THE RELATIONSHIP BETWEEN ELECTRICITY CONSUMPTION AND ECONOMIC GROWTH IN BOTSWANA

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Abstract

Concerted effort to diversify Botswana economy, in recent years, has seen increased activity of major sectors, which includes higher reliance on electricity. The demand and consumption of electricity within the Botswana economy increased substantially from the 1980's. However there have been shortfalls in the country's electricity generation capacity causing increased reliance on imports from neighbouring countries especially South Africa. Given the importance of electricity in Botswana, this study examined the relationship between electricity and economic growth, employing bounds testing approach to co-integration. Results obtained confirmed the importance of electricity for Botswana's economic growth. The result also passed a battery of diagnostic tests. This study recommends the need for energy policy reforms that will enable increased electricity production capacity.***

JEL Classification: C32, Q43

Keywords: Electricity Consumption, Economic Growth, Cointegration, Botswana

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1. Introduction

Electricity consumption is increasingly becoming important in increasing economic growth for many African economies. More and more, the development of economic activities such as industrial production and the service industry is driving growth and increasing output in many developing countries. This has necessitated higher demand for and consumption of electricity. The onset of economic development in Botswana brought with it increased demand for electricity by both household and business sectors. Botswana's relatively high economic growth has over the years been sustained by the mining sector, especially diamond mining. In recent years, there has been a concerted effort in the diversification of the economy with increased activity in other sectors. Diversification has brought with it higher reliance on electricity.

Compared to other Southern African countries, the growth in the country's demand for electricity is the highest, standing at 6 percent, Southern Africa Power Pool (SAPP). The demand and consumption of electricity within the Botswana economy increased substantially from the 1980's. However there remains a shortfall in the country's electricity generation capacity resulting in increased reliance on imports from neighbouring countries especially South Africa. Presently, electricity import, generation and transmission are overseen by the Botswana Power Corporation (BPC). Morupule, the sole electricity generating power station in the country provides approximately 33 percent of the nation's electricity demand and the shortfall is met by imports from South Africa, Mozambique and the SAPP.

Between 2009 and 2010, the shortfall in electricity generation in South Africa forced the authorities to restrict their supply of electricity to Botswana. Botswana experienced severe load shedding which affected households and businesses. It is estimated that the period of load shedding cost the economy millions of dollars. The rural electrification plan implemented in Botswana to connect more households to the national electricity will increase demand for electricity and put even more pressure on its sources of electricity. The potential shortage in the region's electricity pool and from other countries will without a doubt affect the economy negatively.

The realization of the importance of electricity in increasing growth has generated renewed interest in this area for both developed and developing countries (Ebohon, 1996; Yang, 2000; Soytas and Sari, 2003; Jumbe, 2004; Oh and Lee, 2004; Shiu and Lam, 2004; Wolde-Rufael, 2006; Squalli, 2007; Akinlo, 2008; Odhiambo, 2009; Gupta, and Chandra, 2009; Quedraogo, 2010). Studies examining the relationship between electricity consumption and economic growth can be generalized into two main categories, those that determine the nature of the relationship between electricity consumption and economic growth and others that examine the direction of causality between the electricity consumption and economic growth.

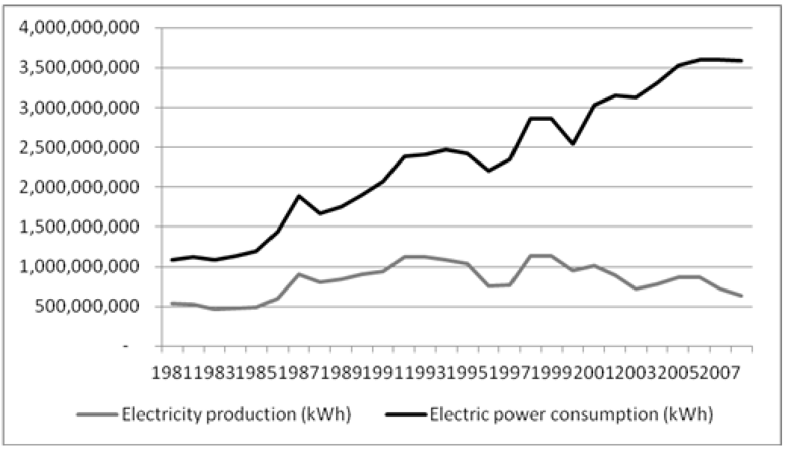
This study contributes to the literature in two major ways. Firstly, it is crucial to understand the exact nature of the relationship between growth and electricity consumption. This is due to the fact that the realization of the importance of electricity for the economy has prompted the government to increase electricity production capacity by building new plants in order to reduce both the shortfall between electricity demand and generation and the country's reliance on external electricity sources. This study therefore intends to fill that gap. Secondly, this study utilizes econometric developments in its methodology, employing an ARDL bounds testing approach to cointegration to determine both the long run and short run impacts of electricity consumption on economic growth.

The rest of the paper is organized as follows; section 2 provides a description of Botswana's energy sector and Section 3 provides a review of selected literature. Section 4 explains the data and methodology employed; section 5 provides the report and discussion of empirical results and section 6 draws conclusions and offers policy recommendations.

2. Botswana's Energy sector

Botswana is well endowed with coal, fuel wood and solar energy and its energy sector is comprised of coal, electricity and petroleum products, a significant amount of which is imported from foreign sources. Botswana Power Corporation (BPC) oversees the internal generation, transmission and distribution of electricity in the country. Morupule power station produces thermal energy from coal and is the main source of electricity supply domestically. ESKOM in South Africa, Mozambique and SAPP make up the external sources of electricity supply in Botswana. The power generating capacity has failed to keep up with this increase in consumption. Presently the Morupule power station, the single power generating station in the country, is only able to meet about 33 percent of the country's electricity needs (SAPP, 2005). Figure 1 below indicates the divergence between electricity production and consumption in the country.

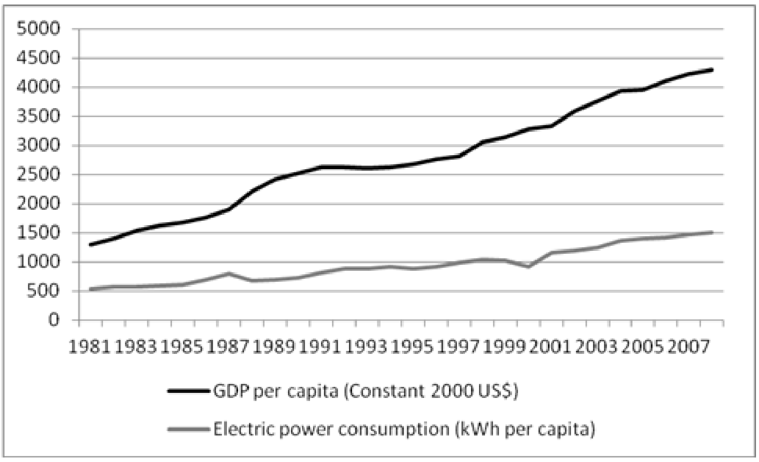
Figure 1. Electricity Production and Consumption in Botswana (kWh). 1980-2008



The short fall between electricity production and consumption is met by imports from neighboring countries (South Africa, Mozambique) and the SAPP. The short fall between the demand and the supply of electricity has resulted in increased load shedding episodes in the country due to supply pressures from South Africa. As Botswana's economy has grown, so has the demand for electricity[8] within all types of economic activity. In 2009 for example, mining, domestic, commercial and government sectors accounted for 39, 26, 25 and 10 percent of the demand of electricty, underscoring the importance of electricty for the country's growth. The economy relies predominantly on the mining sector therefore it is not suprising to find the demand for electricity highest in mining Observation of the electricity consumption and economic growth indicates a co-movement between the two variables. Figure 2 displays trends in real gdp per capita and per capita electricity consumption (1981-2010). Both variables are observed to move in the same direction, indicating a positive correlation.

[8] Electricty consumtion has increased significantly since the 1980's. Electricity consumption per capita increased from 5741kWh in the 1980's to 9055 kWh in the 1990's and 11670kWh in 00's.

Figure 2. Trend in electricity consumption and GDP per capita, 1981 – 2008



Source: World Bank, World Development indicators

3. Review of selected literature

There exists a rich literature that examined the electricity consumption and growth nexus in both single and multi country contexts for developed and developing countries and employing a variety of estimation techniques. Studies that consider the nexus for African countries are numerous. Wolde-Rufael (2006) employed time series analysis in examining the relationship between electricity consumption and growth in nineteen African economies. The study addresses the limitations of methods in previous studies that require time series aggregates to be integrated of order zero, I(0), suggesting that this limits the ability to make inference from variables that are otherwise integrated of a higher order, I(1).

In addition, in the examination of causality, prior studies use the F-statistic. However this suffers from a lack of standard distribution when the variables are cointegrated. To this end, the study used bounds testing approach to cointegration to investigate the long run and causal relationship between electricity consumption and growth. The results obtained are mixed. For six of the countries causality runs from growth to electricity consumption, indicating the importance growth for electricity. In four countries, causality was observed to run from electricity consumption to economic growth. For the remaining countries no long run relationship was observed between electricity consumption and growth.

For Burkina Faso, Quedraogo (2010) utilized time series data from 1968-2003 in a bounds testing approach to cointegration framework to examine the relationship between electricity consumption and economic growth. The findings indicate the importance of electricity consumption for the Burkina- Faso economy, reflected by the bi-directional relationship between electricity consumption and economic growth. Jumbe (2004) applied granger causality together with an error correction modelling approach to examine the cointegration of and causality between electricity consumption and economic growth in Malawi between 1970 and 1999. The study considered GDP, non agriculture GDP and agriculture GDP to account for the importance of the agriculture sector in Malawi's GDP. The study found cointegration between electricity consumption, non agriculture - GDP and GDP. The results from the error correction model indicated that electricity consumption is not an important factor in Malawi's economic growth, a plausible result given that Malawi's economic growth is highly dependent on the agricultural sector.

Unlike many studies that investigate the relationship between electricity consumption and economic growth, Odhiambo (2009) uses trivariate causality test to examine the impact of electricity consumption on electricity growth in South Africa. The study used electricity consumption, economic growth and manufacturing sector employment level (as proxy for employment level) in the estimations. Bi-directional causality was found between electricity consumption and economic growth, while unidirectional causality was observed from employment to economic growth. The results imply that electricity consumption drives economic growth and economic growth is also important for electricity consumption in South Africa.

Studies on the relationship between electricity consumption and economic growth in Asian, Middle Eastern and developed countries also yielded mixed results. Gupta and Chandra (2010) examined the relationship for India between 1960 and 2006. Unidirectional causality from electricity consumption to economic growth is observed for India. The authors concluded that reforms in the country's power sector are essential if India hopes to meet its growth potential. For Taiwan, Cheng and Lai (1997) observed similar unidirectional causality from electricity consumption to economic growth. In a multivariate framework, Narayan and Singh (2007) found the causality to be unidirectional from electricity consumption and economic growth in Fiji. Squalli (2007) employed the Toda-Yamamoto and bounds testing estimation technique in investigating the relationship between electricity consumption and economic growth for Indonesia and six Middle Eastern countries respectively. For Indonesia, causality ran from electricity consumption to economic growth, while in the Middle Eastern countries, causality was observed to run from economic growth to electricity consumption.

A few studies found evidence of bi directional causality between electricity consumption and economic growth. For example, Masih and Masih (1997) investigated the causality between electricity consumption and economic growth in India, Indonesia, Pakistan, Malaysia, Singapore and the Philippines using an error correction modelling approach. Causality is found to run from electricity consumption to economic growth in India, from economic growth to electricity consumption in both Indonesia and Pakistan. For the other countries, the relationship was determined to be neutral.

Narayan and Smyth (2005) using multivariate granger causality test in the case of Australia, Hondroyiannis and Papapetrou (2002) using error correction modelling approach in the case of Greece found that causality ran from economic growth to electricity consumption. Soyta and Sari (2003) using error correction modelling approach, Lee (2006) employing Toda –Yamamoto causality tests for 10 western countries found evidence of unidirectional causality from economic growth to electricity consumption for some countries and for other countries causality ran from electricity consumption to economic growth.

4. Data and model specification

4.1 Variable Description and Data Sources

A bivariate approach to investigate the relationship between electricity consumption and economic growth is taken in this study, using annual time series data from 1981 to 2010. The variables considered are real gross domestic product (GDP) as a proxy for economic growth measured in millions of U.S. dollars, 2000 constant prices, and electricity consumption measured in kilowatt hours. The data on these variables is sourced from World Bank, *World Development Indicators* database.

4.2 Model Specification

The specification of the model which explains the relationship between electricity consumption and economic growth for Botswana, using the recently developed autoregressive distributed lag (ARDL) approach to co-integration, is discussed in this section. The ARDL modelling was initially introduced by Pesaran and Shin (1999) and later further developed by Pesaran, Shin and Smith (2001). Some of the many advantages of using the ARDL model include first, its attractiveness in conducting co-integration analysis in small samples as it avoids the finite sample bias, second its efficiency over the vector autoregressive (VAR) methods (Banerjee *et.al*, 1993; Inder, 1993), third, It allows the undertaking of cointegration analysis irrespective of the order of integration of the underlying regressors. I.e. whether the regressors are integrated of zero order [I(0)], order [I(1)]. Lastly, ARDL uses a single reduced form equation instead of the system of equations as used in the conventional Johansen co-integration with consistent estimates and valid *t*-ratios (Inder, 1993; 68).

The model is thus:

$$\ln GDP_t = \beta_0 + \beta_1 \ln EC_t + \varepsilon_t \tag{1}$$

where $lnGDP_t$ is the log of real GDP in time t; $lnEC_t$ is log of electricity consumption in kilowatt hours at time t. Our objective is to find the marginal effect of electricity consumption on economic growth, that is, whether β_1 is positive or negative and if statistically significant.

4.3 Co-integration – Autoregressive Distributed Lag (ARDL)

This approach is based on estimating the long-run relationship between the variables, as well as estimating the short-run and long-run coefficients of each variable in equation 1 using a conditional unrestricted error correction model (UECM) to co-integration. Although, many time series data are not stationary and overlooking such could result in spurious regression, the method of ARDL does not require pre-testing for the presence of unit root and the order of integration does not have to be the same. It is only important that the maximum order of integration be of order one, I(1).

Equation (1) is modeled as a conditional autoregressive distributed lag (ARDL) with each variable regressed on each other:

$$\Delta \ln GDP_t = \phi_0 + \sum_{i=1}^{m} \phi_{1i} \Delta \ln GDP_{t-i} + \sum_{j=0}^{n} \phi_{2j} \Delta \ln EC_{t-j} + \psi_1 \ln GDP_{t-1} + \psi_2 \ln EC_{t-1} + \varepsilon_{1t} \tag{2}$$

$$\Delta \ln EC_t = \beta_0 + \sum_{i=1}^{m} \beta_{1i} \Delta \ln EC_{t-i} + \sum_{j=0}^{n} \beta_{2j} \Delta \ln GDP_{t-j} + \rho_1 \ln EC_{t-1} + \rho_2 \ln GDP_{t-1} + \varepsilon_{2t} \tag{3}$$

where Δ denotes first difference, the parameters ϕ's and β's capture the coefficients of the short run dynamic, ψ's and ρ's give the long run coefficients. The other variables are as earlier defined.

The long-run equations are as follows:

$$\hat{\psi}_1 \ln GDP_{t-1} + \hat{\psi}_2 \ln EC_{t-1} = 0$$
$$\hat{\rho}_1 \ln GDP_{t-1} + \hat{\rho}_2 \ln EC_{t-1} = 0 \qquad (4)$$

The ARDL approach to co-integration uses the F-statistic (or Wald statistic) to test the joint significance of the lagged levels of the variables $ln\text{GDP}_{t-1}$, $ln\text{EC}_{t-1}$. The null hypotheses of 'no co-integration' against the alternative are:

In equation 1:

$$H_0 : \psi_1 = \psi_2 = 0; \qquad H_1 : \psi_1 \neq \psi_2 \neq 0$$

In equation 2:

$$H_0 : \rho_1 = \rho_2 = 0; \qquad H_1 : \rho_1 \neq \rho_2 \neq 0$$

Pesaran *et al.* (2001) developed two sets of critical values for a given level of significance namely, the upper bound I(1) and the lower bound I(0). If the computed test statistic at a chosen level of significance lies below the lower bounds value, the null hypothesis of 'no co-integration' cannot be rejected. If the test statistic obtained from the Wald test lies between the upper bound and the lower bound, there is no conclusive inference on the co-integration test. If the computed F-statistic exceeds the upper bound, we reject the null hypothesis of no co-integration. The coefficients of the variables in their first differences gives the short-run effects and the long-run coefficients are obtained by multiplying the coefficients of the one lag of the explanatory variable by a negative sign, then divide by the coefficient of the one-period lag of the dependent variable. Thus, the long-run coefficients of the electricity consumption will be $-\psi_2/\psi_1$ and real GDP coefficient will be $-\rho_2/\rho_1$.

5. Empirical results

The unit root tests performed indicate that both variables are not stationary at levels. They became stationary after the first difference; that is, they are integrated of order one, I(1). Table 1 shows the results of the unit root test using both DF-GLS and Phillips-Perron (PP) tests for unit root.

Table 1. Summary of Unit root tests:

Variables	**DF-GLS**				
	Levels		First difference		Conclusions
	Intercept	Trend & Intercept	Intercept	Trend & Intercept	
lnGDP_t	-4.024***	-1.626	-3.013	-3.650**	I(1)
lnEC_t	-1.048	-3.592**	-5.511***	-5.471***	I(1)
	Phillips-Perron				
Variables	Levels		First difference		
	Intercept	Trend & Intercept	Intercept	Trend & Intercept	
lnGDP_t	-3.645***	-1.285	-2.944**	-3.27**	I(1)
lnEC_t	-2.055	-2.704	-8.128***	-10.192***	I(1)

**10%; **5%; ***1%.*

A general-to-specific ARDL model was first performed where a lag length of one was chosen (based on all the lag length criteria, except the LogL criterion (See Appendix A). Then the insignificant variables were dropped one after the other while observing the Akaike information criterion to determine the importance of the dropped variables. The result of the bounds test is shown in Table 2, where each variable is in turn regressed as a dependent variable.

Table 2. Cointegration test results

Critical value bounds of the F statistics: restricted intercept and no trend						
	Critical Values					
F-statistics	1% level		5% level		10% level	
(k = 1, T = 30)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
	6.84	7.84	4.94	5.73	4.04	4.78
lnGDP = (lnGDP\lnEC) = 4.86*						
lnEC = (lnEC\lnGDP) = 4.79*						

*Critical values obtained from Pesaran, Shin and Smith (2001), Case III, p.300. I(0) – lower bound; I(1) – upper bound. *10%; **5%; ***1%.*

The result shows that the null of 'no co-integration' among the variables is rejected. The coefficients ψ and ρ are significantly different from zero in both instances; that is, where real GDP and electricity consumption are in turn used as the dependent variable. The result shows that the calculated F-statistics, 4.86 and 4.79, exceed the upper critical limit obtained from Pesaran *et. al* (2001) at 10% level in both cases, that is, when GDP is taken as the dependent variable and when electricity consumption is taken to be the dependent variable. This therefore implies that there is a long-run relationship between the two variables, GDP and electricity consumption.

Table 3 below shows the short-run and long-run effects in both equations. Electricity consumption does not have a short-run effect on GDP, in the model where GDP is the dependent variable. However, in the long-run, electricity consumption has a positive and significant effect on GDP, where a percentage increase in electricity consumption will lead to an increase in GDP by over 80%.

Table 3. Short-run and long-run relationships

Dependent	Short-run		Long-run	
variables	ΔlnGDP	ΔlnEC	lnGDP(-1)	lnEC(-1)
lnGDP	___	___	___	0.882 (0.072)*
lnEC	-0.545 (-1.895)	___	0.836 (0.015)**	___

**10%; **5%; ***1%. Figures in parentheses indicate P-value*

On the other hand, GDP shows a negative effect on electricity consumption in the short-run, but this is insignificant. Nevertheless, there is a significantly positive relationship in the long-run of GDP on electricity consumption. A percentage increase in GDP will cause an equally over 80% increase in electricity consumption in the long-run. This further affirms the result of the bounds test, where an evidence of a long-run relationship between the variables, co-integration, was found. A battery of diagnostic tests of normality, autocorrelation, heteroskedasticity and model mis-specification, was carried out and the result fails to reject any of the null hypotheses. The result of the diagnostic tests is shown in Table 4. CUSUM and CUSUM of squares (see Appendix B) were also adopted to test the stability of the model and the result shows that the parameters of the model are stable as the cumulative sum of squares lie inside the 5% significance lines.

Table 4. Set of diagnostic tests

Tests	**Dependent variable: lnGDP**	**Dependent variable: lnEC**
Jarque-Bera	JB: 1.417 (0.492)	0.928 (0.231)
Serial Correlation LM Test+	F-statistic: 0.174 (0.841)	0.708 (0.504)
Heteroskedasticity Test++	F-statistic: 1.124 (0.359)	0.143 (0.933)
Ramsey RESET Test	F-statistic: 1.297 (0.208)	0.006 (0.995)

**10%; **5%; ***1%. [+]Breusch-Godfrey. [++]Breusch-Pagan-Godfrey.*
Figures in parentheses indicate P-value

6. Conclusion and Recommendations

The study utilizes bounds testing approach to cointegration in examining the relationship between electricity consumption and economic growth in Botswana from 1981-2010. The study aimed at investigating whether electricity consumption is important for the growth. Despite the myriad of literature on the relationship between electricity consumption and growth, very little has been done to understand the role of electricity in Botswana's economy which is driven predominantly by the mining sector.

In this study, DF-GLS and PP were used to test for stationarity and the variables were found to be integrated of order one, although a pre-test of the presence of unit root is not required. We therefore continued to apply the ARDL technique of bounds test approach to co-integration and we found evidence of a long-run relationship between GDP and electricity consumption in Botswana. Furthermore, the result showed that electricity consumption does not have a short-run effect on GDP, but it has a significantly positive effect on GDP in the long-run. Conversely, GDP has both short-run and long-run effects on electricity consumption, although not significant in the short-run, it has a positive and significant effect on electricity consumption in the long-run.

This study is important for a number of reasons; first, the efforts to diversify the economy away from its reliance on the mining sector have meant the development of other economic sectors. This has brought with it increased demand for electricity in these sectors, putting further pressures on the already limited energy capacity and supply. Second, the country's electricity production capacity is inadequate and unable to match the demand. This means the economy will be vulnerable to any shocks in electricity supply from neighboring countries. This has been evidenced in the last few years, where frequent load shedding or electricity rationing as a result of declining supply from foreign suppliers especially South Africa has negatively impacted on the economy, with losses reported in the millions of US dollars. Third, the study and its findings have a bearing on the country's energy policy. It points to the need for increased electricity production ability in the country. This requires the government to consider opening up the energy sector to private suppliers, thus ensuring increased competition and efficiency which would otherwise not be achievable with BPC monopolizing the generation, transmission and distribution of electricity.

Given that electricity consumption is positively related to growth especially in the long run, the country's energy policy must be structured so as to be able to sustain growth. With projected increase in overall energy demand within all forms of economic activity, and considering that the country is well endowed with coal, fuel wood and solar energy, there is a need to venture into developing alternative energy sources, increase the research into sustainable clean energy such as solar energy to reduce the bottlenecks in electricity supply. This will ensure that the country's reliance on external energy supply is reduced and that growth plans are not jeopardized by electricity shortages similar to those that are presently on going in the country.

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Appendix A

Table A.1. Shortfall in Botswana Electricity demand and supply (Billion kWh). 2000-2010

years	Electricity production	Electricity consumption	Short fall
2000	1	1.62	0.62
2001	0.61	1.52	0.91
2002	0.51	1.45	0.94
2003	0.41	1.56	1.15
2004	0.41	1.56	1.15
2005	0.93	1.89	0.96
2006	0.89	2.64	1.75
2007	0.82	2.46	1.64
2008	0.98	2.57	1.59
2009	0.98	2.57	1.59
2010	1.05	2.65	1.6

Source: CIA World Factbook, Online

Table A.2. VAR Lag Order Selection Criteria

lag	LogL	LR	FPE	AIC	SC	HQ
0	8.61354	NA	0.002101	-0.489892	-0.393904	-0.461350
1	90.01658	144.7165*	6.81e-06*	-6.223450*	-5.935487*	-6.137824*
2	93.48778	5.656773	7.13e006	-6.184280	-5.704340	-6.041569
3	96.18075	3.989583	7.98e-06	-6.087463	-5.415547	-5.887667

** indicates lag order selected by the criterion. LR: sequential modified LR test statistic (each test at 5% level). FPE: Final prediction error. AIC: Akaike information criterion. SC: Schwarz information criterion. HQ: Hannan-Quinn information criterion*

Figure A.3. CUSUM for equation 2

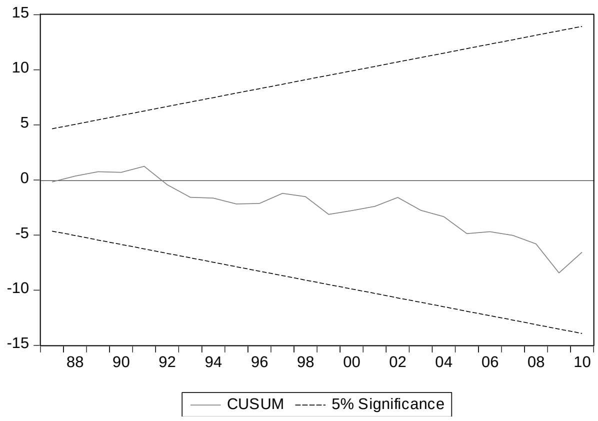

Figure A.4. CUSUM for equation 3