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Evaluating the impact of global oil prices on the SADC and the potential for increased trade in biofuels and natural gas within the region

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Abstract: This paper investigates whether Southern African Development Community countries that are vulnerable to changes in oil prices could instead substitute oil and petroleum products with biofuels and gas from within the region. A pooled mean group estimator was used to determine the impact of oil prices on the gross domestic product of 15 Southern African Development Community countries. Results indicate that Mauritius, Mozambique, Tanzania, and Zambia would be negatively affected by oil price changes. Next, two gravity models capturing bilateral trade between South Africa and Zambia and those countries identified as being vulnerable were estimated using pseudo-Poisson maximum likelihood. The main finding, based on the gross domestic products of the exporter and importer countries, is that potential for trade is higher with South Africa than Zambia. This implies that these countries are more likely to import gas and biofuels from there. Transport costs are the main impediments to importing from Zambia.

Keywords: economic growth, global oil price, panel data models, regional integration, SADC
JEL classification: C23, F10, Q43

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1 Introduction and background to the study

Countries within the Southern African Development Community (SADC) region are heavily reliant on petroleum products made from imported crude oil, particularly in their transport sectors. Most of these countries are net importers of these petroleum products, with Angola being an exception. The challenge they face is that, while they require petroleum products for economic activity, they have no control over the price of crude oil used to produce such products. SADC countries are price-takers and therefore vulnerable to global oil price changes. Oil price increases could have a detrimental effect on their economies, and energy security could also be compromised by the high dependency on oil imports.

Global crude oil prices have generally been volatile over the past decades, as evidenced by data from the World Bank (2019). Major increases in global oil prices were experienced in 1978 when Iran cut its production and terminated contracts with companies from the USA, and from 2001 to 2007 due to limited supply following the 9/11 attack and the US invasion of Iraq. The Arab Spring uprisings and the instability in Libya reduced supply, leading to increases in global oil prices in 2011. On the other hand, oil prices dropped significantly when Saudi Arabia increase production in 1986 to maintain its market share, during the Asian financial crisis in 1997 and the global financial crisis in 2007, and when there was excess supply in 2014. Growth in the production of shale or tight oil in the USA has been largely responsible for the recent excess supply of crude oil in the global market. Saudi Arabia, the world's largest oil exporter, decided to continue producing the same amount of output as before to maintain its market share, thereby keeping oil supply high. On the other hand, global demand for oil declined over this period, due in part to the slowdown in the economy of China, a major importer. The relatively low global oil prices in the last few years can thus be attributed to changes in both supply and demand of oil.

Considering that the economies of some SADC countries that import crude oil from outside the region could be vulnerable to oil price fluctuations, the aim of this paper is to investigate whether they could substitute oil with biofuels and natural gas from the region. This could have economic benefits for the individual countries and the region. As the crude oil would be substituted by zero- or lower-carbon alternatives, the substitution would also contribute to emissions reductions in the SADC and promote sustainable development.

South Africa and Mozambique have the potential to contribute large amounts of natural and/or shale gas into the Southern Africa region. Total, the multinational oil and gas company, recently announced a major offshore natural gas discovery on the Brulpadda prospect, situated south of Mossel Bay in South Africa (Steyn 2019). It is estimated that the discovery could have as much as one billion barrels of gas condensate. If exploited successfully, this natural gas discovery would be expected to change South Africa's future energy profile significantly. On the other hand, although initial estimates were that as much as 500 trillion cubic feet (tcf) of shale gas resources could be obtained in the Karoo region, these have since been revised downwards to around 20 tcf, although de Kock et al. (2017) pointed out that this revised amount is still large and will contribute positively to South Africa's petroleum industry. Mozambique also has large amounts of natural gas that are currently being exploited by, among others, Sasol, with some of this natural gas being exported to South Africa. Although Sasol's current natural gas operation has reserves of 2.6 tcf, over 180 tfc of natural gas reserves has been discovered in the Rovuma basin. Mozambique will therefore contribute significantly to the supply of natural gas in the SADC.

The demand for biofuels is mostly driven by the transport sector (Fundira and Henley 2017). Although some countries in the SADC have attempted to use fuel-blending mandates as a way of creating demand for biofuels, this approach has largely been unsuccessful. The production of biofuels in Zambia, Mozambique, and South Africa has so far been minimal due to several factors, including lack of access to finance, land, and guaranteed markets, as well as the presence of fossil fuel subsidies on imports (Fundira and Henley 2017). Some recent studies have, however, highlighted that Zambia and Mozambique still have huge potential to produce biofuels (Hartley et al. 2016, 2017). Zambia has now removed its fossil fuel import subsides, and has abundant arable land that can be used to grow crops such as sugarcane and cassava that can be used as feedstock to produce ethanol (Hartley et al. 2017). The Mozambique government has also approved sugarcane as a feedstock to produce bioethanol (Hartley et al. 2016), which could contribute towards increasing biofuel production in the country. The production of these biofuels could help reduce the demand for imported crude oil in the SADC region. The demand for most of the biofuels produced within the SADC is expected to come from South Africa. The Department of Energy indicated in its 2015–2020 Strategic Plan that it will import biofuels from other countries in the SADC region to meet domestic demand (Department of Energy 2015). Hartley et al. (2017) note that this demand for biofuels could reach 1,550 million litres by 2025.

The first objective of this paper is to identify those countries whose economies are vulnerable to global oil price changes. The second is to investigate the possibility of substituting the petroleum products made from imported oil with biofuels and natural gas from within the SADC region.

The rest of the paper is organized as follows: Section 2 presents a literature review, followed by a description of the methodological approach adopted in Section 3. Section 4 presents the results and discussion. The paper then concludes and policy recommendations are made.

2 Literature review

This literature review focuses on two aspects. First, it considers empirical studies that have investigated the relationship between global oil prices and economy growth in the SADC. This is followed by a review of studies that have assessed the determinates of bilateral trade.

2.1 Empirical studies on the impact of oil prices on the economy

Previous studies have highlighted the different transmission channels or avenues through which oil price changes influences economic activity in a country. These include effects on inflation, production (or the supply side), consumption (or the demand side), trade balance, and wealth (Canta 2014; Ferderer 1996; Hamilton 1983; Jiménez-Rodríguez and Sánchez 2005; Lardic and Mignona 2006; Mork et al. 1994). Some of these studies and others have gone on to investigate the causal relationship between oil prices and economic growth and to estimate its magnitude. These studies also show that theoretically there is an inverse relationship between oil price and economic growth, mostly in net oil-importing countries. On the other hand, net oil-exporting countries would be expected to exhibit a positive oil price–economic growth relationship. One of the earliest and most widely cited studies on the causal effect between oil prices and economic growth was by Hamilton (1983), whose analysis of the impact of oil prices in the USA concluded that they influenced the amount of economic output produced. Since then, most empirical studies have generally employed two estimation techniques, namely computable general equilibrium modelling for ex-ante analysis, and econometric models, both time series and panel data, for ex-post estimation. As this study uses historical data on global oil prices and economic output, the literature reviewed on the relationship focuses on the ex-post studies.

Jiménez-Rodríguez and Sánchez (2005) analysed the impact of oil price shocks on gross domestic product (GDP) growth for some industrialized Organisation for Economic Co-operation and Development (OECD) countries using a multivariate vector autoregressive model. Their study showed that the effect of oil prices is asymmetric, with increases leading to a bigger effect on economic activity than oil price decreases. The relationship for the latter was, however, found to be statistically insignificant. Oil price increases were also found to have a negative effect on the economic activity of oil-importing countries. The impact on the two oil-exporting countries considered in their study produced conflicting results, with the UK exhibiting a negative relationship between the two and Norway a positive one.

Several studies have also considered the asymmetric or non-linear impact of oil prices, initially identified by Mork (1989). The results of these studies further support the hypothesis that the impact of oil prices on economic growth or aggregate output is asymmetric (Cuñado and de Gracia 2003; Hamilton 2003; Jiménez-Rodríguez and Sánchez 2005; Lardic and Mignona 2006; Zhang 2008). Canta (2014) found that in the long- and short-run oil prices have had a negative effect on the economic growth of Ghana. The study used an autoregressive-distributed lag (ARDL) model with real GDP as the regressand. The data used to conduct the analysis covered the period 1967–2011. In its conclusion, the study suggested that Ghana should consider using alternatives to crude oil, such as compressed natural gas (CNG), liquefied petroleum gas, or ethanol in order to mitigate the negative impacts of oil prices.

Simohammed et al. (2015) investigated the impact of oil prices on several macroeconomic variables, including the economic growth rate, in countries in the Middle East and North Africa. Similar to Canta (2014), a panel ARDL model was used to conduct the analysis. Results from their study indicated that there was a short-run relationship between oil prices and economic growth, but in the long run there was no cointegration relationship between the two variables.

Berument et al. (2010) conducted an analysis of the effects of oil prices on the output of 16 Middle East and North African countries, some oil-exporting and some oil-importing. The study used a vector autoregressive (VAR) model and found that oil price increases had a positive impact on the output of most of the net oil-exporting countries, including Iran, Iraq, and Qatar. The impact on the output of the mostly net oil-importing countries was found to be statistically insignificant.

Some have investigated the impact of oil price volatility on economic variables, including growth. Rafiq et al. (2009) used a VAR model to assess the impact of oil price volatility on Thailand's economy, finding that it had a negative effect on unemployment and investment. Jawad (2013) analysed the impact of oil price volatility on the economic growth of Pakistan, a net crude oil importer, using a linear regression model and data covering the period 1973–2011. In their model, GDP was regressed on oil price volatility, with private and public sector investment and trade balance included as control variables. Their main finding was that oil price volatility has an insignificant impact on GDP in Pakistan. Difeto et al. (2018) considered the impact of oil price volatility on the real GDP per capita of 17 mainly industrialized countries that were members of the OECD and mostly net oil importers. Using a wide array of panel data econometric models, they found that oil price volatility had a negative impact of economic growth.

While several studies have used general equilibrium models to investigate the economy-wide implications of oil prices changes on countries in Southern Africa, empirical literature on ex-post analysis of their impact on the economic growth of SADC member states and the region is scarce. Nkomo (2006) considered the impact of higher oil prices on 11 Southern African countries by assessing their oil vulnerability decomposed into three components: oil import dependence, the share of oil in the energy mix of individual countries, and energy intensity. The study postulated that oil price shocks would have a negative impact on the import bill of countries due to the inability to shift production to less oil-intensive alternatives in the light of higher oil prices. Matekenya (2013) used a cointegration approach to estimate the impact of oil price volatility on economic growth in South Africa. Using a vector error correction model (VECM), the study found a positive relationship exists between oil price volatility and economic growth, but with a negative relationship in the short run.

While numerous econometric studies on the relationship between global oil prices and economic growth exist, most of them have focused on developed countries, and some on other parts of the African continent. There is currently limited understanding of the impact of oil prices on the economic growth of countries in the SADC. The present study contributes to existing knowledge by filling this gap.

2.2 Empirical studies on the determinants of bilateral trade flows

As the aim of this paper is to investigate whether the countries that are vulnerable to global oil price changes could substitute the oil with biofuels and natural gas from the region, the following literature review focuses on studies that have investigated the determinants of bilateral trade between countries.

Tinbergen (1963) pioneered the use of gravity models to conduct ex-post analysis to explain the flow of trade between two countries. The specification of this model was that bilateral trade flows were a function of the two countries' GDPs and the distance between their economic centres. Although the model proved to be useful and predicted trade well, its foundations were in physics—that is, Newton's gravitation theory. Studies such as those of Linnemann (1966), Bergstrand (1985), and Anderson and Van Wincoop (2003) contributed to the establishment of theoretical microeconomics for the gravity model. While Linnemann viewed the gravity model as a reduced form of a partial equilibrium model of export supply and import demand, Bergstrand postulated that it was rather a subsystem of a general equilibrium model composed of nationally differentiated products. Anderson and Wincoop contributed to the further development of the microeconomic foundation by formulating a specification that accounted for endogeneity of trade costs as well as institutional barriers. Emphasis was placed on the inclusion of multilateral resistance, which refers to the barriers that countries involved in bilateral trade face with all their other trading partners, as an important factor influencing trade flows in gravity models.

Numerous empirical studies have applied the gravity model in order to assess the effectiveness of regional trade agreements (RTAs) in increasing intraregional trade. Some of these studies have proceeded to explore the implications of RTAs on trade creation and diversion. Most of the earlier empirical studies used ordinary least squares (OLS) models to estimate gravity models (Chauvin and Gaulier 2002; Kang and Fratianni 2006; Roberts 2004; Sarker and Jayasinghe 2007). Other studies have used fixed effects and random models (Egger 2002; Grant and Lambert 2008). According to Baier and Bergstrand (2009), fixed effects models account for multilateral resistance. Various other models, such as the Heckman model, pseudo-Poisson maximum likelihood (PPML), and the Tobit model have also been used to estimate gravity models (Rojid 2006; Santos Silva and Tenreyro 2010; Seid 2013).

In investigating the prospects of increasing trade within the SADC, Chauvin and Gaulier (2002) estimated a gravity model. Their aim was to understand whether establishing a free trade area (FTA), expected to be launched by 2012, would increase intra-SADC trade. Their sample was comprised 30 exporting and 50 importing countries. This sample was made up of emerging countries, some of them African and industrialized countries. Factors influencing trade in their model included GDP, population, distance and common border in their model, and remoteness. A dummy variable for the presence of a preferential trade agreement (PTA) between trade partners was also included. The gravity model was estimated using weighted OLS and the results indicated that the potential for expanding intra-SADC trade was limited, although there was the possibility of some trade creation.

Herman et al. (2011) used an augmented gravity model to explore whether establishing a common-currency union of countries in Southern Africa was feasible. Variables accounted for in their model included public debt, deficit, and expenditure, as well as inflation and foreign reserves. Existing trade blocs to which these countries belonged were also included. Results from their fixed effects gravity model showed that these trading blocs, namely the East African Community and Southern African Customs Union, led to increased trade between countries that belonged to them. They also found that convergence of fiscal and monetary variables within the SADC did not influence trade, and thus adoption of a common currency would not stimulate trade.

Seid (2013) used a PPML model to investigate the determinants of intraregional trade. This model was applied in part to deal with the problem of zero trade between countries. Their gravity model considered the influence of economic communities such as the Common Market for Eastern and Southern Africa (COMESA), the Economic Community of West African States (ECOWAS), the Intergovernmental Authority on Development, and the SADC in encouraging bilateral trade. Results indicated that only the SADC and ECOWAS stimulated trade among their member countries. Other variables included in most traditional gravity models—such as GDP, population, distance, and order—were also found to be important in influencing trade. Fadeyi et al. (2014) also used a PPML specification of gravity model to investigate the effect the SADC FTA had on agricultural trade. According to their results, the FTA had a trade-creating effect, with increased trade in beef and maize within the SADC region.

Using a Tobit gravity model, Rojid (2006) investigated whether COMESA liberalized or created more trade internally. The sample was made up of 147 exporting countries, including those from outside COMESA, in a time frame from 1980 to 2001. Their study also sought to estimate the trade potential of COMESA. Their results showed that COMESA encouraged trade creation within the bloc. The potential for trade was, however, found to be limited, except in Angola and Uganda.

Some studies have focused on bilateral trade between a particular country and its trading partners. Simwaka (2006) used a fixed effects model to investigate the determinants of trade between Malawi and its partners. Results showed that the GDP of the importing country and being members of the same regional integration agreement had a positive effect on trade, while distance and exchange rate volatility had an adverse effect. Eita (2008) used a fixed effects gravity model to analyse the determinants of Namibia's exports. Exports were found to have been positively influenced by increases in Namibia's GDP and that of its trading partners, as well as the presence of a common border. On the other hand, the results indicated that distance and the trading partners' GDP per capita would affect exports negatively. Darku (2009) applied a gravity model with specific country dummy variables to assess the factors that influenced bilateral trade between Tanzania and its trading partners. One of the main findings of the study was that there was trade creation through the exchange of goods and services between Tanzania and the European Union (EU) and East African Community. The results also showed that Tanzania's non-traditional trading partners, such as Japan and India, were more open to exports and this would present an opportunity for Tanzania to grow its export market. Using a fixed effects gravity model to analyse the trade effects of EU–South Africa and SADC PTAs, Jordaan and Kanda (2011) found that the EU–South Africa PTA increased trade while the SADC PTA seemed to reduce it. The researchers, however, indicated that the SADC PTA was not fully operational in the time period covered by the study, so these results need to be taken with caution.

3 Methodology

A two-step approach was used to investigate whether SADC countries whose economies were vulnerable to changes in global crude oil price could substitute their imported oil with alternatives such as biofuels and natural gas from within the region.

The first step was to estimate the impact of global oil prices on economic growth of countries within the SADC region. As indicated in the literature review, some studies have used a panel ARDL model to estimate the effect of oil price increases on economic growth (Canta 2014; Simohammed et al. 2015). In this study, a pooled mean group (PMG) estimator, which uses the maximum likelihood method to estimate parameters of a dynamic panel ARDL model, was used (Pesaran et al. 1999). This model was chosen primarily because country-specific results could be obtained from it, but another advantage is that both stationary and non-stationary data can be used to estimate the model, if the data are not integrated of order 2. However, a drawback of the model is that it assumes that in the long run the effect of global oil prices will be the same across all countries. In this study, the focus is more on the country-specific results provided by the short-run estimation of the model.

Once the countries that were impacted adversely by oil price changes had been identified, the next step would be to estimate separate gravity models for Zambia and South Africa, capturing their bilateral trade with the countries identified in the first step. These gravity models would provide insight into the trade between these countries and the potential for future trade. Due to limited availability of data, this study did not estimate a gravity model for Mozambique. In this study the PPML was chosen to estimate the traditional gravity model, similarly to Seid (2013). The advantage of using a PPML over the other methods mentioned in the literature review is that it deals with the problem of heteroscedasticity in trade data. It also deals with cases of zero trade between countries in the data. The PPML model is therefore able to produce unbiased and consistent estimates despite these two problems. However, a disadvantage of the model is that if the data were censored significantly, then that would result in limited dependent variable bias (Gómez-Herrera 2013). The data used in this analysis were not censored significantly, so this bias was not a concern.

The models used in this two-step approach, as well as the data used, are described in more detail in the following subsections.

3.1 Econometric models

Oil prices economic growth model

A PMG estimator was used to analyse the impact of oil prices on economic growth. A PMG estimator is appropriate for analysing non-stationary dynamic heterogeneous panels. It constrains long-run coefficients of the estimated model by making them equal or homogeneous but allows the short-run coefficients and error variances to vary across groups in the panel (Pesaran et al. 1999). Since the purpose of this first step of the approach adopted in this study is to identify which countries in the SADC are impacted negatively by global oil developments, the ability of these models to provide country-specific estimates makes them ideal. Also, as the country-specific short-run coefficients are all from the same PMG estimator, it makes it easier to compare impacts compared to estimating separate models for each country. As mentioned earlier, PMG estimators determine parameters of a dynamic panel ARDL model using the maximum likelihood method (Pesaran et al. 1999). According to Blackburne and Frank (2007: 198) a dynamic panel ARDL is specified as follows:

$$y_{it} = \sum_{j=1}^{p} \lambda_{ij} y_{i,t-j} + \sum_{j=0}^{p} \delta_{ij}^{'} X_{i,t-j} + \mu_i + \epsilon_{it} \quad (1)$$

where the number of groups $i = 1,2, \ldots N$; number of periods $t = 1,2, \ldots T$; X_{it} is a $k \times 1$ vector of explanatory variables; δ_{it}^{*} are the $k \times 1$ coefficient vectors; λ_{ij} are the scalars; and μ_i is the group-specific effect.

The ARDL model in Equation (1) can be specified as an error correction equation as follows:

$$\Delta y_{it} = \varnothing_i \left(y_{i,t-1} - \theta_i^{'} X_{it} \right) + \sum_{j=1}^{p-1} \lambda_{ij}^{*} \Delta y_{i,t-1} + \sum_{j=0}^{p-1} \delta_{ij}^{'*} \Delta X_{i,t-j} + \mu_i + \epsilon_{it} \quad (2)$$

where $\varnothing_i$ is the error correction coefficient. It will be between 0 and –1 if there is cointegration, and it should be statistically significant.

This study estimated an ARDL (1,0) model based on Equation (2), with additional variables included in the short-run specification of the model. The dependent variable in the model is real GDP and the explanatory variables are global oil price, inflation, and investment.

However, before applying the PMG estimator, Im, Pesaran, and Shin (IPS) unit root tests were carried out to ascertain the univariate characteristics of the data and ensure that none of the variables were integrated of order 2.

Following this, tests for cointegration were done using the Pedroni (1995) test. The results of the test are provided in Table 2 in Section 4. A precondition for the application of the panel ARDL model is that the variables should be co-integrated. The Pedroni test allows specific parameters to vary across individual units in the sample, thereby accounting for heterogeneity. The null hypothesis of the Pedroni test is that there is no cointegration. The test provides seven statistics which are then used to determine whether there is cointegration or not. The PMG estimator was estimated after confirming that there was indeed cointegration—that is, a long-run relation exists between the global oil price variable and that of real GDP.

Gravity model of bilateral trade flows

Having identified the countries whose economies are relatively more vulnerable to oil price changes, two gravity models of bilateral trade were estimated to develop a better understanding of the enablers and barriers of trade between the countries that could potentially substitute oil with gas or biofuels (identified from the PMG estimator), and those countries in the SADC with the potential to supplying these alternatives.

The traditional gravity model specification explained bilateral trade, defined as the sum of exports and imports or just exports, as a function of GDP and the geographical distance between capital or economic centres in the trading partners.

In this study, the PPML was used to estimate the traditional gravity models. The log-linearized specification of the model is as follows:

$$\begin{aligned} X_{ijt} = {} & \alpha + \beta_1 \ln GDP_{it} + \beta_2 \ln GDP_{jt} + \beta_3 \ln Pop_{it} + \beta_4 \ln Pop_{jt} + \beta_5 \ln Dist_{ij} + \\ & \beta_6 lang_{ij} + \beta_6 border_{ij} + \beta_6 colony_{ij} + \varepsilon_{ij} \end{aligned} \quad (3)$$

where:

X_{ijt} are exports from country *i* to country *j*;

$\ln GDP_{it}$ is the exporter's real GDP;

$\ln GDP_{jt}$ is the importer's GDP;

$\ln Pop_{it}$ is the exporter's population size;

$\ln Pop_{jt}$ is the importer's population size;

$\ln Dist_{ij}$ is the distance between country *i* and country *j*;

$lang_{ij}$ is a dummy variable for a common language between countries *i* and *j*;

$border_{ij}$ is a dummy variable for a common border between countries *i* and *j*; and

$colony_{ij}$ is a dummy variable for a common colonial history between the countries *i* and *j*.

The coefficients of the continuous explanatory variables are interpreted as elasticities.

While the traditional gravity model would only have GDP and distance as explanatory variables, to capture the effect of the size of the economy and transport or logistic cost respectively, the model used in this study also included population size, common languages, border, and colonial history between countries. The choice of these variables was based on literature reviewed in Section 2.2, but was limited by the availability of data.

3.2 Data

The dataset used to estimate the models was made up of information obtained on 15 SADC member states, namely Angola, Botswana, Democratic Republic of the Congo (DRC), Lesotho, Madagascar, Mozambique, Mauritius, Malawi, Namibia, Republic of South Africa, Swaziland, Seychelles, Tanzania, Zambia, and Zimbabwe. Comoros was excluded from the dataset as it only joined the SADC recently and could therefore distort the results of this study. For the PMG estimator, data on GDP, inflation, and investment measured by gross fixed capital formation as a share of GDP was obtained from the World Development Indicators database of the World Bank. Global oil prices were sourced from the Short-Term Energy Outlook database of the United States Energy Information Administration (EIA 2018). For the PPML gravity models, data on exports from South Africa as well as Zambia to their trading partners was sourced from the International Monetary Fund's Direction of Trade Statistics database. Population sizes were obtained from the World Development Indicators. Data on common language, common border, and colonial history were obtained from the SADC website. Distances between economic centres in these countries was taken from Google Maps by considering the distance if travelling by major roads. For Mauritius the distance by air was used. However, although it was indicated earlier in this paper that Mozambique had the potential to produce large amounts of both biofuels and natural gas, we did not estimate a gravity model for Mozambique due to limited data availability.

The data used in this paper covered the period 1990–2017, except for the database for the South African gravity model, which used data ranging covering 1998–2017.

4 Empirical results and discussion

This section begins by presenting results from the modelling of the effect of oil prices on real GDP. Tests were done to establish the univariate properties of the variables, to ensure that none of them were integrated of order 2, that is, I(2). The presence of variables that were I(2) would invalidate the model. The results from the IPS panel unit root tests are presented in Table 1.

Table 1: Panel unit root test results

	IPS test		Order of integration
	Levels	First difference	
Real GDP	3.1042	–9.2013***	I(1)
Global oil prices	0.4358	–9.3737***	I(1)
Inflation	–4.9742***	–15.5246***	I(0)
Investment	–1.2870	–8.1484***	I(1)

Notes: null hypothesis: The series has a unit root—that is, it is non-stationary.

* significant at 10 per cent level, ** significant at 5 per cent level, *** significant at 1 per cent level.

Source: author's computation based on World Bank and EIA data.

As shown in Table 1, all the variables that were tested were either integrated of order 0 or 1. None of them were I(2). Having established the univariate properties of the variable, tests for a cointegration were conducted. The Pedroni panel cointegration test results are presented in Table 2.

Table 2: Pedroni panel cointegration test

	Test statistics	
	Within-dimension/panel	Between-dimension/group
v-statistics	3.986***	
rho-statistics	–15.09***	–12.26***
PP- statistics	–15.37***	–16.48***
ADF- statistics	–14.73***	–14.77***

Notes: null hypotheses: no cointegration. All test statistics are distributed N(0,1). The test statistics are one-sided tests with a critical value of –1.64, except the v-statistic that has a critical value of 1.64. * significant at 10 per cent level, ** significant at 5 per cent level, *** significant at 1 per cent level.

Source: author's computation based on World Bank and EIA data.

Based on all seven statistics provided by the Pedroni test, the null hypothesis of no cointegration is rejected. It was therefore concluded that there is a long-run relationship between global oil prices and real GDP. Following this confirmation, the PMG estimator was applied. The results from the model are presented in Table 3.

The negative and statistically significant error correction term and the statistically significant coefficient of the long-run model confirm its validity. This means that if there is any deviation from long-run equilibrium, the error term will adjust the model so that it returns to equilibrium. The PMG estimator results in Table 3 indicate that in the long run a 1 per cent increase in the global oil price will lead to a 2.9 per cent decrease in the real GDP of SADC member states. This is in line with expected results, as most of the countries in the region are net oil importers and would therefore have to pay more for oil, hence the negative impact on economic growth. These results show that economies in the SADC countries are vulnerable to oil price changes. The results in Table 3 are, however, for the pooled data. PMG estimators allow for heterogeneity in short-run coefficients. The country-specific effects of oil prices on real GDP are presented in Table 4. The results on the other control variables included in the model are not from the table.

Table 3: PMG estimator results: dependent variable is log real GDP

	Coefficient	Standard error
Long run		
Log oil price	–2.8953***	1.0397
Short run		
Error correction	–0.0262*	0.0149
d.log oil price	–0.1877***	0.0457
d.log inflation	0.0656*	0.0382
d.log investment	0.0814	0.0497
Constant	1.2154**	0.6067
No. observations	280	

Notes: * significant at 10 per cent level, ** significant at 5 per cent level, *** significant at 1 per cent level.

Source: author's computation based on World Bank and EIA data.

Table 4: Short-run country-specific results from the PMG estimator: dependent variable is log real GDP

Country	Variable	Coefficient	Standard error
Angola	Error correction	–0.0917***	0.0099
	D. log Oil price	–0.2830	0.2455
Botswana	Error correction	–0.0021	0.0070
	D. log Oil price	–0.0592	0.0916
DRC	Error correction	–0.1459***	0.0224
	D. log Oil price	–0.7029	0.5485
Eswatini	Error correction	–0.0033	0.0081
	D. log Oil price	–0.1594*	0.0748
Lesotho	Error correction	0.0543	0.0389
	D. log Oil price	–0.2217*	0.0895
Malawi	Error correction	–0.0120	0.0072
	D. log Oil price	–0.0384	0.0954
Madagascar	Error correction	–0.0153	0.0090
	D. log Oil price	–0.0824	0.0843
Mauritius	Error correction	–0.0089*	0.0047
	D. log Oil price	–0.1441***	0.0425
Mozambique	Error correction	–0.1194**	0.0521
	D. log Oil price	–0.2583**	0.1012
Namibia	Error correction	0.0231	0.0195
	D. log Oil price	–0.1635**	0.0623
Seychelles	Error correction	0.0163	0.0107
	D. log Oil price	–0.0295	0.0947
South Africa	Error correction	–0.0100	0.0081
	D. log Oil price	–0.1379*	0.0728
Tanzania	Error correction	–0.0111**	0.0049
	D. log Oil price	–0.0782*	0.0436
Zambia	Error correction	–0.0414*	0.0229
	D. log Oil price	–0.2701***	0.0416

Notes: Zimbabwe dropped due to missing data/limited availability of data. * significant at 10 per cent level, ** significant at 5 per cent level, *** significant at 1 per cent level.

Source: author's computation based on World Bank and EIA data.

According to the short-run results from the model, global oil prices have a negative and significant effect on the economies of four of the 15 SADC countries, namely Mauritius, Mozambique, Tanzania, and Zambia. Zambia is the most adversely affected, with a 1 per cent increase in oil prices leading to a 0.3 per cent decrease in the country's economic output. Tanzania is the least affected, with a 1 per cent increase in oil prices associated with a 0.1 per cent decrease in real GDP.

Most of the other short-run oil price coefficients in Table 4 are negative but insignificant. Expectations were that Angola and the DRC would have positive coefficients as they are net oil exporters. The results, however, show that they would also be affected negatively, although the coefficients are statistically insignificant.

Through the estimation of the PMG estimator, the first objective of the study was achieved. The group of SADC countries that are vulnerable to oil price changes was identified. This group of countries was then generally used as the set of importing countries in the bilateral gravity models of South Africa and Zambia. The results of the gravity models are presented in Table 5.

Table 5: Bilateral trade flow gravity model: dependent variable is exports

	Model	
	South Africa	Zambia
Independent variable		
Log GDP exporter	2.2516*** (0.8458)	–2.8953 (2.2936)
Log GDP importer	1.2961* (0.7865)	–2.8953* (2.1381)
Log distance	–1.3430*** (0.2153)	–30.7113** (15.3505)
Log pop exporter	–7.4495*** (2.7480)	6.3053 (4.3537)
Log pop importer	–.2966 (0.2507)	–4.8721* (2.5338)
Dummy variables		
Common language	0.2214 (0.5006)	7.0153* (3.6701)
Common border	–	–
Common colonial history	–	–
No. observations	57	81
R-squared	0.84	0.53

Notes: * significant at 10 per cent level, ** significant at 5 per cent level, *** significant at 1 per cent level. Numbers in parentheses are standard errors.

Source: author's computation based on IMF and EIA data.

Table 5 gives the results of the two estimated gravity models. The gravity model explaining bilateral trade between South Africa and those countries that are vulnerable to oil price changes performs much better than the Zambia model, as shown by the higher R-squared value of 0.84 for the former, compared to 0.53 for the latter. In the South African model, the size of the economy or GDP of the exporting country has a larger effect on trade than the size of the economy of the importing countries. This seems to imply that exports from South Africa to these countries could be driven more by an increase in South Africa's national output. This could be due to the influence of South Africa as the biggest economy in the region. The implications of this could be that if South Africa exploited its natural and or shale gas resources, it would be able to export these to some countries within the SADC and these countries could in turn substitute their oil imports with these alternatives. There would be trade creation provided that the costs of switching to these alternatives are lower than the costs of importing oil, even from within the region.

Results from the gravity model of Zambia indicate that if the economies of the countries importing from Zambia grow, this would lead to reduced trade between them and Zambia. At the same time, the gravity model of South Africa suggests a positive relationship between the economic growth of those countries and South Africa. This seems to imply that there is more potential for trade between these countries and South Africa, than with Zambia.

As expected, distance, which is a proxy for transportation/logistic and information costs, has a negative effect on bilateral trade in both models. The effect is much larger for Zambia than for South Africa. Given that Zambia has the potential to be a large producer of biofuels in the region, high transportation or logistic costs could hinder these countries from importing them. This could also limit bilateral trade and regional integration.

In the South African gravity model, population growth in the exporting country (South Africa) would have a negative effect on exports. This could be due to increased demand for goods and services within the country. On the other hand, the Zambian gravity model indicates that growth in the population of the importing countries would have a negative effect on trade. This could mean that as these importing countries' populations expand, they become more self-sufficient.

The results also indicate that a common language seems to benefit trade with Zambia. With South Africa the effect of language is also positive, but statistically insignificant.

5 Conclusion and policy implications

This study investigated the impact of global oil price changes on the economic growth of 15 countries within the SADC region and then proceeded to assess whether countries that were vulnerable to oil prices changes could substitute imported oil and petroleum products with biofuels and gas from within the region. A PMG estimator was used to model the oil price–economic growth relationship in the 15 SADC countries. The main finding from the model was that the economies of four of these countries—Mauritius, Mozambique, Tanzania, and Zambia—would be adversely affected by oil price increases. After identifying the countries that were vulnerable to oil price changes, the potential of those countries to substitute their oil imports with alternatives such as biofuels and gas from within the SADC region was assessed. Two gravity models of bilateral trade were estimated, one for South Africa and another for Zambia. The main finding from these models was that the potential for bilateral trade was higher with South Africa than Zambia. As South Africa has the largest economy in the region, increases in its GDP had more impact on trade. If South Africa increased its production of natural gas, the other countries would import these. The main impediment to trade between the countries that are vulnerable to oil price changes and Zambia, a potential larger producer of biofuels, are the transportation/logistic and information costs.

Following these findings, it is recommended that biofuels and natural gas for transport should be included in the region's policies and strategies. The SADC's Regional Indicative Strategic Development Plan has some broad energy objectives, but its focus is mostly on electricity generation (Fundira and Henley 2017). SADC countries should recognize their vulnerability to global oil price increases and consider alternatives to petroleum products from imported crude oil. This could involve formulating policies and strategies at the regional level with the aim of promoting the production of biofuels and natural gas within the region and stimulating a market for these within the region.

Additionally, the Zambian government could support the development of its biofuels industry in several ways. They could subsidize the production of biofuels to make them more price-competitive. Tax breaks or exemptions could also be used to incentivize the production of biofuels (Fundira and Henley 2017). The market for biofuels is expected to be mostly from other countries within the SADC region, particularly South Africa. This market can be stimulated by enforcement of existing blending mandates in South Africa and Mozambique, and the adoption of these mandates by those countries that do not currently have them in place. The enforcement of these blending mandates would in part take place once supply is guaranteed. The most cost-effective mode of transport for ethanol, which is used to produce biofuels, is rail. Development of a reliable rail network between Zambia and its market could strengthen trade within the region.

Despite interest in biofuels in the early 2000s, the industry has not taken off for various reasons, including the lack of a guaranteed market, financing, food security, and access to land rights by investors (Fundira and Henley 2017). As mentioned earlier, in its Strategic Plan 2015–2020, South Africa's Department of Energy indicated that it is prepared to import biofuels from the SADC region to meet demands (Department of Energy 2015). Zambia can be a major producer of biofuels. A stakeholder process to match demand for biofuels from South Africa and supply from Zambia is recommended. Stakeholders from the two countries should engage and come up with a joint plan or strategy on how to overcome constraints that are limiting the expansion of biofuels production in Zambia.

Members of the SADC have identified weak infrastructure as being a key challenge constraining the exploitation of these natural gas resources in the region. The lack of infrastructure such as pipelines and storage facilities hinders the distribution of natural gas across countries in the SADC. A regional pipeline network that could be used to transport natural gas should therefore be developed, and would be crucial to enhancing regional trade in gas. While the use of CNG as an alternative to petroleum would not require the construction of gas-to-liquid production facilities, it would still require the retrofitting of the existing vehicle fleet. Facilities for retrofitting and refuelling vehicles with CNG will have to be constructed or installed in countries that do not have them.

In 2017, the SADC established an interstate natural gas committee to promote the use of natural gas within the region. This committee is tasked with overseeing the development of a Regional Gas Master Plan. Full participation by SADC member states will be essential in ensuring that a comprehensive plan is developed and that it has buy-in from all the key stakeholders in the region. This could make the plan more acceptable to countries in the region and improve the likelihood of its implementation.

References

Anderson, J.E., and E. Van Wincoop (2003). 'Gravity with Gravitas: A Solution to the Border Puzzle'. *American Economic Review*, 93(1): 170–92.

Baier, S.L., and J.H. Bergstrand (2009). 'Bonus Vetus OLS: A Simple Method for Approximating International Trade-Cost Effects Using the Gravity Equation'. *Journal of International Economics*, 77(1): 77–85.

Bergstrand, J.H. (1985). 'The Gravity Equation in International Trade: Some Microeconomic Foundations and Empirical Evidence'. *The Review of Economics and Statistics*, 67(3): 474–81.

Berument, H., N. Ceylon, and C. Dogan (2010). 'The Impact of Oil Price Shocks on the Economic Growth of the Selected MENA Countries'. *Energy Journal*, 31(1): 149–76

Blackburne III, E.F., and M.W. Frank (2007). 'Estimation of Nonstationary Heterogeneous Panels'. *The Stata Journal*, 7(2): 197–208.

Canta, W (2014). 'Crude Oil Price and Economic Growth: The Case of Ghana'. Paper presented at the Centre for Study of Africa Economies Conference, Economic Development in Africa. St Catherine's College, University of Oxford, 23–25 March 2014. Available at: https://editorialexpress.com/conference/CSAE2014/program/CSAE2014.html#55 (accessed 10 January 2019).

Chauvin, S., and G. Gaulier (2002). 'Prospects for Increasing Trade Among SADC Countries'. Paper presented at the Annual Forum on Trade and Industrial Policy Strategies, Glenburn Lodge, Muldersdrift, South Africa, 20–22 September 2002.

Cuñado, J., and F. Pérez de Gracia (2003). 'Do Oil Price Shocks Matter? Evidence for Some European Countries'. *Energy Economics*, 25(2): 137–54.

Darku, A.B. (2009). 'The Gravity Model and the Test for the Regional Integration Effect: The Case of Tanzania'. *The Journal of Developing Areas*, 43(1): 25–44.

de Kock, M.O., N.J. Beukes, E.O. Adeniyi, D. Cole, A.E. Goetz, C. Geel, and F.G. Ossa (2017). 'Deflating the Shale Gas Potential of South Africa's Main Karoo Basin'. *South African Journal of Science*, 113(9–10): 1–120.

Department of Energy (2015). Strategic Plan 2015–2020. Pretoria: Department of Energy. Available at: www.energy.gov.za/files/aboutus/DoE-Strategic-Plan-2015-2020.pdf (accessed 14 March 2019).

Difeto, M., R. van Eyden, R. Gupta, and M.E. Wohar (2018). 'Oil Price Volatility and Economic Growth: Evidence from Advanced OECD Countries Using Over One Century of Data'. Working Paper 201813. Pretoria: Department of Economics, University of Pretoria.

Egger, P. (2002). 'An Econometric View on the Estimation of Gravity Models and the Calculation of Trade Potentials'. *World Economy*, 25(2): 297–312.

EIA (Energy Information Administration) (2018). 'Short-Term Energy Outlook: Real and Nominal Prices, September 2018'. Washington, DC: EIA. Available at: www.eia.gov/outlooks/steo/realprices (accessed 29 August 2018).

Eita, J.H. (2008). 'Determinants of Namibian Exports: A Gravity Model Approach'. Paper presented at the 13th African Econometric Conference, University of Pretoria, South Africa, 9–11 July 2008.

Fadeyi, O.A., T.Y. Bahta, A.A. Ogundeji, and B.J. Willemse (2014). 'Impacts of the SADC Free Trade Agreement on South African Agricultural Trade'. *Outlook on Agriculture*, 43(1): 53–59.

Ferderer, J.P. (1996). ‘Oil Price Volatility and the Macroeconomy’. *Journal of Macroeconomics*, 18(1): 1–26.

Fundira, T., and G. Henley (2017). ‘Biofuels in Southern Africa: Political Economy, Trade, and Policy Environment’. UNU-WIDER Working Paper 2017/48. Helsinki: UNU-WIDER.

Gómez-Herrera, E. (2013). ‘Comparing Alternative Methods to Estimate Gravity Models of Bilateral Trade’. *Empirical Economics*, 44(3): 1087–111.

Grant, J.H., and D.M. Lambert (2008). ‘Do Regional Trade Agreements Increase Members’ Agricultural Trade?’ *American Journal of Agricultural Economics*, 90(3): 765–82.

Hamilton, J.D. (1983). ‘Oil and the Macro Economy since World War II’. *Journal of Political Economy*, 91: 228–48.

Hamilton, J. (2003). ‘What is an Oil Shock?’ *Journal of Econometrics*, 113(2): 363–98.

Hartley, F., D.E. van Seventer, E. Tostão, and C. Arndt (2016). ‘Economic Impacts of Developing a Biofuel Industry in Mozambique’. UNU-WIDER Working Paper 2016/177. Helsinki: UNU-WIDER.

Hartley, F., D.E. van Seventer, P. Samboko, and C. Arndt (2017). ‘Economy-Wide Implications of Biofuel Production in Zambia’. UNU-WIDER Working Paper 2017/27. Helsinki: UNU-WIDER.

Herman, M.O., K. Wandschneider, T. Warin, and P.V. Wunnava (2011). ‘Southern African Economic Integration: Evidence from an Augmented Gravity Model’. *African Finance Journal*, 13(1): 1–13.

International Monetary Fund (2018). *Direction of Trade Statistics*. Washington, DC: IMF. Available at: http://data.imf.org/?sk=9D6028D4-F14A-464C-A2F2-59B2CD424B85 (accessed 21 October 2018).

Jawad, M. (2013). ‘Oil Price Volatility and Its Impact on Economic Growth in Pakistan’. *Journal of Finance and Economics*, 1(4): 62–68.

Jiménez-Rodríguez, R., and M. Sánchez (2005). ‘Oil Price Shocks and Real GDP Growth: Empirical Evidence for Some OECD Countries’. *Applied Economics*, 37: 201–28.

Jordaan, A. and P. Kanda (2011). ‘Analysing the Trade Effects of the EU-SA & SADC Trading Agreements: A Panel Data Approach’. *South African Journal of Economic and Management Sciences*, 14(2): 229–44.

Kang, H., and M. Fratianni (2006). ‘International Trade, OECD Membership, and Religion’. *Open Economies Review*, 17(4–5): 493–508.

Lardic, S., and V. Mignon (2006). ‘The Impact of Oil Prices on GDP in European Countries: An Empirical Investigation Based on Asymmetric Cointegration’. *Energy Policy*, 34: 3910–15.

Linnemann, N.H. (1966). *An Econometric Study of International Trade Flows*. Amsterdam: North-Holland.

Matekenya, W. (2013). ‘The Impact of Oil Price Volatility on Economic Growth in South Africa: A Cointegration Approach’. Masters dissertation. Alice: University of Fort Hare.

Mork, K.A. (1989). ‘Oil and Macroeconomy When Prices Go Up and Down: An Extension of Hamilton’s Results’. *Journal of Political Economy*, 97(3): 740–44.

Mork, K.A., O. Olsen, and H.T. Mysen (1994). ‘Macroeconomic Responses to Oil Price Increases and Decreases in Seven OECD Countries’. *The Energy Journal*, 15(4): 19–36.

Nkomo, J.C. (2006). 'The Impact of Higher Oil Prices on Southern African Countries'. *Journal of Energy in Southern Africa*, 17(1): 10–17.

Pedroni, P. (1995). 'Panel Cointegration: Asymptotic and Finite Sample Properties of Pooled Time Series Tests with an Application to the PPP Hypothesis'. Working Papers in Economics 95-013. Bloomington, IN: Indiana University.

Pesaran, M.H., Y. Shin, and R.P. Smith (1999). 'Pooled Mean Group Estimation of Dynamic Heterogeneous Panels'. *Journal of the American Statistical Association*, 94(446): 621–34.

Rafiq, S., R. Salim, and H. Bloch (2009). 'Impact of Crude Oil Price Volatility on Economic Activities: An Empirical Investigation in the Thai Economy'. *Resources Policy*, 34(3): 121–32.

Roberts, B. (2004). 'A Gravity Study of the Proposed China–ASEAN Free Trade Area'. *The International Trade Journal*, 18(4): 335–53.

Rojid, S. (2006). 'COMESA Trade Potential: A Gravity Approach'. *Applied Economics Letters*, 13(14): 947–51.

Santos Silva, J.M.C., and S. Tenreyro (2006). 'The Log of Gravity'. *The Review of Economics and Statistics*, 88(4): 641–58

Sarker, R., and S. Jayasinghe (2007). 'Regional Trade Agreements and Trade in Agri-food Products: Evidence for the European Union from Gravity Modeling Using Disaggregated Data'. *Agricultural Economics*, 37(1): 93–104.

Seid, E.H. (2013). 'Regional Integration and Trade in Africa: Augmented Gravity Model Approach'. Working Paper 3/13. Addis Ababa: Horn Economic and Social Policy Institute.

Simohammed, K., A. Benhabib, and S. Maliki (2015). 'The Impact of Oil Prices on Macroeconomic Fundamentals, Monetary Policy and Stock Market for Eight Middle East and North African Countries'. MPRA Paper 75278. Munich: University Library of Munich.

Simwaka, K. (2006). 'Dynamics of Malawi's Trade Flows: A Gravity Model Approach'. MPRA Paper 1122. Munich: Munich University Library.

Steyn, L. (2019). 'Total Offshore Find Could Bring R1-Trillion to SA Economy'. *Businesslive*. Available at: www.businesslive.co.za/bd/companies/energy/2019-02-07-total-makes-significant-discovery-offshore-sa (accessed 12 March 2019).

Tinbergen, J. (1963). *Shaping the World Economy*. New York: The Twentieth Century Fund

World Bank (2018). *World Development Indicators*. Washington, DC: World Bank. Available at: https://databank.worldbank.org/data/reports.aspx?source=world-development-indicators (accessed 15 September 2018).

World Bank (2019). 'Commodity Price Data, Pink Sheet'. Washington, DC: World Bank.

Zhang, D. (2008). 'Oil Shock and Economic Growth in Japan: A Nonlinear Approach'. *Energy Economics*, 30(5): 2374–90.