Energy Consumption and Economic Growth: A Trivariate Framework of South Africa

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Abstract
The study investigates the causal relationship between energy consumption and economic growth in South Africa, covering the period of 1980-2014. In a trivariate framework which includes electricity and inflation as additional variables by applying the Autoregressive Distributed Lag (ARDL) integration method. First unit root test was employed; results indicated that all variables were non-stationary at the level and stationary at their first differences, using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP). The results show a long-run relationship among the variables using the ARDL integration approach. The Granger causality test indicates a unidirectional running from inflation to economic growth, which supports the growth hypothesis as documented in the literature and there was no causality between electricity consumption and economic growth, supporting the neutrality hypothesis. Any policies concerning energy consumption should be re-evaluated to confirm that it will not disturb economic growth.
Keywords: ARDL, Economic Growth, Energy Consumption, Granger Causality, and South Africa.
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1. Introduction

Energy plays a crucial role in the economic development of a country and is a key to achieve a solid economic, social and environmental aims of sustainable development. Policy makers and researches and economists of South Africa need to apprehend which variables among the five in question cause another. So that, the right strategies can be identified and implemented that will have a major impact on economic development. Therefore, investigating the impact of energy consumption on economic growth is crucial in explaining which variable plays a major role in the economic growth of South Africa. The association between energy consumption and economic growth is now well established in the literature, yet the direction of causality of this relationship remains controversial see Asafu-Adjaye (2000); Glasure and Lee (1997); and Masih and Masih (1997). The big question is, whether energy consumption leads to economic growth or vice versa, is still debatable.

In this case, it seems equitable to undertake studies on the relation between economic growth, energy consumption, capital, and inflation. From a theoretical point of view, these variables have a tendency to impact one another. Therefore, without a deep understanding of the direction of these variables, it will be difficult to find the most effective policies to be implemented. Then, it makes sense to investigate the causality relation between these variables to make it easier in policy making in South Africa. The direction of causality has an impact on policy implication. Few studies have focused on economic growth, electricity consumption, energy use, capital, and inflation. The nexus between energy consumption and economic growth has been widely studied over the years, using modern advances in time series econometrics of co-integration and causality. Although to the best of our knowledge few studies have been conducted about South Africa.

The purpose of this study is to provide a recent understanding of analysis in the five variables in question and add up to the existing literature, while the specific objective is to investigate the causal relationship between gross domestic product and energy consumption in the case of South Africa. This is accomplished by examining the unit root tests to test for stationarity of the variables, then, co-integration test by employing autoregressive distributed lag (ARDL) bounds testing approach proposed by Pesaran et al. (2001). Pairwise Granger causality test to determine the direction of the variables and diagnostic tests are conducted to check whether the variables are free from heteroscedasticity, correlation, and normality problems, while stability test is used to check if coefficients are stable or not.

This study is organized into five parts, Parts One covers the introduction of the study, Part Two Review of literature, Part Three covers the data and methodology, Part Four is the empirical results and discussion, and Part Five covers conclusion and recommendation.

2. Review of Literature

Since the seminar study of Kraft and Kraft (1978), the literature on economic growth and energy consumption has been growing. The view that energy consumption is of the basic indicators of economic growth has concerned economists all over the world to investigate the correlation between economic growth and energy consumption. Ozturk (2010) summarized the empirical evidence of testing the causality relation between economic growth and energy consumption into four testable hypotheses namely; the feedback, conservation, growth, and neutrality. First, the feedback hypothesis refers to a state in which causality runs from both directions that are from energy consumption to economic growth and vice versa. It entails that energy consumption and economic growth are interrelated. Studies that support feedback or bidirectional causality include Masih and Masih (1997) for Pakistan; Jumbe (2004) for Malawi; Belloumi (2009) for Tunisia; Zhang (2011) for Russia; Amusa and Leshoro (2013) for Botswana. Second, the conservation hypothesis refers to a state in which a unidirectional causality runs from economic growth to energy consumption. It implies that guidelines intended to reduce energy consumption will not adversely affect economic growth indicating that the economy is less energy dependent. The conservation hypothesis was demonstrated by Odhiambo (2014); Baranzini et al. (2013) for Switzerland; Azlina (2012) for Malaysia; Akinlo (2008a) for Nigeria; and Zhang and Cheng (2009) for China. Third, a condition in which unidirectional causality runs from energy consumption to economic growth is referred as growth hypothesis. It suggests that a growth in energy consumption may contribute to economic growth, while a decrease in energy consumption may adversely affect economic growth, indicating that the economy is energy dependent. This hypothesis is illustrated by Aslan et al. (2014) for the United States; Tsai (2010) for Greece; Narayan and Smyth (2005) for Australia; Ouedraogo (2013) for 15 ECOWAS countries; and Soytas and Sari (2003) for G7 countries. Lastly, the neutrality hypothesis asserts a condition in which no causality exists in either direction between economic growth and energy consumption. Numerous studies such as Stern and Enflo (2013); Ozturk and Acaravci (2010) for Albania; Narayan and Prasad (2008) for 30 OECD countries; Wolde-Rufael (2006) for 17 African countries; and Soytas and Sari (2003) supports the neutrality hypothesis. If an increase in economic growth does not cause an increase in energy consumption and vice versa, the neutrality hypothesis is recognized.

Table 1 Selected studies on energy consumption and economic growth

Author(s)	Country(s)/Periods	Methodology	Findings
Aslan et al. (2014)	Turkey (1968-2008)	ARDL bound test and Granger causality test	Bi-directional causality
Odhiambo (2014)	Ghana (1972-2006)	ARDL-Bounds Testing Procedure	Unidirectional causality test
Amusa and Leshoro (2013)	Botswana (1981-2010)	ARDL-Bounds Testing Procedure	Bi-directional causality
Baranzini et al. (2013)	Switzerland		Unidirectional causality
Ouedraogo (2013)	15 ECOWAS Countries (1980-2008)	Panel Co-integration, Causality Tests	Unidirectional causality
Stern and Enflo (2013)	Sweden (1850-2000)	Granger Causality	No causality
Azlina (2012)	Malaysia	Multivariate	Unidirectional causality
Zhang (2011)	Russia (1970-2008)	Toda-Yamamoto	Bi-directional causality
Akinlo (2008a)	Nigeria (1980-2006)	VECM. Co-Feature Analysis	Unidirectional causality
Tsai (2010)	Greece (1960-2006)	Toda-Yamamoto Causality Test	Unidirectional causality
Ozturk and Acaravci (2010)	Turkey (1968-2005)	ARDL-Bounds Testing Procedure	No causality
Belloumi (2009)	Tunisia (1971-2004)	VECM	Bidirectional causality
Zhang and Cheng (2009)	China (1960-2007)	Toda-Yamamoto Test, Generalized Impulse Response	Unidirectional causality
Narayan and Prasad (2008)	30 OECD Countries	Bootstrapped Causality tests	No causality
Wolde-Rufael (2006)	17 African Countries (1971-2001)	ARDL-Bounds Testing Procedure	No causality
Narayan and Smyth (2005)	Australia (1966-1999)	Structural Break Test	Unidirectional causality
Jumbe (2004)	Malawi (1970-1999)	Granger Causality	Bi-directional causality
Soytas and Sari (2003)			No causality
Masih and Masih (1997)	India	MVECM	Bi-directional causality
Kraft and Kraft (1978)	United States (1947-1974)	Sims causality test	Unidirectional causality

The review of literature indicates that the direction of causality between energy consumption and economic growth remains debated and provide mixed results, therefore making this study a meaningful exercise, especially with the use of recent data and methodology.

3. Data and Methodology

3.1 Data Source

Annual time series data covering the period of 1980-2014 was used and drawn from the World Development Indicators (World Bank 2018). The limitation of this time period was due to the unavailability of the data. The real GDP per capita (constant 2010 US$) is the proxy of economic growth and the dependent variable, electricity consumption (kWh per capita), and the annual rate of inflation (percentage) as explanatory variables. All variable are in their natural logarithm. Eviews 10 was employed to estimate the model.

In order to avoid spurious relation among the variables, two different unit root test, namely Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) were conducted in the time series variables for the gross domestic product, capital, energy use, and inflation. After the unit root testing, it is important to test for the existence of co-integration among variables, this study employed the ARDL model. Lastly, the Granger causality test was employed to determine the direction of the causal relation of the variables. To be sure that the model is robust, diagnostic tests have been conducted to check whether the variables are free from heteroscedasticity, correlation, and normality problems, while stability test is used to check if coefficients are stable or not.

3.2 Estimation of ARDL Model

The approach adopted in this study is ARDL procedure bounds-testing proposed by Pesaran, Shin, and Smith (2001). Following recent studies (see Odhiambo 2014), the generalized ARDL (p, q) model was specified as:

$$\boldsymbol{Y}_t = \gamma_{0i} + \sum_{i=1}^{p} \delta_i \boldsymbol{Y}_{t-1} + \sum_{i=0}^{q} \beta'_i X_{t-1} + \varepsilon_{it} \qquad (1)$$

Where $\boldsymbol{Y'}_t$ is the vector and the variables in $\boldsymbol{X'}_i$ are allowed to be purely $I(0)$ or $I(0)$ or integrated; $\boldsymbol{\beta}$ *and* $\boldsymbol{\delta}$ are coefficients; γ is the constant; i = 1,… k; p, q are optimal lag orders; $\boldsymbol{\varepsilon_{it}}$ is the vector of the error terms – unobservable zero mean white noise vector process (serially uncorrelated or independent).

Hypotheses:

$H_0: b_{1i} = b_{2i} = b_{3i} = 0$ (where i =1, 2, 3)

$H_1: b_{1i} \neq b_{2i} \neq b_{3i} \neq 0$

$$\Delta InY_t = \sigma_0 + \sum_{i=1}^{P} \sigma_{1i} \Delta InY_{t-1} + \sum_{i=1}^{P} \sigma_{2i} \Delta InEC_{t-1} + \sum_{i=1}^{P} \sigma_{3i} \Delta InINF_{t-1} + \sigma_4 \Delta InY_{t-1} + \sigma_5 \Delta InEC_{t-1} + \sigma_6 \Delta InINF_{t-1} + \mu_{1t} \qquad (2)$$

$$\Delta InEC_t = \tau_0 + \sum_{i=1}^{P} \tau_{1i} \Delta InEC_{t-1} + \sum_{i=1}^{P} \tau_{2i} \Delta InY_{t-1} + \sum_{i=1}^{P} \tau_{3i} \Delta InINF_{t-1} + \tau_4 \Delta InEC_{t-1} + \tau_5 \Delta InY_{t-1} + \tau_6 \Delta InINF_{t-1} + \mu_{1t} \qquad (3)$$

$$\Delta InINF_t = \rho_0 + \sum_{i=1}^{P} \rho_{1i} \Delta InINF_{t-1} + \sum_{i=1}^{P} \rho_{2i} \Delta InY_{t-1} + \sum_{i=1}^{P} \rho_{3i} \Delta InEC_{t-1} + \rho_4 \Delta InINF_{t-1} + \rho_5 \Delta InY_{t-1} + \rho_6 \Delta InEC_{t-1} + \mu_{1t} \qquad (4)$$

Following the stationarity test, the co-integration analysis is run to make sure that the variables are not co-integrated, that is whether there is any long-run relation among them. This analysis is based on the assumption that the long-run structure of non-stationary series can be stationary Gujarati and Porter, (2009).

To test for co-integration the Autoregressive Distributed Lag (ARDL) approach developed by Pesaran et al. (2001) is applied. This approach has received greater emphasis since a couple of years back due to its ability to return both short-run and long-run multipliers, and its ability to estimate both $I(0)$ and $I(1)$ series in the same model. Furthermore, it is simple to implement and interpret since it only involves just a single equation set-up.

The ARDL co-integration test developed consist of two significant stages, in which during the first stage, the presence of a long-run relationship among the series is examined. Once it is detected, the second stage examines the structure of the short and long-run relation. In summary, to carry out this procedure, the computed F-statistics are compared to the critical lower and upper bound values. The decision rule is that if the F-statistic exceed the critical upper bound value, then the null hypothesis of no co-integration is rejected; if the F-statistic is below the critical lower bound value, then the null hypothesis of no co-integration is accepted; but if the F-statistic fall between the critical lower and upper values, then knowledge of order of integration is required or else it is inconclusive Pesaran et al., (2001).

3.3 Granger causality test

In order to scrutinize the short and long run causality between economic growth, electricity consumption, and inflation the study with previous works (see Odhiambo 2014, Narayan & Smyth 2005) the model is as follows:

$$\Delta InY_t = \alpha_0 + \sum_{i=1}^{P} \alpha_{1i}\,\Delta InY_{t-1} + \sum_{i=1}^{P} \alpha_{2i}\,\Delta InEC_{t-1} + \sum_{i=1}^{P} \alpha_{5i}\,\Delta InINF_{t-1} + \alpha_{6i}ECM_{t-1} + \mu_{1t} \quad (5)$$

$$\Delta InEC_t = \beta_0 + \sum_{i=1}^{P} \beta_{1i}\,\Delta InEC_{t-1} + \sum_{i=1}^{P} \beta_{2i}\,\Delta InY_{t-1} + \sum_{i=1}^{P} \beta_{5i}\,\Delta InINF_{t-1} + \beta_{6i}ECM_{t-1} + \mu_{1t} \quad (6)$$

$$\Delta InINF_t = \vartheta_0 + \sum_{i=1}^{P} \vartheta_{1i}\,\Delta InINF_{t-1} + \sum_{i=1}^{P} \vartheta_{2i}\,\Delta InY_{t-1} + \sum_{i=1}^{P} \vartheta_{3i}\,\Delta InEC_{t-1} + \vartheta_{6i}ECM_{t-1} + \mu_{1t} \quad (7)$$

ECM_{t-1} is the error-correction term of the immediate period before t; this term was formulated from the long run equilibrium equation; α, β and γ are the parameters of the model; and μ_{1t} is the error term. The Error correction model specification is the combination of the short-run and long-run representation.

4. Results and Discussions

4.1 Unit Root Test

The results of our estimations are presented step by step and are as follows:

Unit root tests were designed to study the stationary properties of time series observation. ADF and PP were used to examine the unit root property with the inclusion of trends and intercepts at both level and first difference. The two tests reveal that all variables are non-stationary in their level data. The results in Table 2 illustrate that all variables are stationary after the first difference, suggesting that all the variables are integrated of order *I*(1) at 1% and 5% level of significance.

Table 2 Unit Root Tests

Variables	Level		First difference	
	ADF	PP	ADF	PP
InY	-0.4032	-0.05869	-3.5773**	-3.6221**
InEC	-2.8761	-2.8723	-4.9231***	-4.8888***
InINF	-2.1451	-1.9044	-5.4940***	-11.2455***

*** and ** denote 1% and 5% level of significance

Source: Author used EViews 10

4.2 Estimating ARDL Model in Eviews (10)

Using Model 3 (Constant): Unrestricted constant and no trend

The Autoregressive Distributed Lag (ARDL) model was employed to determine the long-run relation between the variables. Since the variables were found to be stationary *I*(1), it was likely that they would move together in the long-run. To determine optimal lags, Akaike Information Criterion (AIC) and Schwarz Information Criterion (SIC) were used in the lag structure criteria, the optimal lags deemed appropriate were found to be (1, 2, 2,) for equation 1 to 3. Pesaran et al. (2001) emphasized that an F-test would suit to observe whether or not there is co-integration relation between variables. Using the optimal lags, F-test was performed on equation 1 to 3 as reported in Table 3. The results indicated in Table 3 shows that the F-statistic 9.5676, calculated for equation (1) is higher than the upper bound value. The null hypothesis of no cointegration between the variables is rejected. The conclusion for equation (1) is that there is a long-run relation between the variables. The electricity consumption equation (2), the F-statistic calculated 6.3004 are higher than the upper bound value at 1%, 5% and 10% level of significance. This indicates that the null hypothesis of no co-integration is rejected. The F-statistic 1.5876 estimated for equation (3), the inflation equation, was lower than the upper bound value even at a 10% level of significance. Hence, the null hypothesis of no co-integration is inclusive. Results of short-run relationship are shown on the appendix. Where the coefficient of ECM (-1) is statistical significance at 1% level of significance, which indicates that the speed of adjustment for short run to reach the long-run equilibrium.

Table 3 ARDL Bound test for Co-integration

Dependent variables	F-Statistics	Function
InY	9.5676	InY (InEC, InINF)
InEC	6.3004	InEC (InY, InINF)
InINF	1.5876	InINF (InEC, InY)

Source: Author used EViews 10

4.4 Granger causality test

After establishing the co-integration relation between variables, the next is to test the direction of the causality among the variables. The co-integration suggests the existence of causality at least in one direction. The results for testing of the presence and direction of causality between economic growth, electricity consumption, and inflation are presented in Table 4. The findings indicate a unidirectional between inflation and economic growth with F-statistic 10.0812 meaning we fail to accept the null hypothesis of LINF does not Granger cause LGDP at 1% level of significance. These results are constant with Odhiambo (2014); Shahbhaz et al. (2013); Tsani (2010); Ho and Siu (2007) and Wolde-Rufael (2004). There is no causality between electricity consumption and economic growth, these results are in line with as Stern and Enflo (2013); Ozturk and Acaravci (2010); Narayan and Prasad (2008), meaning that both variables are interdependent to each other. But differ from those of Kraft and Kraft (1978); Aslan (2014); Ogundipe and Apata (2013) and Shiu and Lam (2004), who found unidirectional and bidirectional causality.

Table 4 Pairwise Granger Causality Test

Null Hypothesis	F-Statistic	Probability	Decision
LELE does not Granger Cause LGDP	2.4453	0.1050	Accept
LGDP does not Granger Cause LELE	0.9675	0.3924	Accept
LINF does not Granger Cause LGDP	10.081	0.0005***	Reject
LGDP does not Granger Cause LINF	0.2617	0.7716	Accept

*** denotes the level of significance at 1%.
Source: Author used EViews 10

5. Conclusion and Recommendations

This study investigated the causal link between economic growth, electricity consumption, and inflation, using South African annual time series data from 1980-2014, to form a trivariate outline in the analysis. The main findings were as follows: First, the study found that all variables were non-stationary at the level and became stationary at their first difference, meaning the variables were integrated at order one *I(*1). Using Augmented Dicky-Fuller (ADF) and Phillips-Perron (PP). Second, using the Autoregressive Distributed Lag (ARDL) model, the study found the presence of long-run equilibrium co-integration between the variables. Third, the study found a unidirectional running from inflation to economic growth, which supports the growth hypothesis. Lastly, there was no causality between electricity consumption and economic growth, supporting the neutrality hypothesis, this results are in line Acaravci and Ozturk (2010) and Chen et al. (2007) but differ from previous studies of Kraft and Kraft (1978); Aslan (2014); Ogundipe and Apata (2013) and Shiu and Lam (2004), who found unidirectional and bidirectional causality between these two variables. By employing Pairwise Granger causality test, the direction of causality among the variables was determined.

These results may suffer from omitting other relevant variables; future research should attempt to include more relevant variables in the analysis. This study may contribute to the existing literature especially for South Africa. There were unavoidable limitations, first the study used data from 1980 to 2014, the current was not included due to the unavailability of data and some variables have limited periods. This study can be influential in the formation of policies that can avoid negative effects on economic growth. Any policies concerning energy consumption should be re-evaluated to confirm that it will not disturb economic growth.

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Appendix A: Data Set

	Economic Growth	Electricity	Inflation
YEAR	LGDP	LELE	LINF
1980	6447.094	3376.929	13.66025
1981	6620.851	3534.312	15.25424
1982	6427.623	3609.003	14.63904
1983	6150.042	3654.42	12.30321
1984	6305.916	3900.001	11.52648
1985	6084.253	3989.458	16.29423
1986	5951.199	4084.439	18.65492
1987	5948.618	4064.604	16.16059
1988	6070.901	4152.287	12.77955
1989	6085.949	4177.063	14.73088
1990	5934.224	4152.977	14.32099
1991	5739.733	4051.059	15.33477
1992	5485.441	3927.213	13.8747
1993	5423.588	3956.758	9.717447
1994	5474.197	4003.843	8.938547
1995	5528.169	4093.122	8.680425
1996	5657.328	4633.82	7.354126
1997	5706.175	4744.597	8.59777
1998	5643.261	4535.281	6.880553
1999	5688.309	4399.498	5.181491
2000	5837.885	4503.774	5.338953
2001	5912.67	4226.646	5.701901
2002	6045.963	4444.525	9.164038
2003	6142.94	4470.822	5.85898
2004	6343.03	4498.979	1.385382
2005	6599.357	4547.651	3.3993
2006	6892.362	4638.224	4.641625
2007	7185.753	4777.059	7.09842
2008	7337.84	4606.629	11.53645
2009	7145.784	4385.254	7.13
2010	7275.382	4510.217	4.257416
2011	7416.714	4543.628	5.000473
2012	7475.781	4352.392	5.653583
2013	7551.963	4279.248	5.751534
2014	7582.553	4198.401	6.067198

Appendix B: Unit Root Test Results

a) Variable InGDP (Economic Growth)

Null Hypothesis: D(LGDP) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.577387	0.0119
Test critical values:	1% level	-3.646342	
	5% level	-2.954021	
	10% level	-2.615817	

*MacKinnon (1996) one-sided p-values.
Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LGDP,2)
Method: Least Squares
Date: 10/18/18 Time: 04:09
Sample (adjusted): 1982 2014
Included observations: 33 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LGDP(-1))	-0.572072	0.159913	-3.577387	0.0012
C	0.002059	0.004040	0.509558	0.6140

R-squared	0.292200	Mean dependent var	-0.000683
Adjusted R-squared	0.269368	S.D. dependent var	0.026659
S.E. of regression	0.022788	Akaike info criterion	-4.666516
Sum squared resid	0.016097	Schwarz criterion	-4.575819
Log likelihood	78.99752	Hannan-Quinn criter.	-4.635999
F-statistic	12.79770	Durbin-Watson stat	1.748961
Prob(F-statistic)	0.001164		

b) Variable InEle (Electricity)
Null Hypothesis: D(LELE) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.923139	0.0003
Test critical values:	1% level	-3.646342	
	5% level	-2.954021	
	10% level	-2.615817	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LELE,2)
Method: Least Squares
Date: 10/18/18 Time: 04:13
Sample (adjusted): 1982 2014
Included observations: 33 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LELE(-1))	-0.866924	0.176092	-4.923139	0.0000
C	0.004263	0.006501	0.655740	0.5168

R-squared	0.438785	Mean dependent var	-0.001958
Adjusted R-squared	0.420681	S.D. dependent var	0.048128
S.E. of regression	0.036631	Akaike info criterion	-3.717137
Sum squared resid	0.041597	Schwarz criterion	-3.626439
Log likelihood	63.33275	Hannan-Quinn criter.	-3.686620
F-statistic	24.23730	Durbin-Watson stat	1.980511
Prob(F-statistic)	0.000027		

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c) Variable lnINF (Inflation)

Null Hypothesis: D(LINF) has a unit root
Exogenous: Constant
Lag Length: 3 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.494024	0.0001
Test critical values:	1% level	-3.670170	
	5% level	-2.963972	
	10% level	-2.621007	

*MacKinnon (1996) one-sided p-values.
Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LINF,2)
Method: Least Squares
Date: 10/18/18 Time: 04:18
Sample (adjusted): 1985 2014
Included observations: 30 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LINF(-1))	-2.492338	0.453645	-5.494024	0.0000
D(LINF(-1),2)	1.284478	0.363328	3.535311	0.0016
D(LINF(-2),2)	0.718468	0.265164	2.709519	0.0120
D(LINF(-3),2)	0.484863	0.177055	2.738489	0.0112
C	-0.072137	0.066793	-1.080006	0.2904

R-squared	0.690925	Mean dependent var	0.003955
Adjusted R-squared	0.641473	S.D. dependent var	0.595026
S.E. of regression	0.356285	Akaike info criterion	0.924838
Sum squared resid	3.173467	Schwarz criterion	1.158371
Log likelihood	-8.872566	Hannan-Quinn criter.	0.999547
F-statistic	13.97164	Durbin-Watson stat	1.924507
Prob(F-statistic)	0.000004		

Dependent Variable: LGDP
Method: ARDL
Date: 01/31/19 Time: 23:00
Sample (adjusted): 1981 2014
Included observations: 34 after adjustments
Maximum dependent lags: 1 (Automatic selection)
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (2 lags, automatic): LELE LINF
Fixed regressors: C
Number of models evalulated: 9
Selected Model: ARDL(1, 1, 1)
Note: final equation sample is larger than selection sample

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LGDP(-1)	1.000057	0.031164	32.08992	0.0000
LELE	0.315755	0.097074	3.252712	0.0030
LELE(-1)	-0.261667	0.082125	-3.186207	0.0035
LINF	-0.008250	0.008217	-1.004041	0.3240
LINF(-1)	-0.019160	0.008878	-2.158059	0.0396
C	-0.390953	0.543757	-0.718984	0.4781

R-squared	0.979275	Mean dependent var	8.744965
Adjusted R-squared	0.975574	S.D. dependent var	0.105986
S.E. of regression	0.016565	Akaike info criterion	-5.204321
Sum squared resid	0.007683	Schwarz criterion	-4.934963
Log likelihood	94.47345	Hannan-Quinn criter.	-5.112462
F-statistic	264.5994	Durbin-Watson stat	1.781875
Prob(F-statistic)	0.000000		

*Note: p-values and any subsequent tests do not account for model selection.

Appendix D: Long-Run and Short-Run Relationship.

System: UNTITLED
Estimation Method: Least Squares
Date: 01/31/19 Time: 22:53
Sample: 1982 2014
Included observations: 33
Total system (balanced) observations 99

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.004491	0.001522	-2.951265	0.0041
C(2)	0.073091	0.214164	0.341286	0.7337
C(3)	-0.022166	0.108567	-0.204169	0.8387
C(4)	-0.006562	0.009392	-0.698678	0.4867
C(5)	0.003747	0.003536	1.059700	0.2923
C(6)	0.003567	0.002855	1.249221	0.2151
C(7)	0.157838	0.401858	0.392771	0.6955
C(8)	0.091698	0.203715	0.450129	0.6538
C(9)	-0.023374	0.017623	-1.326287	0.1883
C(10)	0.003190	0.006634	0.480920	0.6318
C(11)	-0.010379	0.030681	-0.338277	0.7360
C(12)	4.038638	4.317879	0.935329	0.3523
C(13)	1.033204	2.188877	0.472025	0.6381
C(14)	-0.067856	0.189359	-0.358349	0.7210
C(15)	-0.056490	0.071282	-0.792484	0.4303
Determinant residual covariance		2.60E-08		

Equation: D(LGDP) = C(1)*(LGDP(-1) - 22.2158351949*LELE(-1) + 3.59847750601*LINF(-1) + 169.215092092) + C(2)*D(LGDP(-1)) + C(3)*D(LELE(-1)) + C(4)*D(LINF(-1)) + C(5)

Observations: 33

R-squared	0.465673	Mean dependent var	0.004110
Adjusted R-squared	0.389340	S.D. dependent var	0.024885
S.E. of regression	0.019446	Sum squared resid	0.010588
Durbin-Watson stat	1.923568		

Equation: D(LELE) = C(6)*(LGDP(-1) - 22.2158351949*LELE(-1) + 3.59847750601*LINF(-1) + 169.215092092) + C(7)*D(LGDP(-1)) + C(8)*D(LELE(-1)) + C(9)*D(LINF(-1)) + C(10)

Observations: 33

R-squared	0.120008	Mean dependent var	0.005218
Adjusted R-squared	-0.005706	S.D. dependent var	0.036385
S.E. of regression	0.036489	Sum squared resid	0.037280
Durbin-Watson stat	2.009981		

Equation: D(LINF) = C(11)*(LGDP(-1) - 22.2158351949*LELE(-1) + 3.59847750601*LINF(-1) + 169.215092092) + C(12)*D(LGDP(-1)) + C(13)*D(LELE(-1)) + C(14)*D(LINF(-1)) + C(15)

Observations: 33

R-squared	0.129973	Mean dependent var	-0.027938
Adjusted R-squared	0.005683	S.D. dependent var	0.393182
S.E. of regression	0.392063	Sum squared resid	4.303977
Durbin-Watson stat	1.980865		

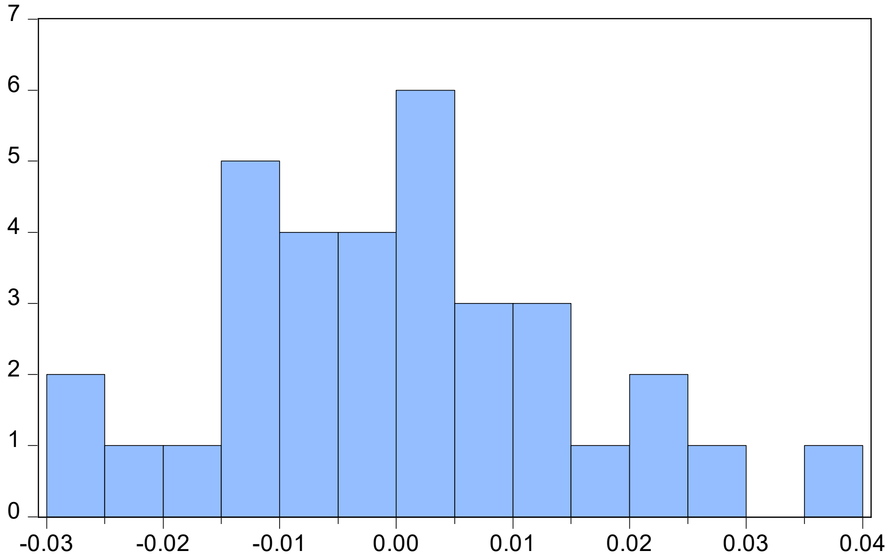
Appendix E: Pairwise Granger Causality Test

Pairwise Granger Causality Tests
Date: 01/31/19 Time: 23:02
Sample: 1980 2014
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
LELE does not Granger Cause LGDP	33	2.44530	0.1050
LGDP does not Granger Cause LELE		0.96757	0.3924
LINF does not Granger Cause LGDP	33	10.0812	0.0005
LGDP does not Granger Cause LINF		0.26175	0.7716
LINF does not Granger Cause LELE	33	1.91196	0.1666
LELE does not Granger Cause LINF		2.00042	0.1542

Appendix E: Diagnostics Tests

A) Normality



Series: Residuals
Sample 1981 2014
Observations 34

Mean	-1.99e-16
Median	-0.000655
Maximum	0.035795
Minimum	-0.029860
Std. Dev.	0.015258
Skewness	0.261488
Kurtosis	2.819448
Jarque-Bera	0.433646
Probability	0.805073

B) Autocorrelation

VEC Residual Serial Correlation LM Tests
Date: 01/31/19 Time: 02:07
Sample: 1980 2014
Included observations: 33

Null hypothesis

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	5.313100	9	0.8062	0.581202	(9, 56.1)	0.8069

C) Hetoskedasticity

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	3.752521	Prob. F(5,28)	0.0100
Obs*R-squared	13.64185	Prob. Chi-Square(5)	0.0181
Scaled explained SS	8.416686	Prob. Chi-Square(5)	0.1347

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 01/31/19 Time: 23:09
Sample: 1981 2014
Included observations: 34

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.009093	0.008531	1.065787	0.2956
LGDP(-1)	0.000481	0.000489	0.984607	0.3332
LELE	9.45E-05	0.001523	0.062050	0.9510
LELE(-1)	-0.001698	0.001289	-1.317894	0.1982
LINF	0.000168	0.000129	1.300473	0.2040
LINF(-1)	-2.06E-05	0.000139	-0.147937	0.8835

R-squared	0.401231	Mean dependent var	0.000226
Adjusted R-squared	0.294308	S.D. dependent var	0.000309
S.E. of regression	0.000260	Akaike info criterion	-13.51381
Sum squared resid	1.89E-06	Schwarz criterion	-13.24445
Log likelihood	235.7347	Hannan-Quinn criter.	-13.42195
F-statistic	3.752521	Durbin-Watson stat	2.304036
Prob(F-statistic)	0.010018		

D) Stability