Energy consumption, trade openness, economic growth, carbon dioxide emissions and electricity consumption: evidence from South Africa based on ARDL

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ABSTRACT

This paper undertakes to investigate the interplay between economic growth, energy consumption, electricity consumption, carbon emission and trade by employing recent South African trade and energy data during the period from 1971 to 2013. South Africa is used as a case study given its status as perhaps the most developed country in the African continent with a very high energy consumption as well as its unique position in its current history where it relies on the somewhat antiquated coal industry to provide most of its energy as well as being one of its main imports. The effect of trade openness on environmental conditions has spawned a great deal of controversy in the current energy economics literature. Although research on the relationship between energy consumption, carbon emissions and economic growth are quite prevalent, no study to our knowledge specifically addresses the role that South Africa's trade plays in this context. The ARDL bounds testing approach to cointegration has been used to test the long run relationship among the variables, while short run dynamics has been investigated by applying error correction method (ECM). The main finding of interest in this paper is that a positive relationship exists between energy consumption and economic growth. However, it seems the results suggest that electricity prices have a negative impact on economic growth. The results further evidenced that trade openness and electricity are leading variables, while the rest are lagging. Furthermore, our results demonstrate trade reduces overall pollutions caused by carbon emission, thus it improves environmental quality by contracting the growth of energy pollutants. Our empirical results are consistent with the existence of environmental Kuznets curve. It is, thus, imperative for policymakers to take better care of these two exogenous variables that will have a profound effect on the country's economy as a whole. The policymakers should make decision on GDP based on trade openness because changes in trade openness will have impact on GDP, as trade is a leading variable.

Key words: GDP, Energy consumption, Trade openness, EKC, Carbon Emission, South Africa.

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1.0.Introduction

Although there isn't any concrete connection given in mainstream economic theories that point to a relationship between energy consumption and economic growth, empirical analysis attempting to prove or disprove this potential relationship has been one of the most pursued areas of energy economics literature in recent decades. Many studies have investigated the causal relationship between energy consumption and economic growth. With energy being one of the most crucial aspects of modern life and as such, its consumption is an essential component of economic development. To this end, according to economic theory such as the Jevons Paradox[3], an increase in energy consumption ultimately does have an effect on economic growth. As such, energy is crucial for the economies of both developed countries as well as developing countries, and as mentioned previously, this area of study on the relationship between energy consumption and economic growth has been heavily focused on by experts as it is very consequential towards the policies implemented by the policy makers. The ever-increasing production in the world throughout history has naturally increased the need for energy. However, the finite nature of oil and natural gas resources in the world poses a threat overall economic growth.

There has been a continuing discussion over how the existence and use of abundant natural resources and energy sources affect and are affected by geopolitics and corruption, and how this can propel or stagnate economic progress. This debate is usually referred to as the Resource Curse[4] which posits that there is a paradox present in countries with an abundance of non-renewable natural resources, in that they tend to have less economic growth, less democracy, and worse development than countries with fewer natural resources (Venables 2016). This is theorized to happen for multiple reasons, and there is much debate among experts over these particulars. Most experts believe that this so-called curse is not in fact universal or unavoidable, but instead affects only certain types of countries under specific conditions.

Overall, emerging economies have experienced significant economic growth rates during the past decades. This paper will focus on the relationship between energy consumption, trade,

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[3] Jevons, William Stanley, 1865/1965. In: Flux, A.W. (Ed.), The Coal Question: An Inquiry Concerning the Progress of the Nation, and the Probable Exhaustion of Our Coal-mines, 3rd edition 1905. Augustus M. Kelley, New York

[4] Soros, G. (2007). *Escaping the Resource Curse* (HUMPHREYS M., SACHS J., & STIGLITZ J., Eds.). Columbia University Press. Retrieved from http://www.jstor.org/stable/10.7312/hump14196

carbon emission, electricity use and economic growth for one such economy, namely that of South Africa. South Africa was selected as a case study because it is one of the largest economies in the economically fast-growing and resource-rich continent of Africa. In fact, it is the world's most carbon-intensive non-oil-producing developing country as well as being one of the 6 largest exporters of coal in the world. Most of South Africa's liquid fuel requirements are imported in the form of crude oil. Also, South Africa's per capita energy consumption as of 2013 is 2655.9 kg oil equivalent, which is much more than the world average of 1680 kg oil equivalent and has the highest demand for electricity in Africa.

This leaves South Africa in a conundrum however, as their economic growth relies on their coal production and exportation. How does the African power decrease Greenhouse Gas emissions without negatively affecting its economy? As such, this paper will investigate that the nature of the relationship between energy consumption, trade, electricity use, economic growth and carbon emissions is investigated in order to determine the most suitable policies to address this conundrum.

South Africa has a high level of energy consumption and a heavy dependence on energy imports. As such it relies heavily on coal as its main source of energy. This presents multiple problems; for one, the developed countries have been moving away from coal as an energy source for many years. In countries such as the United States for example, multiple coal mines have been shut down as the country moves forward. The complicated by concerns the fact that price of coal is increasing especially relative to other energy sources. This issue is also intertwined with the very harmful issue of the Greenhouse Effect which is a by-product of coal emissions. This leaves South Africa at a very crucial juncture in its history regarding its economic future.

In addition, South Africa is facing constant power outages between the years 2008 and 2014, this crisis occurred due to the sudden drop in the electricity supply reserve margins (Eskom,2014). As a consequence, production levels in major sectors of the economy such as commercial, mining industries and industrial have decline. Thus, the signal that arise from these on-going power outages is the consideration of the dissonance between economic growth and electricity production in South Africa

2.0.Literature Review and Theoretical Bases

One of the primary sources of energy in today is electricity. Electricity is an essential source of energy and it is effective in taking care of households and industrial consumers (Salehen et al., 2012). It provides a considerable amount of benefit to capital and labor (Ghosh, 2009). It also boosts international trade[5]. This is because the supply of electricity is enhanced by technology, and emerging nations are supported to import high technological inputs into generation from developed nations. As a result, a productive supply of electricity can lead to a reduction in poverty and expand economic growth. [6]. But still it can also be said that economic growth can be improved by boosting electricity consumption.

A collection of studies proved that electricity consumption and economic growth have a long run relationship (Mozumder and Marathe, 2007; Ahamad et al., 2013; Adebola and Shahbaz, 2013; Masuduzzaman, 2013. The studies confirmed that electricity consumption and economic growth move together in a long run. Although there is a wealth of scholarship addressing and analysing the relationship between energy consumption and economic growth, there hasn't been a consensus among experts by any measure. Many scholars have found a positive causal link, take for instance, Khan and Qayyum (2006) who found a positive relationship between energy consumption and GDP and that energy use played a crucial role in generating and stimulating economic activity in these nations. However, there were some who even found a negative link. In fact, there is empirical evidence linking resource abundance with poor economic growth this was found by Sachs and Warner in 1995. More specifically, over a period of 33 years from 1965 - 1998, OPEC member nations experienced an average decrease of 1.3% in per capita gross national product versus an average growth rate of 2.2% in the rest of the developing world (Gylfason, 2000). This showed that although these countries were wealthy in terms of natural resources, their economy still suffered on average.

Esso (2010) also noted lack of consensus among scholars about this relationship. He attributes it to the level of development the country in question has reached, different methodologies used by the scholars, omitted variable bias and climate conditions among other things. One inadequacy noted by Fallahi (2011) in the literature is the assumption that energy and economic

[5] Samuel, U.P., Lionel, E. (2013), The dynamic analysis of electricity supply and economic development: Lessons from Nigeria. Journal of Sustainable Society, 2(1), 1-11.

[6] Morimoto, R., Hope, C. (2004), The impact of electricity supply on economic growth in Sri Lanka. Journal of Energy Economics, 26, 77-85.

growth maintain the same relationship over time. Gross (2012) posits that to overcome this single relationship between energy and growth one must account for structural breaks when the world experienced, for example, serious crises.

Saad and Belloumi (2015) found in their analysis of the energy consumption, carbon emissions and economic growth of Saudi Arabia that energy price in particular is the most important variable in explaining economic growth according to the results of the variance composition. According to them, this result is to be expected, using Saudi Arabia as an example where it is noted that rises in oil prices contribute significantly to their economic growth. In India, Mohapatra and Giri (2015) observe that the energy consumption has a positive impact on economic growth. Their use of the Granger causality test also illuminated the existence of a bi-directional causal relationship between energy consumption and economic growth in India.

Closer to South Africa, in Nigeria, Akpan & Akpan (2012) observe that their empirical analysis using the Multivariate Vector Error Correction (VECM) framework returns evidence of long-run relationship among the variables. However, they found that the EKC hypothesis[7] was not validated by their results. Instead they found that electricity consumption and emissions are negatively related. This negative could be as a result of the large imbalance between the supply and demand of electricity in Nigeria. Similarly when it comes South Africa itself, Ben Nasr et al. (2014) also found no support for the EKC hypothesis.

In a large study of the impact of CO2 emissions and economic growth on energy consumption encompassing 58 countries, Saidi and Hammami (2015) found a positive and statistically significant relationship. Similarly, CO2 emissions also have a positive effect on energy consumption. They conclude that this implies that economic growth, CO2 emissions and energy consumption are complementary.

Ben Aïssa et al (2014) studied the link amongst GDP, trade, and renewable energy consumption by employing data of 11 African countries between 1980 and 2008. The long run analysis results show a bidirectional links between GDP and trade variables and unidirectional relationship going from renewable energy and trade to GDP. nonetheless, the findings for the

[7] The EKC approach indicates that the environment and economic growth has a non-linear relationship with an inverted U-shaped curve. In the start of economic development, environmental degradation is essential for economic growth. Once the economy reaches a particular threshold of economic development, environment cleanliness plays a vital role in the economy.

short term agree with the bidirectional relationship among trade and GDP and deny the possible link across GDP and renewable energy and between trade and renewable energy. Antweiler et al. (2001) analyzed multiple trade measure and demonstrated that that there is in fact a positive and significant relationship amongst trade openness and growth. Furthermore, economic theories in international trades postulates that some of the gain and losses is linked with environmental influence of trade. Free trade has beneficial and detrimental effects on environmental condition. Free trade is beneficial in the sense that it introduces friendly techniques of production.[8] It may be detrimental by moving corrupt industries from wealthy to poor nation. To add, there is positive link among carbon emission and energy consumption. The measure of trade openness can be separated into two categories. First, measures of trade volume and second, measures of trade restrictions.

Many reports have theorized that exports are a key element in economic growth (Vamvoukas, 2007). This confirms with macroeconomic theory since exports are injections to the economy (Kaldor, 1967; Romer, 1989; Krueger, 1990; Ahmed et al., 2000). The export sector has also spill-over effects on the production process of the rest of the economy which leads to a higher total productivity. Furthermore, through a higher degree of specialization, the country can reap the benefits of economies of scale and comparative advantage. It could be then said that promoting exports may aid the country to import high value inputs, products and technologies that may have a positive impact on economy's overall productive capacity (Krisna et al., 2003; Vamvoukas, 2007). Therefore, exports eases the biding foreign exchange constraint and permits increases in productive intermediate imports. They may also accelerate the adoption of new practices since firms that operate in the world economy are compelled to remain efficient and competitive by utilizing the latest technological developments in their production process. In addition, firms have incentives to increase R&D in order to keep up with foreign competition.

Another study by Arman and Barzegar (2012) studied the impact of trade liberalization on energy use in a sample of 62 developing countries during 1990-2010. Results show a meaningful and positive effect of trade liberalization on energy use in these countries. It means with 1% of increment in trade liberalization, energy use would climb by 0.02%

[8] The literature on trade and the environment is surveyed in Dean (1992, 2001) and Copeland and Taylor (2003b).

In this paper, we will attempt find out whether energy consumption incites or hinders economic growth. This paper is not confined to only the nexus between energy consumption and economic growth, but also extends to trade, electricity use and carbon emissions (pollution) by employing the autoregressive distributive lag (ARDL) method.

3.0.Data and Methodology

3.1.Data

In this paper, we have taken annual data over the period from 1971 to 2013 (before and after the oil crisis). The study comprises of time series data on economic growth, energy consumption, CO2 emissions (metric tons per capita) per capita, trade openness, electricity consumption and GDP, a proxy for economic growth, of the South African economy. All the necessary information was extracted from the World Development Indicators (WDI) published by the World Bank. The figure below tabulates a description of each variable.

- Gross domestic product (GDP) in US$ constant used as proxy for economic growth.
- Energy consumption (ENCON) measured in kg of oil equivalent per capita.
- Carbon dioxide emission (CO) measured in metric tons per capita is used as proxy for environmental pollution.
- Electricity consumption (EL) is quantified as Kilowatt hours (kWh) per capita, which measures the production of power plants and combined heat and power plans less transmission, distribution, and transformation losses and own use by heat and power plants.
- Trade openness (OP) is the sum of exports and imports of goods and services measured as a share of gross domestic product

4.0. Methodology

In this paper, we employ the ARDL bounds testing cointegration approach created by Pesaran, Shin, and Smith (2001) to inspect whether a long run dynamic relationship exists between GDP, energy consumption, trade openness, carbon emission and electricity consumption. Various approaches have been applied to test the presence of cointegration between variables in numerous studies. Two of these approaches are taken from Engle and Granger (1987) in the bivariate case and Johansen and Juselius (1990) when multivariate, and require that all the series should be integrated at the order of integration I(1). The ARDL bounds testing approach is more appropriate compared to those traditional cointegration approaches. The approach avoids endogeneity problems and the inability to test long run relationships of variable associates with the traditional Engel-Granger method. Both short run and long run parameters are calculated simultaneously and the ARDL approach can be used regardless of whether the data are integrated of order I(0) or I(1). Narayan (2005) argues that the ARDL approach is superior in small samples to other single and multivariate cointegration methods. The following 5 regressions are constructed without any prior information as to the direction of the relationship between the variables. The ARDL model specifications of the functional relationship between Gross Domestic Product (GDP), Energy Consumption (ENCON), Carbon Emission(CO), Electricity consumption (EL), Trade openness as % of GDP (OP) can be estimated below:

$$\Delta GDP_t = a_0 + \sum_{i=1}^{p} b_i \Delta GDP_{t-1} + \sum_{i=1}^{p} c_i \Delta ENCON_{t-1} + \sum_{i=1}^{p} d_i \Delta CO_{t-1} + \sum_{i=1}^{p} d_i \Delta EL_{t-1} + \sum_{i=1}^{p} e_i \Delta OP_{t-1} + \delta_1\, GDP_{t-1} + \delta_2 ENCON_{t-1} + \delta_3 CO_{t-1} + \delta_4 EL_{t-1} + \delta_5 OP_{t-1} + \varepsilon_t$$

$$\Delta ENCON_t = a_0 + \sum_{i=1}^{p} b_i \Delta GDP_{t-1} + \sum_{i=1}^{p} c_i \Delta ENCON_{t-1} + \sum_{i=1}^{p} d_i \Delta CO_{t-1} + \sum_{i=1}^{p} d_i \Delta EL_{t-1} + \sum_{i=1}^{p} e_i \Delta OP_{t-1} + \delta_1\, GDP_{t-1} + \delta_2 ENCON_{t-1} + \delta_3 CO_{t-1} + \delta_4 EL_{t-1} + \delta_5 OP_{t-1} + \varepsilon_t$$

$$\Delta CO_t = a_0 + \sum_{i=1}^{p} b_i \Delta GDP_{t-1} + \sum_{i=1}^{p} c_i \Delta ENCON_{t-1} + \sum_{i=1}^{p} d_i \Delta CO_{t-1} + \sum_{i=1}^{p} d_i \Delta EL_{t-1} + \sum_{i=1}^{p} e_i \Delta OP_{t-1} + \delta_1\, GDP_{t-1} + \delta_2 ENCON_{t-1} + \delta_3 CO_{t-1} + \delta_4 EL_{t-1} + \delta_5 OP_{t-1} + \varepsilon_t$$

$$\Delta EL_t = a_0 + \sum_{i=1}^{p} b_i \Delta GDP_{t-1} + \sum_{i=1}^{p} c_i \Delta ENCON_{t-1} + \sum_{i=1}^{p} d_i \Delta CO_{t-1} + \sum_{i=1}^{p} d_i \Delta EL_{t-1} + \sum_{i=1}^{p} e_i \Delta OP_{t-1} + \delta_1\, GDP_{t-1} + \delta_2 ENCON_{t-1} + \delta_3 CO_{t-1} + \delta_4 EL_{t-1} + \delta_5 OP_{t-1} + \varepsilon_t$$

$$\Delta OP_t = a_0 + \sum_{i=1}^{p} b_i \Delta GDP_{t-1} + \sum_{i=1}^{p} c_i \Delta ENCON_{t-1} + \sum_{i=1}^{p} d_i \Delta CO_{t-1} + \sum_{i=1}^{p} d_i \Delta EL_{t-1} + \sum_{i=1}^{p} e_i \Delta OP_{t-1} + \delta_1\, GDP_{t-1} + \delta_2 ENCON_{t-1} + \delta_3 CO_{t-1} + \delta_4 EL_{t-1} + \delta_5 OP_{t-1} + \varepsilon_t$$

5.0. Unit Root Test.

Granted the bounds test for cointegration does not demand pretesting of the variables for unit root, it is imperative that this test is carried out to guarantee that the series are not integrated of an order higher than one. This approach is necessary to avert the issue of spurious results. I have implemented the Augmented Dickey Fuller (ADF), Phillip Peron and KPSS tests to determine stationarity. The results of the ADF test, PP tests and KPSS tests are displayed in table 2,3 and 4 respectively. The test results of ADF and PP below indicate that all the variables are stationary after first difference except DEL found in the KPSS test was found to be non-stationary after the first difference. This result gives support to the application of ARDL bounds method to find out the long-run relationships among the variables. Even though ARDL has a few drawbacks, it’s still regarded as one of the best time series and is implemented widely in the world of economics

5.1. ADF Test

Table 2

	VARIABLE	ADF	VALUE	T-STAT.	C.V.	RESULT
LOG FORM	LGDP	ADF(1)=SBC	84.4865	-1.5294	-3.5348	Non-Stationary
		ADF(1)=AIC	87.7083	-1.5294	-3.5348	Non-Stationary
	LENCON	ADF(1)=SBC	64.4798	-2.2927	-3.5348	Non-Stationary
		ADF(1)=AIC	67.7016	-2.2927	-3.5348	Non-Stationary
	LCO	ADF(1)=SBC	89.2331	-2.4107	-3.5348	Non-Stationary
		ADF(1)=AIC	94.6522	-2.4107	-3.5348	Non-Stationary
	LEL	ADF(1)=SBC	67.949	-2.109	-3.5348	Non-Stationary
		ADF(1)=AIC	71.1709	-2.109	-3.5348	Non-Stationary
	LOP	ADF(1)=SBC	41.2044	-1.8747	-3.5348	Non-Stationary
		ADF(1)=AIC	44.4263	-1.8747	-3.5348	Non-Stationary

	VARIABLE	ADF	VALUE	T-STAT.	C.V.	RESULT
DIFF FORM	DGDP	ADF(1)=SBC	83.1327	-4.101	-2.9446	Stationary
		ADF(1)=AIC	85.508	-4.101	-2.9446	Stationary
	DENCON	ADF(1)=SBC	60.6237	-3.8165	-2.9446	Stationary
		ADF(1)=AIC	62.999	-3.8165	-2.9446	Stationary
	DCO	ADF(1)=SBC	51.3415	-3.7953	-2.9446	Stationary
		ADF(1)=AIC	53.7168	-3.7953	-2.9446	Stationary
	DEL	ADF(1)=SBC	62.2149	-3.3675	-2.9446	Stationary
		ADF(1)=AIC	64.5901	-3.3675	-2.9446	Stationary
	DOP	ADF(1)=SBC	39.9146	-4.1213	-2.9446	Stationary
		ADF(2)=AIC	42.4038	-4.1932	-2.9446	Stationary

5.2. PP TEST

Table 3

PP test					
	VARIABLE	**PP**	**T-STAT.**	**C.V.**	**RESULT**
LOG FORM	**LGDP**	PP	-1.5129	-3.4806	Non-Stationary
	LENCON	PP	-1.6187	-3.4806	Non-Stationary
	LCO	PP	-1.3957	-3.4806	Non-Stationary
	LEL	PP	-2.3283	-3.4806	Non-Stationary
	LOP	PP	-1.4908	-3.4806	Non-Stationary

Table 4

PP test					
	VARIABLE	**PP**	**T-STAT.**	**C.V.**	**RESULT**
DIFFERENCE FORM	**DGDP**	PP	-4.3998	-2.9324	Stationary
	DENCON	PP	-5.976	-2.9324	Stationary
	DCO	PP	-5.7881	-2.9324	Stationary
	DEL	PP	-4.6242	-2.9324	Stationary
	DOP	PP	-4.7342	-2.9324	Stationary

5.3. KPSS

Table 5

KPSS TEST					
	VARIABLE	**KPSS**	**T-STAT.**	**C.V.**	**RESULT**
LOG DIFFERENCE	**DGDP**	KPSS	0.12933	0.37864	Stationary
	DENCON	KPSS	0.26134	0.37864	Stationary
	DCO	KPSS	0.2068	0.37864	Stationary
	DEL	KPSS	0.43273	0.37864	**Non stationary**
	DOP	KPSS	0.21713	0.37864	stationary

6.0. VAR ORDER

The Schwartz-Bayesian Criterion (SBC) and Akaike Information Criterion (AIC) are used to figure out the optimal number of lags included in the test. Upon analysing, both the AIC and SBC recommended the lag order of 1.

Table 6

Order	AIC	SBC	p-Value	C.V.
1	364.665	340.101	[.000]	5%

7.0. F-TEST Long Run Relation.

Cointegration test indicates the presence of long-run equilibrium relationship, it demonstrates whether a long run relationship among the variables in this paper are present or not. In each of the following equations depicted below, the null hypothesis of no cointegration is applied against the alternative hypothesis of cointegration. The generated F-statistic is compared with the critical values given by Pesaran et al. (2001). If our F-statistic is higher than the upper bound level, the null hypothesis is rejected. This entails that the variables are cointegrated. However, if the calculated F-statistic is below the lower bound level, it can be said that the null hypothesis stands, there is no cointegration. Nonetheless, if the F-statistic falls within the lower and upper bound level, the results are deemed inconclusive. Our results of the F-test for cointegration are presented in Table 7.

Table 7

Models	F-statistics
F_{LGDP} (LGDP | LENCON, LCO, LEL, LOP)	1.3408
F_{LENCON} (LENCON | LGDP, LCO, LEL, LOP)	**5.0739**
F_{LCO} (LCO| LGDP, LENCON, LEL, LOP)	2.3523
F_{LEL} (LEL | LGDP, LENCON, LCO, LOP)	**6.0182**
F_{LOP} (LOP| LGDP, LENCON, LCO, LEL)	1.4281
F-stat- Lower bound: 2.649 Upper bound: 3.804 At 95%	

The ARDL bound test above in table 7 reveals that not all the 5 estimated models are cointegrated as only two models have estimated F-statistics well above the upper bounds of critical value at 95% significance level (2.649 – 3.804). When GDP is taken as a dependent variable, there is no evidence of the existence of a cointegrating relationship as the calculated F-statistic (1.3408) falls below the lower bound. However, we did find out that there were long run relationships when LENCON (5.0739), LEL (6.0182) were set as the dependent variables.

8.0. Results of Estimated Long-Run Coefficients using the ARDL Approach:

LONG RUN AIC

Table 8

	LGDP	**LENCON**	**LCO**	**LEL**	**LOP**
K	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
LGDP		0.077911***	-0.11979***	-4.5023	-1.5795
LENCON	15.0664***		1.498***	45.7904	1.8314
LCO	-9.5201***	0.65509***		-32.6476	-1.6724
LEL	-0.75444*	0.041356**	-0.050992*		-2.2839*
LOP	-1.0784**	0.051305***	-0.067626**	-0.71234	
INPT	-58.7051***	3.6738***	-5.5035***	-149.9394	-1.8595

*Significant at 10%
**Significant at 5%
***Significant at 1%

The above table shows that there is a long run relationship between energy consumption and GDP. They are both positive and highly significant at 1%. That means a 1% increase in energy consumption would increase GDP by 15.06%. This supports several studies such as the Jevon's paradox and Khan and Qayyum (2006) that found a positive relationship between energy consumption and GDP. Therefore, energy consumption plays an important part in generating economic growth. The same can be said about GDP, a 1% increase in GDP increases energy consumption only by 0.07 %. In regards to the relationship between trade and carbon emission, it seems that both have a negative and significant long run relationship. a 1% increase in trade, reduces carbon emission by about 1.07%, this means open trade environments have been quite conducive to mitigating carbon emission. However, the same cannot be said about energy consumption, energy consumption shares a positive and significant relationship with carbon emission. A 1% rise in energy consumption would lead to an increase of carbon emission by 0.655%. This concurs well with Kumar Tiwari, and Nasir

(2013), who found that energy consumption plays a vital role in the degradation of the environment whilst trade openness mitigates the deterioration of the environment. On the relationship between energy consumption and carbon emissions, the figure shows that an increase in energy consumption leads to an increase in CO2 emissions. Specifically, a 1% increase in energy consumption leads to 0.655% increase in carbon emission(pollution). This result supports the view that energy consumption is the main factor of carbon emissions. This implies that reducing energy consumption, especially the consumption of fossil fuels, is a feasible option that can aid to reduce carbon dioxide emissions. This is particularly important because about 70% of South Africa's total primary energy supply is derived from coal, and coal-fired power stations provide more than 93% of electricity production (World Bank,2008). Interestingly, we find that trade openness and GDP share a negative and significant relationship. Specifically, a 1% increase in trade would lead to a decline in GDP by 1.07%. Even though this goes against previous studies, Feenstra (1990), Matsuyama (1992) demonstrated that countries lacking technological development can be guided by trade to concentrate in traditional goods and this would lead to a contraction in economic growth.

9.0.Error Correction Model of ARDL

In the following table, the ECM's representation for the ARDL model is selected with AIC Criterion.

Table 9: Error Correction Model of ARDL

ecm1(-1)	Coefficient	Standard Error	T-Ratio [Prob.]	Significance	C.V.	Result
DLGDP	-0.32243	0.16805	-1.9186[.079]	significant	10%	endogenous
DLENCON	-4.0432	0.86847	-4.6555[.001]	significant	1%	endogenous
DLCO	-3.9159	0.78984	-4.9578[.000]	significant	1%	endogenous
DLEL	-.22009	0.26777	-.82193[.427]	not significant	5%	exogenous
DLOP	0.91841	0.66241	1.3865[.193]	not significant	5%	exogenous

As discussed before, cointegration reveals that there is a long run relationship between the variables but it cannot distinguish the endogeneity or exogeneity of the variables. This is handled by the error correction model. Since there could be a short-run deviation from the long-run equilibrium. Cointegration does not disclose the process of short-run adjustment to bring about the long-run equilibrium. To get a grasp of the adjustment process we need to proceed to the error-correction model (Table 9). the results reveal that all variables are endogenous except for trade openness which is exogenous at 5% significance and electricity consumption at 5% significance. The exogenous variables would receive market shocks and transmit the effects of those shocks to other variables. The coefficient of e_{t-1} tells us how long it will take to get back to long term equilibrium if that variable is shocked. This means when we shock trade and electricity consumption which are shown to be the leader variables, the followers like GDP, carbon emission and energy consumption will be affected. Thus, it is imperative for policymakers to take better care of the said variables that will have a profound effect on the country's economy as a whole. Although the ECM model tends to show the absolute endogeneity and exogeniety of a variable, they do not give us the relative degree of endogeneity or exogeneity. For that, we need to proceed to the variance decomposition technique (VDC) to recognize the relativity of these variables.

10.0. Variance Decomposition (VDC)

Variance decomposition finds out to what extent shocks to specified variables are explained by other variables in the system. Variance decomposition measures the amount of forecast error variance in a variable that is explained by innovations or impulse in it and by the other variables in the system. For instance, it discloses to what proportions of the changes in a particular variable can be associated to changes in the other lagged explanatory variables. Moreover, if a variable explains most of its own shock i.e exogenous, then it does not permit variances of other variables to assist to its explanation and is therefore said to relatively exogenous. There are two types of VDC that is orthogonalized and generalized. The difference between these two is that in orthogonalized forecast error variance decomposition, the amount of percentage of the forecast error variance of a variable which is counted for by the innovation of another variable in the VAR will sum to one across all the variables. On the other hand, generalized forecast error VDC permits one to make robust correlation of the strength, size and persistence of shocks from one equation to another (Payne, 2002) and for that reason we employ generalized VDC as opposed to orthogonalized VDC. According to table 10, it can be seen that in the 5-year horizon, trade openness is the most exogenous while energy consumption is shown to be the most endogenous. These standing remained well pass 15 years. However, in the 20-year horizon, trade still remained the most exogenous. However, it seems GDP and energy consumption became more exogenous and electricity consumption became the most endogenous. This indicates that trade has an impact on not only economic growth but on the other aforementioned variables.

	Horizon	LGDP	LENCON	LCO	LEL	LOP	TOTAL	RANK
LGDP	5	66%	12%	5%	13%	3%	100%	3
LENCON	5	6%	42%	47%	4%	2%	100%	5
LCO	5	4%	42%	49%	4%	1%	100%	4
LEL	5	14%	6%	5%	74%	1%	100%	2
LOP	5	2%	0%	3%	1%	94%	100%	1

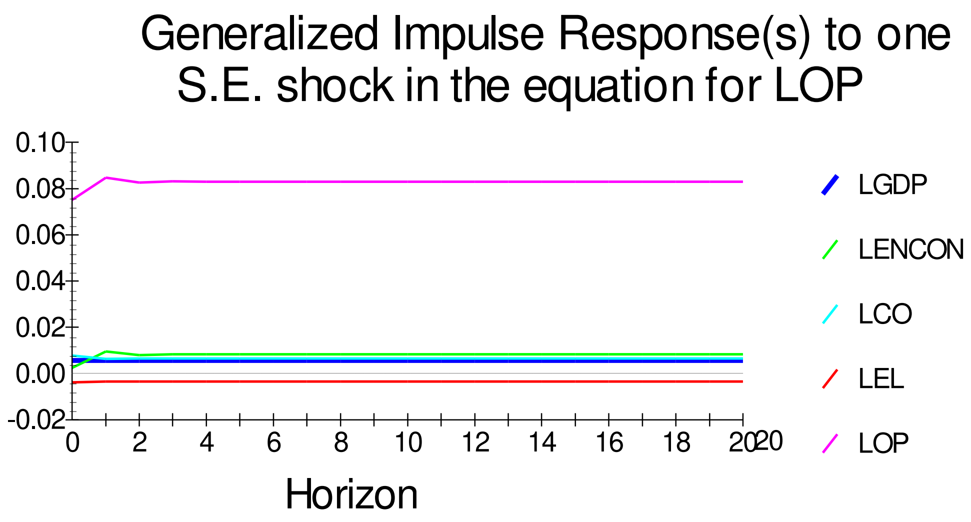
	Horizon	LGDP	LENCON	LCO	LEL	LOP	Total	Ranking
LGDP	10	66%	12%	5%	13%	3%	100%	3
LENCON	10	6%	41%	47%	4%	2%	100%	5
LCO	10	4%	42%	49%	4%	1%	100%	4
LEL	10	14%	6%	5%	74%	1%	100%	2
LOP	10	2%	0%	3%	1%	94%	100%	1

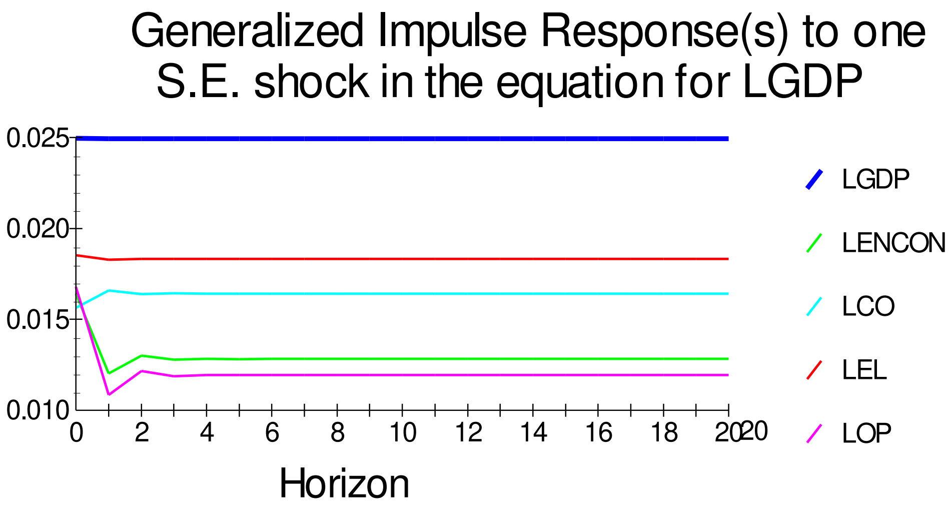
	Horizon	LGDP	LENCON	LCO	LEL	LOP	Total	Ranking
LGDP	15	66%	12%	5%	13%	3%	100%	**3**
LENCON	15	6%	41%	47%	4%	2%	100%	**5**
LCO	15	4%	42%	49%	4%	1%	100%	**4**
LEL	15	14%	6%	5%	74%	1%	100%	**2**
LOP	15	2%	0%	3%	1%	94%	100%	**1**

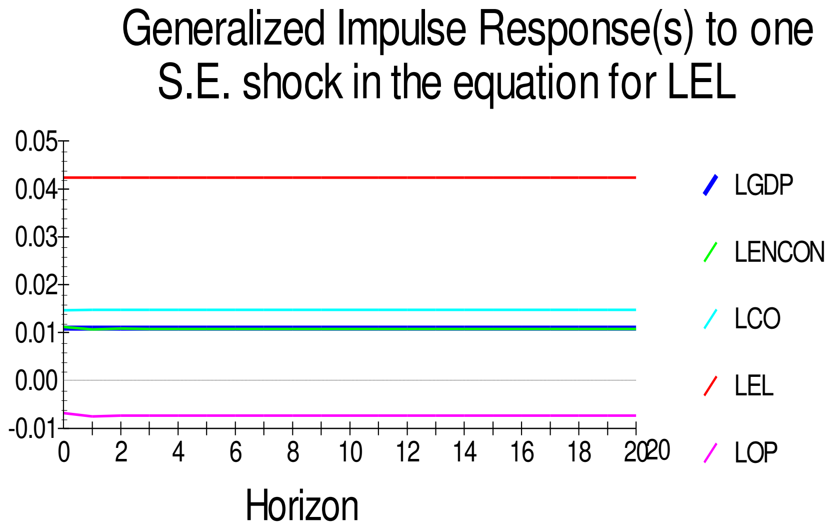
	Horizon	LGDP	LENCON	LCO	LEL	LOP	Total	Ranking
LGDP	20	66%	12%	5%	13%	3%	1	2
LENCON	20	6%	41%	47%	4%	2%	1	4
LCO	20	4%	42%	49%	4%	1%	1	3
LEL	20	4%	42%	49%	4%	1%	1	5
LOP	20	2%	0%	3%	1%	94%	1	1

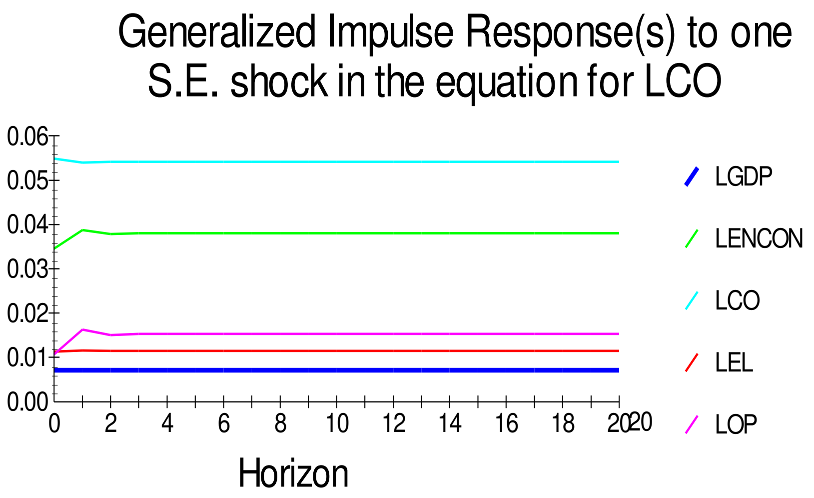
11.0. Impulse response Function

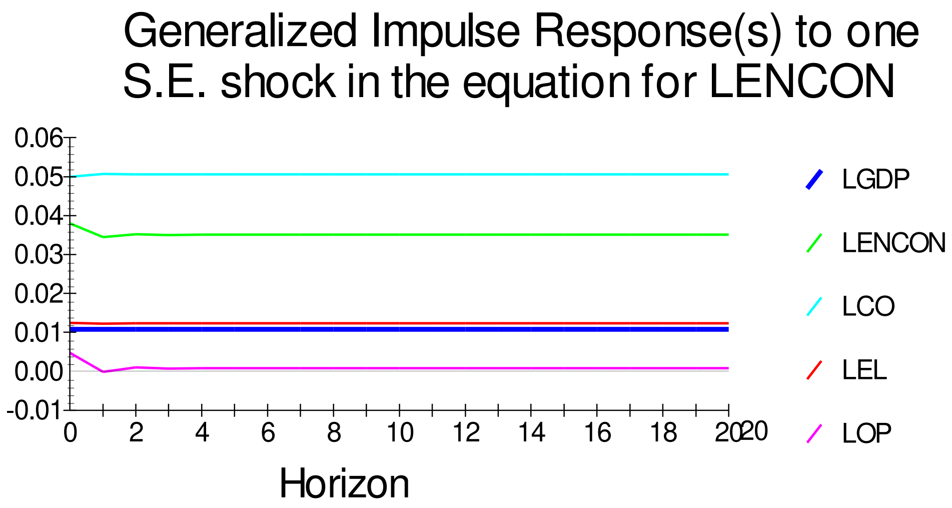
From the below graph regarding the generalized impulse response function, the generalized impulse responses therefore, measure a response from an innovation to a variable. It gives us the same information as VDC but in graphical form. Judging by the graph, it is quite evident that all the variables seem to take about 2 years in order to normalise after a ‘shock’. It is interesting to note that the shock of trade and electricity greatly affects the other variables. In other words, when there is a shock, the endogenous variables are more affected while the exogenous variables are less effected. Therefore, the trade openness of a country will depends on the exchange rate of a country. The policymakers will make decision on GDP based on trade openness because changes in trade openness will give impact on GDP, as trade is a leader variable.




Generalized Impulse Response(s) to one
S.E. shock in the equation for LGDP
0.025
0.020
0.015
0.010
0
2
4
6
8
10
12
14
16
18
20
20
Horizon
LGDP
LENCON
LCO
LEL
LOP

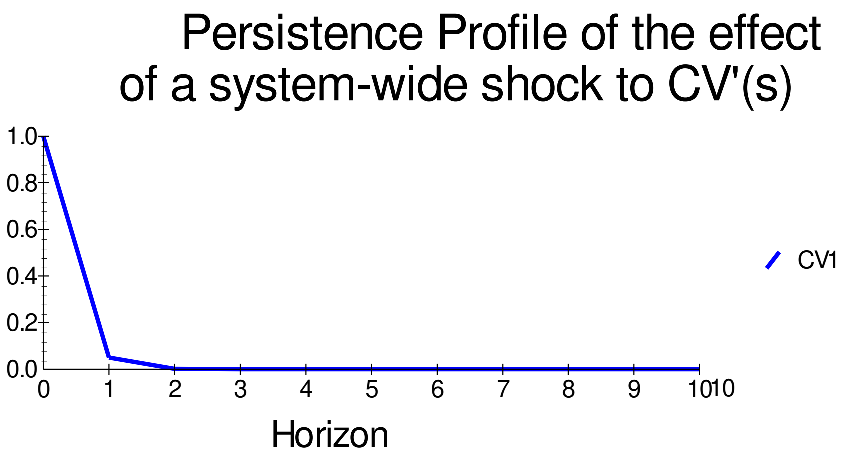

Generalized Impulse Response(s) to one
S.E. shock in the equation for LEL
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
0
2
4
6
8
10
12
14
16
18
2020
Horizon
LGDP
LENCON
LCO
LEL
LOP


Generalized Impulse Response(s) to one
S.E. shock in the equation for LCO
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
2
4
6
8
10
12
14
16
18
2020
Horizon
LGDP
LENCON
LCO
LEL
LOP



12.0. Persistence Profile (PP)

The graph below presents the persistence profile from a system wide shock it shows that if the whole cointegrating relationship is shocked, it will take approximately 2 years for the equilibrium to be re-established.



13.0. Conclusion and policy implication.

This paper investigated the relationship between economic growth and energy consumption as well as electricity use, trade and carbon dioxide emission using annual time series data covering the period of 1971 – 2013 of South Africa. The results suggest that there is co-integration among the variables. However, it is interesting to note that trade openness and electricity consumption became the leader variable, leaving the rest of the variables endogenous. Even though most studies suggest trade promotes economic growth, we can argue that poor economic growth in South Africa between the years 1993-2002 through to 2013 may have been afflicted by relatively trade polices compared to those in the BRICS(brazil, Russia, India, China, South Africa) and these policies played somewhat of a role in negatively affecting economic growth. To add, Moon (1998) argues that the unbalanced specialisation of a certain product, which arises from an outward-oriented paradigm, may shock economic growth. Thus, it is imperative for policymakers to take better care of these two strong variables as they will have a profound impact on the country’s economy as a whole. In other word, the policymakers will make decision on GDP based on trade openness because changes in trade openness will impact on GDP, as trade is a leader variable. The challenge for the South African authorities is to carry on improving and maintaining the trade openness policy in order to sustain economic growth and development.

Electricity consumption is the second exogenous variable in our study, thus, the government and policy makers should also advocate and promote restructuring of the electricity supply industry. This may lead to more supply of electricity as more players will be allowed entry into this industry. Therefore, the policymakers should select electricity policies which will support economic growth and reduce environmental pollution in South Africa.

Furthermore, it seems that trade in South Africa has not contributed to long run development of pollution, rather our study demonstrates that a higher level of trade openness contracts CO_2 emission possibly through an environment which encourages technological innovation by promoting expenditures on energy research and development which leads to less pollution and energy efficiency. It is quite unusual for trade to reduce the country's pollution in such a way because as stated before, South Africa is highly dependent on coal as its primary source of energy. The increase of liberalization of trade will ease the attitude on acting together in the policies upon environment. This is in line with Antweiler et al (2001) findings on which trade is good for the environment and that trade improves environment through technological effect. We hope that as time goes by, the robustness of the results will be tested with further innovative data and more advanced econometric techniques.

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