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Electricity Production, Economic Growth and Employment Nexus in Sudan: A Cointegration Approach

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ABSTRACT

The present study examines the relationship between electricity production (EP), economic growth and employment in Sudan between 1980 and 2013 by using cointegration and causality techniques. We use the Wald test to determine the direction of the causality relationship between the variables. The results show that there is a long run relationship between the variables. The causality relationship test detects the existence of bi-directional relationship between energy generation and economic growth in the short run. The causality analysis also detects the existence of long as well as strong long run bi-directional relationship between each pair of the variables. Overall, the results suggest that even in short run, decrease in the electricity will lead to fall in the economic growth, and vice versa. Thus, the results lend support to the recent effort by Sudan's government in the expansion of EP, since it has significant impact on the country's economic development.

Keywords: Economic Growth, Electricity Production, Employment
JEL Classifications: O10, Q43, J21

1. INTRODUCTION

The electricity sector is one of Sudan's major industries. During the period between 1970 and 2012, the share of the electricity production (EP) in the total real gross domestic product (GDP) had increased from 8% to 33%. The generation of hydro-electricity in Sudan began in 1925 with the adoption of extensive policies towards producing sufficient supply of electricity for irrigation schemes and industrial sector. However, in the last decade the government had allocated considerable amount of domestic and foreign resources (i.e., loans from abroad) to finance the construction of new electricity projects. According to International Monetary Fund (IMF 2012), the total new external debts in Sudan arising from projects in the energy sector during 2010 and 2011 were at 13% and 55%, respectively. The significant increase in the foreign debt has been one of the most debatable issues between two groups in the country, i.e., the politicians and economists. One of the groups believed that devoting resources for EP is a waste of valuable resource. In contrast, the second group believed in the importance of energy production for development process. Despite these debates, no systematic study has been conducted to evaluate the present and/or the future benefit from these projects in terms of their overall impact on the country's economic development.

Extensive studies have been conducted to examine the impacts of EP on economic development of several countries. In addition, the causality technique is frequently used as a method to assess the relationship between EP and economic development. This is because the direction of the causality relationship between the variables has important policy implications (Asafu-Adjaye 2000; Ghosh 2002, Narayan and Smyth 2005, Shahbaz et al. 2011; Ozturk & Acaravci 2011). If the Granger causality is unidirectional running from economic growth to EP, or if there is no causality in either direction, this implies that EP will not affect economic development of a country. In contrast, unidirectional causality relationship that runs from electricity generation to economic growth indicates that reduction in EP could lead to a fall in economic growth. However, as we see later, the outcomes of the studies on the direction of the causality relationship between these variables are inconsistent. Irrespective of the sources of these inconsistencies, the variation itself implies differences in policy implication for each country.

Present study seeks to contribute to this debate by investigating as to whether the construction of new electricity project offers expected returns that justify the burden of financing these projects. Generally, many studies pointed out to the existence of causality relationship between economic growth and EP (Yoo and Kim 2006; Odhiambo 2009). The studies examined the relationship repeatedly by using the Granger causality concept. Granger causality does not imply that "X causes Y" in the conventional sense. According to Diebold (2004), "X causes Y" in Granger sense means that "X contains useful information for predicting Y." With regard to the effectiveness of Granger causality tests, the lack of consensus in most literature still exists. One major reason for the lack of consensus is that many Granger causality studies suffer from omitted variables bias. The omission of relevant variables affecting energy production and economic growth in a bivariate framework contributes to the biasness of these studies (Stern 2000). For this reason, some of the Granger causality studies examining the relationship between energy consumption and economic growth had incorporated other relevant variables such as capital and/or labour (Stern 1993; Anthony and Shaikh 2015); employment (Narayan and Smyth 2005, Shahbaz et al. 2011); foreign direct investment/or human development (Daniel and Manuel 2015), exports (Narayan and Smyth, 2009); pollutant emissions (Ang, 2008); prices (Masih and Masih 1997; Adjaye, 2000, Lean and Smyth, 2010); and urbanization (Mishra et al., 2009).

To avoid biasness of omitted variables, we followed Narayan and Smyth (2005), Ghosh (2009) and Shahbaz et al. (2011) in the present study by incorporating employment as a variable in our model. In doing so, the study contributes to the literature on Granger causality on both the energy-GDP nexus and employment-GDP nexus. Thus, the main objective of this study is to examine as to whether there is a stationary, long run equilibrium relationship between electricity generation, economic growth and employment in Sudan. The study will also examine the characteristics of the causality relationships between the variables.

This paper is comprised of six sections. After the introduction, we provide an overview on Sudan's economy. The second section deals with EP. Meanwhile, Section 3 provides a brief literature review. Section 4 explains the methodology and model specification issues. Section 5 presents the results and discussion. The final section concludes and summarizes the present study.

2. SUDAN CONTEXT

The generation of hydroelectricity in Sudan began in 1925 with the construction of Sennar Dam followed by other similar projects, such as the Jbal Awlia Dam in 1937; the Khashm Al-Gerba Dam in 1964; the Roseires Dam in 1971; and most recently, the Marawe Dam in 2008. Currently, the government is constructing two additional dams in the northern and western regions of the country. The construction of such dams has two main objectives: To generate a cheaper electrical supply to support the industrial sector and to provide various agricultural schemes throughout the country with sufficient water (Prowde 1926). However, because of the previous low contribution of the industrial sector to GDP (which significantly affecting other macroeconomic indicators, such as employment and exports), recent improvements in the industrial sector have turned the production of electricity in Sudan to a priority. Most studies and international reports (UNIDO) on Sudan's industrial sector attribute the low share of GDP to the inadequate supply of electricity (Mohsin 2002, various annual reports of the Central Bank of Sudan).

In Sudan, the production of electricity during the period between 1980 and 2010 registered a growth rate of 726% or an average annual growth rate of approximately 24%. Compared to other countries in the MENA region, Sudan's EP is very low. For example, in 1980, 1990 and 2000, total EP in Egypt amounted to approximately 18,939 million kWh; 42,256 million kWh; and 78,143 million kWh, respectively. In 1980, 1990 and 2000, EP in Tunisia amounted to approximately 2,924 million kWh; 2,811 million kWh; and 10,596 million kWh, respectively. Comparing these figures with those of Sudan's EP (Table 1), Sudan clearly lags behind these two countries.

The primary reason for the progress in energy production in Sudan is the increased usage of oil as a source of EP. More specifically, the World Bank's database shows that the percentage of the total electricity supply produced by hydroelectric dams had decreased from 70% in 1980 to 50% in 2010, while the percentage of the total electricity supply produced by petroleum-based production increased from 30% to 52% during the same period. The dependency on oil as a primary source of energy production after the 1990s is due to oil discovery and production in the Sudan in 1995. The increase in per-capita electricity consumption from 35 kWh in 1980 to 114 kWh in 2010 demonstrates the achievement accomplished in the production of electricity in Sudan. However, the per-capita consumption of electricity does not really reflect on the reality in the case of Sudan. The fact that Sudan is the biggest country in Africa (one million square miles) and has suffered from continuous civil war since 1956, alongside with other factors, has resulted in considerable parts of the country are still living without access to electricity, particularly in rural areas.

In terms of economic growth (Table 2), the real per-capita GDP shows growth during the period between 1970 and 2011. However, if achievement relating to per-capita GDP in Sudan is compared in terms of PPP (constant 2005 international US$) with that of selected MENA countries, Sudan's per-capita GDP is found to be very low. For example, the per-capita GDP of Egypt in 1980, 1990 2000 was at 2,431, 3,184 and 3,992 respectively. Furthermore, the per-capita GDP of Tunisia in 1980, 1990 and 2000 was at 3,616, 4,018 and 5,444 respectively. Arguably, the relatively small population size of Tunisia could justify the higher per-capita GDP when compared with that of Sudan's. However, per-capita GDP is also higher in Egypt which has population greater than that of Sudan's.

The contribution of the agricultural sector to GDP fluctuates over the time, which is primarily due to the rainfall-dependent nature of the agricultural sector in Sudan. Thus, fluctuation in the annual rainfall produces similar fluctuation in agricultural production. While the contribution of the manufacturing sector to GDP is generally stable over the time, the industrial sector shows

Table 1: Electricity source, production and consumption in Sudan, 1970-2010

Statements	1980	1990	2000	2010
EP (Million kWh)	817	1515	2569	675
EP from hydroelectric sources (% of total)	70.01224	63.234323	46.049046	47.808057
EP from oil sources (% of total)	29.98776	36.765677	53.950954	52.191943
Electric power consumption (kWh per capita)	34.976069	48.388006	63.473067	114.27009

Source: World Bank database, CD-ROM (2010), EP: Electricity production

Table 2: Per capita GDP and sectorial contribution to the GDP (% GDP) in Sudan, 1970-2011

Statements	1970	1980	1990	2000	2011
Real per capita GDP (Sudanese Pound)	309	336	328	441	717
Agriculture, value added	43.6186	32.85805	40.57702	41.70707	27.24569
Manufacturing, value added	7.76866	7.461716	8.66907	8.551329	6.708734
Industry, value added	14.35717	-	15.26117	21.50963	39.77021
Services, etc., value added	42.02423	53.01119	44.16181	36.78329	32.98411

Source: World Bank database, CD-ROM (2010), GDP: Gross domestic product

a considerable increase. The main problem faced by the industrial sector in Sudan is the lack of sufficient energy supply. The obvious importance of the industrial sector to economic development is one reason behind the efforts of the government to improve the supply of electricity to all sectors, particularly the industrial sector. Obviously, a positive correlation exists between the increase in EP (Table 1) and the share of the industrial sector in total GDP. However, the contribution to GDP of the services sector during the period from 1970 to 2011 fluctuates.

The above information depicts an upward trend in the real per-capita GDP, EP in Sudan and other MENA countries, such as Tunisia and Egypt. The fact that these variables, which are all major economic indicators increase together suggests that a causality relationships may exist between them. Since Sudan continues to lag behind other countries in the region, the primary observation concerning the positive correlation between these variables may have useful policy implications that could assist Sudan to achieve the development level attained by other countries in the region and enhance the overall well-being of its population.

3. LITERATURE REVIEW

A considerable number of existing studies had examined granger causality between GDP and energy consumption for a range of countries using various methodologies. As a result, an array of literature had tested four competing hypotheses: Unidirectional granger causality runs from electricity generation to GDP (growth hypothesis); unidirectional granger causality runs from GDP to electricity generation (conservation hypothesis); bi-directional Granger causality runs between GDP and electricity generation (feedback hypothesis); and no Granger causality runs in either direction (neutrality hypothesis). The existence of unidirectional causality running from economic growth to electricity consumption implies that electricity conservation policies designed to reduce electricity consumption and wastage have little or no effect on economic growth. The most often-supported causality relationship running from electricity consumption to economic growth implies that a reduction in electricity consumption due to electricity conservation-oriented policies may have a detrimental impact on economic growth (Ozturk and Acaravci, 2011; Shahbaz et al., 2011; Acaravci and Ozturk, 2012).

Several studies had applied the autoregressive distributed lag (ARDL) bounds test during their investigation on the relationship between energy and GDP. Rather than discussing the voluminous literature in detail, the present discussion focuses upon the main conclusions of these surveys. A strong conclusion that can be drawn from these studies is that there is no consensus concerning the four aforementioned hypotheses; and the results are often conflicting. The diverse results are due to different data sets, alternative econometric methodologies and countries' characteristics (Ozturk, 2010; Bouoiyour et al., 2014; Shahbaz et al., 2014). The actual causality is different for each country and this is most likely due to different characteristics of those countries in relation to energy supplies; political and economic history; political arrangement; institutional arrangement; culture; and energy policies. Payne (2010) calculated the support for those competing hypotheses in studies published up until 2009 and concluded that 31.15% of studies support the neutrality hypothesis; 27.87% support the conservation hypothesis; 22.95% support the growth hypothesis; and 18.03% support the feedback hypothesis. Hence, support for each of the competing hypotheses in the energy consumption-economic growth literature is evenly distributed.

However, very few extensive studies had examined the nexus between EP or consumption, economic growth and employment. For example, in the case of India, Ghosh (2009) found that in the short run, the direction of the causality relationship is from real GDP and electricity supply to employment and from real GDP to electricity supply. For the long term, he found that there is unidirectional Granger causality running from real GDP and electricity supply to employment. In the case of Australia, Narayan and Smyth (2005) revealed that long-term employment and real income (economic growth) Granger cause electricity consumption. Whilst in the short run they revealed that there is weak unidirectional Granger causality running from income to electricity consumption and from income to employment. Similarly, Shahbaz et al. (2011) detected the existence of bi-directional Granger causality between the three variables in the long run in Portugal. With the exception of Granger causality between electricity consumption and economic growth, the rest of the variables are also bi-directional Granger causality in the short run.

Clearly, as mentioned previously, the outcomes of the studies on the direction of the causality relationship between these variables are inconsistent. Irrespective of the sources of these inconsistencies, the variation itself implies differences in policy implication for each country. Given the absence of extensive studies in Sudan, the present seeks to examine and formulate appropriate policy implications pertaining to this issue.

4. MODEL, METHOD OF ESTIMATION AND SOURCES OF DATA

4.1. The Model

Following the empirical literature, the standard log-linear functional form specification of the long run relationships between electricity generation, real GDP and employment for Sudan takes the following form:

$$\ln Y_t = \alpha_0 + \beta_1 \ln EP_t + \beta_2 \ln EMP_t + \varepsilon_t \quad (1)$$

Where lnY is the natural logarithm of real per capita GDP (Sudanese Pound), lnPE is natural logarithm of EP in Kilowatt-hours (kWh); lnEMP is the natural logarithm of employment in terms of the number of employed people and ϵ_t is the error term. We followed Ghosh (2009) and Lean and Smyth (2010) who utilised data of energy production, rather than consumption due to problems regarding data on electricity consumption in developing countries (including Sudan). Lean and Smyth (2010) claimed that high non-technical transmission and distribution (T and D) losses in developing countries[1] are generally due to the theft and pilferage of electricity, which are not accounted in the consumption data. The World Bank (1997) reported that T and D losses in developing countries are two to four times higher than that of OECD countries. In 1997, Sudan's T and D losses, as a percentage of total electricity output, was 37%, compared to 9% for Malaysia and 4% in Japan and Singapore (World Bank 2000). However, except for technical losses, all electricity generated contributes to GDP.

4.2. Method of Estimation

The present study adopts bounds testing approach for cointegration as explained in the literature review. Past studies demonstrated that bounds test is the most appropriate technique for cointegration due to certain econometric advantages compared to other cointegration procedures. First, all variables are assumed endogenous. Second, the econometric methodology relieves the burden of pre-testing of unit roots and is applicable irrespective of whether the underlying variables are I(0), I(1), or fractionally integrated. Third, the approach has superior properties for small samples. Recent studies (for example, Mah 2000; Tang and Nair 2002) suggested that estimates utilizing the Engle and Granger or the Johansen and Juselius method for cointegration are not sufficiently robust for small sample sizes, such as the sample employed in the present study. Additionally, Narayan (2005) demonstrated the robustness of the bounds test for small sample sizes and calculation of precise critical values for the bounds test that are suitable for the present study.

The bound testing approach to cointegration involves the determination of the presence of long run equilibrium relationship in Equation (1) using the following unrestricted error correction model:

$$\Delta \ln Y = a_1 + \sum_{i=1}^{s} \beta_1 \Delta \ln Y_{t-i} + \sum_{i=0}^{z} \beta_2 \Delta \ln EP_{t-i} + \sum_{i=0}^{k} \beta_3 \Delta \ln EMP_{t-1}$$
$$+\varphi_1 \ln Y_{t-1} + \varphi_2 \ln EP_{t-1} + \varphi_3 \ln EMP_{t-1} + \omega_i \quad (2)$$

$$\Delta \ln EP = a_2 + \sum_{i=0}^{s} \beta_4 \Delta \ln Y_{t-i} + \sum_{i=1}^{z} \beta_5 \Delta \ln EP_{t-i} + \sum_{i=0}^{k} \beta_6 \Delta \ln EMP_{t-1}$$
$$+\varphi_4 \ln Y_{t-1} + \varphi_5 \ln EP_{t-1} + \varphi_6 \ln EMP_{t-1} + \omega_{2t} \quad (3)$$

$$\Delta \ln EMP = a_3 + \sum_{i=0}^{s} \beta_7 \Delta \ln Y_{t-i} + \sum_{i=0}^{z} \beta_8 \Delta \ln EP_{t-i} + \sum_{i=1}^{k} \beta_9 \Delta \ln EMP_{t-1}$$
$$+\varphi_7 \ln Y_{t-1} + \varphi_8 \ln EP_{t-1} + \varphi_9 \ln EMP_{t-1} + \omega_{3t} \quad (4)$$

Where Δ is the first difference operator; s, z and k are the lag length; and the residuals $\omega_{1t}, \omega_{2t}, \omega_{3t}$ that are assumed normally distributed and white noise. The F statistic used in equation (1-3) is to examine whether a cointegration relationship exists between the variables by testing the significance of lagged level variables. The null hypothesis of no cointegration is given by H_0: $\varphi_i = 0$ (i=1…..9). At different lag lengths and for each equation, we compared the value of computed F-statistic with the critical value provided by Narayan (2005). In this process of testing co-integration, it is important to determine the order of the lags on the first difference variables. Bahmani and Bohl (2000) suggested that the results of this first step are usually sensitive to the order of lags.

The F-test has a non-standard distribution that depends on: (i) Whether variables included in the model are I(0) or I(1); (ii) the number of repressors; and (iii) whether the model contains an intercept and/or a trend. The test involves asymptotic critical value bounds, depending upon whether the variables are I(0), I(1) or a mixture of both. Two sets of critical values are generated: One set refers to the I(1) series and the other set to the I(0) series.

The critical values for the I(1) series are referred to as upper bound critical values, while the critical values for I(0) series are referred to as lower bound critical values. The long run relationship between variables exists if the F-test statistics exceed their respective upper critical values regardless of the order of integration. We cannot reject the null hypothesis of no cointegration if the F-test statistic is below the lower critical value. If the F-test statistic lies between the bounds, the order of integration of the underlying repressors is inconclusive. In this case, we conducted the t-test corresponding with electroconvulsive therapy (ECT_{-1}). If the value of ECT_{-1} is significant, the finding suggests the existence of cointegration among the variables (Banerjee et al. 1998; Mosayeb and Mohammad, 2009). Essentially, if cointegration exists, the independent variables are long run forcing variables for the particular dependent variable examined.

1. Electric power T and D losses include losses in transmission between sources of supply and points of distribution; and in the distribution to consumers, including pilferage.

Since co-integration is detected, the next step is to determine the direction of the causality relationship. The existence of a long run relationship does not indicate the existence of causality relationship between the cointegrated variables. Granger (1989) argued that cointegration does not always mean causality. Cointegration is necessary, but not a sufficient condition towards rejecting Granger causality.

However, traditional causality tests suffer from two methodological deficiencies (Odhiambo 2009). First, these standard tests do not examine the basic time series properties of the variables. If the variables are cointegrated, then these tests, which incorporate different variables, will be miss-specified unless the lagged error-correction term is included (Granger, 1988). Second, these tests turn the series stationary mechanically by differencing the variables and, consequently, eliminating the long run information embodied in the original form of the variables. In contrast to the conventional Granger causality method, the error-correction-based causality test allows for the inclusion of the lagged error-correction term derived from the cointegration equation. By including the lagged error-correction term, the long run information lost through differencing is reintroduced in a statistically acceptable form. In this respect, the error-correction model applied for the testing of Granger causality between electricity generations, real GDP and employment takes the following forms:

$$\Delta \ln Y = \beta_1 + \sum_{i=1}^{s} \gamma_1 \Delta \ln Y_{t-i} + \sum_{i=0}^{z} \gamma_2 \Delta \ln PE_{t-i} + \sum_{i=0}^{k} \gamma_3 \Delta \ln EMP_{t-i} + \theta ECT_{t-1} + \upsilon_{1t} \quad (5)$$

$$\Delta \ln EP = \beta_2 + \sum_{i=0}^{s} \gamma_1 \Delta \ln Y_{t-i} + \sum_{i=1}^{z} \gamma_2 \Delta \ln PE_{t-i} + \sum_{i=0}^{k} \gamma_3 \Delta \ln EMP_{t-i} + \theta ECT_{t-1} + \upsilon_{2t} \quad (6)$$

$$\Delta \ln EMP = \beta_3 + \sum_{i=0}^{s} \gamma_1 \Delta \ln Y_{t-i} + \sum_{i=0}^{z} \gamma_2 \Delta \ln PE_{t-i} + \sum_{i=1}^{k} \gamma_3 \Delta \ln EMP_{t-i} + \theta ECT_{t-1} + \upsilon_{3t} \quad (7)$$

Here, γ_{th} is the short run dynamic coefficients of the model's convergence to equilibrium and θ_1 is the speed of adjustment.

Following Adjaye (2000), Odhiambo (2009), Shahbaz et al. (2011), Acaravci & Ozturk (2010), equations (5-7) are utilised to examine Granger causality in the following three ways: (i) Short run or weak Granger causalities are detected by the significance of the joint F statistic on the sum of lagged explanatory variables (H_0: $\gamma_2 = 0$; $\gamma_3 = 0$ in each equation). (ii) Another possible source of causation is the significance of the one period lagged error correction term, ECT_{-1}. The null hypothesis of no long run causality in each equations is H_0: $\theta = 0$. (iii) Lastly, strong Granger causalities are exposed through a joint significance F statistic on both ECT_{-1} and lag of the explanatory variables. From the equation above, the H_0 of strong long causality relationship is $\gamma_2 = \theta = 0$; $\gamma_3 = \theta = 0$ for Equation (5) and $\gamma_2 = \theta = 0$, $\gamma_3 = \theta = 0$ for Equation (6) and for Equation (7) is $\gamma_2 = \theta = 0$, $\gamma_3 = \theta = 0$.

4.3. The Source of Data

The present study uses annual data for the period between 1980 and 2013[2]. The study gathered the data from the World development indicators CD-ROM 2013 of the World Bank's database. The annual data of real per capita GDP is in Sudanese Pound (2000 = 100); total EP is in kWh; and employment is the number of employed people.

5. EMPIRICAL RESULTS

This section describes the empirical results of the study. We shall start by illustrating the order of the integration between the variables (i.e., unit root tests); and thereafter we will conduct the cointegration test. After we identify the existence of long run relationship, we shall present the results of the causality relationship.

5.1. Unit Root Test

Since the present study adopts the bounds test approach, the first step is to ensure that all the variables satisfy the requirements of the bounds test. One of the basic requirements of the bounds test is that the order of the integration between the variables must not exceed one (e.g., no variable I(2)). If the order of integration of any of the variables is >1, for example an I(2) variable, then the critical bounds provided by Pesaran and Smith (2001) and Narayan (2005) are not valid (Ozturk and Acaravci 2011; Shahbaz et al. 2011). The critical bounds are calculated on the basis that the variables are either I(0) or I(1). For this purpose, it is necessary to perform a unit root test to ensure that all the variables satisfy the underlying assumptions of the ARDL bounds testing approach before proceeding to the estimation stage.

In practice, choosing the most appropriate unit root test is difficult. Enders (1995) suggested that the safest option is to use both the unit root tests, *viz*., the Augmented Dickey and Fuller (1981) (ADF) test and Kwiatkowski et al. (1992) Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test. The null hypothesis in the ADF is that the series has unit root; while the null hypothesis of the KPSS is that the series is stationary. It is reliable if the results support each other. In the present study, we tested the stationarity of the data series using the ADF and KPSS tests as the starting point to assess the order of integration.

The results of the two-unit root tests, as reported in Table 3, consistently suggested that a unit root problem exists with the variables in their level form, but the variables are stationary after differencing. Since no variable is stationary at I(2), the bounds test for cointegration is valid.

5.2. Co-integration Test

After confirming the order of integration, the next step is to test the existence of long run relationship by estimating Equations (2-4) at different lag lengths. We selected the optimal order of lags for the models based on Schwarz–Bayessian information criteria (SBI) as suggested by Pesaran et al. (2001). Table 4 reports the results of this test. The F statistic results in Table 4 above indicate

2. The period of the study is limited because the data on employment is not available for Sudan before 1980.

Table 3: The unit root tests

Variables	At level				At first difference			
	ADF		KPSS		ADF		KPSS	
	Without trend	With trend	Without trend	With trend	Without trend	With trend	Without trend	With trend
Ln Y	0.73 (0.99)	–1.89 (0.64)	0.59**	0.19**	–5.00*** (0.000)	–5.18*** (0.000)	0.34	0.44*
Ln EP	1.67 (0.99)	–0.85 (0.96)	0.76***	0.17**	–5.26*** (0.000)	–4.50*** (0.000)	0.16	0.07
Ln EMP	–1.45 (0.54)	–1.50 (0.8)	0.67**	0.07	–3.96*** (0.004)	–4.10*** (0.015)	0.16	0.07

*,**,*** In (ADF) and denote rejection of the null of non-stationary of the variable at 10%, 5% and 1% significant level respectively, *,**,*** in (KPSS) denote acceptance of the null of the stationary of the variable at 10%, 5% and 1% significant level respectively, ADF: Augmented Dickey and Fuller, KPSS: Kwiatkowski-Phillips-Schmidt-Shin

Table 4: Bound tests results

Function	F-statistic						Conclusion
	Lag length						
	1	2	3	4	5	6	
lnY/(lnEP, lnEMP)	2.72	3.87	3.84	7.15*	1.65	1.66	Cointegration at lag 4
lnEP/(lnY, lnEMP)	4.30	7.01*	4.73	1.69	1.76	2.66	Cointegration at lag 2
lnEMP/(lnEP, lnY)	2.67	5.58**	3.94	2.71	3.80	2.64	Cointegration at lag 2

Note: *,** Denote significance at the 1% and 5% levels, respectively, The critical value is obtained from Naryan (2005, p. 1988), The lower and upper critical value for the F test (with intercept and no trend) with two variables (k=2) are (5.893-7.337) (4.133-5.260) and (3.373-4.378) under the 1%, 5% and 10% significance level, respectively, EP: Electricity production

the existence of a long run relationship between the variables. More specifically, when we considered economic growth (Y), EP and employment (EMP) as dependent variables, the *F* statistics detected cointegration at lags 4, 2 and 2 respectively. Pesaran et al. (1997) argued that the existence of cointegration implies that the selected explanatory variables are long run forcing variables for the dependent variable.

To ascertain the goodness of fit of the ARDL model, we performed the diagnostic and stability tests. The diagnostic tests examine the stability of the long run coefficients together with the short run dynamics, based on Pesaran and Pesaran (1997), and the application of cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ), as proposed by Brown et al. (1975). Further diagnostic tests were performed on the model, including a serial correlation test (F statistics of Breusch-Godfrey test); a model specification test (F statistics of ARCH); a normality test (Jargue-Bera test); and a Heteroskedasdasticity test (F statistics of white Heteroskedasdasticity test).

The results of the diagnostic tests (not reported here - but available upon request) suggested that the three equations have the desirable statistical properties. More importantly, the normality test cannot reject the null hypothesis, indicating that the estimated residuals are normally distributed and the standard statistical inferences (i.e., t statistic, F statistic, and R^2) are valid. Moreover, the results of the CUSUM and CUSUMQ plots indicated that the regression coefficients are generally stable over the sample period, as well as providing further evidence on the robustness of the present analysis.

5.3. Causality Test

Since a cointegration relationship has been discovered in Equations (1-3), the next step is to apply the Wald F test on Equations (5-7) to examine the short, long and strong long causality relationships. Table 5 represents the results of the causality tests as estimated by the Schwarz Bayesian criterion.

From Table 5, the F statistics detect the existence of bi-directional causality relationships between energy generation and economic growth in the short run. This implies that the inclusion of past values of energy generation in the economic growth equation provides a better explanation of the current values of economic growth than when excluded. In addition, the significance of the ECT_{-1} in the EP equation, and economic growth equation, indicates the existence of bi-directional causality relationships between energy generation and economic growth in the long run. This means if a particular variable deviates from the long run equilibrium path, because of any shock, the other two variables take the burden of adjusting this disequilibrium. Thus, if economic growth variable deviates from the long run equilibrium path, because of any shock, EP and employment will interact in a dynamic fashion to restore long run equilibrium. The joint short and long run causality test detected the existence of strong long bi-directional causality relationships between energy generation and economic growth. This implies that the weak bi-directional causality between the two variables in the short run tends to be very strong over time. It is possible to interpret this strong long run causality relationship as follows; it is widely accepted that electricity enhances the productivity of capital, labour and the others factors of production. However, over time and because of growing economic globalization, the greater utilization of information and communications technologies is causing worldwide transition towards a digital society which may require further electricity generation. To proactively cope with increasing electricity demand accompanying economic growth, it is imminent that Sudan endeavours to uncover the casual relationship between EP and economic growth.

Overall, the results suggest that even in the short run, decrease in EP will lead to fall in economic growth. Therefore, devoting further resources to EP should not be considered wasting of valuable resource since it will result in further economic development over time. The results support the current effort of the Sudan's government in the expansion of EP, since it has consequences to the country's economic development.

Table 5: Results of Granger causality

Dependent variable	Type of Granger causality						
	Short run or weak causality			Long run causality (ECT-1)	Strong long causality (joint-short and long run)		
	ΔlnY (H0: γ_1=0)	ΔlnEP (H0: γ_2=0)	ΔlnEMP (H0: γ_3=0)		ΔlnY (H0: γ_1=θ=0)	ΔlnEP (H0: γ_2=θ=0)	ΔlnEMP (H0: γ_3=θ=0)
ΔlnY	-	4.56 [0.003]	6.17 [0.003]	–0.60 (0.000)	-	22.47 [0.000]	28.68 [0.000]
ΔlnEP	11.11 [0.001]	-	3.54 [0.06]	–0.15 (0.058)	16.07 [0.000]	-	4.30 [0.067]
ΔlnEMP	1.12 [0.29]	0.30 [0.58]	-	–0.33 (0.012)	8.39 [0.015]	7.47 [0.024]	-

Note: *,** Denote significance at the 1% and 5% levels, respectively, Prob for F-statistic in [ ] and t-statistic value in ( ), EP: Electricity production

6. CONCLUSION

The present study investigates the linkages between economic growth, EP and employment in Sudan between 1980 and 2013. The specific objective of the present study is to determine whether a long run equilibrium relationship exists between the variables and identify the direction of the causality relationships. The study uses the bounds test to determine the existence of cointegration relationships, whilst the Wald's test to identify the direction of the causality relationships.

The importance of the present study stems from the fact that the government of Sudan has adopted various policies to improve energy production as reflected in the construction of several dams over the past decades. In spite of a considerable allocation of local and foreign resources to this sector, the effect on the country's economic development is yet to be sufficiently examined. Consequently, this study seeks to evaluate as to whether the expected return supersedes the burden of the financing of the construction of new electricity projects.

The results show that there is long run relationship between the variables. The Wald test for non-causality relationship detects the existence of unidirectional relationships flow from employment to each EP and to economic growth in the short run. Interestingly, in the same time horizon, the F statistic suggests the existence of bi-directional causality relationship between energy generation and economic growth. The significance of the ECT_{-1} in all equations indicates the existence of bi-directional causality relationship between each pair of variables in the long run. The F statistic also detects the existence of strong long bi-directional causality relationship between each pair of the variables.

Overall, the results suggest that, even in the short run, decrease in electricity (or economic growth) will lead to fall in economic growth (or EP), and over time, the effect will extend to include reduction in the number of employment. The results support the current effort by the Sudan's government in the expansion of EP, since it has positive impact on the country's economic development.

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