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Resolving the energy-growth nexus in South Africa

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Energy use is a pivotal element in the economic life of any country, especially in a developing economy such as South Africa. Based on trends such as load-shedding and oil supply shocks, it is essential to investigate the relationship between electricity and oil consumption to economic growth. This is particularly relevant in the South African context, where policy-makers have had to grapple with excess demand for electricity. The Johansen cointegration and vector error correction model approaches have been used to examine a short- and long-run relationship between energy consumption and economic growth. It has been found that electricity consumption has a negative relationship with economic growth and oil consumption has a positive relationship. Therefore, conservation policies like electricity rationing may be implemented, thereby proving to be beneficial to the broader economy. To offset periodical effects such as oil supply shocks, the country should keep high or adequate amounts of oil reserves and/or invest in oil exploration. It is highly recommended, regarding electricity, that the government is to adopt policy measures and direct interventions to promote an efficient use of electricity.

Introduction

Energy use is a pivotal element in the economic life of any country, especially in a developing economy such as South Africa. Energy in this study is measured by electricity and oil consumption. Electricity consumption showed fluctuating trends in the period 1971–2012 (Stats SA 2008). For instance, between the periods 1971 and 1990, there was a gradual increase in electricity consumption from 50.77 to 155.99 terawatt per hour (TWH). During the period 1998–2001, electricity decreased from 201.20 to 198.24 TWH and from 205.95 in 2000 to 196.05 TWH in 2001, and reached 230.54 TWH in 2012. The fluctuations were as a result of an increase in rural electrification, industrialisation and expansion of the middle class, which resulted in urbanisation and load shedding (Stats SA 2008). Oil, a heavily imported commodity in South Africa, has seen an increase in consumption from 15.82 metric tons in 2003 to 24.89 metric tons in 2012.

Economic growth, which is the value addition in the economic output of a country from one period to another, has been found to gradually increase. Based on the trends of energy consumption previously discussed, it was interesting to investigate if there is relationship between energy consumption and economic growth, hence the energy-growth nexus. This is because of the fact that the economy is structured around large-scale, energy-intensive mining and primary minerals industries, pushing its energy intensity to above-average levels (Stats SA 2008).

It can be argued that industrial use of energy is directly related to economic growth and household consumption essential for improved living conditions (Stern 2004). However, from literature, there has been contradicting debates about the energy-growth nexus. For example, Bildirici and Bakirtas (2014) found a positive relationship between oil consumption and economic growth. Raheem and Yusuf (2015) found a negative but insignificant relationship between energy and growth. Phiri and Nyoni (2015) found that electricity consumption had no impact on economic growth. Moreover, oil-producing nations have been known to cause supply shocks by reducing production in the markets; therefore, oil-importing countries such as South Africa may have had to make consumption adjustments. Based on these contradicting views, this research is motivated to examine if there is a short- and long-run relationship between the energy consumption and economic growth in the South African context.

The relationship between energy consumption and economic growth has not been entirely concluded in South Africa. This relationship could benefit the industrial sector because the more industries consume energy, the better will be infrastructural development. Hence, the problem is uncertainty over whether energy consumption is a stimulus for growth or not. 'Causality from energy to economic growth is found to be more prevalent in the developed Organisation for Economic Co-operation and Development (OECD) countries compared to the developing non-OECD countries' (Chontanawat, Hunt & Pierse 2008). As mentioned above, improving the energy sector, especially in relation to electricity capacity, has been the government's priority over the past few years. Therefore, this article seeks to justify the government's efforts on the issue of an energy growth nexus. The structure of the article is as follows, literature review, research methodology, results and discussions and conclusion.

Literature review

This section of the article seeks to explain and give theoretical and empirical evidence on how energy consumption relates to economic growth. Literature suggests that there is a fixed relationship between historical rates of energy consumption and historical growth rates (Glasure & Lee 1997; Odhiambo 2009a; Phiri & Nyoni 2015). Therefore, energy consumption and economic growth are strongly correlated. This can be summarised as:

$$Economic\ growth = f\left(Energy\ consumption\right) \qquad \text{[Eqn 1]}$$

There are four plausible underlying theories relating to energy-growth causality, which are the growth hypothesis, conservation hypothesis, feedback hypothesis and neutrality hypothesis. The growth hypothesis suggested that causality can run from energy consumption to gross domestic product (GDP) and implies that energy-conserving measures would impact negatively on growth prospects in the economy; hence, load-shedding would have an adverse effect on GDP in the country. Alkhathlan and Javid (2013) carried out research on the relationship between aggregated and disaggregate energy consumption and economic growth on an annual time series from 1980 to 2011 employing an autoregressive distributive lag (ARDL) approach. Among other findings, a strong linkage was evident, concluding that oil and electricity consumption leads to economic growth. Soytas and Sari (2003) conducted a multi-country study to find the energy-growth nexus. The Granger causality and the vector error correction (VEC) techniques were used in the study covering the period 1950–1992. The results indicated a negative energy growth nexus in Turkey, France, Germany and Japan while there was a reverse relationship in Italy and Korea.

The relationship between energy consumption and economic growth was studied in Nigeria using annual time series data from 1970 to 2005 based on the ARDL procedure (Olusegun 2008). The findings showed that there exists a long term relationship between oil consumption and economic growth; furthermore, oil consumption causes economic growth with no feedback. This means economic growth has no effect on oil consumption, though consumption of oil feeds economic growth. Rudra (2010) explored the oil and electricity consumption growth nexus in five SAARC (South Asian Association for Regional Cooperation) countries over the period 1970–2006 on an annual time series. The study employed a cointegration and error correction model (ECM). Among the countries concerned, it was suggested that energy policies should be noted regarding the relationship between energy consumption and economic growth as policies do affect the growth potential of those countries. Also, oil consumption caused economic growth in the short-run and long-run in Nepal and Bangladesh. Electricity consumption caused economic growth in the short-run and long-run in Pakistan and Sri Lanka. Other studies advocating for the growth hypothesis theory are those by Bildrici (2013), Lee (2005), Chun-Yu and Siu (2007) and Damette and Seghir (2013).

The conservation hypothesis implies that energy conservation policies would have little to no effect at all to economic growth as causality is said to run from GDP to energy consumption. Therefore, measures such as load-shedding may be implemented without any adverse impact on the growth of the economy. Ozturk, Aslan and Kalyoncu (2010) carried out a study in 51 countries from 1971 to 2005 using the panel cointegration method. Grouped in classes of lower to high income, findings were that economic growth Granger causes energy consumption in the long-run for low-income countries. There was no strong relationships found between energy consumption and GDP in all groups.

In a study on Ghana using annual time series data from 1971 to 2008 employing the Toda and Yamamoto Granger causality method, it was found that electricity conservation measures were a viable option for Ghana, as causality results showed growth-led electricity hypothesis (Adom 2011). Ghosh (2000) examined Granger causality in India between electricity consumption and economic growth using annual data from 1950–1951 to 1996–1997 and employed the Engel-Granger model. Evidence detected the absence of long term relationships between the variables concerned, but it was found that there is a unidirectional Granger causality from economic growth to electricity consumption. Cowana et al. (2014) studied the BRICS (Britain, Russia, India, China & South Africa) countries for the period 1990–2010 using panel causality analysis on the electricity-growth nexus, accounting for dependency and heterogeneity for each country. Empirical results reflected conservation hypothesis for South Africa alone, that is, economic growth causes energy consumption without any feedback, that is, energy consumption does not feed or stimulate economic growth.

Shahbaz and Feridun (2012) studied electricity consumption and economic growth covering the period from 1971 to 2008 by means of an annual time series commissioning an ARDL model in Pakistan. The variables were found to exhibit a long-run relationship, and without electricity feeding or stimulating GDP, economic growth causes electricity consumption. A study on 11 oil-exporting countries was carried out with oil consumption as proxy to economic growth covering the period 1971–2002 and a panel technique was used (Mehrara 2007). The results verified a strong causality from economic growth to oil consumption. This means as economic growth increases, it strongly stimulates the consumption of oil. Other studies supporting the conservation hypothesis are those by Kalyoncu, Gürsoy and Göcen (2013), Damette and Seghir (2013), Sharaf (2016) and Shahateet, Al-Majali and Al-Hahabashneh (2014).

The feedback hypothesis has bidirectional causation, that is, there is a simultaneous causality running between energy consumption and economic growth. Therefore, policy measures directed at energy consumption and economic growth would suffice to impact the broader economy. An energy growth nexus for 21 African countries for the period 1970–2006, using panel cointegration and causality, was concluded (Eggoh, Bangake & Rault 2011). Results concluded that an increase or decrease of energy consumption lead to an increase or decrease of economic growth; similarly, when economic growth does likewise, electricity consumption will react as such; hence, the relationship is bidirectional.

Belke, Dobnik and Dreger (2011) explored energy growth relationships in 25 OECD countries, including energy prices, assessing the period from 1981 to 2007 on an annual time series modelled on VEC. On the energy growth nexus, results evidenced a feedback hypothesis energy consumption and GDP, with oil consumption as proxy to the energy sector. An empirical study on electricity consumption, capital and economic growth covering the period 1980–2008 using Toda and Yamamoto (1995) in vector autoregression to measure causality was carried out by Muhammad and Mete (2012). Results on the causality between electricity consumption and economic growth were in favour of feedback hypothesis. Similar studies advocating for a feedback hypothesis include those by Pao, Li and Fu (2014), Oh and Lee (2004), Glasure and Lee (1997), Gollagari and Rena (2013) and Ozturk et al. (2010).

The neutrality hypothesis means either energy consumption or GDP Granger cause each other, that is, neutral to each other. Therefore, policies aimed at energy conservation such as load-shedding would not have any effect on economic growth and an improved economic growth would not alter energy consumption. Studies in favour of the neutrality hypothesis between energy consumption and economic growth include Shahateet (2014), Rahman and Mamun (2016), Fatai (2014), Raheem and Yusuf (2015), Bouoiyour and Selmi (2013) and Cowana et al. (2014).

Other studies that dealt with the relationship between energy consumption and economic growth have been found in literature. For instance, Odhiambo (2009a) recommended that policy geared towards the expansion of the electricity infrastructure should be intensified in order to cope with the increasing demand exerted by the country's strong economic growth and rapid industrialisation programme. These recommendations were as a result of empirical evidence which reflected a bidirectional relationship between electricity consumption and economic growth; as consumption of electricity increases so does economic growth, and vice versa.

Bildrici and Bakirtas (2014) studied the relationship among oil, natural gas and coal consumption and economic growth in BRICTS (Brazil, Russian, India, China, Turkey and South Africa) countries. With an ARDL approach, the elasticity between oil consumption and economic growth was found to be less than 1% for South Africa. This means that a unit change in oil consumption will impact a certain coefficient fraction on growth because of long term strong causality results, that is, bidirectional causality between oil consumption and economic growth. Raheem and Yusuf (2015) found that a low regime of energy consumption retards growth after applying a nonlinear model in selected African countries including South Africa. In applying a linear specification model, it was found that energy consumption growth relationship in most of the countries, including South Africa, was negative, though insignificant. However, on the opposite ends, Phiri and Nyoni (2015) found the neutrality hypothesis in that electricity consumption has no impact on economic growth, and GDP too has no impact on electricity consumption in South Africa.

Few recent studies were conducted for the South African case with varying results and also the use of varying methodologies such as Engel-Granger to Trivariate causality methods. For example, Odhiambo (2009a) found a bidirectional causality. This study will extend the work of Odhiambo (2009a) by focusing on the period incorporating rolling blackouts (2008–2012). This extreme case of load-shedding is not reflected in his results. There is also extension on the work of Phiri and Nyoni (2015), who focussed exclusively on electricity as proxy to energy in studying energy growth nexus. This study will extend energy proxy by including oil consumption as it covers energy consumption in a different subset of the economy such as the logistics and transport sectors of the economy. Therefore, this study will receive greater coverage in energy with electricity and oil consumption as proxy for energy growth nexus in the period 1980–2012.

In conclusion of literature review, it has been proven through empirical studies that energy in some countries is a factor input to economic growth. Study findings are consistent in developed countries; however, mixed breeds of findings have been affirmed in some countries, including South Africa. An important factor to note for this phenomenon could be varying time series and differing methods of model estimation.

Methodology

The article aims to study the link between energy consumption and economic growth in South Africa. This section comprises the data source, specification of the model and estimation techniques.

Data and model specification

This article employs annual time series data spanning the period 1980–2012. Secondary time series data were collected from the International Energy Agency (IEA) and the South

African Reserve Bank (SARB). Data collected from the IEA include electricity consumption and oil consumption, while GDP, net gold exports, other subsidies on production in all industries and investment in government stock data were all sourced from SARB. The general empirical model is specified as follows:

$$GDP_t = \alpha_t + \beta_1 EC_t + \beta_2 OILC_t + \beta_3 NGE_t + \beta_4 SPI_t + \beta_5 IGS_t + \varepsilon_t \quad \text{[Eqn 2]}$$

$$LGDP_t = \alpha_t + \beta_1 LEC_t + \beta_2 LOILC_t + \beta_3 LNGE_t + \beta_4 LSPI_t + \beta_5 LIGS_t + \varepsilon_t \quad \text{[Eqn 3]}$$

where

α_t: constant parameter

LGDP: logarithm of gross domestic product at market price (2010 constant prices, R million)
LEC: logarithm of electricity consumption (measured in TWH)
LOILC: logarithm of oil consumption (net oil imports, million metric tons)
LNGE: logarithm of balance of payments: net gold exports (R million)
LSPI: logarithm of other subsidies on production in all industries (R million)
LIGS: logarithm of South African Reserve Bank assets: investments in government stock
ε_t: an error term (a term which encompasses any omitted factors which may affect the model.

Energy use is measured using electricity and oil consumption while economic growth is measured with GDP at market price. All the variables are transformed into logarithmic form to obtain linearity. To give strength and negate the impact of the white noise, three control variables, such as net gold exports, investment in government stock and subsidies on production in all industries, are included (Gujarati 2004; Mongale 2016).

Estimation of results

The first test to be carried out is unit root testing, sometimes called stationarity test. Firstly, the motive is that economic theory suggests that certain variables should be integrated through a random walk or a martingale process (Gujarati 2004). Secondly, the most common motive is to investigate the properties prior to the construction of an econometric model because most time series data are non-stationary at levels. It is by this test that a spurious regression model will be avoided. This article employs the Augmented Dickey-Fuller test (ADF). Then the stationary results will be confirmed with the Phillips-Perron (PP) stationary test.

The next step after determining the stationarity is finding whether the variables are cointegrated. To test for cointegration between the time series, we rely on Johansen (1991) likelihood ratio tests for evaluating the number of cointegration vectors within the system of time series. In addition, if these variables are cointegrated, then we can exploit the idea that there may exist movements in their behaviour and possibilities that they will trend together towards a long-run equilibrium state (Ghali & El-Sakka 2004). This study employs the Johansen cointegration approach and the vector error correlation model (VECM). According to Ang (2007), a VECM framework is said to restore the information lost in the differencing process, therefore allowing for long term equilibrium as well as short term dynamics. The variables are to be measured in their natural logarithm so that their first difference approximates their growth rate (Ghali & El-Sakka 2004).

In addition to the above estimation techniques, this article employs the diagnostic and stability test. This is done to check for robustness so as to ensure that the results of the error correction model yield true estimates. Furthermore, for stability the cumulative sum (CUSUM) and the cumulative sum of square (CUSUMSQ) tests were employed to check for steadiness of the model throughout the period.

Results and discussion

Unit root test results

Table 1 gives the results of the ADF and the PP tests, thereby testing whether a spurious regression model exists. After running the ADF and the PP tests for unit root testing, Table 1 presents the results by testing the null hypothesis that LGDP, LEC, LOILC, LNGE, LSPI and LISG are non-stationary (where L denotes logged variables like logged GDP). The unit root testing was carried out for all forms at intercept, trend and intercept, and at none. The testing was done at all regression forms based on the automated SIC lag length for ADF and PP automated at Newey–West using the Bartlett kernel.

Johansen cointegration

The Johansen cointegration test was carried out based on both the trace and the maximum-eigenvalue tests. Table 2 shows the order of criteria for lag selection; the order selection indicated a lag length of 1.

The trace test shown in Table 3 indicates two cointegration equations as all the critical values at none and at most 1 are greater than the critical value at 5%. However, the maximum-eigenvalue test indicates no cointegration as all 5% critical values are greater than the maximum-eigenvalue critical values at all levels. Therefore, the trace test is adopted as a measure of cointegration, which implies that there is a long term relationship between the variables.

The vector error correction model results

The discovery of two cointegration equations in the previous section implies that VECM can be used. Furthermore, the stationarity test results indicated that all variables became

TABLE 1: Unit root test results, 1980–2012.

Order of integration	Variable	Augmented Dickey-Fuller test			Phillips-Perron test		
		Intercept	Trend and intercept	None	Intercept	Trend and intercept	None
Level	LGDP	-0.058482	-1.723457	3.300776	0.216433	-1.035423	6.115370
First difference	LGDP	-4.433321*	-4.385880*	-2.639211*	-4.273492*	-4.200682*	-2.450371*
Level	LEC	-5.099623*	-1.433220	2.105412	-5.576958*	-1.419962	3.380788
First difference	LEC		-5.587908*	-3.023474*		-5.560968*	-2.897203*
Level	LOILC	-0.147627	-1.035104	1.070324	-1.078321	-2.096077	1.101233
First difference	LOILC	-10.66435*	-10.87067*	-10.58356*	-10.79337*	-12.28530	-10.66637*
Level	LSPI	-1.550405	-1.691712	2.939943	-1.644850	-1.644386	2.953368
First difference	LSPI	-6.618161*	-6.852484*	-5.161694*	-6.619091*	-6.860049*	-5.314982*
Level	LNGE	-2.665402	-2.673284	3.085826	-5.074873*	-3.039993	3.027602
First difference	LNGE	-5.347270*	-5.599678*	-4.486632*		-6.656938*	-4.401877*
Level	LIGS	-1.265326	-2.673568	0.693259	-1.055333	-2.707841	1.337327
First difference	LIGS	-7.931689*	-7.84871*	-7.744302*	-8.720836*	-8.594155*	-7.795054*

*, Rejection of the null hypothesis at the 0.05 level.

LGDP, logarithm of gross domestic product at market price (2010 constant prices, R million); LEC, logarithm of electricity consumption (measured in TWH);LOILC, logarithm of oil consumption (net oil imports, million metric tons); LNGE: logarithm of balance of payments: net gold exports (R million); LSPI: logarithm of other subsidies on production in all industries (R million); LIGS, logarithm of South African Reserve Bank assets: investments in government stock.

TABLE 2: Vector autoregression lag order selection criteria, 1980–2012.

Lag	Log *L*	LR	FPE	AIC	SC	HQ
0	-11.06144	Not Applicable	9.66e-08	0.874946	1.130878	0.966772
1	212.9975	367.6865*	6.41e-12*	-8.769102*	-6.977574*	-8.126317*
2	245.0978	42.80048	8.97e-12	-8.569120	-5.241997	-7.375377
3	281.0734	36.89797	1.32e-11	-8.567865	-3.705147	-6.823164

*, Lag order selected by the criterion.

LR, sequentially modified likelihood ratio test statistic (each test at the 5% level); FPE, final prediction error; AIC, Akaike information criterion; SC, Schwarz information criterion; HQ, Hannan–Quinn information criterion.

TABLE 3a: Johansen cointegration results, 1980–2012. (Unrestricted Cointegration Rank Test [Trace])

Hypothesised (Number of CE[s])	Eigenvalue	Trace (Statistic)	0.05 (Critical value)	Probability**
None*	0.581980	105.9746	95.75366	0.0082
At most 1*	0.531216	71.08553	69.81889	0.0395
At most 2	0.314953	40.78104	47.85613	0.1957

Trace test indicates two cointegration equations at the 0.05 level.

*, Rejection of the hypothesis at the 0.05 level; **, MacKinnon–Haug–Michelis (1999) *p*-values.

CE, cointegrating equations.

TABLE 3b: Johansen cointegration results, 1980–2012. (Unrestricted Cointegration Rank Test [maximum-eigenvalue])

Hypothesised (Number of CE[s])	Eigenvalue	Maximum-Eigenvalue (Statistic)	0.05 (Critical value)	Probability**
None*	0.581980	34.88907	40.07757	0.1712
At most 1*	0.531216	30.30449	33.87687	0.1259
At most 2	0.314953	15.13071	27.58434	0.7378

Maximum-eigenvalue test indicates no cointegration at the 0.05 level.

*, Rejection of the hypothesis at the 0.05 level; **, MacKinnon–Haug–Michelis (1999) *p*-values.

CE, cointegrating equations.

stationary after first differencing, allowing employment of VECM (Pesaran & Shin 1997; Pesaran, Shin & Smith 2001). The VECM estimates the effects of explanatory variables where economic growth is a function of electricity consumption, oil consumption, net gold exports, production and investment.

Table 4 reflects the results of the VECM estimates with special focus on the coefficient of cointegration variable, which measures the speed of adjustment. The speed at which the variables converge is 0.3374%, which is quite a slow convergence and insignificant (Table 4). However, the negative sign reflects that the model will come to equilibrium at some time.

Looking at the dilemma that the speed of adjustment is slow and insignificant, the electricity and oil consumption models were estimated on separate linear regressions. It turns out that the speed of adjustment improved to be 4.4% and 9.4% for the electricity and oil consumption models, respectively. The speed of adjustment in both cases is negative and significant as *t*-statistics are approximately 2 (Brooks 2008).

TABLE 4: Summary of Vector Error Correction Model estimates, 1980–2012.

Variable	Coefficient	Standard error	*t*-statistics
Cointegration (overall model)	-0.003374	0.04068	-0.08294
Constant	0.016451	0.00608	2.70588
Cointegration (electric consumption model)	-0.044148	0.03287	-1.34327
Cointegration (oil consumption model)	-0.093655	0.08294	-1.12922

Considering the long-run effects of the series, Table 5 indicates normalised cointegration coefficients, which are presented by the following equation:

TABLE 5: Normalised cointegrating coefficients (standard error in parentheses).

LGDP	LEC	LOILC	LNGE	LSPI	LIGS
1.000000	1.139301	-0.098320	-0.479733	-0.051687	-0.077500
	(0.26809)	(0.07911)	(0.09487)	(0.05402)	(0.02229)

LGDP, logarithm of gross domestic product at market price (2010 constant prices, R million); LEC, logarithm of electricity consumption (measured in TWH); LOILC, logarithm of oil consumption (net oil imports, million metric tons); LNGE, logarithm of balance of payments: net gold exports (R million); LSPI, logarithm of other subsidies on production in all industries (R million); LIGS, logarithm of South African Reserve Bank assets: investments in government stock.

$$LGDP_t + \alpha_t + \beta_1 LEC_t + \beta_2 LOILC_t + \beta_3 LNGE_t + \beta_4 LSPI_t + \beta_5 LIGS_t = 0 \quad \text{[Eqn 4]}$$

In reversing the signs of the coefficients by taking all the independent variables to the right-hand side of equation 4 and making an equation of the dependent variable, LGDP enables us to get an expressive representation of the model relationship of the study. Therefore, the new equation with coefficient variables based on Table 5 gives rise to equation 5 as follows:

$$LGDP = 0.0165 - 1.1393 LEC + 0.0983 LOILC + 0.479 LNGE + 0.0517 LSPI + 0.0775 LIGS \quad \text{[Eqn 5]}$$

Based on equation 5, the implications are that economic growth is negatively related to the consumption of electricity. This is in line with Raheem and Yusuf (2015) who found the negative relationship in African countries. However, oil consumption has a positive relationship with GDP at market price. Therefore, as per the coefficient of the variables in the model, for every one percentage increase in electricity consumption, there would be a 1.139% decline in economic growth. These findings of a negative relationship are against a theory notion of energy being an input factor to economic growth. Furthermore, logically these findings suggest that energy conservation policies, such as load-shedding experienced from 2008 to 2012, may not have had an adverse effect on economic growth. According to Bildirici, Bakirtas and Kayikci (2012), if a positive unidirectional causality running from electricity consumption to GDP does not exist, then this provides a basis for electricity conservation policies, such as electricity rationing. A similar study found that after 1988 South Africa realised a negative relationship and advocated efficient use of electricity by educating consumers (Esso 2010).

A 1% increase in oil consumption will stimulate economic growth by 0.098% (equation 5). These oil growth findings are also supported by Ziramba (2015), where growth hypothesis was verified in that oil consumption contributed both directly and indirectly to economic growth as a complement to other input factors. Equation 5 thus also reflects that all the intermittent variables have a positive relationship with GDP, as reflected by the positive coefficients of the variables. A 1% increase in net gold exports, subsidies on production in all industries and investment in government stock will increase economic growth by 0.479%, 0.0517% and 0.0775%, respectively.

Stability and diagnostic tests

Putting the underlying model to test for stability, this article performed a stability test by using the CUSUM and CUSUM square tests. In Figure 1, the CUSUM test indicates a positive

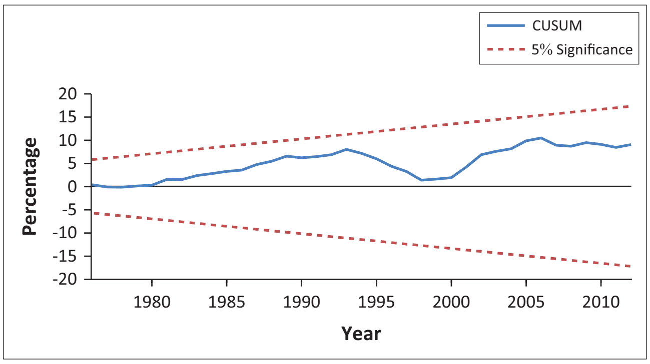

FIGURE 1: Cumulative sum test, 1980–2012.

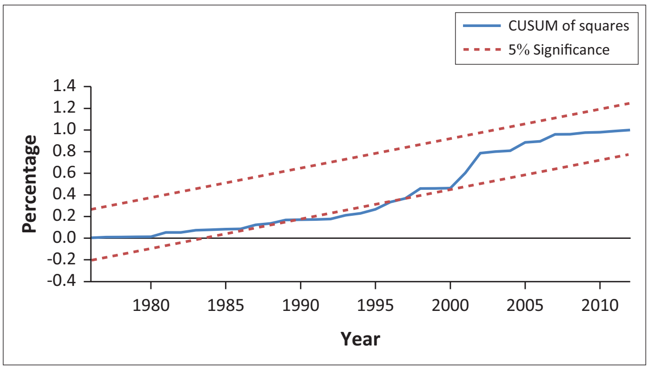

FIGURE 2: Cumulative sum of square test, 1908–2012.

feedback in that the cumulative sum moves inside the critical line throughout the period covered, therefore indicating stability of the model. In Figure 2, the CUSUM sum of square test indicates stability as the cumulative sum moves inside the critical line, however with the exception of the period between 1990 and 1997.

The diagnostic tests in this study are reported as: for heteroscedasticity the White test had p-value of 0.2073, which indicates that there is no heteroscedasticity in the residuals. The Jarque–Bera normality test indicated a p-value of 2.328311 meaning that we do not reject the hypothesis and the residuals are normally distributed. The Breusch-Godfrey Lagrange multiplier test had a p-value of 0.1398, which is more than 0.05 and therefore we do not reject the hypothesis and conclude that there is no serial correlation within the model.

Conclusion and recommendations

The aim of the study was to examine the relationship between energy consumption and economic growth covering the period 1980–2012. This is particularly relevant in the South African context, where policy-makers have had to grapple with excess demand for electricity, thus resulting in what is known in the popular press as load-shedding and/or oil supply shocks as dictated by oil-producing nations.

The Johansen cointegration and VECM were employed to test the relationship of the understudy, and it was verified that there exists a long-run relationship between economic growth and energy consumption. Moreover, the empirical results reveal that there exists a negative relationship between electricity consumption and economic growth, whereas oil consumption has a positive energy-growth relationship.

Because oil consumption has a beneficial impact on the economy, there should be measures to protect the country from supply shock effects. One possible recommendation is that the government should keep a high or adequate level of oil reserves against such volatile periods. Another option is to intensify oil exploration to offset the country's dependence on imports. On the other hand, electricity consumption presents a conundrum in that electricity remains a necessity even though it has its drawback on economic growth. A possible recommendation would be electricity rationing, that is, a controlled distribution of electricity or an artificial restriction of demand. This means that the load-shedding phenomenon could have been beneficial to the country. It is found that in case of an absence of a positive relationship between energy consumption and economic growth, conservation policies should be adopted (Bildrici, Bakirtas & Kayikci 2012). Another recommendation to consider would be sufficient price increase on electricity. This reasoning is argued in favour because as more electricity is produced, high prices force consumers to reduce wastage. Therefore, the government should implement policy measures that adopt an efficient use of energy to promote healthy relations to the broader economy.

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Competing interests

The authors declare that they have no financial or personal relationships which may have inappropriately influenced them in writing this article.

Authors' contributions

S.B.M. and T.N. contributed equally to the writing of this article.

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