic economy against the effects of high external crude oil prices, if not through lower prices then at least through higher income to the sector itself.

[5] It is worth noting that South Africa also exports significant amounts of energy to neighbouring countries in the forms of electricity and refined petroleum products.

[6] Such as Joule or, at this scale, Petajoule (PJ).

[7] Synthetic fuel production was originally developed in the context of declining levels of known oil reserves and blockades and dangers to sea transport associated with World War II. Low oil prices until the 1970s meant that interest in synthetic fuels waned internationally, allowing Sasol in South Africa to emerge as a world leader in the field.

Final prices of fuel in South Africa are tightly controlled by legislation that effectively tries to set the price of fuel to equal the cost as if the fuel were imported from international markets instead of produced locally. The dollar-denominated refinery prices of finished petroleum products in Bahrain and Singapore are used as a basis, and several additions are made to account for sea transport, insurance and domestic distribution and retail costs. In addition, various taxes such as the fuel tax, customs and excise and the road accident fund are levied per litre of product sold.

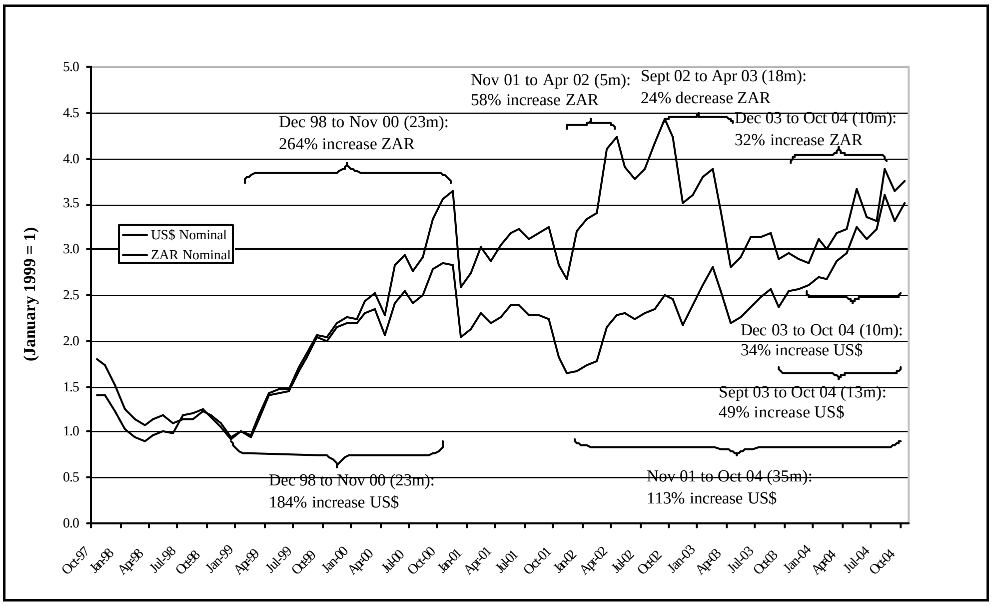
2.2. Oil Price Movements

While the international price of crude oil has shown sharp increases, a part of this is simply a reflection of the current weakness of the US Dollar. Additionally, the steepest increases recently have been in a particular group of prices affecting the U.S.A., of which the Brent benchmark price is typical. Middle Eastern crudes, which are more important from a South African perspective, have also increased sharply, but not to the same extent. For the remainder of this section, we therefore use the Dubai benchmark price as representative of South African crude oil imports[8].

Figure 1 illustrates oil prices in Rand terms for the period October 1997 to October 2004. While there clearly is a sharp rise during 2004 in the nominal Rand price of oil, 32% from December 2003 to October 2004, this rise is not as severe as previous price rises, nor have the same Rand prices been reached. Much of this is due to currency depreciation; for example, from November 2001 to April 2002, a period of 5 months, the price increased by 58%, driven by a combination of sharp currency depreciation and price increases internationally. Subsequently, the strengthening Rand brought relief despite still increasing oil prices. Removing the effect of inflation (not shown in Figure 1) would further dampen the apparent magnitude of price rises, though inflation has been exceptionally low in 2004.

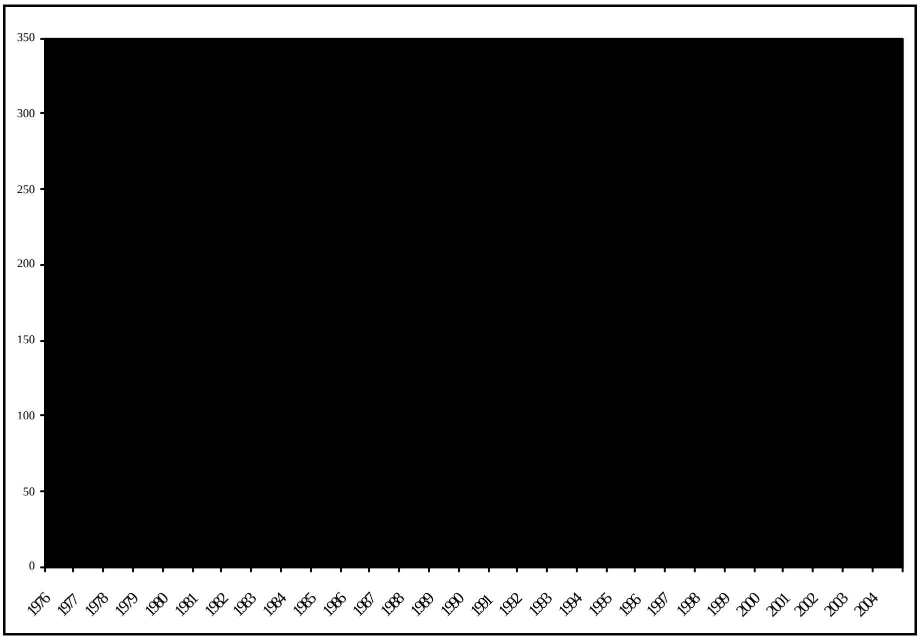
Figure 1. Monthly Oil Price Movements Oct 1997 to Oct 2004

[8] Dubai oil is usually cheaper than Brent oil because it has higher sulphur content and therefore is more difficult to refine and produces more pollution. Recently, this price differential has increased.



Data sources: Monthly Oil Market Reports (http://omrpublic.iea.org/), http://www.oanda.com, SARB

Figure 2. Annual Real Oil Price Movements 1976 to 2004



Data sources: 1997/2003 Oil Market Annual Supplements (http://omrpublic.iea.org/), http://oanda.com, SARB, Stats SA

While the recent price increase (during 2004) therefore does not stand out as particularly severe in the case of South Africa, it is clear that the economy must currently be in a process of adjustment as a result of a series of price increases since December 1999, and that prices will continue to be substantially higher than they were in the previous decade.

Figure 2 shows the real Rand prices of crude oil over a longer period, and it can be seen that a long period of low oil prices following the collapse in 1986 has come to an end in 2000. It also confirms that current real oil prices are still not as high as they were in during the height of the oil shocks of the 1970s and 1980s.

3. Computable General Equilibrium Model

3.1. CGE model

The PROVIDE standard computable general equilibrium (CGE) model is a member of the class of single country computable general equilibrium (CGE) models that are descendants of the approach to CGE modelling described by Dervis, de Melo and Robinson (1982)[9]. More specifically, the implementation of this model, using the GAMS (General Algebraic Modelling System) software, is a direct descendant and development of models devised in the late 1980s and early 1990s, particularly those models reported by Robinson, Kilkenny and Hanson (1990), Kilkenny (1991) and Devarajan, Lewis and Robinson (1994). Following Pyatt (1998), the model is calibrated using a Social Accounting Matrix (SAM). The SAM serves to identify the agents in the economy and provides the database with which the model is calibrated. It also serves an important organisational role since the groups of agents identified by the SAM structure are also used to define sub-matrices of the SAM for which behavioural relationships need to be defined.

Households are assumed to choose the bundles of **commodities** they consume so as to maximise utility where the utility function is a Stone-Geary function that allows for subsistence consumption expenditures, which is an arguably realistic assumption when there are substantial numbers of very poor consumers. The households choose their consumption bundles from a set of 'composite' commodities that are aggregates (using the Armington constant elasticity of substitution (CES) specification) of domestically produced and imported commodities. Changes in relative prices between domestic produce and imports cause partial (as opposed to total) substitution, resulting in realistic adjustments in the model.

Domestically produced commodities are produced by **activities**, each activity being able to produce multiple commodities (using a fixed-coefficient, Leontief, specification) and each commodity potentially being produced by multiple activities (using CES aggregation). **Activities** combine different **factors** into aggregate value added, which in turn is combined with intermediate inputs using a CES specification. Intermediate inputs are bundles of commodities (one per activity) combined using Leontief technology. At each stage of the production nest, profit maximisation is assumed along

[9] This section provides a very brief summary; for a detailed description, see PROVIDE (2003).

with a zero-profit (i.e. perfect competition) assumption. This ensures that costs are minimised and that the level of each activity is such that the cost of inputs is equal to their respective marginal revenue products and no profits are made.

Factors receive payment for their services from activities, which are subsequently paid to their owners, either households or **enterprises**. Enterprises will in turn transfer surpluses towards households. Imported commodities are sourced from the **Rest of the World (ROW)**, which also pays for domestically produced commodities that are exported. Domestic production is divided between domestic supply and exports using a reverse-Armington constant elasticity of transformation (CET) specification. In the model, South Africa is generally modelled as a small country, i.e., price taker, on all export markets, but selected export commodities can be deemed to face downward sloping export demand functions. For this study, the affected sectors are gold, Coal and Other Mining[10].

Government levies taxes on commodities (sales tax), imports, activities (production), factors, direct income taxes on household and enterprises. Government consumes a bundle of government goods, and also makes transfer payments to other agents. Each of households, enterprises, government and ROW saves a part of their income, which is accumulated in the **Savings-Investment** account, from which investment commodities are purchased.

Additional elements of the model specification are embodied in the specification and choice of closures, which are discussed below, in section 5.

4. Benchmark Data and Adjustments

4.1. Overview

The data used for this study are arranged in three groups; a SAM that records all transactions between agents in the economy, a factor use matrix that identifies the quantities of each different factor used by each activity in the period to which the SAM refers, and a series of elasticities that control aspects of the model's behavioural functions.

The SAM is a 167 account aggregation of the PROVIDE SAM for South Africa in 2000 (See PROVIDE (2005) for a full description of the South Africa SAM database). The model SAM has 65 commodity groups, 55 activity groups, 9 factor accounts (capital and one each for skilled and unskilled labour for each of the four racial groups) and 22 household groups (distinguished by

[10] The Other Mining commodity includes important export commodities such as diamonds, natural gas and many other minerals and chemical substances. It does not include crude oil; see the next section.

rural/urban location, race and income level). There are also accounts for enterprises, government (including tax accounts), savings and investment and the rest of the world. A full list of the SAM accounts is provided as Appendix 1.

The SAM includes supply-use features allowing separation between commodities and activities; this structure allows secondary production in each activity. The nine agricultural activities (geographically differentiated) each produce multiple commodities and each of the 16 agricultural commodities (differentiated by product type) can be produced by multiple activities. Importantly, the crude oil commodity, a pivotal account in this study, has no corresponding activity, and is instead produced by the "other mining" activity. This is a result of the procedure used to introduce crude oil into the database, explained below.

4.2. Introducing Crude Oil and Adjusting Supply-Use Data

The source dataset for the PROVIDE SAM, based on a supply-use (SU) table supplied by Statistics South Africa (Statistics South Africa 2003), does not include specific accounting for crude oil. Instead, as is historically the case in South Africa, crude oil is included in the "other mining" category. However, this category also includes many other economically important but very different commodities, including iron ore, diamonds and mining of chemical substances. In order to conduct useful analysis regarding price movements for crude oil, it is essential that it be separated out from the aggregate "other mining" category.

In addition, there is a serious inconsistency between the SU tables and our knowledge of the petroleum industry, namely that the use of petroleum is significantly understated. This subsection documents the procedure that we use to disaggregate the other mining commodity and adjust the data to address the inconsistency. The process now forms an integral part of the compilation of the PROVIDE SAM.

For most commodities in the Stats SA tables, it would be very difficult to make custom disaggregations unless additional supply and use data can be sourced for the proposed sub-commodities. However, in the case of crude oil we know that virtually all of the imported crude oil is used solely by the petroleum refiners. In addition, we know that there are no import taxes or any other taxes on crude oil before it reaches the refineries. It therefore stands to reason that the value of imported crude oil should equal the difference between the total use of crude oil by the petroleum activity and domestic production of crude oil. Since trade data is available fom customs data supplied by South African Revenue Service (SARS) at a more disaggregated level, we can identify the portion of the aggregate commodity imports that relate to crude oil: 75% or R24.2bn[11]. South

[11] There is some doubt as to the reliability of this figure (i.e. the Rand value of crude oil imports). Alternative figures we have been able to source include (Department of Minerals and Energy 2000), which gives R12.8bn and the Department of Trade and Industry (DTI)'s online trade database, which reports the same figure as the SARS

Africa does not export crude oil. However, the entire use of "other mining" (which *includes* crude oil) by the petroleum activity in supply-use tables is only R10.9bn in the Stats SA use table. This is far too low and constitutes a serious discrepancy, and we therefore adjust the relevant parts of the SU data using the following assumptions:

?? Trade. The value of crude oil imports is set to 75% of the original "other mining" category, which equates to R23.4bn, and the remainder of the "other mining" commodity (now called "other other mining") is set to account for the remainder of the original total for the aggregate. Exports are left unchanged, since there are no crude oil exports.

?? Domestic crude oil production. While 2000 represents one of the early years for South African crude oil production, it was nevertheless well-established, with production at 689 thousand metric tons, or 3.5% of total crude oil used (South African Petroleum Industry Association 2003). We assume local crude oil has the same price as imported oil, giving a value of R850m. In actual fact, specific prices do depend on product grades, but actual differences are likely to be small. Domestic crude oil is produced by the *original* "other mining" activity; there is no crude oil activity[12].

?? Taxes and margins. There are no product taxes on crude oil imports or production, hence the values for the original category are assumed to apply to the non-oil portion of the original category. Trade and transport margins are disaggregated using the same proportions as the column totals excluding margins for the two new commodities.

?? Crude oil use. The entire supply of crude oil – the commodity's column total – is used by the petroleum industry. The resultant SAM therefore has only one user of crude oil, which becomes an important consideration when interpreting the model results.

?? Other inputs to the petroleum industry. As mentioned, petroleum is produced from sources other than oil, including coal and gas. We do not know the values of these inputs, nor can crude oil be subtracted from the original use of "other mining" to derive the sum of these, since crude oil use is now in fact much larger than the original "other mining" use. The best available information relates to the proportions of *output products* from different sources, actually the 6 different refinery complexes (See Table 1). The Sasol facilities produce oil from coal, the PetroSA facility produces oil from gas and the

data and therefore probably derives from the same source. An attempt to derive our own estimates, using average annual international oil prices (Dubai benchmark) and import volumes from (South African Petroleum Industry Association 2003), average annual exchange rates from the Reserve Bank and allowing an additional 10% for overseas transport and insurance costs, gives a figure of R27.9bn. We opted to use the original SARS figure (i.e. R24.2bn) as the most reasonable at this stage.

12 Introducing a meaningful crude oil activity is not possible because we do not have data on the factor and intermediates inputs use by the crude oil producers.

remainder are conventional crude refineries. The (strong) assumption is made that the *values of primary inputs* to these facilities are proportional to the *volumes of primary outputs*. Therefore coal and gas usage is set so that coal represents 22.5% of primary inputs (i.e. R7.99bn) and gas 6.8%. As gas is still included in the "other other mining" category, an additional allowance is added for the non-gas inputs in this category to arrive at a total of R4.32bn for use of "other other mining" by the petroleum activity.

Table 1. Sources of Petroleum Products in South Africa

Facility	Output (bbl equiv / day)
Sapref (Durban)	180 000 (27.0%)
Enref (Durban)	115 000 (15.8%)
Calref (Cape Town)	100 000 (15.0%)
Natref (Sasolburg)	86 000 (12.9%)
Sasol II & III (Secunda)	150 000 (22.5%)
PetroSA (Mossel Bay)	45 000 (6.8%)

Source: ((South African Petroleum Industry Association 2002) (2000 figures)

Using the Stats SA SU tables as a basis, we incorporate the adjusted SU table and disaggregated crude oil commodity account into the PROVIDE (unbalanced) best estimate SAM. Finally, a new balanced (i.e. conforming to accounting identities) SAM is estimated using cross entropy techniques (see McDonald and Robinson (2004)) and aggregated to form the 167 account SAM used in this study. In the process of making the adjustments above, some fairly large *additional* (see below) imbalances are introduced into the best estimate SAM. Consistent with the information theoretic basis of the estimation techniques, the estimation process is allowed to resolve these (and existing) imbalances. This effectively means that:

a) Prior information needed to resolve these imbalances manually is not available. For example, the adjustments cause considerable expansion in primary input use by the petroleum industry, without a corresponding increase in receipts. This could be resolved by assuming that there is a corresponding increase in the output of the activity or a corresponding decrease in non-primary inputs (or a combination of these)[13]. The imposition of arbitrary facts is avoided by refraining to make such an adjustment.

b) There are allowances for errors in the adjustments.

[13] The other major unresolved imbalance flowing from the adjustment procedure is on "other other mining", where imports are lower than the original "other mining" category by a larger amount than the use of it has decreased. Put differently, there is still a large amount of exports (which includes *inter alia* diamonds and iron ore), for which production is inadequately accounted for.

Note that the original (unadjusted) balanced PROVIDE SAM has been estimated using the same techniques. Our adjustments were in fact made to the unbalanced best estimates version of the PROVIDE SAM. The resultant new balanced SAM arguably represents an improvement upon the previous version in terms of providing an accurate reflection of the South African economy.

4.3. Energy-related Structural Characteristics

It is instructive to examine certain structural energy-related aspects of the SAM prior to CGE analysis. Appendix 2 gives a measure of the intensity of energy commodities' (Crude Oil, Coal, Petroleum and Electricity) use by activity, as a percentage of their respective total expenditures (SAM column totals). No distinction is made between energy consumption and transformation, which explains why petroleum and electricity rank highest on the list.

It can be seen that, apart from the energy activities themselves, the most energy-dependent activities are metals manufacturing, plastics, tyres, transport and gold mining. Agriculture, especially in the Free State and North West, is also a fairly intensive user of energy, particularly in the form of diesel. Amongst heavy users of energy, agriculture and transport are particularly dependent on liquid fuels while the heavy secondary activities tend more towards coal and/or electricity. All services (except transport) and light industries (perhaps by definition) are light users of energy according to these measures.

4.4. Other Model Parameters

As mentioned, in addition to the SAM, there are certain other data required by the model, namely a factor use matrix and a set of various elasticities. Factor use data calibrates the model with meaningful measures of quantities of factor use, such as number of labourers or hectares of land. However, they do not affect model results, only the interpretation of some of the variables, and as such we follow the Harberger convention, setting a price of 1 for each unit of each factor.

Elasticities are chosen to reflect reasonable values in the context of the study. Specific assumptions include:

- High trade elasticities (Armington for imports, constant elasticity of transformation (CET) for exports) for crude oil reflecting its near-homogenous nature (value: 2);
- A low elasticity of substitution between value added and intermediate inputs in the petroleum industry (value: 0.2);
- A low elasticity of substitution between various factors of production in the petroleum industry, based upon the observation that refining is necessarily capital intensive value (value: 0.2);

?? Low elasticities of substitution between value added and intermediates in the transport sector. Value added for fuel substitution would represent investment in more fuel-efficient vehicles, which tends to be a slow process (value: 0.4);

?? A fairly low income elasticity of consumption for petroleum purchases by households, implying that quantities consumed will not respond dramatically to petroleum price changes (value: 0.8).

5. Model Closures

The model contains certain conditions that must be satisfied – government account balance, external balance, factor market balance and savings-investment equality. These closure rules represent important assumptions on the way institutions operate in the economy and can substantively influence model results.

In most cases, closure rules are chosen due to their appropriateness in the South African context given the experiments that will be conducted (discussed in subsequent sections). While all combinations of these closures were used in each experiment, the discussion is limited to an appropriate selection. The rules are named and detailed here, and are referred to again where the experiments and results are discussed.

5.1. Government Closures

None of the experiments directly involve government finances, but the fiscal policy reaction of government to, say, a contraction in the economy can still influence results by determining the mechanism for resolving pressures on the fiscal balance. We use two alternative closures:

?? GC1: Under this closure, government maintains its expenditure levels in volume terms despite macroeconomic shocks. Adjustment falls to the government deficit, so that an economic contraction (at constant tax rates) will put pressure on the savings-investment balance.

?? GC2: In this "balanced" scenario, government makes "reasonable" adjustments to its expenditure levels. Specifically, the *share* of government consumption of total final demand in the economy is fixed. This is convenient since it allows economic expansion or contraction without substantially altering the role government plays.

In both cases, tax rates are fixed and the deficit adjusts to arrive at a balance.

5.2. External Balance

An increase in the oil price is likely to have important effects on the trade balance. In the medium and long runs, it is reasonable to assume that the exchange rate will adjust, especially if the rise in oil prices is seen to be permanent. We therefore use a flexible exchange rate and a fixed trade balance.

5.3. Savings-Investment Closures

We use a balanced investment-driven savings configuration whereby the share of investment in absorption is fixed, and savings rates adjust equally in order to balance the identity,

investment = government balance + external balance + savings (household & other)

The external balance is fixed because of the selected external balance, but the government balance will vary. If the GC1 government closure is used, government finances may have a substantial effect on this equation, whereas the GC2 balanced closure's effect will be muted because government expenditure and income both depend on the size of the economy. In either case, the burden of adjustment will fall on households and enterprises savings, effectively reducing their non-savings expenditure if, say, the government balance worsens substantially.

5.4. Factor Market Closures

Factor market closures are chosen to best reflect the realities of the South African economy; hence unskilled labour is not fully employed; this is achieved by holding nominal wages constant. For skilled labour and capital, which are scarce factors, we use two alternative closures, one short-term and one long-term:

- FCST: In the short-term closure, skilled labour and capital are fixed and sector-specific. Effectively, this also means that wages in different sectors can vary independently of each other[14].
- FCLT: In the long-term closure, these factors are fixed and mobile. Wages/returns move equally in all sectors to balance supply and demand. However, there are two exceptions, namely that the scarce factors are held fixed in the petroleum and other mining sectors. This prevents large-scale capital flight from the petroleum sector when oil prices are increased, which would tend to dominate the results[15], and prevents unreasonable expansion in the other mining activity[16].

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[14] In the model (see PROVIDE (2003)), we fix WF(f) and allow WFDIST(f,a) to vary, which leaves WF(f).WFDIST(f,a), the effective wage for factor f in sector a, flexible. In the FCLT closure, WFDIST(f,a) is fixed and WF(f) is flexible.

[15] It could be argued that capital investments in the petroleum sector are made over very long time horizons, and therefore it seems unreasonable to allow capital flight from this sector even over the "long term". Furthermore,

5.5. Numeraire

We use the consumer price index (CPI) as the *numeraire*; all prices are therefore relative to the CPI, which is held fixed.

6. Simulating a Rise in Crude Oil Import Prices over the Short Term

The experiments are covered over the next three sections. This section describes a simple experiment, SIM01, where the price of imported crude oil is increased and everything else is held constant. The experiment consists of 7 stages, labelled SIMSTEP00 to SIMSTEP06, where SIMSTEP00 is the base case (no shock introduced) and each subsequent stepping increases the size of the oil price increase linearly, from 5% (SIMSTEP01) to 30% (SIMSTEP06) compared to the base case. Throughout the discussion, the focus will be on SIMSTEP04 (20% increase) and references to magnitudes will refer to SIMSTEP04 unless otherwise indicated.

Scarce factors (capital and skilled labour) are immobile under the FCST closure used in this section, which further simplifies the effects. In the next section, the experiment will be repeated, but with scarce factors allowed to relocate across sectors. Unskilled labour is unemployed – in infinite supply at prevailing wage rates – and it is therefore immaterial whether they are considered mobile or not. In the third section (section 8), more realistic scenarios, where related international price rises occur simultaneously in other energy and energy-intensive commodities, are investigated.

6.1. Commodity Price Effects

We begin by looking only at the results for GC2, i.e. the balanced government closure. Figure 3 illustrates the immediate effect of the shock, namely a rise in the price of the imported crude oil commodity. The chart shows changes in the domestic prices of imports, which reflects exchange rate effects in addition to the shock itself; hence the price increases in all other commodities are directly attributable to a mild depreciation that is induced by the price increase of an important import commodity.

there is a degree of public direction of the sector, and as such it is sensible to hold fixed unless we wish to specifically model developments in the sector.

[16] The expansion would follow from the increased domestic demand for crude oil. This is undesirable for two reasons, firstly because domestic expansion is limited by natural resources, which the model does not account for, and secondly because a domestic-demand driven expansion in the sector would lead to an unreasonable expansion in exports of the other mining commodity. The latter effect can be strong enough to cause a currency appreciation following an oil price increase.

Figure 3. Domestic Price of Competitive Imports of Commodities (PM) (SIM01/GC2/FCST)

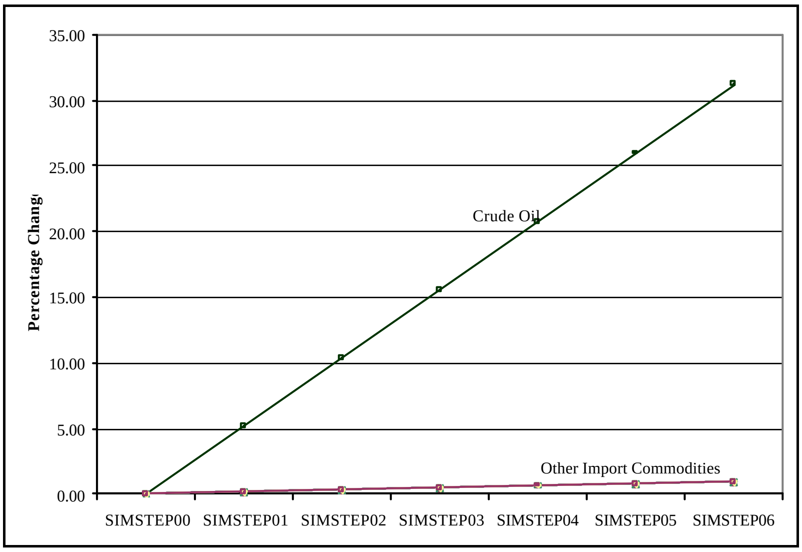


Figure 4. Price of Aggregate Intermediate Inputs to Activities (PINT) (SIM01/GC2/FCST)

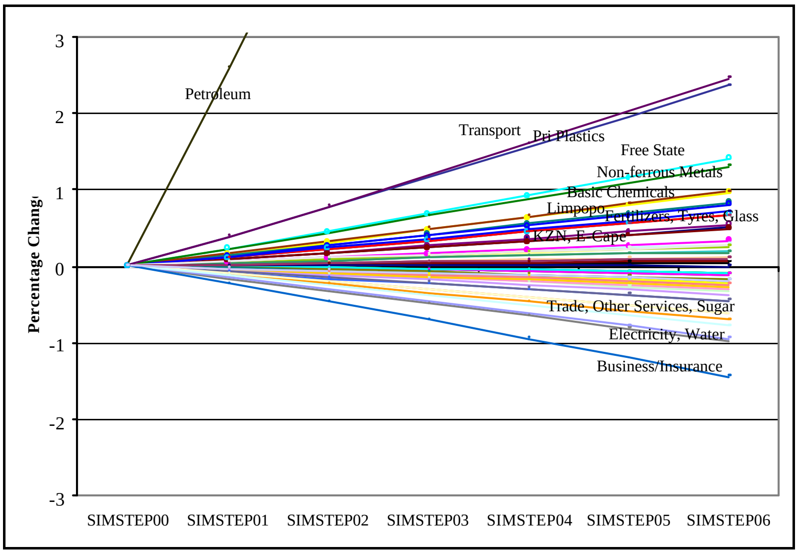


Table 2. Price of Aggregate Intermediate Inputs to Activities (PINT) (SIM01/GC2/FCST)

Activity	Change in Price of Aggregate Intermediate Inputs to Activity (PINT)
Western Cape Agriculture	0.3%
Northern Cape Agriculture	0.2%
North West Agriculture	0.6%
Free State Agriculture	0.9%
Eastern Cape Agriculture	0.4%
KwaZulu-Natal Agriculture	0.3%
Mpumalanga Agriculture	0.6%

Limpopo Agriculture	0.5%
Gauteng Agriculture	0.4%
Coal	0.2%
Grain Mills	0.1%
Animal Feeds	0.2%
Paper and products	0.1%
Petroleum	10.4%
Fertilizers	0.4%
Primary Plastics	1.6%
Tyres	0.4%
Glass and plastic products	0.5%
Non ferrous metals	0.9%
Motor Vehicles	0.2%
Transport Services	1.6%

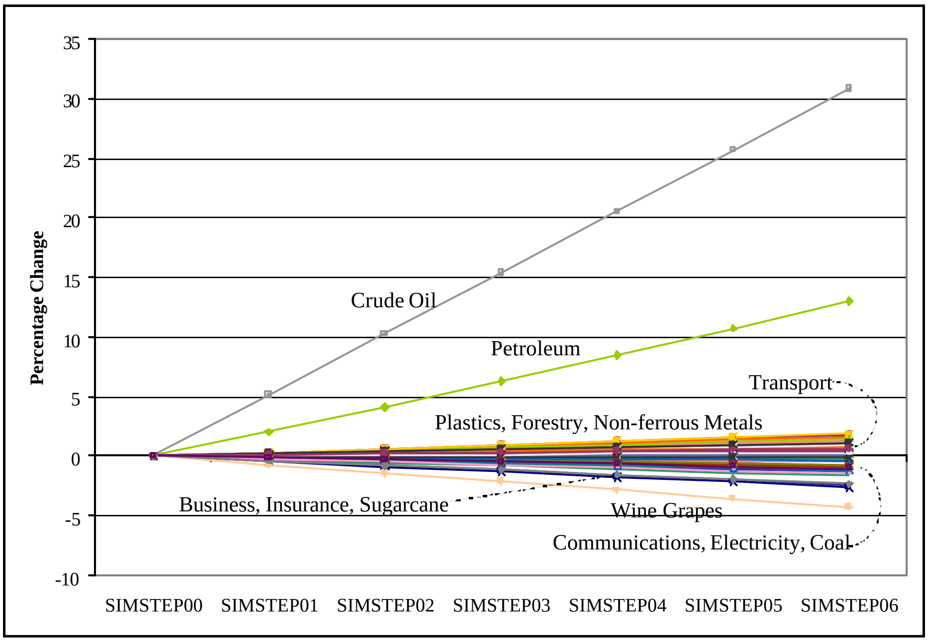
Since the domestic production of crude oil represents a small share (3.5%) of crude oil usage, most of the price increase in imports will also be reflected in the final consumer price for crude oil. Crude oil is used only by the petroleum activity. We would therefore expect the price of the primary production commodity of this activity to increase, followed by commodities that are particularly reliant on petroleum. Since the model *numeraire*, the CPI, is held constant, some prices will need to decrease as these increase. The increase in crude oil prices feeds through to the prices of intermediate inputs of crude oil using activities, either directly (petroleum activity) or indirectly, via increased petroleum costs.

Figure 4 and Table 2 show how the prices of aggregate intermediate input bundles change for different industries. The petroleum industry, being directly affected, clearly has the worst of it. Industries that are dependent on petroleum are also affected, but to a far lesser extent. All agricultural activities see cost increases, with the Free State most affected due to its relatively higher fuel dependence. The price of inputs to electricity declines because of the decline in coal prices (see below).

Figure 5 shows final consumer prices changing in response to the oil price shock. Crude oil and petroleum increase sharply, petroleum (8.5%) increasing by just less than half the increase in crude oil (in percetages) – reflecting the fact that crude oil constitutes around half (54.2%) of the costs for the petroleum industry and the assumption that prices are set competitively.

Prices of energy-intensive commodities such as plastics (1.3%), chemicals (1.3%) and transport (0.4%) increase while price effects for others such as gold, coal and iron/steel are dominated by the exchange rate effect (domestic consumer prices of export goods tending to decrease due to the CET export formulation) or the fact that real consumer incomes have decreased. On top of this there is the need to maintain a constant CPI (due to its role as *numeraire*), which implies that prices of commodities that are not energy or trade dependent, such as most services, will decrease.

Figure 5. Purchaser Price of Composite Commodities (PQD) (SIM01/GC2/FCST)



The price of coal decreases (-1.1%), which seems counterintuitive given that it acts as an oil substitute in the energy sector in South Africa. The reason is that coal is effectively modelled as an oil complement (due to the Leontief bundling of intermediate inputs), hence the demand for coal is decreased as the price of oil increases. Since coal is an important cost element for electricity, the price of electricity also decreases.

6.2. Effects on Activities

Under conditions of perfect competition as in the CGE model, increases in costs will force industries to increase their output prices and/or decrease payments to factors. There is also limited substitution of factors for intermediate inputs, which will dampen but not remove the negative effects.

The choice of factor market closure is instrumental in the response of an industry to a cost increase. Over the short term that we are examining (long-term results are examined in the next section), scarce factors are immobile and can therefore be paid less, but they cannot be retrenched. On the other hand, unemployed unskilled labour cannot be paid lower wages but employment can be reduced. Contraction of an industry is a sensible response given a cost increase or a drop in demand, in order to bolster prices and maintain revenue. However, because some factors are immobile, contraction is at best a costly affair because it implies a change in the input mix between factors. For this reason, price effects dominate the short-term closure, as can be seen in Figure 6, Figure 7 and Table 3.

Figure 6. Value Added Price of Activities (PVA) (SIM01/GC2/FCST)

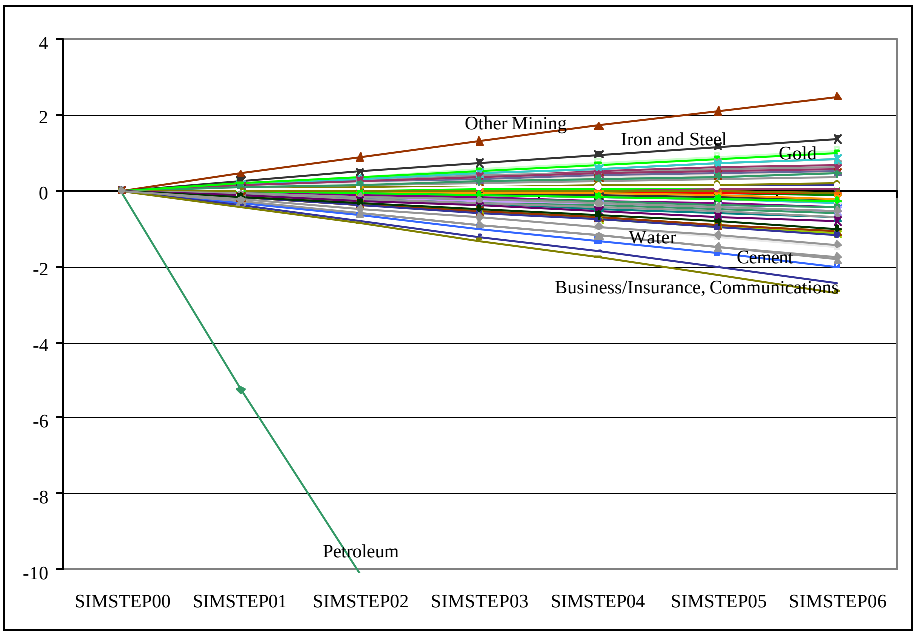
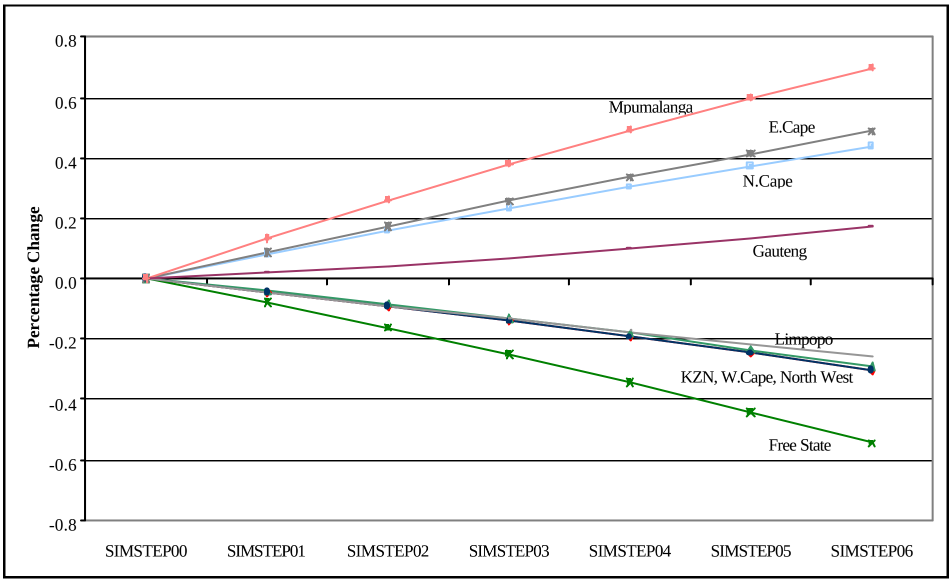


Figure 7. Value Added Price of Agricultural Activities (PVA) (SIM01/GC2/FCST)



Activities producing for export show overall gains, heavy users of petroleum tend to be worse off and there are mixed results for the remainder. Clearly the petroleum industry itself is hurt the most;

the scarce factors invested (locked) here drawing sharply decreased returns following the shock. On the other hand domestic crude oil producers (i.e. the Other Mining activity) benefit because domestic oil can be substituted for the more expensive imported oil. Effects for agricultural activities are mixed, with some provinces showing increased and some decreased prices of value added. They are very small, however.

Table 3 shows the cumulative effect on the economy – a 1% decline in value-added – and the relative contributions made by different sectors thereto. A large part of the decline occurs in the petroleum sector itself and the rest is mainly concentrated in tertiary activities, possibly because the currency depreciation offers little relief in these sectors due to their low export intensities. The Other Mining activity makes a fairly strong positive contribution.

Table 3. Effects of an Oil Price Increase on Value Added (SIM01/SIMSTEP04/GC2/FCST)[17]

Activity/Group	Value Added		Change	Contri-bution	Quantity Change	Price Change
	Base Case	SIM01				
Total Agriculture	257.3	257.2	-0.06%	0.2%	-0.02%	-0.05%
Western Cape	63.7	63.5	-0.3%	0.1%	-0.1%	-0.2%
Northern Cape	17.8	17.9	0.4%	0.0%	0.1%	0.3%
North West	20.3	20.2	-0.2%	0.0%	0.0%	-0.2%
Free State	32.0	31.9	-0.4%	0.0%	-0.1%	-0.3%
Eastern Cape	18.0	18.1	0.5%	0.0%	0.2%	0.3%
KwaZulu-Natal	36.3	36.2	-0.3%	0.0%	-0.1%	-0.2%
Mpumalanga	26.7	26.9	0.6%	0.0%	0.1%	0.5%
Limpopo	27.1	27.1	-0.2%	0.0%	0.0%	-0.2%
Gauteng	15.4	15.4	0.1%	0.0%	0.0%	0.1%
Coal	102.1	100.2	-1.91%	2.5%	-0.73%	-1.19%
Other Mining (includes Crude Oil)	270.8	277.4	+2.44%	-8.5%	+0.72%	+1.71%
Gold	166.8	169.9	+1.84%	-4.0%	+1.09%	+0.73%
Food	149.9	149.4	-0.33%	0.6%	-0.15%	-0.18%
Petroleum	91.0	73.8	-18.95%	22.3%	-0.07%	-19.19%
Other Secondary	1630.8	1627.1	-0.23%	4.8%	-0.07%	-0.16%
Trade	857.2	849.1	-0.95%	10.5%	-0.23%	-0.72%
Transport	475.0	471.3	-0.77%	4.7%	-0.13%	-0.65%
Communications	298.8	293.6	-1.72%	6.6%	-0.10%	-1.62%
Business/Insurance	998.3	980.1	-1.83%	23.6%	-0.06%	-1.77%
Other Services	1134.1	1120.2	-1.23%	18.0%	-0.46%	-0.77%
Government / Social Services	1408.1	1393.8	-1.02%	18.5%	-0.08%	-0.94%
TOTAL	7840.4	7763.0	-0.99%	100.0%	-0.10%	-0.88%

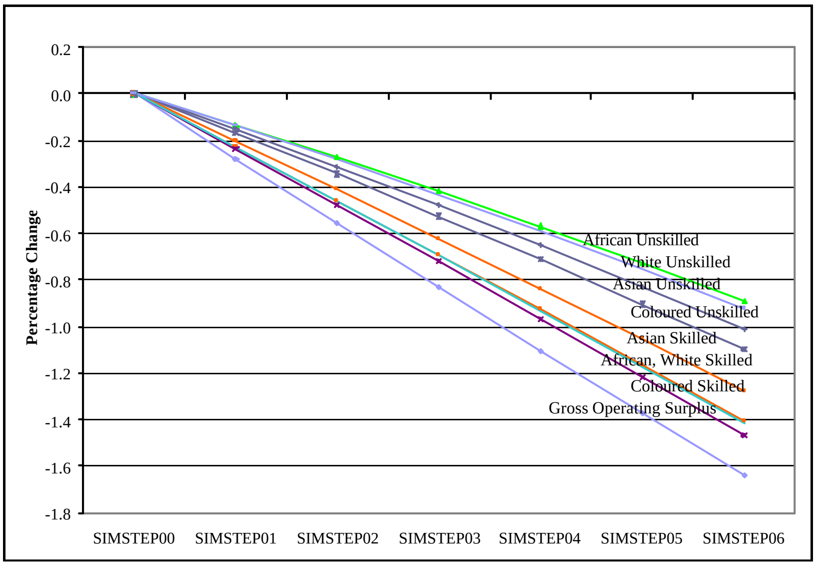
[17] Notes: Aggregate Prices/Quantities weighted by base case value added. Value added in units of R100 000 000.

6.3. Effects on Factors and Households

In the previous subsection it was shown that factor incomes, which in total equals value added, are reduced overall. Figure 8 shows unskilled labour (-0.6% on income-weighted average), skilled labour (-0.9%) and capital's (-1.1%) incomes declining. Capital is particularly hurt because of its importance in the petroleum industry. Note that capital and skilled labour's wages decrease while unskilled labour becomes unemployed but wages remain constant. Scarce factors cannot relocate to damp down the effects under the current closure.

These small differences are also reflected in household incomes – rural households have a slightly smaller decline in incomes than their urban counterparts (-0.76% versus -0.83%), and less affluent households tend to be less adversely affected.

Figure 8. Income to Factors (YF) (SIM01/GC2/FCST)



6.4. Effects on Government Finances and Implications of an Alternative Government Closure

Hitherto, all results shown relate to GC2, the balanced government closure where government expenditures are adjusted to make up a constant share of final demand. Repeating the experiment with the alternative closure, GC1, shows virtually no differences in product, activity or factor markets. The only differences relate to government finances, which are shown in Table 4 along with selected macroeconomic results. GC2 shows, compared to GC1, a slight increase in the share of government expenditure in the economy, which is because government does not reduce its expenditure to adapt to the lower GDP. Notice that the overall effect on GDP is slightly better (GC1 compared to GC2), which is attributable to the slightly larger currency depreciation (and consequent increase in trade).

For the remainder of this study we will only use GC2, not only because the differences are small (this holds also for SIM02 and SIM03 in the next section), but also because it is arguably more appropriate in the medium and long terms because it represents a policy response that is neutral in its effect on the economy.

Table 4. Selected Macro and Government-related Variables under Different Government Closures (SIM01/SIMSTEP04/FCST)

(Percentage change from base case unless otherwise indicated using *)	GC1: Government consumption volumes fixed	GC2: Value share of Govt consumption in total final domestic demand fixed
Gross Domestic Product (GDP) by Value Added	-0.95%	-1.01%
Value of Final Domestic Demand	-0.79%	-0.84%
Value share of Govt Consumption in total final domestic demand	+0.35%	0.00% (fixed)
Value share of Govt Consumption in total final domestic demand *	19.34%	19.27%
Government income	-0.53%	-0.51%
Expenditure by government	-0.30%	-0.58%
Government Dissavings * (% of GDP by Value Added)	2.2%	2.1%
Value of Imports	+0.97%	+0.95%
Value of Exports	+0.86%	+0.84%
Exchange Rate (LCU/FCU)	+0.65%	+0.64%

7. Allowing Scarce Factor Mobility

In this section, the same experiment (SIM01) is repeated, but this time using a long-term closure for scarce factor market (FCLT) where capital and skilled labour are able to relocate to sectors where their respective returns will be maximised. We can view the results either in the conventional sense as an alternative way to model the same shocks for the same experiment, comparing them against the base case, or we could compare them against results using the short-term factor closure (FCST) where scarce factors are immobile. The latter comparison would isolate the differential effect of allowing scarce factor mobility given the oil price increase, which is useful for separating the effects of the oil price increase and the "subsequent" scarce factor reallocations[18].

[18] Note however that in actual fact we are conducting two separate experiments and the results of FCST may not necessarily constitute a phase of the adjustment towards FCLT.

Figure 9 shows percentage changes for selected macroeconomic variables under the alternative closures. The exchange rate depreciation is lessened under FCLT, leading to reduced trade compared to FCST, but still an increase compared to the base case. This fits well with the role factor reallocation could be expected to play in this case, namely to contract oil-dependent sectors in favour of others, thereby reducing the economy's dependence on oil.

Also shown is that the reallocation of factors does not soften the decline in GDP, rather the decline in GDP is slightly worse under the long-term closure. This requires explanation, as it runs counter to the normal macroeconomic effect of factor reallocation. All factors seek the highest returns, and therefore we would expect that locking capital into their respective sectors (as under FCST) would lead to a worse outcome than when they can be reallocated. Indeed, we find that, following reallocation, factor income is reduced even for the reallocated factors themselves (see Figure 10), but to a lesser extent than the reduction in income for unskilled labour (which can effectively reallocate under FCST due to its unemployed status).

Figure 9. Macroeconomic Variables under the Mobile Scarce Factors Closure (SIM01/SIMSTEP04/GC2)

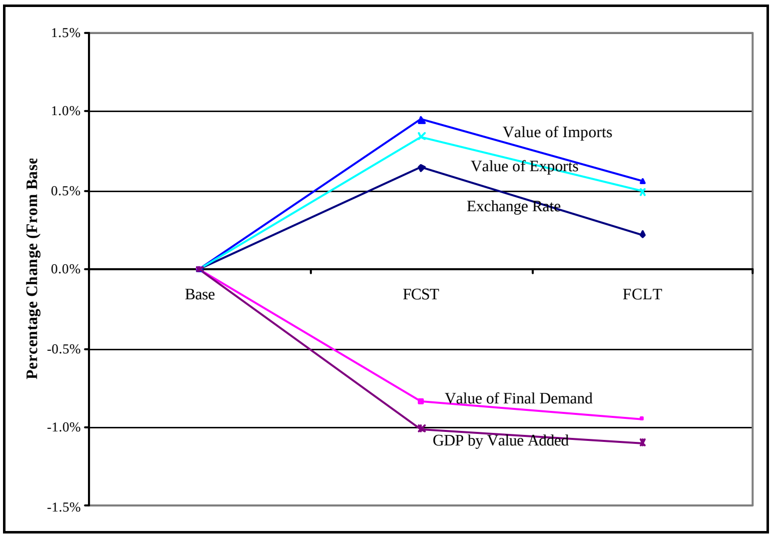
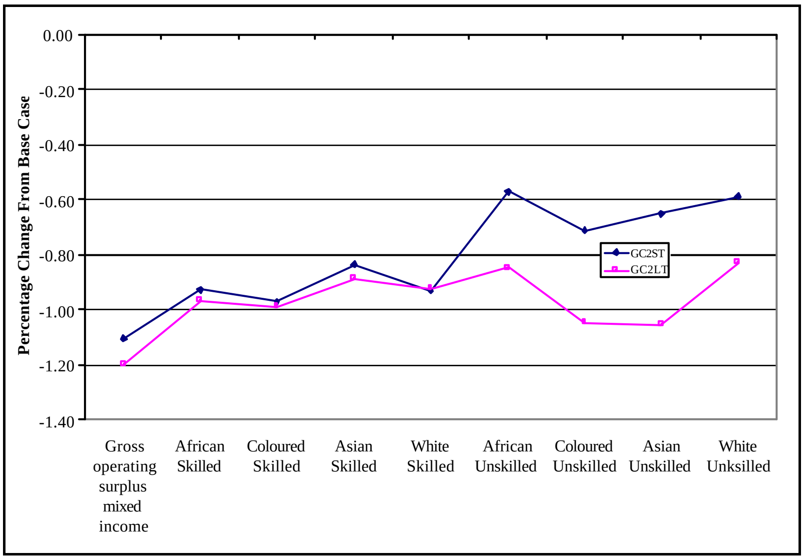


Figure 10. Factor Income Before and After Reallocation (SIM01/SIMSTEP04/GC2)



This raises several interesting issues. How is it possible, and is it appropriate, that owners of a scarce factor can reallocate it in such a way that it derives a lower return than before? The answer brings to light the assumptions on factor market structure embedded in the model. Under perfect competition, the owner of each unit of capital or labour takes prices as given under conditions of perfect competition, and aims to maximise its own income irrespective to the effects that it will have on others. When mobile, a factor is therefore employed in each sector until its marginal revenue product equals its marginal cost, or price. The factor unit at the margin has maximum revenue, but total revenue for all units is not necessarily maximised. Specifically, when the effective elasticity of demand for a factor in the declining sector is relatively high and/or the declining sector starts off with a relatively low share of the factor, total income for the factor is more likely to decline following reallocation. In a CGE model such as the current one, there are also other issues at play, such as the exchange rate (firmer following reallocation), and the assumption of fixed nominal (rather than real) wages for unskilled labour (which results in slightly higher relative wages for unskilled labour and hence higher unemployment)[19].

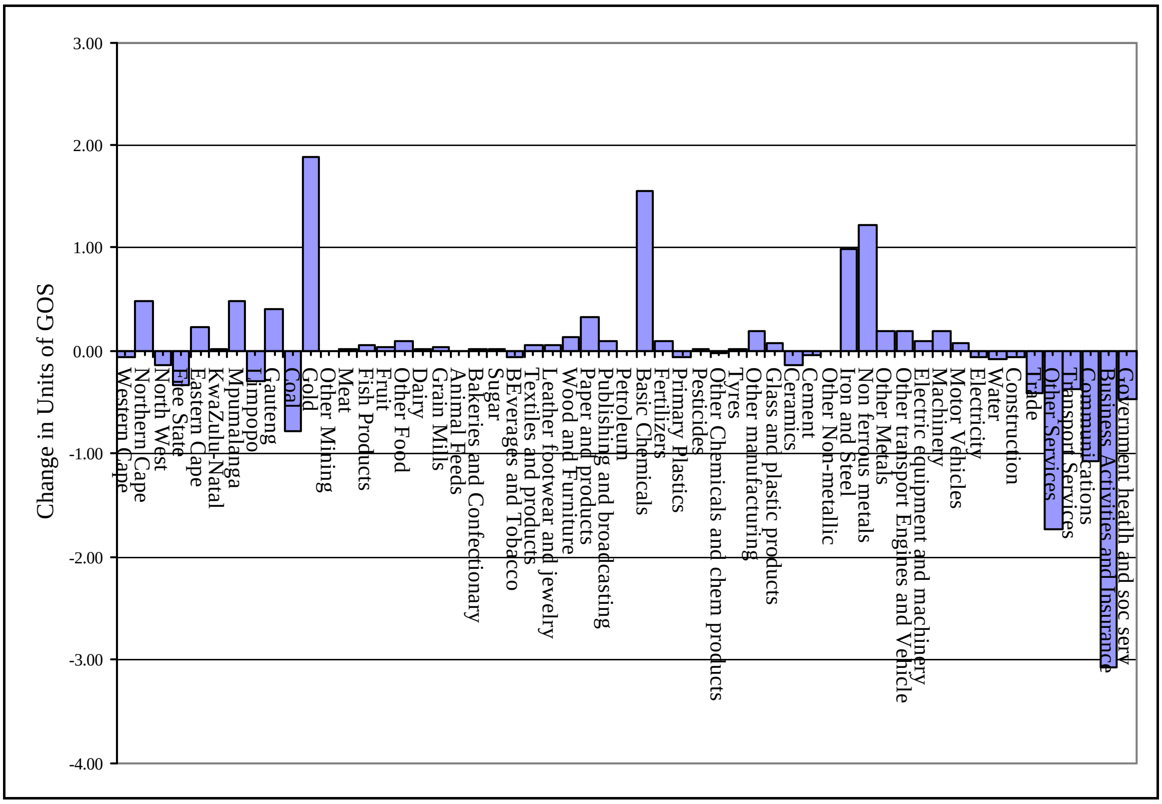
In this sense an economy-wide decrease in income following introduction of capital mobility can be viewed as a coordination failure, i.e. there is a suggestion that centrally directed investment has the potential to raise total income even without recourse to dynamic arguments. However, there are serious caveats accompanying such a suggestion; suffice to say that we have not identified any circumstances under which such policies could be applied in a consistently positive way and in most cases would be expected to have negative effects.

To look more closely at what reallocations took place, it is useful to focus on Gross Operating Surplus (GOS, the capital factor in the model), since the effects for the skilled labour factors are very

[19] We are also looking at nominal GDP. The differences between nominal and real (deflated) GDP is small because CPI is held constant, however, if unskilled labour is assumed to be fully employed, the decrease in real, but not nominal GDP disappears.

similar. The reallocations that have taken place from FCST to FCLT are shown in Figure 11. The figure shows absolute changes in the quantity of capital employed, so that changes in the various sectors sum to zero. Recall that scarce factors employed in the petroleum and other mining activities are fixed, as discussed earlier (see page 13). Generally, capital is reallocated from service sectors[20] towards gold, basic chemicals, iron and steel and non-ferrous metals, all of which have a strong export component. The services have low export intensities and are relatively intensively used as intermediate inputs. The pattern of capital reallocation can therefore be explained by reference to the exchange rate depreciation and general economic decline caused by the oil price increase.

Figure 11. Reallocation of Capital in the Long Term (SIM01/SIMSTEP04/GC2/FCLT)



8. A General Rise in Energy Commodities and Energy Intensive Products

In the previous section, a simple increase in the price of international crude oil is simulated. In the real world, international commodity prices are interrelated, especially in that energy commodities have strong price correlations, and subsequently all commodities that are energy-dependent could be expected to rise following an oil price increase. Alternatively, reversing the causality, one could argue that there is increased global demand generally for many commodities (including crude oil), which also suggests correlated prices.

[20] The service sectors employ a large portion of GOS, so the capital reductions in these sectors do not represent an unduly large relative decline in these sectors. For example, business activities and insurance provide 32.9% of the freed capital, but it only represents a reduction of 0.6% of the capital in this sector.

In this section experiments are conducted where international prices – import and export prices – are adjusted for crude oil as before, but in addition prices of other energy commodities (SIM02) are also increased and subsequently also energy-intensive commodities (SIM03). The specific adjustments are detailed in Table 5. Only the adjustment for SIMSTEP04 are shown, as only results for SIMSTEP04 will be reported; there is little additional information gained from other SIMSTEPs.

In SIM01, an important import commodity's import price was increased, but in SIM02 and SIM03 many of the prices being increased are important export goods for South Africa (especially gold, coal and iron/steel), which be expected to benefit rather than hurt the South African economy. However, the price of crude oil still increases, so that the net effect is difficult to anticipate.

Table 5. Simulation Adjustments (SIM01, SIM02 and SIM03)

Commodity Group	Commodities	Adjustments to Import and Export Prices (at SIMSTEP04)		
		SIM01	SIM02	SIM03
Crude Oil	Crude Oil	+20%	+20%	+20%
Energy	Petroleum Coal Electricity	N/A	+12%	+12%
High Energy-intensive	Iron and Steel Gold	N/A	N/A	+6%
Med Energy-intensive	Other Mining incl natgas Basic Chemicals Fertilizers Pesticides Other Chemicals and chem. Products	N/A	N/A	+4%
Low Energy-intensive	Transport Services Textiles and products Paper and products Primary Plastics Tyres Glass and plastic products Non ferrous metals Other Metals Water Cement	N/A	N/A	+2%

Table 6. Selected Macroeconomic Results for Different Simulations and Factor Market Closures (under GC2)

(Change from base case unless otherwise indicated using *)	SIM01		SIM02		SIM03	
	FCST	FCLT	FCST	FCLT	FCST	FCLT
GDP by Value Added	-1.0%	-1.1%	-0.9%	-1.0%	-0.2%	-0.3%
Value of Final Demand	-0.8%	-0.9%	-0.7%	-0.8%	-0.2%	-0.3%
Value of Imports	+0.9%	+0.6%	+1.0%	+0.8%	+0.8%	+0.8%
Value of Exports	+0.8%	+0.5%	+1.0%	+0.8%	+0.9%	+0.9%
Exchange Rate (LCU/FCU)	+0.6%	+0.2%	-0.3%	-0.6%	-2.9%	-3.4%
Government Dissavings * (% of GDP by Value Added)	-2.1%	-2.2%	-2.1%	-2.1%	-2.1%	-2.1%

From Table 6 it is clear that the overall effect for SIM02 is slightly better than for SIM01, and SIM03 is substantially better, with a GDP decline of only 0.3% (under FCLT). However, the price increases in export goods do not sufficiently offset the negative effects of the oil price increase in SIM03, so that the final effect is still slightly negative. This is explained by the relatively large exchange rate appreciation under this closure, which must have a substantial negative effect on exporters. For each experiment (SIM01, SIM02 and SIM03), the effect of changing the closure from FCST to FCLT is similar – the exchange rate depreciation is slightly weaker and GDP is slightly lower.

Table 7. Effects of Energy (SIM02) and Energy-Intensive (SIM03) Commodity Price Increases on Value Added (SIMSTEP04/GC2/FCST)

(Change From Base Case)	SIM02				SIM03			
	Quantity	Price	Value	Contri-bution	Quantity	Price	Value	Contri-bution
Agriculture	-0.1%	-0.3%	-0.4%	1.5%	-0.2%	-0.8%	-1.1%	17.2%
Coal	4.8%	7.7%	12.9%	-19.3%	4.1%	6.6%	11.0%	-70.4%
Gold	-0.1%	-0.1%	-0.2%	0.6%	4.7%	3.1%	7.9%	-82.8%
Other Mining (Incl Crude Oil)	0.0%	0.1%	0.1%	-0.4%	1.0%	2.3%	3.3%	-57.0%
Food	-0.3%	-0.4%	-0.7%	1.5%	-0.5%	-0.9%	-1.5%	13.9%
Other Energy-Intensive Secondary	-0.2%	-0.9%	-1.1%	4.6%	-0.1%	-0.2%	-0.3%	5.5%
Other Secondary	-0.3%	-0.5%	-0.8%	10.7%	-0.5%	-0.9%	-1.4%	87.8%
Petroleum	0.0%	-0.2%	-0.2%	0.3%	0.0%	-0.9%	-0.9%	5.4%
Iron and Steel	-0.2%	-0.4%	-0.6%	0.8%	2.3%	3.7%	6.0%	-35.4%
Non ferrous metals	-0.2%	-1.3%	-1.4%	1.7%	-0.3%	-2.7%	-3.1%	15.6%
Electricity	-0.2%	-1.3%	-1.5%	4.1%	0.1%	0.6%	0.7%	-8.0%
Trade	-0.3%	-0.9%	-1.1%	14.3%	-0.4%	-1.3%	-1.7%	92.2%
Other Services	-0.5%	-0.8%	-1.3%	20.8%	-0.1%	-0.2%	-0.4%	26.3%
Transport	-0.1%	-0.5%	-0.6%	4.1%	0.1%	0.6%	0.7%	-20.2%
Communications	-0.1%	-1.7%	-1.8%	7.9%	-0.1%	-1.3%	-1.4%	26.2%
Business/Insurance	-0.1%	-1.9%	-1.9%	28.4%	0.0%	-1.0%	-1.0%	65.0%
Government / Social Services	-0.1%	-0.8%	-0.9%	18.4%	0.0%	-0.2%	-0.2%	18.6%
TOTAL	-0.1%	-0.7%	-0.9%	100.0%	0.1%	-0.3%	-0.2%	100.0%

Table 7 shows changes to value-added for various activity groups following the shocks (compare to Table 3). As before, quantity changes are constrained because scarce factors are held fixed. It is immediately obvious that the first and second-rounds effects of these shocks are more complicated than for SIM01. There is a substantial increase in value for export industries when the prices of their export goods are increased (especially mining sectors and iron/steel). On the other hand, import-competing sectors benefit when the prices of their respective import goods are increased. In short, SIM02 and SIM03 represent improved terms of trade compared to SIM01, but not enough to offset the negative effects of the rise in crude oil prices. It is likely that minor changes in various elasticities or the experiment composition could change the results for SIM03 to be beneficial on the balance.

9. Further Considerations and Conclusion

The results presented in this paper show that an oil price increase affects the real South African economy moderately negatively (with a 20% increase in crude oil import price resulting in a drop in GDP of 1% under SIM01). The choice of government expenditure closure is immaterial in these simulations, but the choice of factor market closure is significant. Curiously, we find that in each case, allowing scarce capital mobility, there is a small additional welfare loss, which in itself would be worth investigating further.

The terms of trade effect the exchange rate is critical in our results. Specifically, despite a degree of dependence on petroleum, sectors with reasonably strong export intensity either gain overall (e.g. gold, iron/steel) or are marginally affected (notably agricultural sectors, where value added declines only 0.06% under SIM01). In SIM03, where a favourable terms of trade effect results in a large appreciation, the sectoral distribution of effects on value added are markedly different. In all cases, the effects of the simulations manifest most strongly in the sectors directly affected, namely “other mining” (which produces domestic crude oil), petroleum and coal (acting as a complement to crude oil). Surprisingly, the effects on the transport sector is fairly small, reflecting the fact that petroleum accounts for a smaller share of the costs in this sector – 11.2% – than may be supposed.

The model represents a view of the petroleum sector as if it is liberalised. The South African reality is that fuel prices are administered by means of a formula that equates petroleum product prices to international product prices. It may be that these prices are more strongly correlated with crude oil prices than petroleum prices and crude oil prices are correlated within our model, which suggests that there may be an underestimation of the effects of a crude oil price increase. Further effort spent to accurately model the fuel pricing mechanism would be useful not only to address this issue, but it would also enable the model to run petroleum policy experiments, such as a reduction in the fuel tax, or even the liberalisation of the petroleum sector.

More attention is also required to the issue of energy substitution. For the immediate, it would be desirable to model coal as a substitute rather than as a complement to crude oil. Eventually, a fully-fledged energy accounting model would allow much richer energy analysis.

As part of the process of conducting this study, we have uncovered and adjusted for a significant inconsistency in the source data. While this required a number of assumptions and there are still unanswered questions and missing data (notably for natural gas extraction), the standard PROVIDE SAM now includes accounting for crude oil, which should benefit other studies.

Finally, while we have shown the effects of a simple oil price increase in SIM01, we have also shown that, to see the overall effects on the economy, it is important to correctly place in context the global circumstances leading to an oil price increase. In SIM02 and SIM03, an attempt has been made to provide examples of such contexts, specifically a belief that international crude oil prices result in higher prices for other energy commodities and energy-intensive commodities. This has been shown to benefit South Africa (compared to SIM01), which is a strong exporter of many of these commodities. Alternative contexts are also possible – it would not be unrealistic to argue that other international price increases, such as agricultural commodities, would normally rise along with oil prices when world demand is strong. Some may even prefer the traditional oil-shock view whereby oil prices are set completely exogenously in the world.

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Appendix 1: SAM Accounts

Commodities	Activities	Factors	Households
Summer Cereals	Agriculture: Western Cape	Gross operating surplus mixed income	African Urban Quitiles 1 and 2
Winter Cereals	Agriculture: Northern Cape	African Skilled	African Urban Quintile 3
Oilseeds	Agriculture: North West	African Unskilled	African Urban Quintile 4
Sugarcane	Agriculture: Free State	Coloured Skilled	African Urban Quintile 5a
Other Field Crops	Agriculture: Eastern Cape	Coloured Unskilled	African Urban Quintile 5b
Potatoes and Veg	Agriculture: KwaZulu-Natal	Asian Skilled	African Rural Quintiles 1 to 3
Wine grapes	Agriculture: Mpumalanga	Asian Unskilled	African Rural Quintile 4
Citrus	Agriculture: Limpopo	White Skilled	African Rural Quintile 5a
Subtropical	Agriculture: Gauteng	White Unksilled	African Rural Quintile 5b
Deciduous	Coal		Colouted Urban Triciles 1 and 2
Other Horticulture	Gold		Coloured Urban Tricile 3a
Livestock Sales	Other Mining		Coloured Urban Tricile 3b
Milk and Cream	Meat		Coloured Rural
Animal Fibres	Fish Products		Asian Duociles 1 and 2a
Poultry	Fruit		Asian Duocile 2b
Other primary industries	Other Food		White Urban Quartile 1
Forestry	Dairy		White Urban Quartile 2
Coal	Grain Mills		White Urban Quartile 3
Gold	Animal Feeds		White Urban Quartile 4a
Crude Oil	Bakeries and Confectionary		White Urban Quartile 4b
Other Mining	Sugar		White Rural Duociles 1 and 2a
Meat	Beverages and Tobacco		White Rural Duocile 2b
Fish Products	Textiles and products		
Fruit	Leather footwear and jewelry		
Other Food	Wood and Furniture		
Dairy	Paper and products		
Grain Mills	Publishing and broadcasting		
Animal Feeds	Petroleum		
Bakeries and Confectionary	Basic Chemicals		
Sugar	Fertilizers		
Beverages and Tobacco	Primary Plastics		
Textiles and products	Pesticides		
Leather footwear and jewelry	Other Chemicals and chem products		
Wood and Furniture	Tyres		
Paper and products	Other manufacturing		
Publishing and broadcasting	Glass and plastic products		
Petroleum	Ceramics		
Basic Chemicals	Cement		
Fertilizers	Other Non-metallic		
Primary Plastics	Iron and Steel		
Pesticides	Non ferrous metals		
Other Chemicals and chem products	Other Metals		
Tyres	Other transport Engines and Vehicle parts		
Other manufacturing	Electric equipment and machinery		
Glass and plastic products	Machinery		
Ceramics	Motor Vehicles		
Cement	Electricity		
Other Non-metallic	Water		
Iron and Steel	Construction		
Non ferrous metals	Trade		
Other Metals	Other Services		
Oth Transp Engines and Vehicle parts	Transport Services		
Electric equipment and machinery	Communications		
Machinery	Business Activities and Insurance		
Motor Vehicles	Government heatlh and soc serv		
Electricity			
Water			
Construction			
Trade			
Other Services			
Transport Services			
Communications			
FSIM			
Business Activities and Insurance			
General Govt health and social work			

Appendix 2: Energy-related Structural Information From the Adjusted Social Accounting Matrix.

Activity	Total Expenditure (Column Total) (R '00 000 000)	Expenditure on Energy Commodities vs Activity Expenditure	Ranking	Of which liquid (Oil/Petroleum)
Agriculture	527.5	5.0%		83.2%
Western Cape	117.4	4.1%	18	70.1%
Northern Cape	26.3	2.5%	30	72.2%
North West	48.0	6.3%	10	86.3%
Free State	70.5	8.3%	8	94.1%
Eastern Cape	33.0	3.6%	21	79.4%
KwaZulu-Natal	74.0	3.2%	25	82.1%
Mpumalanga	62.0	5.8%	12	87.4%
Limpopo	60.4	5.7%	13	80.5%
Gauteng	35.7	4.3%	16	82.0%
Mining	1014.7	5.0%		23.40%
Coal	205.0	3.3%	24	43.9%
Gold	292.5	8.1%	9	6.4%
Other Mining	517.2	3.9%	20	36.5%
Food	680.6	1.7%		35.1%
Meat	187.0	1.6%	38	26.5%
Fish Products	16.3	5.2%	15	32.5%
Fruit	42.4	2.1%	33	30.9%
Other Food	103.1	0.9%	47	37.6%
Dairy	67.3	1.7%	37	35.0%
Grain Mills	100.4	1.5%	39	27.6%
Animal Feeds	45.7	1.4%	40	39.3%
Bakeries and Confectionary	75.9	3.1%	27	51.9%
Sugar	42.5	0.8%	49	26.2%

Manufacturing				
Beverages and Tobacco	3943.4	4.0%		36.9%
Textiles and products	284.0	0.8%	52	31.0%
Leather footwear and	209.1	1.8%	35	26.0%
jewelry	83.3	1.4%	41	28.7%
Wood and Furniture				
Paper and products	170.0	1.0%	46	26.8%
Publishing and	249.5	0.8%	50	30.7%
broadcasting	182.3	0.6%	53	40.9%
Basic Chemicals	88.3	4.3%	17	79.4%
Fertilizers	64.3	3.4%	23	77.7%
Primary Plastics	116.9	14.0%	4	94.0%
Pesticides	21.2	0.6%	54	78.2%
Other Chemicals/products	313.7	6.0%	11	33.4%
Tyres	36.2	11.4%	7	45.9%
Other manufacturing	133.3	3.2%	26	31.9%
Glass and plastic products	134.1	1.3%	43	69.9%
Ceramics	33.1	4.0%	19	38.0%
Cement	36.0	3.5%	22	25.0%
Other Non-metallic	52.7	2.1%	32	29.3%
Iron and Steel	369.4	11.9%	6	12.2%
Non ferrous metals	203.4	17.5%	3	29.9%
Other Metals	244.4	1.3%	44	32.8%
Transport Equipment	175.2	0.9%	48	49.0%
Electric Eq. and machinery	135.9	2.3%	31	66.8%
Machinery	162.7	1.7%	36	54.0%
Motor Vehicles	444.6	0.4%	55	98.3%
Petroleum	453.7	73.0%	1	80.1%
Electricity	312.1	18.8%	2	1.3%
Water	100.8	5.5%	14	5.8%
Construction	752.9	2.5%	29	91.4%
Transport Services	893.3	12.6%	5	88.7%
Other Tertiary Activities	9158.0	1.4%		55.3%
Trade	1605.0	2.0%	34	56.9%
Other services	1592.9	1.3%	42	28.6%
Communications	527.2	2.7%	28	55.5%
Business activities and Insurance	1724.3	0.8%	51	58.5%
Government and soc serv	2089.2	1.2%	45	73.3%

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