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Do Electricity Consumption and International Trade Openness Boost Economic Growth in Sudan? Empirical Analysis from Bounds Test to Cointegration Approach

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ABSTRACT

Electricity power plays a significant role as an engine factor in boosting economic growth, particularly in developing countries. This paper utilized the autoregressive distributed lag model to study the interrelationship among electricity consumption, international trade openness, and economic growth in Sudan data spanning 1975-2014. The cointegration test result confirms the presence of long run cointegration relationship among electricity consumption, international trade openness, and economic growth. The estimated results of the long run point out that electricity consumption and international trade openness showed a significant positive relationship relating to economic growth. The estimated error correction term coefficient is found to be significant at a 1% significance level with an expected sign. The findings of this paper suggest that Sudan's economy takes advantage of promoting electricity production and more open international trade. Therefore, the policies that support and encourage electricity generation for effective uses are highly recommended. The engagement in international trade creates opportunities for Sudan's economy to benefit from the comparative advantage in exporting some goods that have a comparative advantage in Sudan as well as to import modern technologies particularly, the machineries and equipment relating to agriculture and industrial sectors recently to improve economic growth.

Keywords: Economic Growth, Trade Openness, Electricity Consumption, Autoregressive Distributed Lag, Sudan

JEL Classifications: F43, F16, L94

1. INTRODUCTION

The dramatic changes in energy issues and increasing demand recently sparked up the attention of national and international institutions and governments both in developed and developing countries to switch to energy use from renewable sources and to reduce the economic and environmental impacts such as pollution consequences, environment conservation and achieving sustainable economic development. Therefore, Electricity energy became one of the most essential factors influencing the development process particularly the development of agricultural, industrial, and infrastructure sectors. According to Pao (2009)

Energy represent the basic ground for economic development. Electricity exemplifies as the most resilient types of energy and shapes one of the basic inputs of social and economic development infrastructure. Kasperowicz (2014) stated that electricity is the most foundation factor that economic growth depends on for Poland. Investment deficiency in infrastructure energy and services consider as one factor that interpret poverty in Africa countries.

In Sudan, the electricity sector represents one of the main industries, where electricity production share raised from 8% to 33% in the total gross domestic product in the period 1970-2012. The year 1925 witnessed the initiation of hydroelectricity

generation in Sudan by adopted inclusive policies to producing an adequate supply of electricity for irrigated projects and the manufacturing sector (Awad and Yossof, 2016).

The interaction relationship between electricity consumption and economic growth has been widely discussed in the empirical literature. For instance, (Zhong et al., 2019; Iyke and Odhiambo, 2014; Bekun and Agboola, 2019). While, the relationship among electricity consumption, trade openness, and economic growth was limitedly studied in economic literature (Opeyemi and Paul-Francois, 2019; Acaravci et al., 2015; Khan et al., 2018; Ohlan, 2018). Opeyemi and Paul-Francois (2019) investigated the short term and long term relationship among electricity consumption, trade openness, and economic growth in addition to causality relationship in South Africa by applying the autoregressive distributed lag (ARDL) model. The result indicates that consumption of electricity and international trade openness are positively affected the long term economic growth. The causality test result demonstrates the presence of unidirectional causality flow from electricity consumption and trade openness to economic growth. Khan et al. (2018) applied the ARDL model and VECM to study the association between electricity consumption and economic growth empirical data from Kazakhstan. The study incorporated trade openness in the model. The empirical findings reveal that electricity consumption and openness of trade are associated with the growth of the economy positively. The result of VECM indicates the presence of one-way causal relationship from electricity consumption to economic growth, whereas the two-way causality was found between trade openness and economic growth. For the case of Sudan, Awad and Yossof (2016) tested the link among the production of electricity, employment, and economic growth by utilizing bounds test to cointegration and Wald test to measure the causality direction. The findings indicate the existence of two-way direction Relationship between electricity production and economic growth in the long and short run. Elfaki et al. (2018) utilized the ARDL model to investigate the nexus between energy consumption and economic growth whereas trade openness incorporated in the model as a control variable. The findings reveal that in the long term energy consumption is negatively connected to economic growth. While trade openness is found to be positively influenced economic growth.

To the best of our knowledge that, this paper provides a contribution to the literature on this topic as a pioneering empirical work through examining the relationship among electricity consumption, trade openness, and economic growth in Sudan by applying the ARDL model. For this purpose, the remaining parts of this paper are structured as follows: Section 2 presents the relevant literature. Section 3 illustrates the methodology and data. Section 4 devoted to discuss the empirical results. Section 5 specified to conclude the paper.

2. LITERATURE REVIEW

Electricity energy represents the backbone and one of the most significant factors in modern economies, where the availability of electricity energy contributes to support economic growth, sustainable development, and environmental conservation.

Electricity represents the main source of energy and basic policy attention to achieve sustainable development (Khan et al., 2018). The electricity consumption and economic growth relationship has featured as an issue of massive attention between economic researchers and policymakers recently (Zhong et al., 2019).

The issues of efficient and optimal use of energy have taken the attention of all world countries particularly in developed one, the reason behind that is to reduce CO₂ emission, control the environmental degradation and pollution, and energy sources conservation. Therefore, electric power considers as one of the energy sources that can help in environment conservation and reduce environmental degradation, and then contribute to achieve the ultimate goal of stable economic growth and sustainable development through reducing the economic consequences generated by the inefficient use of energy.

Several studies have been conducted to investigate the relationship between electricity consumption and economic growth. Some of these studies applied the ARDL model to cointegration approach to estimate the long and short run relationship while the other studies used vector error correction model VECM to explore the causality relationship direction. The outputs of these studies varied between the positive and negative relationship between electricity consumption and economic growth, also the bidirectional causality and unidirectional causality relationships were established in some other studies. For example, the studies found unidirectional relationship flow from electricity consumption to economic growth, Ahamad and Islam (2011); Chandran et al. (2010); Shengfeng et al. (2012). The studies supported the existence of two-way causality between electricity consumption and economic growth Hamdi et al. (2014); Polemis and Dagoumas (2013); Tang (2008); Osman et al. (2016).

By applying ARDL and causality test Acaravci et al. (2015) checked the causal relationship among electricity consumption per capita, foreign direct investment, trade openness, and real GDP in Turkey. The empirical results of ADRL in long run reveal that electricity consumption is positively connected with per capita real GDP. Granger causality results show the presence of unidirectional causation from electricity consumption to real GDP in the short run. In the long run, there is a unidirectional causation relationship was found running from electricity consumption, trade openness, and foreign direct investment to real GDP. Ohlan (2018) used the ARDL regression and VECM to test the relationship among electricity consumption, trade openness, and economic growth empirical data from India. The results showed that the long and short term electricity consumption has a significant positive correlation with economic growth. While trade openness it was found insignificant. The causal relationship was found in the long run running from trade openness and electricity consumption to economic growth. In the short term, the causal relationship has established from Economic growth to electricity consumption. Chandran et al. (2010) examined the link between electricity consumption and real GDP in Malaysia using the ARDL and Granger causality. The positive association was found between electricity consumption and real GDP. The causality result points out the presence of unidirectional relationship causality

from electricity consumption to economic growth in the short run. Acaravci and Ozturk (2012) found a positive connection between per capita electricity consumption and per capita GDP in the long run data evidence from Turkey. Granger causality test indicates the presence of unidirectional causal relationship from electricity consumption to real GDP and not vice versa. Iyke (2015) applied a trivariate vector error correction model for the case of Nigeria 1971-2011. The result demonstrates the existence of a unidirectional causal relationship run from electricity consumption to economic growth. Bildirici and Kayıkçı (2012) found a unidirectional causal relationship running from electricity consumption to economic growth in the former Soviet Republic 1990-2009.

Hamdi et al. (2014) studied the link between electricity consumption and economic growth empirical data from Bahrain 1980Q1 to 2010Q4 whereas foreign direct investment and capital use incorporated in the model for their relevant influences to determine economic growth. The study used the ARDL model and VECM. The result reveals that electricity consumption positively contributes to economic growth. Capital use and foreign direct investment promote economic growth in the long term. Electricity consumption and foreign direct investment and were found insignificant in the short run. The result of the VECM analysis indicates the presence of two-way causality direction between electricity consumption and economic growth. Bashier (2016) applied the ARDL model and vector error correction model VECM to test the relationship between electricity consumption and economic growth in Jordan 1976-2013. The result reveals that electricity consumption is positively affected economic growth, similarly, economic growth was found positively connected with electricity consumption. The causality test results showed a bidirectional causality direction between electricity consumption and economic growth. Al-mulali et al. (2014) studied the impact of renewable electricity consumption and non-renewable electricity consumption on economic growth data from 18 Latin American countries spanning the period 1980-2010. This study utilized dynamic ordinary least squares (DOLS) method and vector error correction model VECM. The empirical results of DOLS show that renewable and nonrenewable electricity consumption has a positive influence on economic growth in examined samples. The labor force, gross fixed capital formulation, and total trade as control variables are found positively contribute to economic growth. The findings of VECM causality illustrate the presence of a bidirectional relationship between renewable electricity consumption and economic growth, total trade and economic growth. Although the one-way causal relationship was found running from non-renewable electricity consumption to economic growth. Aslan (2014) applied the ARDL model and causality test to explore the linkage between electricity consumption and economic growth empirical evidence from Turkey 1968 to 2008. The estimated results confirm the presence of a positive correlation between electricity consumption and economic growth. Also, a positive connection was established between economic growth and electricity consumption. The result of Granger causality indicates the presence of a bidirectional relationship between electricity consumption and economic growth in the long run. Bélaïd and Abderrahmani (2013) confirmed the bidirectional

long run and short run causality relationship between electricity consumption and economic growth in Algeria 1971-2010. Bayar and Özel (2014) applied the DOLS and fully modified ordinary least squares (FMOLS) methods to examine the connection between economic growth and electricity consumption empirical data from the emerging countries 1970-2011. The results of (FMOLS) and (DOLS) point out that electricity consumption positively influenced economic growth. The estimated results of Granger causality reveal the existence of a bidirectional correlation between economic growth and electricity consumption. Lu (2017) confirm the positive contribution of electricity consumption to economic growth case of 17 Taiwan's Industries 1998-2014. Granger causality confirms the bidirectional relationship between electricity consumption and economic growth. Recently, Churchill and Ivanovski (2019) analyzed the electricity consumption in 7 Australian states economy 1990-2015 by applying FMOLS, DOLS, and ARDL methods. The empirical result established a positive association between electricity consumption and economic output. Based on causality results there is a bidirectional between electricity consumption and economic growth. Odhiambo (2009) found a bidirectional relationship between electricity consumption and economic growth in South Africa 1971-2006. For the case of Portugal, Shahbaz et al. (2011) found two-way relationship between electricity consumption and economic growth in the long run. Tang et al. (2013) confirm the presence of two-way causality between electricity consumption and economic growth in Portugal 1974-2009. Ciarreta and Zarraga (2010) used the VECM causality for a group of 12 European countries 1970-2007 by applying a generalized method of moment (GMM). The findings reveal a unidirectional relationship from electricity consumption to economic growth.

Bah and Azam (2017) found there is no causality between electricity consumption and economic growth by using the ARDL model and Toda-Yamamoto causality test empirical data from South Africa 1971 to 2012. Faisal et al. (2018) applied ARDL and VECM to analyze the connection among d economic growth, electricity consumption, trade openness, and urbanization empirical data from Iceland. The findings demonstrate that trade openness, economic growth, and urbanization are positively influencing the long and short term electricity consumption. However, the causality result indicates there is no causality between economic growth and electricity consumption. Ozturk and Acaravci (2011) applied ARDL and VECM to study the link between electricity consumption and economic growth data from 11 of the North Africa and Middle East countries. The cointegration relationship has not found in Morocco, Iran, and Syria. The empirical results indicate a unidirectional causality flow from electricity consumption to real GDP in Egypt and Saudi Arabia in the long run.

The interrelationship between international trade and economic growth has been extensively discussed in the literature. The findings of these studies are varied between positive and negative influences of trade to economic growth due to the various in analysis methodologies, time period, country situations (Khobai et al., 2018). Frankel and Romer (1999) used instrumental variables of geographic component proxy for trade to examine

the International trade openness and economic growth nexus. The result points out a positive correlation between trade openness and economic growth. Ma et al. (2019) found a positive contribution of trade openness to gross domestic product in china provinces. Hassen et al. (2013) established a positive relationship between openness and economic growth in Tunisia 1975 and 2010. Khobai et al. (2018) studied the association between openness and economic growth in Ghana and Nigeria 1980-2016 by using ARDL. The findings were mixed, the positive relationship was found in Ghana while the estimated result from Nigeria reveals that trade openness negatively influenced economic growth. Shahbaz (2012) confirms that trade openness shows a positive connection with economic growth in Pakistan 1971-2011 by applying ARDL. On the other hand, the negative linkage between trade openness and economic growth has been found among several studies. Vlastou (2010) found that trade openness negatively correlated to economic growth empirical data from 34 African countries 1960 to 2003. Kim et al. (2011) demonstrate that openness positively influenced economic growth in developed countries, however in developing countries trade openness is negatively interrelated to economic growth. Lawal et al. (2016) established that international trade associated negatively with economic growth in the long run while in the short term this relationship is found to be positive for the case of Nigeria by applying the ARDL model.

3. METHODOLOGY AND DATA

3.1. Data

The paper employed annual data from Sudan during 1975 to 2014. The model included three variables particularly electricity consumption, trade openness, and real GDP per capita. Per capita real GDP (constant 2010US\$) used to measure the growth of the economy, electric power consumption utilized as a proxy for electricity consumption, while trade as a percentage of GDP (trade % of GDP) used to capture trade openness. All the data are extracted from the World Bank Indicators (WBI), World Bank database. All the variables are converted into logarithmic form.

3.2. Model Specification

The paper applied the ARDL model, which provides helpful econometrics tools for analyzing the interrelationship among macroeconomic variables since it was developed Pesaran and Shin (1999) and Pesaran et al. (2001). The ARDL model ARDL to cointegration adopted to test the interrelationship among electricity consumption, trade openness, and real gross domestic product in Sudan. The ARDL model could be applied irrespective of whether whole the variables under consideration are integrated to order $I(0)$ or $I(1)$. However, this paper used the unit root tests to confirm that the overall variables under consideration are nonintegrated at the order $I(2)$. Therefore, Phillips-Perron (PP) and Augmented Dickey-Fuller (ADF) tests were employed to check the stationary of the variables.

In order to examine the association among electricity consumption, trade openness, and economic growth. First, the simple functional formula to explain this relationship is presented in the following model:

$$GDP_t = F(EC_t, OP_t) \tag{1}$$

Where GDP refers to real gross domestic product per capita; EC: electricity consumption; and OP stands for trade openness; t is referred to time.

Equation (1) can be formulated into the logarithmic linear econometric model as following:

$$LnGDP_t = LnEC_t + LnOP_t + \mu_t \tag{2}$$

From equation 2 the ARDL model applied to test the linkage among electricity consumption, trade openness, and economic growth. The ARDL model is expressed in the following equation:

$$\Delta LnGDP = \alpha_0 + \sum_{i=0}^q \gamma_i \Delta LnGDP_{t-i} + \sum_{i=0}^q \delta_i \Delta LnEC_{t-i} + \sum_{i=0}^q \varphi_i \Delta LnOP_{t-i} + \beta_1 LnGDP_{t-1} + \beta_2 LnEC_{t-1} + \beta_3 LnOP_{t-1} + \mu_t \tag{3}$$

Where Δ refers to the first difference operator; μ is an error term. Akaike information criterion (AIC) has been utilized to choose the optimal lag length. γ_i , δ_i , and φ_i are represent the coefficients of the short run; while β_1 , β_2 , and β_3 are utilized to examine the effect in the long run. To test the cointegration relationship among the variables; the null hypothesis of no cointegration relationship $H_0: \beta_1 = \beta_2 = \beta_3 = 0$ tested in contradiction of the alternative hypothesis $H_1: \beta_1 \neq \beta_2 \neq \beta_3 \neq 0$ which indicate the existence of cointegration relationship among the variables. The establishment of a cointegration relationship among the model's variables gives enough evidence for the long term relationships among electricity consumption, international trade openness, and economic growth. Accordingly, the error correction model is useful to capture the short run influence of consumption of electricity and openness of trade on economic growth. Therefore, the error correction model (ECM) is presented in the following model:

$$\Delta LnGDP = \alpha_0 + \sum_{i=0}^q \gamma_i \Delta LnGDP_{t-i} + \sum_{i=0}^q \delta_i \Delta LnEC_{t-i} + \sum_{i=0}^q \varphi_i \Delta LnOP_{t-i} + \psi ECM_{t-1} + v_t \tag{4}$$

ECM denotes the error correction term; ψ is the coefficient of error correction model which measures the convergence speed to equilibrium point; v_t is the error term.

Finally, the diagnostic tests have been conducted to test the stabilization of estimated coefficients in the long run and short run by using cumulative sum (CUSUM) of recursive residual and cumulative sum of squares (CUSUMSQ) of recursive residual tests.

4. EMPIRICAL RESULTS

The main reason for conducting the unit root test is to confirm that the time series data have unit roots or not, in addition, to recognize

that all the variables are stationary at the level, the first difference, or at mix order of integration. For this purpose, the Augmented Dicky-Fuller (ADF) and Phillips-Perron (PP) were applied. The results of ADF and PP are reported in Tables 1 and 2 respectively.

Referring to Augmented Dickey-Fuller's result the null hypothesis has been rejected for gross domestic per capita and openness at level at 1% and 5% respectively meaning that real gross domestic product and trade openness are not content a unit root at level. On the other hand, the alternative hypothesis has been accepted at the first difference for and electricity consumption, trade openness, and real GDP. Accordingly, from the result of Phillips-Perron (PP), the null hypothesis cannot be rejected for real GDP, trade openness, and electricity consumption at 1% level; this provides enough evidence that real GDP, trade openness, and electricity consumption are stationary at first difference at 1% significance level. Likewise, for the purpose of testing the presence of cointegration relationship among electricity consumption, trade openness, and economic growth the cointegration bounds test has been applied. The results are summarized in Table 3.

The results of bounds test as in Table 3 provide enough evidence that null hypothesis of no cointegration relationship among electricity consumption, international trade openness, and economic growth has been rejected and accepted the alternative hypothesis as indicated by F-statistic (8.30) of bounds test which is exceeded the upper bounds test critical value (5) this illustrate the existence of cointegration relationship in the long term among electricity consumption, trade openness, and economic growth at 1% significance level. Once the cointegration relationship among the variables has been found the next step is to estimate the long

run effect of electricity consumption, international trade openness on economic growth in Sudan. The results are reported in Table 4.

Referring to the results in Table 4 the long run coefficients of electricity consumption and trade openness are found to have a positive connection with economic growth and significance at 1% and 5% level respectively. This results implying that 1 percentage rise in electricity consumption will reflect in economic growth rising by 0.76%. While the increase of trade openness by 1% will cause a 0.15% rise in economic growth. These results are consistent with (Opeyemi and Paul-Francois, 2019; Khan et al., 2018). However, inconsistent with (Acaravci et al., 2015; Ohlan, 2018) regarding trade openness. From these empirical results, the action toward high economic growth in Sudan is to use the electricity efficiently and the economy be more open. Following the long run process, the short run effect of electricity consumption, international trade openness on economic growth has been tested by utilizing the error correction model (ECM). The findings are summarized in Table 5.

Table 5 illustrates the results of the short term influence of electricity consumption and trade openness on economic growth through estimating the error correction model ECM. The ECM results explain that trade openness positively influenced economic growth. While electricity consumption found to have insignificant positive impact on economic growth. The error correction coefficient is significant at the 1% level with a negative sign as predicted. These findings explain that the short run variation of economic growth from equilibrium caused by electricity consumption and trade openness shock will be corrected automatically by 22.16% per year. The value of coefficient of determination (R²) indicates that a 0.62% deviation in economic growth has been explained

Table 1: The results of unit root (ADF)

Constant and trend specification		At level		
		LOG(GDP)	LOG(EC)	LOG(OP)
With constant	t-Statistic	-0.4681	1.9446	-2.9711**
With constant and trend	t-Statistic	-5.2503***	-0.7665	-3.0455
Without constant and trend	t-Statistic	1.7700	2.4771	-0.5521
		At first difference		
		d(LOG GDP)	d(LOG EC)	d(LOG OP)
With constant	t-Statistic	-1.1539	-5.7847***	-7.6720***
With constant and trend	t-Statistic	-7.7298***	-5.5318***	-7.5566***
Without constant and trend	t-Statistic	-0.1204	-2.2252**	-7.7522***

(*), (**), and (***) significant at 10%, 5%, and 1% respectively

Table 2: Phillips-Perron (PP) unit root test

Constant and trend specification		At level		
		LOG(GDP)	LOG(EC)	LOG(OP)
With constant	t-Statistic	2.1284	2.1345	-1.8086
With constant and trend	t-Statistic	-0.4429	-0.5299	-1.9149
Without constant and trend	t-Statistic	1.8933	2.4888	-0.6611
		At first difference		
		d(LOG GDP)	d(LOG EC)	d(LOG OP)
With constant	t-Statistic	-4.9696***	-5.7679***	-7.5655***
With constant and trend	t-Statistic	-7.8166***	-6.7727***	-7.4592***
Without constant and trend	t-Statistic	-4.6758***	-5.2005***	-7.6419***

(***), (**), and (*), significance at 1%, 5%, and 10% respectively

Table 3: The cointegration bounds test results

Bounds test	Value	Critical values of bounds test		
		Significant (%)	I(0)	I(1)
F-Statistic	8.302480	10	2.63	3.35
k	2	5	3.1	3.87
		2.5	3.55	4.38
		1	4.13	5

Table 4: The results of long run coefficients

Variable	Coefficient	Std. error	t-Statistic	Prob.
LOG(EC)	0.767577	0.226576	3.387721	0.0023
LOG(OP)	0.156175	0.077593	2.012745	0.0546
C	3.402739	0.815634	4.171896	0.0003

Table 5: The results of short run

Variables	Coefficients	Std. error	t-Statistic	Probability
DLOG(GDP[-1])	0.134772	0.120587	1.117631	0.2739
DLOG(GDP[-2])	0.091286	0.122051	0.747935	0.4612
DLOG(GDP[-3])	-0.457377	0.126831	-3.606196	0.0013
DLOG(EC)	0.034353	0.054492	0.630413	0.5339
DLOG(OP)	0.125806	0.027651	4.549840	0.0001
DLOG(OP[-1])	0.051072	0.027519	1.855907	0.0748
ECM(-1)	-0.221642	0.036417	-6.086200	0.0000
R-squared	0.621441	Adjusted R-squared		0.543118
Durbin-Watson stat.	2.258552			

by the deviation in electricity consumption and trade openness. The value of Durbin-Watson test (2.25) confirms the absence of serial autocorrelation problem in the model.

The stability of the short run and long run of estimated coefficients gives robustness and reliability for the empirical analysis. Therefore, the diagnostic test has been conducted using cumulative sum (CUSUM) of recursive residuals and the cumulative sum of squares (CUSUMSQ) of recursive residuals. The results are illustrated in Figures 1 and 2.

Figures 1 and 2 explain that both cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of recursive residuals (CUSUMSQ) lines are not crossing the straight lines of critical bounds value at 5 significance level. This implied that the long and short run estimated coefficients are stable.

5. CONCLUSION

Electricity power considered as an essential factor to enhance economic activities, particularly in developing countries. Insufficient energy supply impeded economic activities, reduced economic growth, and restricted human well-being. This paper used the ARDL model to examine the long run and short run relationship among electricity consumption, international trade openness, and economic growth in Sudan data from 1975 to 2014. Bounds test result confirms the presence of cointegration relationships among electricity consumption, international trade openness, and economic growth. The empirical results reveal that electricity consumption and international trade openness have a positive significant long run relationship with economic growth at 1% and 5% level respectively. These findings suggest that electricity consumption and international trade openness have a substantial role to foster economic growth in Sudan. The electricity consumption in the short run shows an insignificant positive relationship with economic growth. However, trade openness is positively connected with economic growth. The coefficient of the error correction term is statistically significant at 1% level with an expected sign. This result indicates that the long run deviation from the equilibrium point due to the short run shock will be adjusted by 0.22% each year.

The findings of this paper suggest that Sudan’s economy takes advantage of promoting electricity production and more open international trade. Therefore, the policies that support and encourage electricity generation for effective uses are highly recommended in order to improve the local production in the real sector, reducing environmental degradation, and boosting economic growth. The engagement in international trade creates opportunities for Sudan’s economy to benefit from the comparative advantage in exporting some goods that have a comparative advantage in Sudan as well as to import modern technologies particularly, the machineries and equipment relating to agriculture and industrial sectors recently to improve economic growth.

Figure 1: Cumulative sum of recursive residual

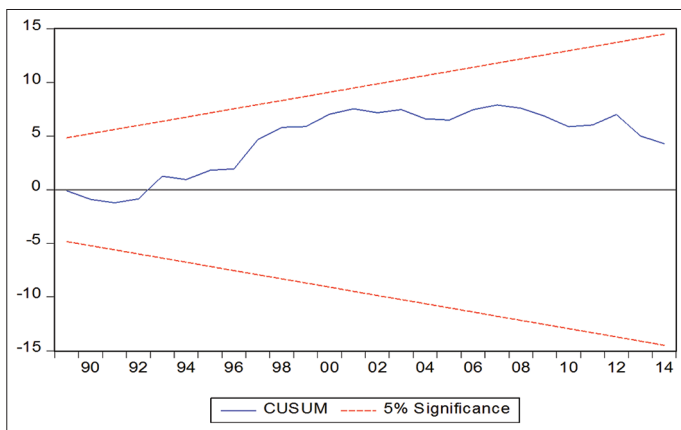
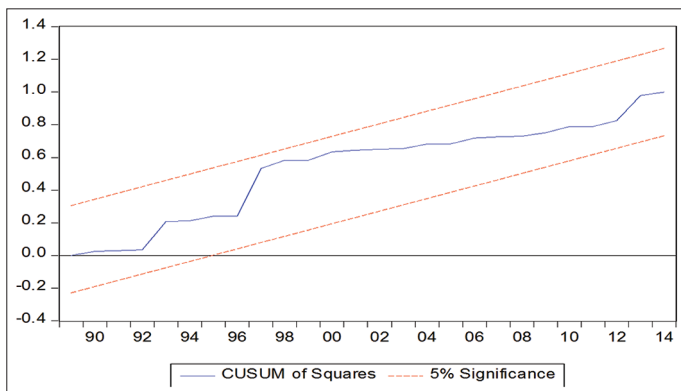


Figure 2: Cumulative sum of squares of recursive residual



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