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"The Effect of Electric Power Consumption on Economic Growth in Sudan: An Empirical Investigation (1990 - 2017)"

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ABSTRACT

In the last few decades, economists have devoted considerable attention to the effect of electric power consumption and investment on economic growth, at both theoretical and empirical levels. This research aims to investigate the effect of electric power consumption on economic growth for Sudan. Annual time series data were collected covering the period (1990-2017). Data on electric power consumption was taken from the National Electric Corporation of Sudan. The real gross domestic product (used to indicate economic growth) and the real total investment were collected from the Central Bank of Sudan (CBS) and Central Bureau of Statistics. The research used the descriptive approach and the applied econometric approach by using Autoregressive Distributed Lag (ARDL) model and the associated Error Correction Model (ECM) to investigate the effect of electric power consumption and investment as explanatory variables on economic growth as a dependent variable. The Units Root test was used to examine the stationarity of data, and the Bound test was used to test the long-run co-integration. Results from the Bound test showed the existence of long-run equilibrium among the variables. The result of the long-run analysis indicates that electric power consumption and total investment exert a positive effect on economic growth as was expected according to economic theory. The long-run elasticity of economic growth with respect to electricity consumption and investment are higher than their short-run elasticity. The ECt-1 coefficient is estimated approximately as (-0.161), which means that the system could get back to equilibrium in about six years and 3 months (6.25 years) after a shock. Generally and overall, the study found out proof to support the assumption that higher electricity consumption and higher investment over time in Sudan give rise to more economic growth. This implies that an increase in electricity consumption raises economic growth. The study also found out an increase in investment raises economic growth. The main recommendations that can be drawn from this study are: first, more plans should be put to activate the renewable energy sources (solar energy, wind, etc.). Besides, the generation of hydroelectricity as renewable energy technology has an enormous potential to solve electricity problems in Sudan. Second, the government should ensure a business-friendly environment to encourage local and overseas investors to invest more in the country to achieve those policies. Action should be taken to increase power generation as well as to attract local and foreign investors to invest in energy and other sectors. Third, as investment positively affects GDP growth and electricity consumption affects investment, the Central Bank of Sudan may undertake appropriate monetary policy to provide finance at cheaper cost rates in the banking sector.

Keywords: ARDL, Electric power consumption, Economic growth, ECM.

1- Introduction

Over the last few decades, economists have devoted considerable attention to the study of the relationship between electric power consumption and economic growth, at both theoretical and empirical levels. The focus was mainly on the effect of electric power consumption on economic growth. However, pioneering work was investigating the causal relationship between economic growth and energy consumption as was done by Kraft and Kraft (Kraft ,1987).

Electricity is a flexible form of energy and a critical resource for modern life and vital infrastructural input for economic development. In all economies, households and companies have extensive demand for electricity. This demand is driven by such important factors as industrialization, extensive urbanization, population growth, a rising standard of living and even the modernization of the agricultural sector. There has been widespread discussion and research over the topic of the relationship between electricity consumption and economic growth since the early seventies of the last century. The degree of interest has been intensified since the Kraft and Kraft (1978) findings. They found evidence of a unidirectional causal relationship running from Gross National Product (GNP) to energy consumption in the United States using data spanning from (1947–1974).

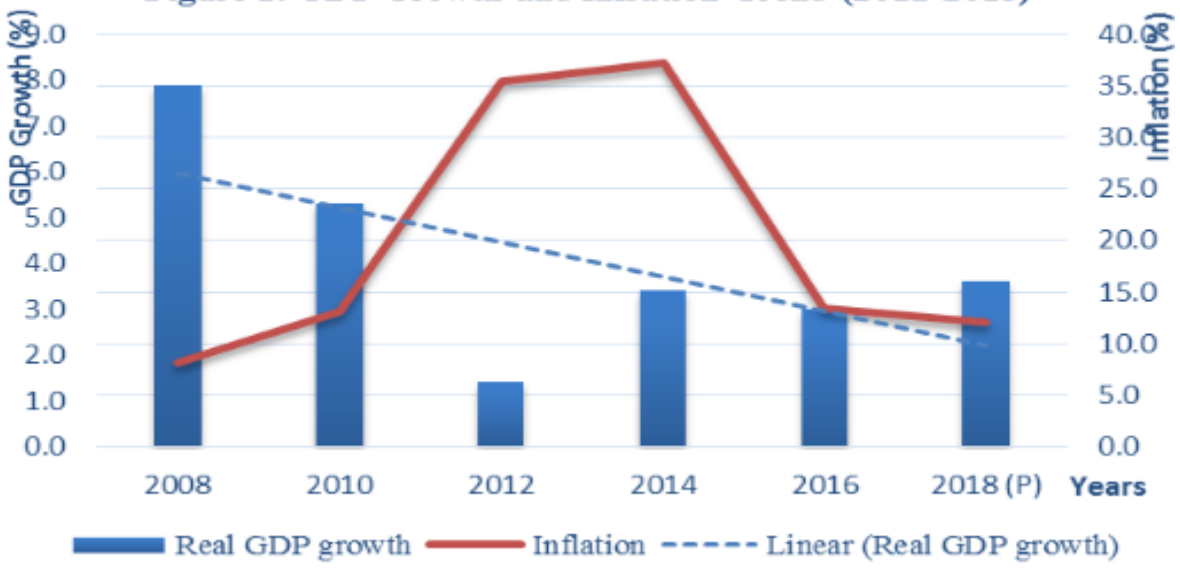
This study will focus on the effect of electricity consumption on economic growth in Sudan.

The generation of hydroelectricity in Sudan began in 1925 with the construction of Sennar Dam followed by other similar projects, such as the Jabal 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 main objective of constructing such dams is 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).

Today, the energy sector in Sudan faces serious challenges, namely, how to expand and improve the delivery of energy services to different sectors in the economy in an environmentally and socially acceptable manner. This is indeed a big challenge and it will require a package of strategies designed to meet the country's energy needs. The second main challenge is the lack of Research and Development (RD) in the energy sector. It is now well documented in the literature that technological advancement enhances energy-related benefits and reduces costs and risks. Research on energy-related issues is likely strengthening the technological base, capabilities and innovation capacity in the country, which in turn enhances competitiveness. The third challenge is the price distortions arising from the administrated energy prices. The energy-pricing policies have a direct impact on the development of the energy sector, because the viability of the public sector, as well as the private sector participation, hinges upon the pricing policies vis-à-vis energy sector.

Sudan's economy declined sharply after South Sudan's secession in 2011, with GDP growth plummeting from an average of 7% in the three years preceding the secession to 0.9% in 2011 and 1.4% in 2012(Figure 1). Although GDP growth started to recover at 4.4% in 2013 and reached 4.9% in 2015, the fundamentals of the economy remain weak. Inflation spiraled to 36.5 percent in 2013 and 36.9 percent in 2014. Current account deficits were huge: 10.3 percent of GDP in 2012 and 8.1 percent of GDP in 2013. The country went from a fiscal surplus of 0.1 percent of GDP in 2011 to a deficit of –3.1 percent in 2012 and –2.2 percent in 2013. Foreign exchange reserves plummeted from 1.9 months of import cover in 2012 to 1 month of import cover in 2016, and the parallel market ex-change rate soared while the official market exchange rate remained virtually fixed. (The gap or premium between the parallel and official market rate was more than 120 percent in August 2017).

Figure 1: GDP Growth and Infration Trend (2012-2018)



During the period 2009-11, the share of Sudan's entrepreneurs outside the agricultural sector declined from 56.8% to 47.3%, whereas the proportion of urban entrepreneurs increased from 46.3% to 49.8%. Thus, there is a need to improve the business environment, given that Sudan's overall score on the World Bank's distance from frontier rating has worsened from 49.3 in 2009 to 44.8 in 2017. Generally, entrepreneurship is not encouraged as a professional career and this is reflected in the lack of a national plan for developing entrepreneurship. (African Economic Outlook, 2017)

The country also slipped into fiscal and current account deficits in 2011 and 2012, from which it has since not fully recovered (Figure 2). The current account deficit hit double digitsof-10.3% of GDP in 2012, and -8.1% of GDP in 2013, which were still higher than the fiscal deficit that stood at -3.1% and -2.2% of GDP in 2012 and 2013 respectively. A fiscal consolidation policy 5 adopted and implemented since 2012 curbed the fiscal deficit to about -1.6% of GDP in 2015and -1.8% in 2016, and the current account to -5.3% of GDP in 2016.

This modest improvement in the fiscal and current account deficits, coupled with reduced monetization of the fiscal deficit, reduced inflation from 37% in 2014 to 17% in 2015 and 13.5% in 2016, though inflationary pressures are slowly

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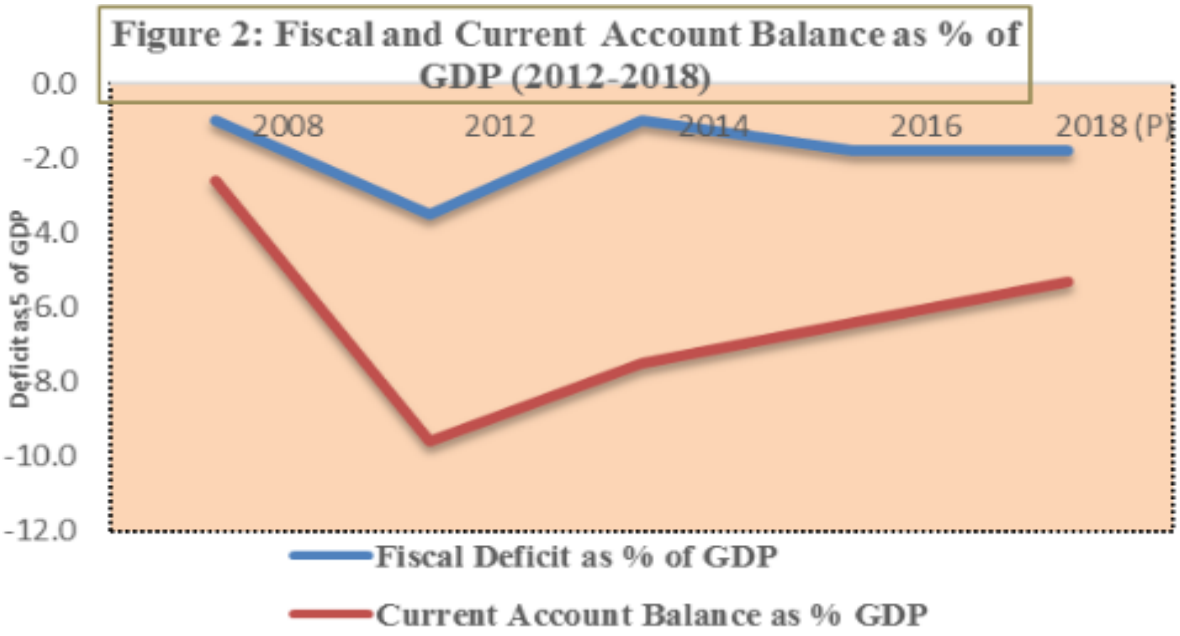
building up again in 2017. However, these reform gains are dampened by the absence of deeper macroeconomic reforms, evident in the slow pace of negotiating an Article IV Consultation Program with the IMF which is planned to succeed the 13 successfully concluded Staff Monitored Programs (SMP) 6prior to 2014. Exchange rate misalignment is another area of concern, as the distortion erodes the competitiveness of the external sector, slows down domestic production and deters economic recovery prospects(AfDB, 2017)



Source: AfDB Statistics

A challenging macroeconomic environment:

Sudan is amongst the top ten economies in Africa. The country has abundant fertile lands and livestock, a reasonable manufacturing base and a strategic location at the crossroad of sub-Saharan African and the Middle East. Oil revenue and a recent boom in gold have resulted in high GDP growth, but chronic conflict and violence combined with governance challenges have restricted the development of Sudan's economy and delivery of public services. The Sudan government has been under US sanctions since 1997 and it was removed recently in October 2017. It has significant arrears and is not able to borrow from development agencies at concessional rates. As of June 2017, Sudan's debt obligation to the Bank stood at UA238.76million (Table 1). This comprises UA 134.87million ADB loan and UA 103.89million ADF loans, all of which were contracted during the 1970s to early 1990s. These loans are predominantly in the agriculture sector (64%), followed by energy (17%) and roads (12%), and the rest in the social sectors. (Central Bank of Sudan, Annual reports)

Source	Principal	Charges	Total
ADB	54,369.98	75,287.07	129,657.05
ADF	80,504.34	28,600.14	109,104.48
NTF	0.00	0.00	0.00
Total	134,874.32	103,887.21	238,761.53

Source: Central Bank of Sudan

Sudan is ranked 184 out of 189 countries on the World Bank's Doing Business index. The fragility impact of the macroeconomic situation is low levels of service delivery, high inflation, low economic competitiveness, spiraling costs of living, pressures on the poorest, social unrest, lack of social cohesion and political instability.

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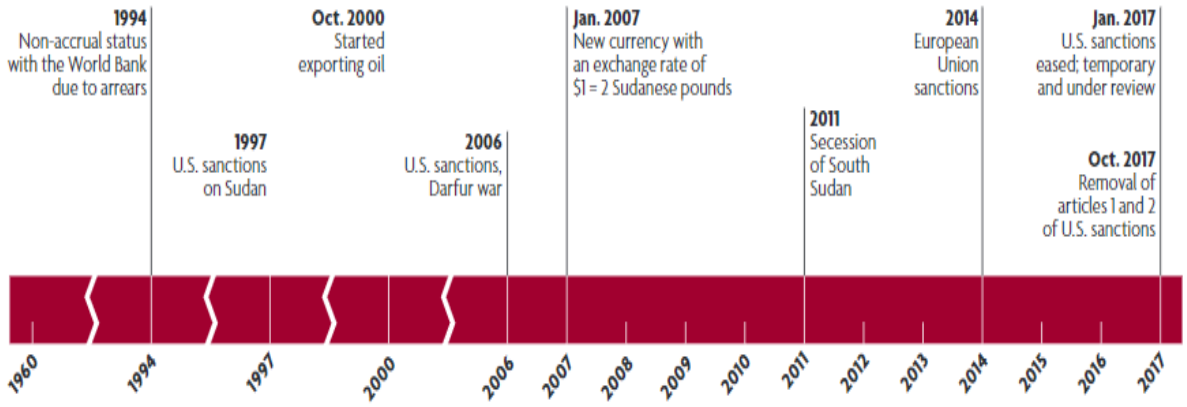
(Figure 3) Timeline of major events in Sudan



1.1 Research Problem

Economic growth in Sudan has witnessed many fluctuations due to different economic policies and other factors especially the civil war. The average rate of economic growth was almost 5% in 1990, while in the first decade of the 21st century the economic growth was increasing until the secession of South Sudan in 2011. After that, Sudan has faced fluctuation in economic growth.

The idea that electric power consumption may be related to economic growth is not new, but the view of this relationship has changed over time. Despite huge economic resources in Sudan, its economic growth is still not showing progress except during the period of petroleum production. This indicates the inefficiency of factors influencing economic growth including the electric power consumption.

Electricity infrastructure plays an important role in economic growth and employment generation for developing countries more than the developed ones (Chen et al, 2007). In Sudan, the expansion of economic activities is restrained by the underdeveloped electricity infrastructure. The energy sector is poorly managed (Mariam, Tareg 2016) and characterized by the limited coverage of supply, inefficiency, poor quality of services and huge government subsidies (Abdellah Abdelrahman, 2016). The supply of electricity is inadequate to meet the economic activities. As a result, frequent electrical power outages or load shading are used to manage the gap between power generation and demand for electricity in Sudan. The production of electricity has increased over the years but failed to match the high demand for electricity leading to a chronic shortage in power supply to cover the economic activities.

This study tries to answer the following question:

What is the effect of electric power consumption on economic growth in the short and long-run?

What is the effect of investment on economic growth in the short and long-run?

1.2 Importance of the Research

The importance of this research lies in the fact that it is investigating the effect of the electric power consumption on economic growth on the short and long term and provides some recommendation, which can help to use the available sources in Sudan to cover the increasing demand on electric power and support the economic growth plans. According to the Sudan National Electric Corporation 2017, the demand for electricity will be increasing at a faster rate. As is known, the increase in consumption of electricity puts responsibility on national electricity companies to develop plans to predict electricity consumption.

The focus of this study will be on analyzing the short and long-run relationship between electric power consumption and economic growth in Sudan to develop appropriate plans for the future in this sector. As, most of the studies confirm the positive effect of electric power consumption on economic growth (Chali, 2008).

1.3 Research Objectives

Objectives of this research are:

1. To investigate the effect of electric power consumption on economic growth in the short and long run.
2. To examine the effect of investment on economic growth in the short and long run.

1.4 Research Hypotheses

The research is conducted to test the following hypotheses:

1. The electric power consumption positively affects economic growth in the short and long run.
2. The investment positively affects economic growth in the short and long run.

1.5 Research Methodology

1.5.1 Data Sources

The study based on annual data for the ELC, RI, and GDP covering the period (1990-2017). The data was collected from different sources.

Data on electric power consumption was taken from the National Electric Corporation of Sudan. The real gross domestic per capita (is used to indicate economic growth) and the real total investment was collected from the Central Bank of Sudan (CBS) and the Central Bureau of Statistics.

1.5.2 Method of Analysis

The study investigated empirically the effect of electric power consumption on economic growth in Sudan using annual time series data for the period (1990-2017). The study used the descriptive approach and the applied econometrics approach, the Autoregressive Distributed Lag (ARDL) approach and the associated Error Correction Model (ECM) to test whether there are short-run and long-run effects made by the electric power consumption and real total investment on economic growth in Sudan. The ARDL modeling approach was developed by Pesaran (1997); Pesaran et al, (2000), and later on by Pesaran et al (2001). Fundamentally, the ARDL approach to co-integration includes two stages for estimating the long-run relationship (Pesaran et al, (2001). Stage one is to test the presence of a long-run relationship between all variables in the equation underestimation, which is identified as the Bound test. If there is a proof of the long-run relationship (co-integration) between variables. The second stage is then applied to examine the long and short-run models. Once estimates of the long-run parameters are attained, the estimated equation also is used to attain an estimate of the error correction model. The autoregressive distributive lag model can be applied without investigating the order of integration (Pesaran and Pesaran,1997). Haug (2002) has argued that the ARDL approach to co-integration provides better results compared to traditional approaches to co-integration i.e. Engle and Granger (1987); Johansen and Juselius (1990) and Phillips and Hansen (1990). Another advantage of ARDL bounds testing is that the unrestricted model of ECM seems to take satisfactory lags that captures the data generating process in a general-to-specific framework of specification (Laurenceson and Chai, 2003). However, Pesaran and Shin (1999) contended that “appropriate modification of the orders of the ARDL model is sufficient to simultaneously correct for the residual serial correlation and the problem of endogenous variables”.

1- Literature Review

The characteristics of the economic growth and electricity sector have been an area of interest of researchers for a long time. However, the pioneering work was investigating the causal relationship between economic growth and energy consumption that was carried out by (Kraft and Kraft, 1987).

2.1 Buysse et al (2012)

Using co-integration and VECM based Granger causality tests, they investigated the possible existence of dynamic causality among electricity consumption, energy consumption, carbon emissions and economic growth in Bangladesh. The results indicated that unidirectional causality exists from energy consumption to economic growth both in the short and long run, while bi-directional long-run causality exists between electricity and electricity generation.

2.2 Ahmad and Islam (2011)

They researched the Bangladesh scenario, and they found short-run unidirectional causality running from per capita electricity consumption to per capita GDP without feedback applying co-integration and VECM based Granger causality test for the period spanning from 1971 to 2008. They also found long-run bidirectional causality running from per capita electricity consumption to per capita GDP.

2.3 Mozumder and Marathe (2007)

They found a reverse relationship that unidirectional causality from GDP to electricity consumption for Bangladesh over the period 1971 to 1999 by energy consumption employing Co-integration and Vector Error Correction Model (VECM).

2.4 Asaduzzaman and Billah (2008)

applying co-integration and VECM based Granger, They found a positive relationship between and economic growth for Bangladesh using data spanning from 1994 to 2004 and reported that a higher level of energy use led to a higher level of growth.

2.5 Ghosh (2002)

The study examined the Granger causality between electricity consumption per capita and Gross Domestic Product (GDP) per capita for India using annual data covering the period 1950–51 to 1996–97. This study found the absence of long-run equilibrium relationship among the variables but there exists unidirectional Granger causality running from economic growth to electricity consumption without any feedback effect. So, electricity conservation policies can be initiated without deteriorating economic side effects.

2.6 Muhammad Shahbaz& Mete Feridun (2011)

The Autoregressive Distributed Lag (ARDL) bounds testing procedure was used to identify the long-run equilibrium relationship between electricity consumption and economic growth. Toda Yamamoto and Wald-test causality tests have identified the direction of the causal relationship between these two variables in the case of Pakistan in the period between 1971 and 2008. Ng-Perron and Clement-Montanes-Reyes unit root tests were used to handle the problem of integrating orders for variables. The results suggest that the two variables are in a long-run equilibrium relationship and economic growth leads to electricity consumption and not vice versa.

Therefore the above literature reveals that due to the application of different econometric methodologies and different sample sizes, the empirical results are very mixed and even vary for the same country and are not conclusive.

2- Economic Growth in Sudan:

The Sudan economy has witnessed major transformations during the last decades. Full government control over economic activities characterized the period of the 1960s, while an inward-looking strategy dominated development policy during the early 1970s and mid-1980s. Economic difficulties assumed crisis proportions during the second half of the 1970s, following the ambitious development program launched in the early 1970s. The failure of the investment boom to increase the economy's productive capacity has accelerated the crisis. By the late 1970s, the government was confronted by falling export earnings, increasing import bill, accelerating budget deficit, and mounting foreign debts (Mahran, 2005).

According to Elbadawi (2002), remittances from Sudanese nationals working abroad averaged more than three times the dollar value of official exports during (1983-84), these huge foreign exchange resources encouraged the government to adopt reforms to unify the exchange rate. Having failed to attract further investment from the oil surplus economies in the Arab region, these reforms aimed at mobilizing the resources of the remittances from these countries. However, these efforts were largely unsuccessful, and Sudanese nationals have continued to send the bulk of their remittances through the parallel foreign exchange market, attracted by its more depreciated exchange rate (Ali and Elbadawi, 2002).

A new historical path of the Sudanese economy was made in 1992 after applying of the economic liberalization policy and adopting a market economy approach for the economic system, which reduced the government economic role to be restricted on policy-making. In this framework, an extensive program of sale and liquidation of some of the public sector institutions and government companies to the private sector was applied to treat the economic stagnation by reducing the

control of the public sector on economic activity and breaking the monopolies in this sector; liberalizing the economy from various restrictions; opening the door to the private sector to take over the reins of economic initiative, and driving economic activity towards achieving the national economic objectives. At this stage, the economy has tested several negative and positive developments. In the first four years of the implementation of the economic liberalization policy, an evident disturbance occurred in the national economy performance expressed by several indicators of which the most prominent was rapid the inflation rapid, which reached 166 percent in 1996, as well as a significant deterioration in the value of the national currency, a decline in the rate of GDP growth to low levels of 1.8 percent in 1991, a decline in the appropriations of the general budget development to 50percent, while the external debt exacerbated until it reached about $ 17 billion in 1996(Almosharaf and Tain, 2014).

However, a significant improvement occurred in the performance of the Sudanese economy after that because of the reforms that took place in the macro-economic policies since July 1996 in the framework of the implementation of economic structural reform strategy, where the indicators of the total economic performance showed remarkable development. Inflation rates have fallen to very low levels of 8 percent in 2000 after it was 166 percent in 1996; significant stability had taken place in the exchange rate, and the rate of GDP growth returned to rise to reach an average of about 6percent during (1997-2000). The thing which has helped to make this improvement was the entry of the oil within the sectoral components of the economy since 1998, as well as its entry within the structure of the Sudanese exports since 1999 (Almosharaf and Tain, 2014).

In 1999 Sudan began exporting oil and since then has become increasingly dependent on oil exports to the extent that the economy has turned into an oil-dependent economy. Since the late 1990s, the implementation of macro-economic reforms along with the positive contribution of oil to the Sudan economy has caused a rapid increase in real economic growth. Consequently, Sudan has moved from a low-income economy into a lower medium-income economy according to World Bank classification (Mohamed Nour, 2011).

Oil has led to a significant positive impact on Gross Domestic Product (GDP) as perceived from the impact of oil in the structure of the Sudanese economy and macro-economic indicators as measured by the share of oil in GDP, its growth rate and its composition. For instance, it was observed that there was an increasing impact of oil, as measured by the rapid and continuous increase in the contribution of the oil sector in GDP from 1% in 1999 to 10% in 2004. Moreover, oil has led to positive impact in real GDP growth, for instance, the average rate of growth of GDP increased to 6.8%, 8%, 10%, 9% and 9.6% over the periods (1997-1999); (2000-2009); (2005; 2006); (2005-2007) and (2006-2008) respectively, putting Sudan among the fastest growing economies in the region. Moreover, oil has led to structural change in the composition of GDP, as the dividends from oil exportation have caused major transformations and structural changes in the economy. The structure of the Sudanese economy has shifted over time from being predominantly reliant on agriculture for growth and exports to its current reliance on the oil sector (Mohamed Nour, 2011).

The fiscal stance in Sudan has weakened since the secession of South Sudan. In 2013, the government introduced austerity measures focusing on the reduction of fuel subsidies by about 9.1% (SDG 3.6 billion), maxi-devaluation (29%), wages were raised by 20% to compensate for the ensuing higher cost of living. The improvements in revenue collections from tariffs and expenditure control through reducing subsidies, as well as the inflow of oil transit fees, helped reduce the deficit in 2013 by an estimated 1.8 percentage points to 1.7% compared with 3.5% in2012.In 2013 real GDP grew by 3.6%, up from 1.4% in 2012, driven by agriculture, oil, gold and transit fees. Inflation remained high at 36.2% (Economic Commission for Africa, 2012).

During the period 2014-2017 Sudan's economic growth was adversely affected by a number of factors, including the breakdown of correspondent banking relationships declining oil revenues because of low export prices, aging oil fields and reduced inflows of oil transit fees from South Sudan. In the short and medium terms, growth will be determined by developments in the agricultural and mineral sectors, skills development and prudent macroeconomic policies and structural reforms aimed at improving the business climate. Significant downside risks include continuing civil wars in some parts of the country and low global commodity export prices.

The once-dominant agriculture sector which contributed over 60% of GDP in the pre-oil days (1960s-1980s), suffered a declining trend during the oil boom (1990s-2000s) that needs urgent action to reverse (Figure 3). In particular, the Government has identified value chain development in agriculture as a pathway to diversifying its economy to create jobs and has ascribed the sector a central role in the Economic Reform Program (2015-2019)

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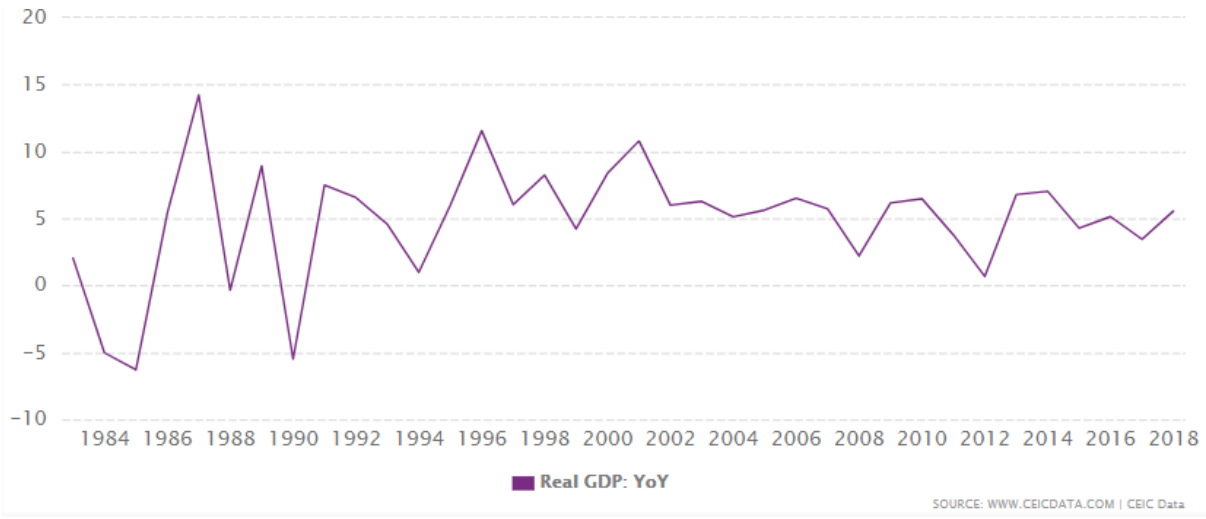
The starting point of the growth story in Sudan is that growth has been volatile over the past 40 years or so since independence in 1956. From the data, the Gross Domestic Product (GDP) in Sudan expanded by 5.6 % in 2018, following a growth of 3.5 % in the previous year. Real GDP Growth data in Sudan is updated yearly, available from 1983 to 2018, with an average rate of 5.7 %. The data reached an all-time high of 14.2 % in Dec 1987 and a record low of -6.3 % in 1985.



Last	Previous	Min	Max	Unit	Frequency	Range
▲ 5.6 2018	▼ 3.5 2017	-6.3 1985	14.2 1987	%	Yearly	1983 - 2018 Updated on 31 Oct 2019

Figure (3.1), (3.2): Sudan's Real GDP Growth from 1984 to 2018

Source: Census and Economic Information Center (CEIC) 2019

3- Electricity Consumption in Sudan

The generation of hydroelectricity in Sudan began in 1925 with the construction of Sennar Dam followed by other similar projects, such as the JbalAwlia 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 affects 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, so there is a shortage in the supply of electric power to meet the scheme provides to be developed (Prowde, 1926).

Following the end of the second civil war in Sudan in 2005, the country's generation and transmission infrastructure were found left in a run-down state with a huge need for new investment. While today the country continues to strive to modernize and extend its power generation and distribution networks, the ever-growing demand for power regularly exceeds supply availability, resulting in frequent power outages and prolonged voltage brownouts.

4.1 Power Sector in Sudan

Sudan is the third-largest country in Africa. In July 2011 South Sudan was separated and became an independent country. National Electricity Corporation (NEC) is the state-owned electricity company in Sudan. It is a statutory corporation under the Ministry of Energy and Mining (ME&M) and is responsible for electricity generation, transmission and distribution in the country. It is estimated that the total installed generation power capacity in Sudan in 2013 amounted to 2,533 MW, with about 70% of the electricity being consumed in the Khartoum area. Domestic power consumption dominates the market, with approximately 65% of electricity consumption being attributable to the sector.

Electricity is transmitted through two interconnected regional grids, the Blue Nile Grid and Western Grid, comprising approximately 8,560 km of high voltage transmission lines. In addition, 14 isolated centers are served by thermal generating plants and local distribution networks.

With the grids only covering a small portion of the country, the parts not connected to the grid depend on off-grid expensive and inefficient diesel-fired generators or firewood to generate power. Erratic power supplies (outages stood at 19 days per year on average in 2009) have contributed to a high level of private generator ownership, particularly in the commercial and industrial sectors.

Hydroelectricity is Sudan's largest source of on-grid power, accounting for 68% of generation in 2011, followed by diesel and heavy fuel oil (27%) and biomass and waste (5%). Hydroelectricity is generated from five dams at Roseires, Sinnar, Jebel Aulia, Khashm el-Girba, and Merowe. The newest hydro plant, Merowe, is located on the Nile River and has the country's largest generation capacity at 1,250 Megawatts (MW).

Although power generation has more than tripled since 2000, millions of people are still without access to on-grid electricity. More than 70% of the population lives in rural and isolated communities and it is estimated that only 30% of Sudan's total population currently has access to electricity, however, the government has ambitious plans to increase coverage to 90% by 2031.

4- Research Methodology

This study investigated empirically the effect of electric power consumption on economic growth in Sudan using annual time series data for the period (1990-2017). The study used a descriptive approach and an applied econometrics approach by using Autoregressive Distributed Lag (ARDL) model and the associated Error Correction Model (ECM) to test whether there is the short and long-run effect of electric power consumption, the real total investment on economic growth in Sudan.

To examine the hypotheses stated by the study, ARDL for co-integration was used to analyze a time series data which was collected from different sources, the electricity consumption was taken from National Electric Corporation of Sudan, the data on real gross domestic product and investment were collected from the Central Bank of Sudan (CBS) and Central

Bureau of Statistics for the period (1990-2017) to identify the **effect of electric power consumption on economic growth in Sudan**. The choice of this period is based entirely on data availability for a sufficiently longer time period and a list of variables used together which are shown in Appendix 1.

5.1 The Empirical Model

The empirical model to be estimated takes the following general form:

RGDP = F (ELC, RI) ---------- (1)

Where:

RGDP: Real GDP per capita used to indicate economic growth

ELC: Electric power Consumption

RI: Real total investment rate

5.2 Unit-root Test

A time series Yt (t =1,2, ...) is said to be stationary (in the weak sense) if its statistical properties do not vary with time (expectation variance, autocorrelation) Stationary tests allow verifying whether a series is stationary or not. There are two different approaches for testing the stationary of the series:

1. Stationary tests such as the KPSS test that considers as null hypothesis H0 that the series is stationary.
2. Unit root tests, such as the Dicicey-Fuller test and its augmented version; the augmented Dickey-Fulier test (ADF), or the Phillips-Perron test (PP), for which the null hypothesis is on the contrary that the series possesses a unit root, and hence is not stationary.

This study uses the Augmented Dickey-Fuller (ADF).

5.3 The ARDL Model for Co-integration

Recently, the ARDL approach to co-integration and error correction models (ECMs) was proposed by Pesaran, Shin and Smith (2001) as an alternative to Johansen's multivariate co-integration test (Johansen and Juselius, 1990). While the popular Johansen multivariate co-integration modeling technique is widely accepted as an improvement on the residual-based Engle and Granger (1987) two-step co-integration test, this approach still has notable limitations because of its dependence on pre-tests for the order of integration and its inapplicability to systems with mixed order of integration. Due to the limited power of existing unit root tests, the Johansen co-integration testing procedure could result in inaccurate inference regarding the causal structure and the nature of long-run relationships among variables.

In contrast, the ARDL approach allows for causal inference based on ECMs and is a very good alternative to conventional co-integration tests because it bypasses the need for potentially biased pre-tests for unit root. The ARDL technique is invariant to mixed orders of integration since the tests do not depend on whether the variables are I(0) or I(1) or a combination of the two (Morley, 2006). Thus, the determination of the existence of long-run relationships does not require that the variables be of the same order of integration. Also, this modeling approach yields desirable statistical properties in small samples. Pesaran, Shin, and Smith (2001) show that long-run estimates from ARDL estimation are super-consistent and that valid inference could be made using standard asymptotic theory. The error correction version of the ARDL model to the variables of this study based on the following equation:

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$$\Delta LogGGDP_t = \beta_0 + \beta_1 Log(RGDP)_{t-1} + \beta_2 Log(ELC)_{t-1} + \beta_3 Log(RI)_{t-1} + \sum_{i=0}^{q} \alpha_1 \Delta Log(ELC)_{t-1} + \sum_{i=0}^{q} \alpha_2 \Delta Log(RI)_{t-1} + \sum_{i=1}^{q} \alpha_3 \Delta LogRGDP_{t-1} + u_t \quad ---(2)$$

Where:

- $\Delta Log(GGDP), \Delta Log(ELC)$ and $\Delta Log(RI)$ are the first differences in the logarithms of the respective variables.
- $\beta 1, \beta_2$, and β_3 are long-run parameters.
- α_1, α_2, and α_3 are short-run parameters.
- U_t: random variable.

The ARDL approach to co-integration analysis involves the estimation of the conditional error correction model by OLS. A 'bounds test' for co-integration (null hypothesis of non-co-integration) is based on F-test restrictions of the joint significance of the estimated coefficients of the lagged level variables in equation (2). Since the asymptotic distribution of the F-statistics is non-standard, Pesaran, Shin, and Smith (2001) provide two sets of adjusted critical values that provide the lower and upper bounds used for inference. While the first set of critical values assumes that the variables are I(0), the other assumes they are I(1). Co-integration exists and there is evidence of a long-run relationship if the computed F-statistic exceeds the upper bound critical value. However, the null hypothesis (no co-integration) cannot be rejected if the F-statistic is below the lower bound. The results will be deemed inconclusive for a value within the bounds. The adequacy of the specified models was also examined with various diagnostic tests for serial correlation (LM test), functional form (Ramsey's RESET test), and structural stability (CUSUM and CUSUMSQ) tests. According to economic theory, it is expected that the electricity consumption and real total investment will be associated positively with the dependent variable which is the real GDP.

5.4 Descriptive Statistics of the Data

To provide an overall understanding of the chosen variables, the study presents the summary statistics of the data used in the following table (5.1).

Table (5.1): Mean, Std. Dev. and Coefficient of Variation of the Variables

	LOG (R GDP)	(ELC)	(RI)
Mean	3.77	3.46	1.2
Std. Dev.	1.08	0.37	0.21
Coefficient of Variation	0.29	0.11	0.17

Source: Own calculation based on data of appendix 1

All the variables are averaged across the period 1990–2017 and presented in percentages. The average real GDP per capita over the sample is 3.77 retelling the low-income level of Sudan under this period. Electric power consumption average is 3.46% and shows substantial differences due to the standard deviation which is 0.37. The real total investment is averaged 1.2% which shows the lower standard deviation 0.21 meaning that it does not show substantial differences. To allow for relative comparison of the variables in terms of fluctuations, the study estimates the coefficient of variation (CV) as the ratio of the standard deviation to the mean (Table 5.1) Real GDP per capita is the most volatile variable given the high value of CV. Electric power consumption is the least volatile. All the variables are skewed to the right.

5.5 Unit-Roots Test

Since the current study is contingent on the examination of the effect of real electric power consumption and total investment on economic growth in Sudan during the period 1990-2017, it requires testing the stationarity of each variable involved. Stationary tests allow for verifying whether the whole series is stationary or not. Here Phillip-Perron (PP) test is

used to test the stationarity. Therefore, the researcher has to investigate the order of integration, to confirm and grantee that, the variables are not 1(2) stationary to avoid spurious results. In the presence of 1(2) variables the computed F-statistics given by Pesaran et al (2001) is not valid, because the bound test is based on the assumption that the variables are 1(0) or 1(1), so, the application of unit root test in the ARDL procedure might still be necessary to guarantee that none of the variables is 1(2) or beyond. The results of the PP test are shown in Table (5.2). The results suggest that all the variables are integrated of order 1(1) which means stationary at first difference. This result supported the use of ARDL bounds procedure to determine the long-run relationship between the variables and it is consistent with economic theory, which assumes that most of the macroeconomic variables are not stationary at the level, but stationary at the first difference 1(1).

Table (5.2**) Unit-roots Test**

Name of Variable	Lag Order	Level			1st Difference		
		Intercept	Trend	None	Intercept	Trend	None
$Log(GDP)$	1(1)	-1.5803	0.8762	10.3708	-4.3464	-4.5298	-0.1261
		0.4786	0.9445	1.0000	0.0022 ***	0.0071 ***	0.6289
$Log(ELC)$	1(1)	0.2298	-2.736	2.0992	-6.6312	-6.8632	-1.5742
		0.9695	0.2317	0.9893	0.0000 ***	0.0000 ***	0.1067
$Log(RI)$	1(0)	-4.2466	-4.743	2.9355	-2.4118	-3.5581	-2.2849
		0.0029 ***	0.0044 ***	0.9985	0.1491	0.0546 *	0.0244

Source: Own calculation based on data in appendix1

Notes:

a: (*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1% and (no) Not Significant

b: Lag Length based on SIC

c: Probability based on MacKinnon (1996) one-sided p-values.

From Table (5.2) the real total investment is stationary in the level and thus integrated from the zero grade, while the other variables; electricity consumption and real gross domestic product are stationary in the first difference and, therefore, they are integrated into the first-class so the ARDL method for co-integration is the most suitable method to be adopted in this case.

5.6 A Bound Test for Co-integration

The next aim of the study is to investigate whether or not real GDP (used to indicate economic growth), electric power consumption and real total investment share a common long-run relationship. To achieve this, the study used the bound test to investigate the long-run relationship among the variables. This identified the optimal number of Lags by using AIC and considered the minimized criterion value. The results of the bound test are shown in Table (2), where it is found that the null hypothesis of no co-integration is rejected at 1% level. The calculated values are greater than the upper bound. This simply means that there is a long-run relationship among electric power consumption, real GDP and real total investment for Sudan.

Table (5.3) ARDL Bounds Test for Co-integration

Variables	F- statistic (calculated)	Co-integration
	40.93573*	Co-integration
Critical value	Lower bound	Upper bound
1%	3.88	5.3
2.5%	3.22	4.5
5%	2.72	3.83
10%	2.17	3.19

Source: Own calculation based on data of appendix (1)

* Statistical significance at 1% level

Therefore, the empirical findings lead to the conclusion that a long-run relationship between the variables in the model is significant at 1% level.

5.7 Estimated Coefficients in the Long and Short Run

5.7.1 Estimated Coefficients in the Short-run

The short-run dynamics are estimated through the ARDL approach, where the residuals resulted from the corresponding estimated long-run equation is used as an error correction term (ECT). The results are presented in Table (5.4).

Table (5.4): Estimated Short-run Coefficients

Variables	Co-efficient	Std. Error	P-value	R^2	R^{-2}	D.W
$Log(ELC)$	0.046673	0.05609	0.0064	0.997514	0.997307	1.626609
$Log(RI)$	0.015875	0.008702	0.0806			
Coint Eq(-1)	-0.161154	0.068028	0.0262			

Source: Own calculation based on data of appendix (1)

From the table above the overall goodness of fit of the estimated equation is moderately high (Adj. R2 = 0.99) which means about 99% of the variation in economic growth is caused by variations in the explanatory variables. Durbin Watson test indicates that there is no autocorrelation problem**.**

The coefficient of the lagged residual (ECt-1) in the ECM model shows the speed of adjustment towards the equilibrium following a shock to the system. The negative and significant ECT validates our system and the statistics show the following results:

- Electric power consumption exerts positive effects on economic growth and is statistically significant in the short-run. A 1% increase in ELC leads to an increase in economic growth by 0.05%.

- Real total investment also exerts a positive effect on economic growth. A 1% increase in RI leads to an increase in economic growth by 0.02%.
- It is cleared that from the above analysis of the short-run situation, the parameter of error correction is equal to (-0.161) and significant at (1%). In addition, it has a negative sign. This increases the accuracy and validity of the equilibrium relationship in the long run and signifies that the error correction mechanism is present in the model, and this means that any error in the system will be corrected after (6.25) years.

5.7.2 Estimated Long run Coefficients

Finally, the results in Table (5.5) show that in the long–run the electric power consumption and real total investment have a positive and significant effect on economic growth. This is completely consistent with economic theory.

Table (5.5): Estimation of Coefficients (elasticity's) in the Long-run

Variables	Co-efficient	Std. Error	P-value
$Log(ELC)$	0.289618 (8.160748)	0.035489	0.0000
$Log(RI)$	0.098511 (4.653078)	0.021171	0 0.0001

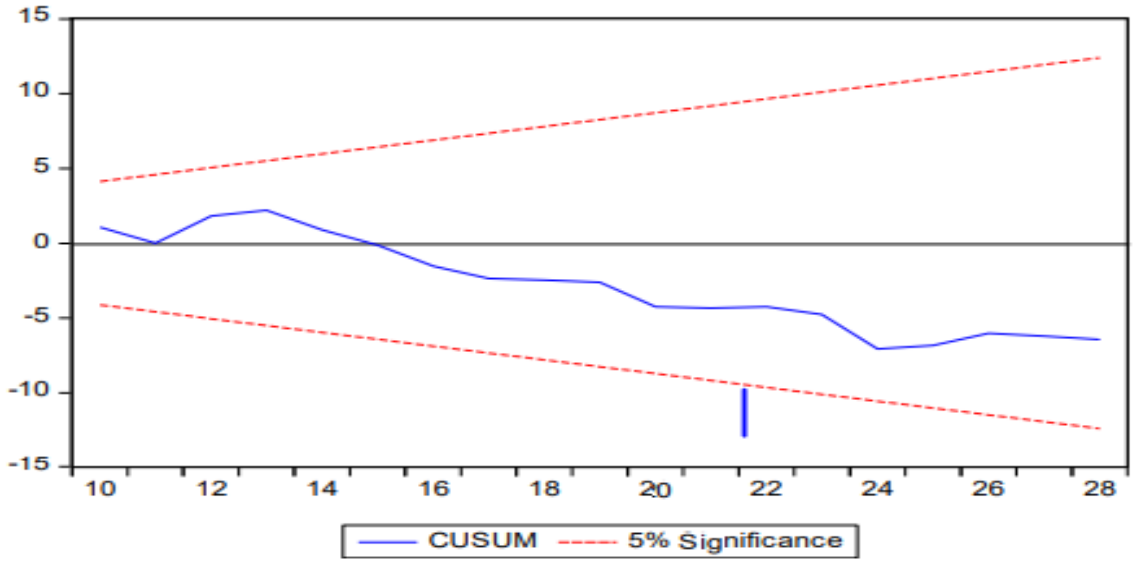
Source: Own calculation based on data of appendix (1)

Log RGDP is the dependent variable

- Table (5.5) shows the results of the long-run relationship between the dependent variable GRGDP and the other regresses. As expected, the electric power consumption variable has the expected positive sign. That means electric power consumption has a positive and statistically significant effect on economic growth in the long run, the relationship between them in term of elasticizes remain strong i.e. a 1% increase in electric power consumption leads to a respective economic growth increase of 0.29%. The estimated coefficient is highly significant in the case of electric power consumption.
- The above results show that real total investment also has a positive and statistically significant effect on economic growth in the long run and expected signs as per the economic theory. For example, a 1% increase in real total investment leads to a respective economic growth increase of 0.098%
- Tables (5-4) & (5-5) indicate that the short-run and long-run electricity consumption and investment have a positive impact on economic growth for Sudan. With respect to electricity consumption is (0.29) higher than short-run elasticity (0.05) and also the long-run elasticity of economic growth with respect to investment is (0.098) higher than short-run elasticity (0.02), indicate that over time higher electricity consumption and higher investment in Sudan give rise to more economic growth.

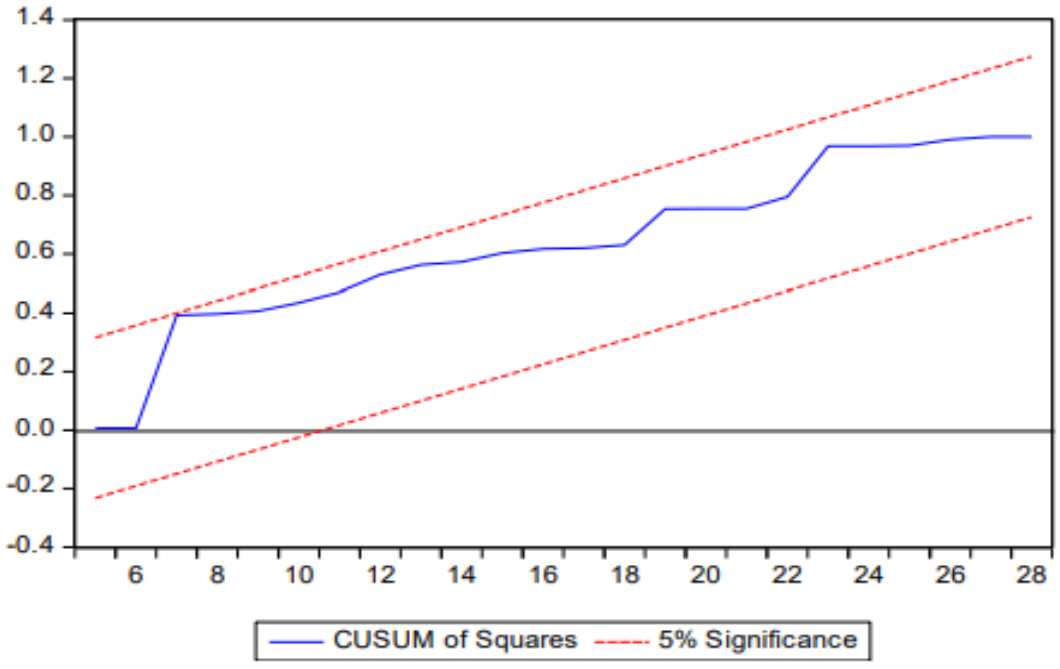
5.8 CUSUM and CUSUMSQ Tests

It is important to investigate whether the above long-run relationships are stable for the entire period of the study. The stability of the model parameters is examined using the cumulative sum (CUSUM) and the cumulative sum of squares (CUSUMSQ) of the recursive residual test for structural stability proposed by Brown et al. (1975). CUSUM and CUSUMSQ are plotted against the breakpoints. Parameter stability is indicated when the CUSUM and CUSUMSQ plotted against time remain within the 5 percent significance level over the sample period, while parameters and hence the variance is unstable if these plots move outside the 5 percent critical lines.



Source: Own calculations

Figure (5.1) CUSUM test



Source: Own calculations

Figure (5.2) CUSUM of squares test

From figure (5.1) and figure (5.2), it could be concluded that the estimated coefficients are stable and have structural stability because the plot of CUSUM and CUSUMSQ statistic stayed within the two lines at 5% significance level.

5- Conclusion

The main goal of this study was the examination of the effect of electric power consumption, and investment on economic growth in Sudan. For this purpose, the study focused on total electricity consumption, total real GDP (used to indicate economic growth) and real total investment for the period (1990 - 2017). The ARDL model has been used to investigate the effect of electric power consumption and total investment as explanatory variables, on economic growth as a dependent variable. The Root Units test was used to examine stationarity of the variables and the bound test was used to test the long-run co-integration. Results from the bound test showed the existence of long-run equilibrium among the variables.

The result of the long-run analysis indicated that electric power consumption and total investment exert a positive effect on economic growth, which were expected signs as per economic theory.

The long-run elasticity of economic growth with respect to electricity consumption and investment are higher than their short-run counterparts. This implies that over time higher electricity consumption and higher investment in Sudan give rise to higher economic growth. This implies that an increase in electricity consumption raises economic growth. The study also finds that an increase in investment raises economic growth. Therefore, much emphasis should be put on electricity generation and more investment.

6- Findings

The results of the study indicated that there is an effect of electric power consumption and real total investment on economic growth. For individual electric power consumption and real total investment values the findings in the short run are as follow:

- Electric power consumption exerts a positive effect on economic growth and statistically significant in the short-run. A 1% increase in ELC leads to a decrease in economic growth by 0.04% point.
- Real total investment also exerts a positive effect on economic growth. A 1% increase in RI leads to an increase in economic growth by 0.01% point.
- It is cleared that from the above analysis in the short run, the parameter of error correction is equal to (-0.161) and significant at (1%). In addition, it has a negative sign. This increases the accuracy and validity of the equilibrium relationship in the long run and signifies that the error correction mechanism is present in the model, and this means that any error in the system will be corrected after (6.25) years.

The findings, in the long run, are as follow:

- The estimated equation of real GDP growth shows that the results of the long-run relationship between the dependent variable GRGDP and the other regress. As expected, the electric power consumption variable has the expected positive sign. That means, electric power consumption has a positive and statistically significant effect on economic growth in the long run, the relationship between them in terms of elasticity remains strong i.e. a 1% increase in electric power consumption leads to a respective economic growth increase of .29%. The estimated coefficient is highly significant in the case of electric power consumption.
- The above results show that the real total investment also has a positive and statistically significant effect on economic growth in the long run with an expected sign as per economic theory. For example, a 1% increase in real total investment leads to a respective economic growth increase of 0.1%

7- Policy Implications and Recommendations

In an attempt to improve its growth performance, there is no other alternative for economic growth than to generate more power for Sudan. However, a question may be raised as to whether electricity consumption could boost economic growth alone; the answer is simply no. Because electricity consumption is just one of the influencing factors. Along with the generation of more power, the government should ensure a business-friendly environment to encourage local and overseas investors to invest more in the country. Only, in that case, more electricity will lead to increased economic activities otherwise it would be costly. In this regard, the government may take policy action to increase power generation as well as attract local and foreign investors to invest in the energy and other sectors.

As mentioned earlier, the findings of this study emphasize that the consumption of electricity as a prerequisite of achieving higher economic growth for Sudan. Therefore, high priority should be placed not only on power generation but also on the

issues of appropriate electricity distribution and management system in the short-run and medium-term policies of the government to take the country to middle-income status.

The development of renewable energy sources and other alternatives for electricity generation besides the generation of hydroelectricity may change the power industry in Sudan. Renewable energy technology has an enormous potential to solve the electricity problem in Sudan. The energy which could be provided by the sun (solar energy) is much greater than the current electricity demand. The wind, waves, and tides have a large potential as well. It is to be understood that renewable energy may be one of the vital sources of future electricity supply besides the traditional energy sources.

As investment positively affects GDP growth and electricity consumption affects investment, the Central Bank of Sudan may undertake appropriate monetary policy to provide loans at cheaper rates for that purpose. The enhancement of capitalization towards small investors at cheaper cost helps in expanding existing business and generates new business activities. As well, that means creating more employment opportunities, increase purchasing power. So, investment is considered as a leading indicator of economic activity, prosperity and hence economic growth.

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"تأثير استهلاك الطاقة الكهربائية على النمو الاقتصادي في السودان: دراسة تجريبية (1990–2017)"

ملخص الدراسة

في العقود القليلة الماضية أعار الاقتصاديون انتباهاً كبيراً لتأثير استهلاك الكهرباء والاستثمار على النمو الاقتصادي على المستويين النظري التطبيقي معاً. هدف هذا البحث هو دراسة تأثير استهلاك الكهرباء على النمو الاقتصادي في السودان. جمعت بيانات السلاسل الزمنية لتغطي الفترة (1990_2017). تم أخذ بيانات استهلاك الكهرباء من الهيئة القومية للكهرباء في السودان. وتم جمع بيانات الناتج المحلي الإجمالي الحقيقي GDP (والذي استخدم للإشارة الى النمو الاقتصادي) والاستثمار الاجمالي الحقيقي من بنك السودان المركزي والجهاز المركزي للإحصاء. استخدم البحث المنهج الوصفي ومنهج الاقتصاد القياسي التطبيقي باستخدام نموذج الانحدار الذاتي للتباطؤ الموزع ARDL ومعامل تصحيح الخطأ EC_{T-1}لدراسة تأثير استهلاك الكهرباء والاستثمار كمتغيرات تفسيرية على النمو الاقتصادي كمتغير تابع. وتم استخدام اختبار جذور الوحدة لقياس استقرار النموذج, واختبار الباوند تم استخدامه لاختبار العلاقة التكاملية المشتركة في المدى الطويل. أظهرت النتائج من استخدام اختبار الباوند وجود توازن طويل الأجل بين المتغيرات. وأشارت نتائج التحليل طويل الأجل أن استهلاك الكهرباء واجمالي الاستثمار له تأثير إيجابي على النمو الاقتصادي كما هو متوقع كعلامة للنظرية الاقتصادية. و قد كان تاثير استهلاك الكهرباء و الاستثمار علي النمو الاقتصادي في الاجل الطويل اعلي مما هو في الاجل القصير. وتم تقدير تصحيح الخطأ (ECt–1)تقريباً ب (0.161–) مما يعني أن النظام سوف يعود الى حالة التوازن في حوالي 6 سنوات و3 شهور بعد صدمة. عموماً وبشكل اجمالي، وجد هذا البحث برهاناً لدعم الافتراض القائل إن زيادة في استهلاك الكهرباء والاستثمار على مدى الزمن في السودان سيؤدي الى زيادة في نمو الاقتصادي. وهذا يوحي بأن الزيادة في استهلاك الكهرباء تزيد النمو الاقتصادي. وجدت الدراسة أيضاً أن الزيادة في الاستثمار تزيد النمو الاقتصادي. وكانت التوصيات الرئيسة التي يمكن استخلاصها من البحث هي: أولاً يجب وضع المزيد من الخطط لتنشيط استخدام مصادر الطاقة المتجددة (الشمس، الرياح، .الخ) بجانب ان توليد الكهرباء المائية كتقنية متجددة للطاقة لها مردود ضخم محتمل لحل مشكلة الكهرباء في السودان. ثانياً يجب على الحكومة التأكيد من البيئة الصديقة للأعمال التجارية لتشجيع المستثمرين المحليين والأجانب للاستثمار أكثر من أجل تحقيق تلك السياسات كما يجب العمل على زيادة انتاج الطاقة وذلك لجذب المستثمرين المحليين والأجانب للاستثمار في الطاقة والقطاعات الأخرى.ثالثا, يؤثر الاستثمار إيجابا على نمو الناتج المحلي الإجمالي ويؤثر استهلاك الكهرباء على الاستثمار لذلك يمكن لبنك السودان المركزي اتخاذ الإجراءات المالية المناسبة لمنح القروض ذات أسعار فائدة أرخص في قطاع المصارف لدعم الاستثمار.