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Energy Consumption and Economic Growth in South Africa

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Key words: ARDL, bounds test, cointegration, Granger causality, Augmented Dickey-Fuller, GDP, petrol, electricity, economic growth, energy

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Abstract: This study examines the long-run and short-run causal relationship among the petrol consumption, electricity consumption and GDP in South Africa using 16 years quarterly data (2005Q1-2020Q2). The results show that electricity and GDP are integrated of the same order, I(1) while petrol is integrated of order zero. There exists a long-run relationship between petrol and GDP models. Only the petrol model system returns to equilibrium with adjustment speed of 128.4%. Petrol and electricity models are found to be stable and significant with no defects, GDP Model is also stable but insignificant and its residuals are not normally distributed. A unidirectional causality runs from GDP to petrol and electricity. However, petrol and electricity do granger cause each other. have and there is no long-run relationship between them. In the short and long run, GDP has a significant negative impact on electricity and petrol consumption in South Africa, respectively.

INTRODUCTION

South Africa is an oil-importing country and one of the countries in Africa with a lot of coal. South Africa imports its oil from the African continent (e.g., Nigeria, Libya, etc), Europe, etc. Due to the impact that energy consumption has on the South African economy, its economy was regarded as an energy-dependent[1]. Yearly implementation of load shedding in South Africa is an indication that its output growth is moving faster than the energy supplied. This situation in the country has led to a lot of problems such as a decline in the sales at retail shops an increase in crime, huge loss of money generated by the ESKOM on the sales of electricity, etc. Thus, it has now become an issue of national interest as the parliamentarians and other stakeholders are on their toes to curb the situation. Ilesanmi[1] suggested that increasing investment in the energy sector increases the generating capacity and this will help South Africa meet up with the excess demand for energy, especially electricity. Not only this is required, exploration of other renewable sources of energy that are environmental and growth-friendly will also help in this situation. The price of petrol in South Africa shows a commercial pattern of an upward trend and seasonal variation that continues into the future[2].

Oil can be seen as an integral factor that sustains the South African economy as most sectors such as transportation and manufacturing rely heavily on it. Thus, an increase in the price of oil leads to an increase in the prices of most goods and services which in turn leads to a high inflation rate. The causality relationship between the various level of oil and the economy is still receiving the attention of researchers as many nation's economies are energy-driven.

Mehrara *et al*.[3] was of the opinion that reduction in the energy consumption if there exist one-way causality running from energy consumption to income may result in a high unemployment rate and decline in income which will later result in economic fall. And the economic growth is not affected only if there is no causal relationship in either direction among energy consumption and income Mehrara[4]. Olayiwola and Seeletse[5] opined that there exists a unidirectional causality from the consumption of petrol to its retail price. Yazdan and Hossein[6] also submitted in a study of causality between oil consumption and economic growth in Iran that, reduction in energy consumption may lead to a decline in the economic growth when there is a unidirectional causal relationship running from energy to income. The duo posited that there is no long-run relationship between energy consumption and economic growth in Iran but there exists a bidirectional short-run causality among these variables. Also, a study on the causality relationship of energy consumption and GDP of Malawi revealed a bidirectional causality among the two variables[7]. Yu and Choi[8] found however no long-relationship between energy consumption and GDP. Almost two decades ago, a unidirectional causal relationship was found funning from economic growth to the consumption of coal in Taiwan[9]. The results of a causal relationship study among economic growth and coal consumption also established a long-run equilibrium relationship among the two variables while in the short-run there exist a two-way directional causality between the variables in Korea[10].

Different views have emerged from the literature on the causal relationship studies between energy consumption and economic growth. There is a view that energy consumption is a limiting factor to economic growth[11, 6]. While some researchers are of the view that energy consumption has nothing to do with the economic growth due to the small proportion of the former to the latter. Argued by many is that the economic structure and economic growth stage of the studied country forms the fundamental basis upon which energy consumption impact on economic growth is based. Cheng[12] and Asafu-Adjaye[13] argued that shifts towards services are like resulted from increasing production structures of the economy.

Different approaches in studying the causal relationship among variables have been identified in the literature, one category assumes the stationarity of the series, the other assumes the non-stationarity of the series while the third one investigates whether the series is stationary or not. This third approach is popularly known as Granger two-stage procedures[14]. Sims[15] used the conventional vector autoregression in his study titled, "money, income and causality". Erol and Yu[16] and Abosedra and Baghestani[17] assumed that stationarity of the series used in their respective studies when testing the Granger-causality hypothesis.

Asafu-Adjaye[13] when studying the causal relationship among economic growth, energy prices and consumption of Asian developing countries assumed that the variables are non-stationary. While the popular Johansen cointegration test requires that the stationarity of the series is established before running the test[18].

Thus, Asafu-Adjaye[13] submitted that the non-uniqueness of the causal relationship between energy and economic growth is a result of different approaches used by the researchers, the country under consideration and the studied period of data used, among many.

This study is thus carried out with a focus on the causal relationship between the consumption of electricity, oil, natural gas and economic growth in South Africa and its implications on the South African economy using cointegration analysis. Based on the findings that there exists a unidirectional relationship running majorly from electricity to economic growth and unidirectional causal relationship from economic growth to oil consumption in South Africa, it was suggested that diligent pursuant of energy efficiency and renewable energy policies will both assist South Africa in mitigating climate change and energy security[1]. This study examines any improvement so far on the submission of Ileasanmi in 2015. Based on submission on the non-uniqueness of a causal relationship between economic growth and energy consumption by Asafu-Adjaye[13] , data from 2005-2020 are used in this study as opposed to the 1980-2012 data used by Ileasanmi and a new set of variables are used.

Econometric procedures: In this study, 16 years (2005-2020) quarterly time series data of economic growth, electricity consumption and petrol consumption in South Africa are used. The data were extracted from the publications of Statistics South Africa and the Department of Energy South Africa.

Unit root test: Nelson and Plosser[19] have argued that ordinarily (naturally) most macro-economic series have a unit root which is dominated by stochastic trend. The calculated F-statistic by simulation, from the regression that involves the time series with a unit root, does not follow the standard distribution[20]. And the regression of such a nonstationary series yields what is called spurious regression[11]. Among many unit root tests is the

Dickey-Fuller test that is developed on the assumption that the error terms and have a constant variance. This test was later improved on due to some resulting problems which are related to the fact that the true data generating process is not known. Thus, the improved version is known as the Augmented Dickey-Fuller (ADF) test. This paper used the ADF test in testing for the presence of unit root in our series Dickey and Fuller[21]. The ADF models are given as[22]:

$$\Delta y_t = \gamma y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t \quad (1)$$

$$\Delta y_t = a_0 + \gamma y_{t-1} + \sum_{i=2}^{p} \beta_i n y_{t-i+1} + \varepsilon_t \quad (2)$$

$$\Delta y_t = a_0 + a_2 t + y y_{t-1} + \sum_{i=2}^{p} \beta_i n y_{t-i+1} + \varepsilon_t \quad (3)$$

Where:
y_t = The value of the series at time-t
Δy_t = The first difference of the series
a_0 = The intercept

$$y = -\left(1 - \sum_{i=1}^{p} a_i\right), \beta_i = -\sum_{i=1}^{p} a_j, y_{t-1}$$

The one lagged period of y and ε_t is the white noise error term.

Another unit root test is the Phillips and Perron test. The serial correlation of the error terms are been taken care of without adding the lagged differenced term as the Phillips and Perron test uses non-parametric statistical methods Gujarati[1]. This, therefore, corrects for any autocorrelation and heteroskedasticity in the error terms and thus the robust estimates are obtained when there are serial correlation and time-dependent heteroskedasticity in the series[23, 24].

The Autoregressive Distributed Lags (ARDL): ARDL bound test is one of the most popular cointegration tests. The other popular ones are the Engle-Granger approach and the Johansen approach. This recently developed model, ARDL was introduced by Pesaran and Shin[25] and extended by Pesaran *et al*.[26], its testing procedure for cointegration is based on the F-statistic (or Wald statistic) whose distribution is nonstandard under the null hypothesis of no cointegration. ARDL is applicable when the integration order of the variable is not < 2 (i.e. I(0) and I(1)), it can as well be used when the variables of interest are of different integration order but no variable must be I(2). Two sets of critical values for a specific level of significance are reported each for I(0) and I(1) variables Pesaran and Pesaran[27] and Pesaran *et al*.[26]. The decision rule is that, reject the null Hypothesis, H_0 if the F-calculated is greater than the F-critical[28]. Rejecting the null hypothesis of no cointegration implies that there exists a long-run relationship among the variables under consideration that is at least there exists one direction Granger-causal relationship among the variables. An error correction model that can be used to correct the disequilibrium and estimate the short and long-run causality among the cointegrated variables was introduced by Sergan and made popular by Engle and Granger[29] . The ARDL Models used in this study are specified. The generalised form of ARDL (p q) model is specified as:

$$Y_t = \vartheta_{0i} + \sum_{i=1}^{p} \delta_i Y_{t-i} + \sum_{i=0}^{q} \beta_i' X_{t-i} + \varepsilon_{it} \quad (4)$$

Where is a vector of endogenous variables is a vector of i^{th} period of exogenous variables δ and β are coefficients; is the constant ϑ and I = 1, k; p and q are the optimal lag orders of endogenous and exogenous variables respectively and is a vector of the error terms.
To perform the bounds test for cointegration, the conditional ARDL (p q) Model with three variables are specified as follows:

$$\Delta Pet_t = a_{01} + b_{11} Pet_{t-i} + b_{21} Elec_{t-i} + b_{31} GDP_{t-i} + \sum_{i=1}^{p} a_{1i} \Delta Pet_{t-i} + \sum_{i=1}^{q} a_{2i} \Delta Elec_{t-i} \sum_{i=1}^{q} a_{3i} \Delta GDP_{t-i} + e_{1t} \quad (5)$$

$$\Delta Elec_t = a_{02} + b_{12} Pet_{(t-i)} + b_{22} Elec_{(t-i)} + b_{32} GDP_{t-i} + \sum_{i=1}^{p} a_{1i} \Delta Pet_{t-i} + \sum_{i=1}^{q} a_{2i} \Delta Elec_{(t-i)} \sum_{i=1}^{q} a_{3i} \Delta GDP_{t-i} + e_{2t} \quad (6)$$

$$\Delta GDP_t = a_{03} + b_{13} Pet_{(t-i)} + b_{23} Elec_{(t-i)} + b_{33} GDP_{(t-i)} + \sum_{i=1}^{p} a_{1i} \Delta Pet_{t-i} + \sum_{i=1}^{q} a_{2i} \sum_{i=1}^{q} a_{2i} \Delta Elec_{(t-i)} \sum_{i=1}^{q} a_{3i} \Delta GDP_{t-i} + e_{3t} \quad (7)$$

The hypothesis based on the bounds test for cointegration is:

$$H_0 : b_{1i} = b_{2i} = b_{3i} = 0, \text{ where } i = 1, 2, 3$$
$$H_1 : b_{1i} \neq b_{2i} \neq b_{3i} \neq 0$$

Case 1: There is cointegration that is the null hypothesis is rejected. The long-run model is specified as:

$$Pet_t = a_{01} + b_{11} Pet_{t-i} + b_{21} Elec_{t-i} + b_{31} GDP_{t-i} + \mu_{1t} \quad (8)$$

$$Elec_t = a_{02} + b_{12} Elec_{t-i} + b_{22} Pet_{t-i} + b_{32} GDP_{t-i} + \mu_{2t} \quad (9)$$

$$GDP_t = a_{03} + b_{13} GDP_{t-i} + b_{23} Pet_{t-i} + b_{33} Elec_{t-i} + \mu_{3t} \quad (10)$$

And the error correction model is then specified as:

$$\Delta Pet_t = a_0 + \sum_{i=1}^{p} a_{1i} Pet_{t-i} + \sum_{i=1}^{q} a_{2i} \Delta Elect_{t-i} + \sum_{i=1}^{q} a_{3i} GDP_{t-i} + \lambda ECT_{t-1} + \in_{1t} \quad (11)$$

$$\Delta Elec_t = a_0 + \sum_{i=1}^{q} a_{1i} Elec_{t-i} + \sum_{i=1}^{p} a_{2i} \Delta Pet_{t-i} + \sum_{i=1}^{q} a_{3i} \Delta GDP_{t-i} + \lambda ECT_{t-1} + \in_{2t} \quad (12)$$

$$\Delta GDP_t = a_0 + \sum_{i=1}^{q} a_{1i} \Delta GDP_{t-i} + \sum_{i=1}^{p} a_{2i} \Delta Pet_{t-i} + \sum_{i=1}^{q} a_{3i} \Delta Elec_{t-i} + \lambda ECT_{t-1} + \in_{2t} \quad (13)$$

Where $\lambda = (1-\sum_{i=1}^{p} \delta_i)$ is the speed of adjustment parameter $= (y_{t-i}-\theta x_t)$, the error correction term $\theta = \frac{\sum_{i=0}^{q} \beta_i}{a}$ is the long-run parameter a_{1i} and a_{2i} and are the short-run dynamic coefficients.

Case 2: There is no cointegration that is the null hypothesis is not rejected. The short-run model is specified as n model is then specified as:

$$\Delta Pet_t = a_0 + \sum_{i=1}^{p} a_{1i} \Delta Pet_{t-i} + \sum_{i=1}^{q} a_{2i} \Delta Elect_{t-i} + \sum_{i=1}^{q} a_{3i} \Delta GDP_{t-i} + \in_{1t} \quad (14)$$

$$\Delta Elec_t = a_0 + \sum_{i=1}^{q} a_{1i} \Delta Elec_{t-i} + \sum_{i=1}^{p} a_{2i} \Delta Pet_{t-i} + \sum_{i=1}^{q} a_{3i} \Delta GDP_{t-i} + \in_{2t} \quad (15)$$

$$\Delta GDP_t = a_0 + \sum_{i=1}^{q} a_{1i} \Delta GDP_{t-i} + \sum_{i=1}^{p} a_{2i} \Delta Pet_{t-i} + \sum_{i=1}^{q} a_{3i} \Delta Elec_{t-i} + \in_{2t} \quad (16)$$

Causal relationship: The existence of a relationship between variables does not prove causality or the direction of influence, therefore it isnecessary to put this relationship into empirical testing using the appropriate causality tests (checks) to establish the direction of causal effect among the variables. This study uses regressor's t-statistic, Wald test and Granger-causality pairwise test. They all based on some of the models explained above.

RESULTS AND DISCUSSION

The results of the unit root test; the estimate of ARDL models; cointegration test, the estimate of short-rum models and the causality test are respectively presented and discussed in this section.

Table 1: Result of unit root test H_0 the series has unit root

	Petrol	Electricity	GDP
Series	p-values	p-values	p-values
Level	0.0000	0.3535	0.6651
First differenced	NA	0.0000	0.0000

Table 2: ARDL Bounds test for cointegration

Dependent variable	F-stat	Sig Level	I(0)	I(1)
Petrol	13.2528	10%	3.17	4.14
		5%	3.79	4.85
Electricity	4.4215	10%	3.17	4.14
		5%	3.79	4.85
GDP	5.0142	10%	3.17	4.14
		5%	3.79	4.85

Researcher's computation using Eviews 11

Unit root: The unit root test results reported in Table 1 indicate that petrol has no unit root at a level while electricity and GDP have a unit root at level but when the two variables are differenced, they both became stationary. This implies that they are both integrated of the same order and petrol is integrated of order zero I (0)

Cointegration test: The optimal lags for petrol, electricity and GDP based on the lowest information criterion are respectively found to be 4, 3 and 4. Now that the order of integration of the two variables is known, testing whether a linear combination of both series is itself stationary then followed. The adopted test here is the ARDL Bounds test for cointegration. Table 2 shows the results of cointegration test based on the ARDL Bounds test.

The results of the cointegration test are reported in Table 2 above. The optimal lag lengths are selected based on the Akaike Information Criterion (AIC). The results show that the F-statistic of the petrol and GDP dependent variable is greater than the critical value of at 5%, therefore the null hypothesis of no cointegration can be rejected. Hence, there is evidence of cointegration at 5% significant level in petrol and GDP dependent variable models. However, for the electricity model, the F-statistic is greater than I(1) at 10% and lies between the I(0) and I(1) at 5%. Hence, there is evidence of cointegration in the electricity model at 10% while the test is inconclusive at 5%. Thus, only the short-run model is estimated for electricity. That is, there exists a long-run relationship in petrol and GDP Models while the electricity model only has a short-run relationship (Table 4-6).

The estimates of the petrol consumption short-run and error correction model together with its model adequacy diagnostic results are reported in Table 3. The petrol consumption model is significant and stable (Appendix I) and its residuals are normally distributed, no serial correlation and no heteroskedasticity. In short-run,

Table 3: Estimate of petrol short-run and ECM Model

Variable	Coefficients	t-statistic	p-values
C	19.37559	0.63155	0.5319
D(PETROL(-1))	0.521126	1.334828	0.1908
D(PETROL(-2))	0.484181	1.695305	0.0992
D(PETROL(-3))	0.447485	2.026041	0.0507
D(PETROL(-4))	0.411113	2.561564	0.015
D(ELECTRICITY(-1))	0.001699	0.140487	0.8891
D(ELECTRICITY(-2))	0.000304	0.024891	0.9803
D(ELECTRICITY(-3))	-0.01806	-1.208545	0.2352
D(ELECTRICITY(-4))	-0.037827	-2.953392	0.0057
D(GDP(-1))	0.00845	0.710958	0.4820
D(GDP(-2))	-0.016689	-1.484078	0.1470
D(GDP(-3))	-0.002377	-0.197929	0.8443
D(GDP(-4))	-0.015131	-1.329917	0.1924
ECT01(-1)	-1.28406	-3.028738	0.0047

Test p-value; A: Serial correlation; B: Normality; C: Heteroscedasticity; Breusch-Godfrey Serial Correlation LM Test; Jarque-Bera test statistic Heteroscedasticity Test: Breush-Pegan-Godfrey; Authors' computation from Eviews 11

Table 4: Estimate of electricity short-run model

Variable	Coefficients	t-statistic	p-values
C	19.37559	0.63155	0.5319
D(ELECTRICITY(-1))	0.521126	1.334828	0.1908
D(ELECTRICITY(-2))	0.484181	1.695305	0.0992
D(ELECTRICITY(-3))	0.447485	2.026041	0.0507
D(PETROL(-1))	0.411113	2.561564	0.015
D(PETROL(-2))	0.001699	0.140487	0.8891
D(PETROL(-3))	0.000304	0.024891	0.9803
D(GDP(-1))	-0.01806	-1.20855	0.2352
D(GDP(-2))	-0.03783	-2.95339	0.0057
D(GDP(-3))	0.00845	0.710958	0.482

Test; p-value; A: Serial correlation; B: Normality; C: Heteroscedasticity; Breusch-Godfrey Serial Correlation LM Test; Jarque-Bera test statistic Heteroscedasticity Test: Breush-Pegan-Godfrey; Authors' computation using Eviews 11

Table 5: Estimate of GDP short-run and ECM Model

Variable	Coefficients	t-statistic	p-values
C	758.0202	1.24595	0.2213
D(GDP(-1))	-0.20663	-0.737	0.4662
D(GDP(-2))	-0.34558	-1.95912	0.0583
D(GDP(-3))	-0.23368	-0.84464	0.4042
D(GDP(-4))	0.701771	3.781828	0.0006
D(PETROL(-1))	2.631718	1.776987	0.0845
D(PETROL(-2))	2.00953	1.153525	0.2567
D(PETROL(-3))	2.093782	1.226966	0.2283
D(PETROL(-4))	0.205107	0.121464	0.9040
D(ELECTRICITY(-1))	-0.26211	-1.95562	0.0588
D(ELECTRICITY(-2))	-0.10261	-0.74375	0.4621
D(ELECTRICITY(-3))	-0.17349	-1.28271	0.2083
D(ELECTRICITY(-4))	-0.08432	-0.62441	0.5365
ECT03(-1)	0.007836	0.0244	0.9807

Test; p-value; A: Serial correlation; B: Normality; C: Heteroscedasticity; Breusch-Godfrey Serial Correlation LM Test; Jarque-Bera test statistic Heteroscedasticity Test: Breush-Pegan-Godfrey; Authors' computation from Eviews 11

Table 6: Granger causcality tests

Null hypothesis	Obs	f-statitics	Prob.
Electricity des not granger cause petrol	48	1.73188	0.1625
petrol does not granger cause electricity		1.26062	0.3019
GDP does not granger cause petrol	58	2.73661	0.0392
petrol does not granger cause DGP		1.72614	0.1593
GDP does not granger cause electricity	48	3.48357	0.0159
Electricity des not granger cause GDP		1.64611	0.1822

IV: Granger causality test; Pairwise Granger causality tests; Date:12/01/20; Time 20:49; Sample: 2005Q1 2020Q4; Lags: 4;

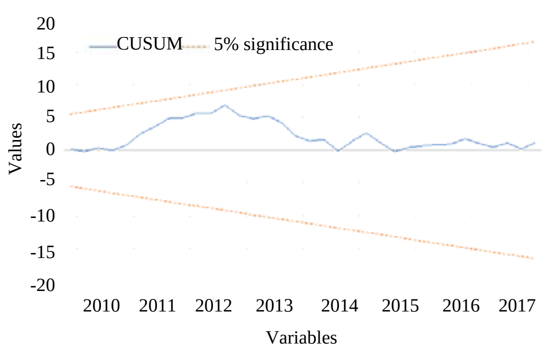
only the fourth lagged of differenced electricity has a significant negative impact on petrol consumption at 5%. The speed of adjustment of the petrol model is and significantly different at that is the system will return to equilibrium.

The estimates of the electricity consumption short-run model together with its model adequacy diagnostic results are reported in Table 4. The electricity consumption short-run model is significant and stable (Appendix II) and its residuals are normally distributed, no serial correlation and no heteroskedasticity. In short-run, the first lagged of differenced petrol has a significant positive impact on electricity consumption at 5%. Also, the second lagged of differenced GDP has a significant negative impact on electricity at 5%.

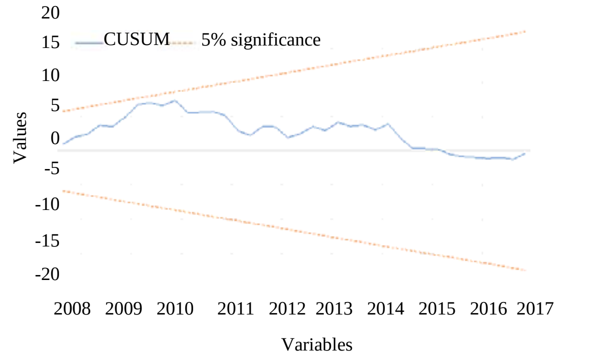
The estimates of the GDP short-run and error correction model together with its model adequacy diagnostic results are reported in Table 5. The GDP Model is stable (Appendix III) but insignificant with the adjusted- of 2.3%.Its residuals are not normally distributed, no serial correlation and no heteroskedasticity. In short-run, the first lagged of differenced petrol has a significant positive impact on GDP at 10%. Also, the first lagged of differenced electricity has a significant negative impact on electricity at 10%. However, the speed of adjustment of GDP Model is and is not significantly different. There is a uni-directional causal effect from GDP to petrol and from GDP to electricity while there is no causal effect from petrol to electricity and vice-versa (Appendix IV).

CONCLUSION

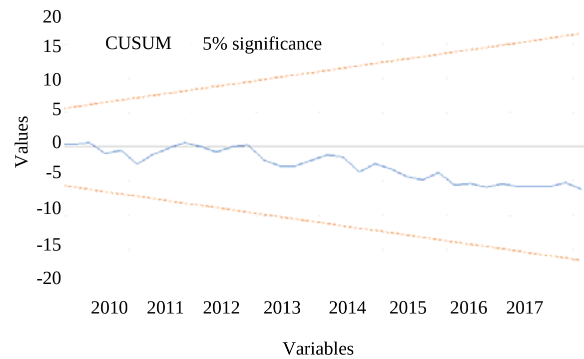
Petrol consumption is integrated of order zero while both electricity and GDP are individually integrated of order one. Since, the three series are integrated of different orders and none is integrated of the other two, then ARDL bounds test was carried out to check for cointegration among the variables. There exists a long-run relationship in petrol consumption and GDP Models. The GDP Model is not significant with a very low adjusted- of 2.3%. However, the petrol and electricity consumption models are significant with a high adjusted-value. The petrol model will return to equilibrium while the GDP Model will explode. GDP is seen to be inversely related to petrol and electricity consumption. That is as the GDP grows the consumption of petrol and electricity decays.



Appendix 1: Stability graph of petrol model Author computation from Eviews 11



Appendix 2: Stability graph of electricity model; Author computation from Eviews 11



Appendix 3: Stability graph of GDP model; Author computation from Eviews 11

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