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ENERGY SECTOR DEVELOPMENT AND MANUFACTURING OUTPUT IN NIGERIA

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Abstract: This study assessed the relationships between various energy sources and manufacturing output with a view to providing information on efficient energy-mix option for enhancing manufacturing output production in Nigeria. Annual data were sourced from World Development Indicators, Central Bank of Nigeria Statistical Bulletins, National Bureau of Statistics, and Power Holding Company of Nigeria and analyzed using Autoregressive Distributed Lag (ARDL) technique. The results showed that hydroelectricity ($t = 10.27$, $P < 0.05$) and gas ($t = 2.21$, $P < 0.05$) have positive and statistically significant long run relationships with manufacturing output in Nigeria, while coal ($t = 1.97$, $P > 0.05$), although has a positive relationship with manufacturing output, is statistically significant at 10% level. However, the short run results reported positive and significant relationships between the contemporaneous values of hydroelectricity ($t=4.08$, $P<0.05$), coal ($t=2.12$, $P<0.05$), gas ($t=2.27$, $P<0.05$) and manufacturing output in Nigeria but the previous year value of hydroelectricity ($t= -3.14$, $P<0.05$) has a significant negative relationship with manufacturing output. Therefore, the study concluded that hydroelectricity, gas and coal are the major energy sources supporting manufacturing output production in Nigeria and recommended that Nigerian manufacturing firms should make use of them as their main energy input.

Keywords: Energy-mix, manufacturing, output, ARDL

1. INTRODUCTION

The importance of energy in economic activity, especially in manufacturing and industrial sector production as well as economic growth has been amply demonstrated and emphasized starting from the pioneering workof Kraft and Kraft (1978). However, Nigeria is facing energy shortage, constraining its economic activity, most especially its manufacturing sector production.

At present, Nigeria's energy need has grown more than the estimated figures of between 10,000 MW and 15,000MW, given a yearly increase in population and level of economic activity in the country. For instance, the current energy need of Nigeria has been put at 41,333 MW while the actual energy supply has been oscillating between 3,000 MW and 6,000 MW. However, existing power stations across the country have a wide gap between their installed capacity and their actual generation capacity(Manufacturers Association of Nigeria(MAN), 2005/2006; Adenikinju, 2009; Energy Commission of Nigeria, 2010; Central Bank of Nigeria (CBN), 2013; Eniayo, 2018).

The attendant manufacturing sector reflection of this state of affairs in the energy sector in Nigeria is low manufacturing sector capacity utilization and hence the sluggish output growth of the sector (see Figure 1). Therefore, given the inadequacy of hydroelectric power supply to the economy emanating from the wide gap between its installed capacity and the actual generation capacity which hampers manufacturing production in Nigeria, there is need to investigate the effects of other various sources of energy on manufacturing sector production in Nigeria with a view to adopting an appropriate energy-mix option to promote the manufacturing sector production, an approach that has not been adequately adopted by previous studies. Review of empirical literatures revealed that most of the earlier studies focused mainly on hydroelectricity and its relationship with manufacturing sector production, even though the defect of relying majorly on it is self-evident from the analyzed wide gap between its installed capacity and generation capacity, which often leads to constricted energy supply to the sector. For instance, the studies of Olayemi (2012); Mojeckwu and Iwuji (2012); Ologundudu (2014); Osobase *et al.* (2014); Haider (2015); Yakubu *et al.* (2015); Akiri, Apochi and Maria (2015); and Ismaila and Salahuddin (2016) were based mainly on hydroelectricity and its relationship with manufacturing sector production. The only few studies such, as Obange, Nelson and Siringi (2013); Edame and Okoi (2015); Wangere (2015); and Rahaman, Shahari and Noman (2015) which examined the relationship between alternative (disaggregated) energy sources and manufacturing output were mainly based outside Nigeria and were based on lesser degree of disaggregation. However, it has been arguedthat, examining the nexus between the components of energy and economic growth, of which manufacturing sector output is part, allows the advantage of comparing the strengths of causal relationship by energy types (Olofin, Olayeni and Abogan, 2014). Also, the submission of Yang (2000) is that using disaggregate energy consumption provides an avenue to determine the extent by which countries depend on different types of energy. That is why using aggregate energy has been criticized on the grounds that it does not allow for evaluation of substitution effect of energy with other economic variables, such as the effects of gas or petrol on manufacturing output or industrial output; or the effects of diesel or petrol on agricultural output (Olofin, Olayeni and Abogan, 2014; Yang, 2000).

Hence, this study favours the above position, that exploring the benefits of components of energy on manufacturing sector output will go a long way in identifying the channels and extent through which each energy source influences manufacturing sector output in Nigeria and thus provide an appropriate or efficient energy-mix option for optimum energy generation and utilization by the manufacturing sector. More so, some of the earlier studies (Stern, 1993; Akinlo,2009; Edame and Okoi ,2015and Akiri, Apochi and Maria, 2015) used small sample size and employed bivariate analysis thereby creating room for the possibility of generating loss in power and danger of omitted variable bias and this study tries to minimize these shortcomings by employing a multivariate, country and output specific modeling approach over a long period of time.

2. LITERATURE REVIEW

For the past two centuries, there has been an unprecedented global upsurge in population and level of economic activities the world over. This has literally translated to rapid increase in energy demand and improvement in energy efficiency brought about by technological development in an attempt to meet consumption demand of energy (Smill, 2000). Following this, the relationship between energy use and economic growth, of which manufacturing output is a substantial part, has witnessed increasing attention in recent times and there has been a growing body of literature dealing with energy issue.

The apparent move to form the link connecting energy supply and consumption with manufacturing and industrial sector production as well as gross domestic product (GDP) has remained a heated debate in the literature. Economists are yet to reach a final conclusion on the type as well as the nature of the causal relationship that connects energy consumption with output. For instance, Sari, Ewing and Soytas (2007) examined the relationship between disaggregate energy consumption and industrial output, as well as employment, in the United States by employing the autoregressive distributed lag (ARDL) approach and with such variables as coal, fossil fuels, hydroelectricity, solar power, wind energy, natural gas' wood and waste for period 2001:1-2005:6. The results of the study revealed that real output and employment were long run forcing variables for nearly all measures of disaggregate energy consumption.

In an adjunct study, Renata, Manuela and Rasa (2014) undertook a study of the impact of energy prices on industrial sector development of Lithuania, specifically to reveale if increasing prices of gas and electricity retarded development of industrial sector of Lithuanian economy by using the method of correlation analysis over time span of 2000 – 2011. The results of the analysis revealedthat an increase of energy prices had notsignificant malign impact on industrial sector development and exports.More so, in a panel study of 23,000 energy-intensive Chinese firms from 1990 to 2004 to examine how firms responded to severe power shortages in the early 2000s, Karen, Erin and Qiong (2014) found that, in response to electricity scarcity, Chinese firms re-optimized among inputs of production by substituting materials for energy (both electric and non-electric sources). While outsourcing could be costly, Chinese firms were able to avoid substantial productivity losses by doing so. As a result of the increase in electricity scarcity from 1999 onwards, they found that unit production costs increased by 8 per cent. Measuring economic cost of electricity shortage on sectorial GDP of Pakistan, and using ordinary least square (OLS) for the period of 1991-2013, Mohammed (2015) demonstrated that electricity shortage was inversely linked with industrial sector output, and recommended a wide-ranging energy policy options for sustainable industrial sector growth.Dongsuk (2016) examined the contribution of multifaceted or composite energy efficiency to the growth of final outputs of the industrial sector, using the two-stage method of Malmquist efficiency analysis (MEA) and the linear regression of panel data from 154 Korean industries from 2010 to 2012. The results found that, composite efficiency and changes in the production factors had positive impacts on industrial sector productivity. In particular, relative efficiency had a positive influence on productivity, but technical efficiency didnot have a significant impact. The study, in the light of these findings, recommended that industries might voluntarily make efforts to improve their use of energy resources, but they also needed to invest in energy technologies and develop efficient production structures, with the help of public policies.

The interdependent relationship between sectorial productivity and disaggregate energy consumption in Malaysia was carried out by Rahaman, Shahari and Noman (2016), using Markov Switching approach with such energy variables as electricity, coal and gas over the period of 1971 to 2011. The study found that industrial and manufacturing productivity of regime-1 and regime-2 responded with disaggregate energy consumption, that is, electricity, coal and gas were all positively and significantly related with manufacturing productivity. The study, however, recommended efficient energy consumption and the use of green technology to minimize energy consumption and environmental pollution. The study carried out by Wangare (2015) on disaggregate energy production and growth of manufacturing sector in Kenya used time series data regession over the period of 1979 to 2009 to establish the fact that energy generally positively related to annual growth of manufacturing with renewable energy,excluding hydroelectricity, making the greatest contribution to the growth of the manufacturing industry. The study, on the basis of the above findings, recommended efforts in increasing and coordinating research in renewable energy, and supporting the Government's initiatives to scale up generation of renewable energy.

In Nigeria**,** the study of Simon-Oke (2008) on electricity crisis and manufacturing productivity in Nigeria from 1980 to 2008, using the ordinary least squares multiple regression to analyze the time series data over the period, showed that electricity generation and supply impacted negatively on manufacturing productivity growth in Nigeria. The study suggested intensification of independent power projects as proposed by states in Nigeria to boost electricity supply.

In an attempt to establish the impact of power supply on the manufacturing sector performance in Nigeria, Mojeckwu and Iwuji (2012) employed time series data from 1981 to 2009. The multiple regression analysis indicated that power supply had a positive significant impact on capacity utilization of energy while interest rate and inflation rate had inverse relationship with capacity utilization. The study recommended that the power reform of privatizing the sector be fully undertaken and a single leading and inflation rate be adequately sustained.

In a contrary study, Olayemi (2012), employing the instrumentality of ordinary least shares (OLS) multiple regression to analyze the time series data between 1980 and 2008 in order to x-ray the relationship between electricity crisis and manufacturing productivity in Nigeria, found that electricity generation and supply under the reviewed period impacted negatively on the manufacturing productivity growth, owing to unnecessary government spending on non-economic and unproductive sectors. The study, therefore, suggested, among others, a reversal of the ugly trend of poor electricity supply through the initiative of independent power projects.

In a technical study of the empirical analysis of productivity of Nigeria Power Sector, Iwuamadi and Dike (2012) used the Malmquist index with Cobb-Douglas Stochastic Production Frontier function to analyze the productivity change in Nigeria's power sector generation data between 1970 and 2010. The results of the study showed that the year 2005 national electric power reform act produced slight technical improvement. It was, therefore, expected that this work might assist the policy makers and regulators to come up with better framework for the full realization of the noble goals envisaged in this act. The study, however, noted that, the shocks from the Nigerian electricity crisis despite several palliative measures by the government had created some wedges in the national socio-economic wheel of development and that unfortunately, the major method by the government to beef up productivity by commissioning new power stations merely solved the problem in the short run, and that the technical issues that put out the older plants would no sooner than later affect the new ones and thus they would also go down.

In a succeeding study, Nwajinka, Akekere and Purumaziba (2013) investigated the impact of electric energy supply on the industrial sector productivity in Nigeria from 1970 to 2010, using a multiple regression analysis. The results, after ensuring stationarity for the variables used through ADF test, showed that national energy supply had no significant impact on industrial productivity in Nigeria. The study recommended sustained sanitization and funding of the power sector and the encouragement of private partnership in the power sector in the hope of enhancing the growth of the economy.

Also, employing a multiple regression model to examine the effect of electricity supply on economic development and likewise the effect of electricity supply on industrial development over the period 1970-2010, Nwankwo and Njogo (2013) established that electricity, gross fixed capital formation, industrial production variables and population were positively signed, implying that they positively related to GDP per capital. Identically, the industrial production expenditure model showed that electricity generation expenditure, gross fixed capital formation and population were positively related to per capital GDP. It was in this light that the study recommended that issues relating to electricity generation and industrial development should be given priority particularly in the budget scheme in the form of substantial amount being allocated to the electricity sector in order to fix the state of electricity permanently in a good shape.

The study of Osabose and Bakare (2014) empirically investigated the relationship between electricity generation/supply and the manufacturing sector performance in Nigeria, using time-series data from 1975 to 2011 and using such variables as index of manufacturing production, electricity generation, government capital expenditure, inflation rate, exchange rate, and capacity utilization. The techniques of correlation analysis, Granger causality test and Johanson co-integration test were employed for the empirical analysis. The correlation results revealed a weak positive relationship between electricity generation and index of manufacturing production in Nigeria, while the Granger causality test indicated a unidirectional causality from electricity generation to index of manufacturing sector production. In view of the findings, the study observed that irregular electricity supply had been a major handicap to manufacturing sector output growth, and therefore recommended that the power sector, through guided private sector initiative, be given more attention for the growth of the nation's economy.

In another collegiate study, Ologundudu (2014) empirically tested the influence of electricity supply on industrial and economic development in Nigeria from 1972 to 2010, employing the Granger causality test and the ARDL bounds testing approach to co-integration proposed by Peserom *et al.* (2001) in order to determine the stationary characteristics of variables used in the regression. The Granger causality results showed a feedback causal relationship between GDP per capital and electricity supply. A unidirectional causal relationship was observed between capital employed and GDP per capital without a feedback effect running from capital to GDP per capital.

In an another attempt to examine the impact of electricity supply on the productivity of manufacturing industries in Nigeria between 1980 and 2012, Akiri, Apochi and Maria (2015) suggested, among other things, a reversal of the ugly trend of poor electricity supply by ensuring that funds allocated for the development of electricity subsector are judiciously utilized, and to ensure that the ongoing deregulation of the power sector be sustained so as to inject competitiveness in the energy industry to finally situate Nigeria within the realm of energy giants.

In another corroborating study,Ogunjobi (2015) revealed that in the long run, there was significant positive nexus between industrial growth and electricity generation and consumption, labour employment, and foreign exchange rates, while there was an inverse relationship between industrial growth and capital input (proxied by gross capital formation).

Employing the technique of autoregressive distributed lag (ARDL) to provide evidence of long run and short run relationship, as well as causality between manufacturing productivity and electricity consumption in Nigeria, Ismail and Sallahuddin (2016) discovered that the bounds test provided a proof of co-integration among electricity consumption, manufacturing productivity, and capital. The work of Edame and Okoi (2015) showed that both electricity and petrol had significant positive relationship with manufacturing sector performance (output), while gas was negatively related with manufacturing output in Nigeria.

In an another effort to empirically evaluate the impacts of the reforms on electricity supply growth in Nigeria, Edet and Boniface (2016), basing their study on elementary supply theory and covering period 1981 to 2015, adopted the contemporary econometric approach of error correction mechanism (ECM) over the time series generated for the time frame of the study. The results revealed that there existed a unique long-run equilibrium relationship between the variables of the model and so, co-integration and normalized coefficients were reported. The study of Ugwoke, Dike and Elekwa (2016) examined the impact of electricity supply on industrial output in Nigeria from 1980 to 2014, using a double-log linear formulation. The results of the study showed that electricity supply and trade openness had a negative impact on industrial production in Nigeria and that the coefficients of the variables were statistically insignificant.

3. MODEL SPECIFICATION

The study made use of framework based on the conventional neo-classical one-sector aggregate production technology by Ghali and El-Sakka (2004), Stern and Cleveland (2004) where energy, labour, and capital were taken as separate inputs. Thus, this study specified its model implicitly, as follows:

$$MAN_t = f(HEL_t, COL_t, GAS_t, DSL_t, PET_t, GCE_t, CAP_t) \quad (1)$$

The explicit version of (3.5) is expressed as:

$$MAN_t = \theta_0 + \theta_1 HEL_t + \theta_2 COL_t + \theta_3 GAS_t + \theta_4 DSL_t + \theta_5 PET_t + \theta_6 GCE_t + \theta_7 CAP_t + \varepsilon_t \quad (2)$$

where θ_0 = intercept;

θ_i (= 1, 2….7) the slopes, i.e. parameters of the set of explanatory variables of the model,

e_i = stochastic error term "*t*" = time trend, MAN_t = Manufacturing output, expressed as the aggregate manufacturing output in the Nigerian economy, HEL_t = Hydroelectricity supply, COL_t = Coal supply, GAS_t = Gas supply, DSL_t = Diesel supply, PET_t = Petrol supply, GCE_t = Government capital expenditure and*CAPt*=Capital formation.

Equation ((3.6) can be written in ARDL form as follows:

$$\Delta InMAN_t = \theta_0 + \sum_{i=1}^{n}\theta_1\Delta InMAN_{t-i} + \sum_{i=0}^{n}\theta_2\Delta InHEL_{t-i} + \sum_{i=0}^{n}\theta_3\Delta InCOL_{t-i} + \sum_{i=0}^{n}\theta_4\Delta InGAS_{t-i} + \sum_{i=0}^{n}\theta_5\Delta InDSL_{t-i} + \sum_{i=0}^{n}\theta_6\Delta InPET_{t-i} + \sum_{i=0}^{n}\theta_7\Delta InGCE_{t-i} + \sum_{i=0}^{n}\theta_8\Delta InCAP_{t-i} + \psi_1 InMAN_{t-1} + \psi_2 InHEL_{t-1} + \psi_3 InCOL_{t-1} + \psi_4 InGAS_{t-1} + \psi_5 InDSL_{t-1} + \psi_6 InPET_{t-1} + \psi_7 InGCE_{t-1} + \psi_8 InCAP_{t-1} + \varepsilon_t$$

MAN_t = Manufacturing
output, HEL_t = the hydroelectricity supply, DSL_t = diesel supply; PET_t =
petrol supply; GCE_t = government capital expenditure;
Cap_t = capital formation; t is time perikod; ϕ_i and ψ_i are parameters.

Autoregressive Distributed Lags (ARDL) analytical technique is employed because of its optimality properties, manifested in its analytical compatibility, logical and structural tidiness. The advantage of ARDL over other estimation techniques is that ARDL estimation yields consistent estimates of the parameters when the variables are all *I(0)* or are all *I(1)*, or are an admixture of both I(0) and *I(1)* and a long run relationship exists (Pesaran and Shin, 1998). This means that the ARDL approach avoids the pre-testing problems associated with standard cointegration, which requires that the variables be already classified as *I(0)* or (1) (Pesaran, Shin and Smith, 2001).

3.1. Variables, Definition and Measurement

In this study, the following variables were used:

1. **Manufacturing Output (Production) (MAN_t) :** This is a proxy for the annual aggregate level of output in the manufacturing sector of Nigerian economy, expressed (measured) in constant term (billons of naira).
2. **Hydroelectricity Supply (HEL_t) :** This represents the annual aggregate amount of hydroelectricity power supply by Power Holding Company of Nigeria (PHCN), formerly Nigerian Electricity Power Authority (NEPA), expressed (measured) in megawatts (MW).
3. **Coal ($COLs_t$):** This is another form of energy that is used in the manufacturing sector, usually expressed in millions/billions cubic tons per day/year.

4. **Natural Gas (GAS_t):** This is another form of energy used in the manufacturing sector as well as in the residential and commercial avenues, usually expressed in thousands/millions of cubic feet (or litres) per day or year.
5. **Diesel (DSL_t):** This is another form of energy, also known as automated gas oil(AGO) used for both manufacturing and residential purposes, expressed in thousands/millions of litres per day/per year.
6. **Petroleum (PET_t):** This is another medium of energy to the manufacturing sector as well as for residential and commercial purposes, measured in thousands/millions of litres per day/year.
7. **Government Capital Expenditure (GCE_t):** This captures the annual government expenditure on infrastructural development to boost manufacturing sector production in the economy, usually in billions of naira, given the weak private sector capacity to provide basic infrastructural facilities like good roads, hospitals, electricity and education.
8. **Capital Formation (CAP_t):** This represents the annual gross fixed capital formation in the economy, expressed or measured in billions of naira. This variable is employed in this model because without capital, manufacturing production cannot take place. As blood is to human body is capital to business.

3.2. Sources of Data

The data sets for this study are annual time series of the relevant macroeconomic variables from 1981 to 2018. They were sourced from Central Bank of Nigeria (CBN) Statistical Bulletin, National Bureau of Statistics (NBS), World Development Indicator (WDI), and Power Holding Company of Nigeria (PHCN), National Control Centre (NCC), Oshogbo, Osun State.

4. ANALYSIS AND RESULTS

4.1. Unit Root Test

The results of the unit root tests involving constant only are depicted in Table 1. The results explicitly showed that both the Augmented Dickey-Fuller and Phillips-Perron tests exhibited high level of consistency in their findings; and therefore, there were no controversies as regards the stationarity properties of the time series data. Specifically, all the time series were integrated of order one *I(1),* except petrol *(PET)* which was stationary at levels *I(0)* under the Phillips-Perron test. These results readily showed that most of the time series data did not exhibit mean reverting behaviour after shocks in their level form until they were differenced.

Table 1
Unit Root Test (Constant only)

	Augmented Dickey Fuller			*Phillips-Perron*		
Variable	*Level*	*1st Difference*	*Remark*	*Level*	*1st Difference*	*Remark*
lnMAN	0.6971	-5.0911*	I(1)	0.9734	-5.0906*	I(1)
lnHEL	0.6715	-7.0608*	I(1)	2.6817	-7.0413*	I(1)
lnCOL	-2.2294	-6.4500*	I(1)	-2.2011	-10.0620*	I(1)
lnGAS	-0.4823	-6.9618*	I(1)	-0.4099	-6.9618*	I(1)
InDSL	-0.2062	-9.3403*	I(1)	-1.2817	-12.6774*	I(1)
InPET	-2.1250	-5.2853*	I(1)	-3.0821**		I(0)
InGCE	-1.2743	-5.8335*	I(1)	-1.2619	-5.8663*	I(1)
InCAP	-0.3704	-3.2594**	I(1)	-1.3542	-4.5006*	I(1)

Note: * ** *** denotes 1%, 5% and 10% levels of significance respectively
The Mackinnon critical values for the ADF and the PP tests with constant for 1%, 5%, and 10% levels of significance are -3.632900, -2.948404, and -2.612874 respectively.
Source: Author's Computation

4.2. Co-integration Test Estimates

Johansen cointegration test was carried out as presented in Table 2. Findings showed that the variables in the model were cointegrated. This conclusion was reached as the Trace statistic and maximum Eigen values were higher than the critical values at 5% level of significance, suggesting five (5) cointegrating relationships (equations). This lead to the rejection of null hypothesis of no cointegration among the variables.

Table 2
Johansen Cointegration Test for All Variables in the Model

No. of CE(s)	*Eigenvalue*	*Trace Statistic*	*0.05 C-value*	*Max-Eigen Value*	*0.05 C-Value*
None *	0.994426	474.8281	159.5297	171.258	52.36261
At most 1 *	0.978735	303.5702	125.6154	127.0735	46.23142
At most 2 *	0.851700	176.4966	95.75366	62.98116	40.07757
At most 3 *	0.790088	113.5154	69.81889	51.51528	33.87687
At most 4 *	0.688159	62.00016	47.85613	38.45359	27.58434
At most 5	0.303040	23.54657	29.79707	11.91392	21.13162
At most 6	0.198429	11.63266	15.49471	7.298986	14.2646
At most 7 *	0.123066	4.333670	3.841466	4.33367	3.841466

Trace and Maximum Eigenvalue indicate 5 cointegrating eqn(s) at the 0.05 level
Trace test and Maximum-Eigen Value indicates 5 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
Source: Author's Computation

4.3. Long Run Estimates of the Relationships between Energy Sources and Manufacturing Output in Nigeria

Table 3 shows the results of the long run model of the relationships between energy sources and manufacturing output in Nigeria. The coefficient of the long run estimates of hydroelectricity (*InHEL*), as presented in Table 3, showed a positive and significant relationship between hydroelectricity supply and manufacturing output *(InMAN)* in Nigeria. This implies that an increase in hydroelectricity supply will lead to an increase in manufacturing output. Specifically, a one percent increase in hydroelectricity supply will result in 1.1 percent increase in manufacturing output. This result is in agreement with the findings of Sari *et al.* (2007), Ziramba (2009), Obange *et al.* (2013), Osabase *et al.* (2014),), Akiri *et al.* (2015), Edame *et al.* (2015),Wanyare (2015), Yakubu *et al.* (2015), Ismail and Sallahuddin (2016) and Rahaman *et al.* (2016), which all indicated significant positive relationship between electricity and manufacturing output. However, few exemptions of the studies of Simon-Oke (2012) and Olayemi (2012) have been observed reporting a negative nexus between electricity supply and manufacturing output. Thus, most manufacturing firms show a high taste for hydroelectricity in Nigeria, being very cheap even though it is not adequate and regular in supply. The results also showed that coal supply *(InCOL)* had a positive relationship with manufacturing output *(InMAN)*, but it was marginally significant at 10%. It showed that a one percent change in coal supply would lead to 0.06% change in manufacturing output. This result agrees with that of the study of Rahaman *et al.* (2016). The marginal coefficient significance of coal could be attributed to its low scale exploitation and utilization in Nigeria.The relationship between gas supply *(InGAS)* and manufacturing output *(InMAN)* also assumed a positive dimension as the coefficient of the long run estimates gave a positive significant relationship between gas supply and manufacturing output (*InGAS* = 0.1028, P < 0,05), showing that one percent change in gas supply would result in approximately 1.0 percent change in manufacturing output. Rahaman *et al.* (2016) obtained similar results in their study of energy-output relation. The positive and significant relationship between gas supply and manufacturing output is a confirmation of the fact that gas is a popular energy input in Nigerian manufacturing sector. This can be attributed to its relatively cheaper price and availability when compared with other energy sources, such as diesel or petrol.

More so, the findings indicated that diesel supply *(InDSL)* had a positive but insignificant relationship with manufacturing output (*InDSL* = 0.1135, P > 0.05), indicating that manufacturing output changes by 0.11 percent with any one percent change in diesel supply. However, this result is at variance with that reported by Agbede (2018), which established an inverse relationship between diesel supply and industrial output in Nigeria. The fact is that, although diesel supply colligated positively with manufacturing output in this study, its relatively higher price tends to drive manufacturing and industrial firms away from its usage, thus accounting for its insignificance, and, at times, negative relationship with output. Diesel has been the most deregulated energy source right from time in Nigeria.The results further revealed that the coefficient of petrol supply *(InPET)* was negatively signed and insignificant (*InPET* = -0.23, P > 0.05), showing that there is an inverse relation between petrol supply and manufacturing output in Nigeria. The implication of these findings is that, a one percent increase in petrol supply decreases manufacturing output by approximately 0.23 percent. These results, however, contradict the findings of Edame and Okoi (2015) and Agbede (2018) that reported a positive relationship. The negative relationship found in this study underscores the fact that petrol is not an efficient and popular energy input in Nigerian manufacturing sector production, perhaps because of the systemic mechanical composition of the activity of the manufacturing sector that does not require petrol as a major energy input. More so, its frequent price changes and, at times, constricted availability may combine to speak against its employment in the sector. This is the view earlier held by Adenikinju (2003) that firms incur huge cost on the provision of expensive backup to minimize the effect of unexpected power outage with the resultant negative impact on cost competitiveness of the manufacturing and industrial sector. In other words, the upward pressure of petrol price leads to a rise in the cost of production of manufacturing firms and invariably reduces the output growth of the manufacturing sector. This view is also supported by Rodriguez (2008) that, energy resources price increase often lowers the level of firms' aggregate output. All the above boils down to the fact that manufacturing firms seek more of hydro energy to avoid high cost of fossil fuels even though there are indications of their enormous potential within the country.

The nexus between government capital expenditure *(InGCE)* and manufacturing output (*InMAN*) was negative with a significant coefficient at 10%. This implies that one percent increase in government capital expenditure in the long run will reduce manufacturing output by 0.08 percent. These results do not go in line with a priori expectation and the findings of Osabese *et al.* (2014) which affirmed a positive relationship and held the view that if more funds are allocated to infrastructural development, the growth of manufacturing output will be enhanced. However, the findings of Simo-Oke (2012) and Akiri *et al.* (2012) agreed with the results of this study, establishing a negative relationship between government capital expenditure and manufacturing output in Nigeria. One possible explanation for this negative relationship may be grounded on the fact that, budgetary allocations for various capital projects in Nigeria from each successive government have not been properly channeled into the target projects, but more often than not diverted into private wealth, serving as drain on the national economy and hence its negative effect on manufacturing output.Finally, the relationship between capital formation and manufacturing output was positive but not significant (*CAP* = 0.043, P > 0.05).

The long run positive results here conformed to the findings of Ismail and Sallahuddin (2015) and Theophilus *et al.* (2016) which supported the positive nexus. This shows the importance of capital in manufacturing production in Nigeria.

4.4. ARDL Short Run Relationships between Energy Sources and Manufacturing Output in Nigeria

Here, a parsimonious model was estimated for the short run relationships between energy sources and manufacturing output in Nigeria. As contained in the table 3, the short run estimates showed that the current year value of hydroelectricity supply (*InHEL)* had positive significant relationship with manufacturing output (*InMAN*) in the short run (*InHEL* = 0.43, $P < 0.05$) which was also in line with the long run results, implying that one percent increase in hydroelectricity supply in the current year would lead to approximately 0.43 percent increase in manufacturing output. However, the short run coefficient of a one-period lag in hydroelectricity supply was negative and statistically significant at 1%, connoting that a one percent increase in previous year of hydroelectricity supply would reduce manufacturing output in the previous year by approximately 0.38%.The current year value of coal *(InCOL*) had a positive and significant relationship with manufacturing output (*InCOL* = 0.46, $P < 0.05$), conforming with the long run estimates. It showed that one percent increase in current year supply of coal lead to approximately 0. 46% increase in current year manufacturing output. In the same vein, the short run coefficient of gas *(InGAS)* was positive and significant at 5% just as was the case in the long run, portraying the fact that gas had a positive relationship with manufacturing output. A one percent current period increase in gas supply would lead to approximately 0.09% percent in increase in manufacturing output in the short run.Furthermore, in the short run, the coefficient of diesel *(InDSL)* was negative and statistically insignificant, contracting the long run position of positive relationships. Petrol supply *(InPET)* behaved in an identical manner in both short run and long run periods, establishing a negative coefficient that was also statistically insignificant. It showed that one percent increase in petrol supply would account for approximately 0.2% decrease in manufacturing output in the current year, which was also approximately the same coefficient value of the long run estimates (0.2). Thus, both the short run and the long run held that petrol is not a popular energy input in manufacturing production in Nigeria.Concerning the control variables, government capital expenditure *(InGCE)* had a short run positive coefficient (0.07) which contrasted with its long run negative coefficient value (-0.83) but with the same statistical significance at 5%, showing that in the short run manufacturing output increased by approximately 0.07% with one percent increase in government capital expenditure. Capital formation *(InCAP)*, on the other hand, maintained the same position in both short run and long run, except in the statistical significance of the short run estimate standing at 5% as against the statistical non-significance of the long run coefficient estimate peaking above 10%. The short run reports that, a one percent increase in capital *(InCAP)* woud lead to approximately 0.15% increase in manufacturing output in the current year.

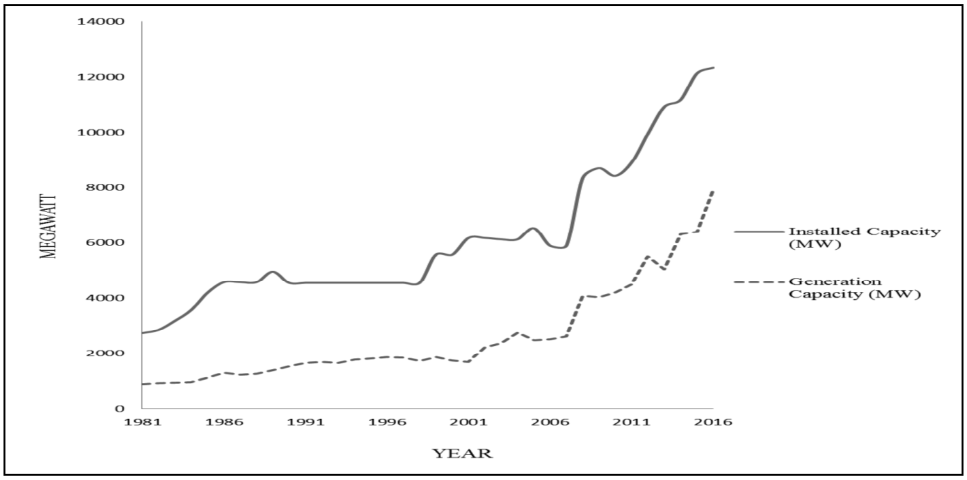
The coefficient of the error correction term (ECM), which indicates the speed of adjustment of a model to equilibrium in case of any shock, was negative and highly statistically significant at 1% level, further confirming the existence of a long run relationship among the variables of the model. The ECM coefficient value of -0.8339 showed that approximately 83% of any disequilibrium behaviour between manufacturing output and the explanatory variables would be corrected for within the period of one year. The F-statistic value of 17.71 which was significant at 1% level showed the overall significance of the model and the joint explanatory power of the model in accounting for variation in manufacturing output. Similarly, the R-squared ($R^{2)}$ and the adjusted –squared (R^2) were high. The short run estimates, as contained in Table 5.6, indicated that the coefficient of the R-squared was

Table 3
Relationships between Energy Sources and Manufacturing Output in Nigeria

Dependent Variable: Manufacturing Output (INMAN)
Selected Model: ARDL (1, 2, 0, 0, 1, 0, 1, 1)

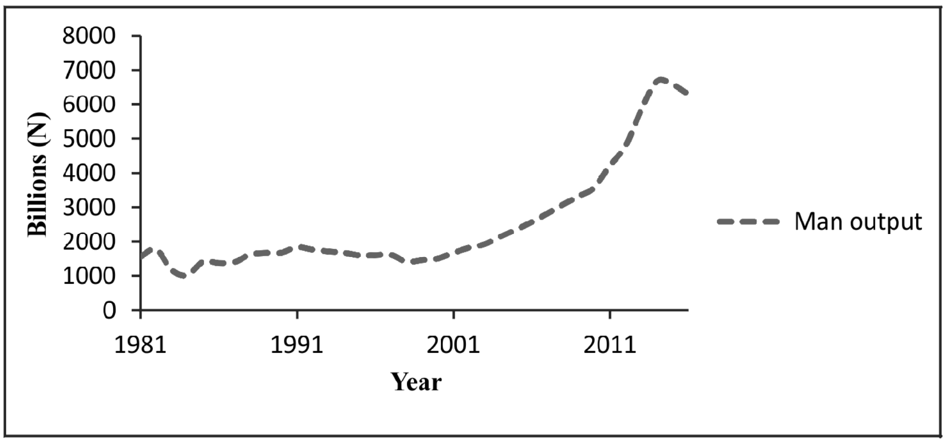
Variables	*Coefficients*	*t-statistic*
Long Run analysis		
Constant	-0.9395	-8.5318*
INHEL	1.1326	10.2686*
INCOL	0.0548	1.9710***
INGAS	0.1028	2.2094**
INDSL	0.1135	1.2421
INPET	-0.2299	-0.9295
INGCE	-0.0829	-2.6433**
INCAP	0.0429	0.5747
Short Run analysis		
D(INHEL)	0.4268	4.0753*
D(INHEL(-1)	-0.3769	-3.1422*
D(INCOL)	0.0457	2.1223**
D(INGAS)	0.0857	2.2651**
D(INDSL)	-0.004	-0.1192
D(INPET)	-0.1917	-0.8887
D(INGCE)	0.0701	2.1431**
D(INCAP)	0.1454	2.7185**
ECM(-1)	-0.8339	-8.7181*
R-Squared	0.79	
Adjusted R-squared	0.75	
F-statistic	17.71*	
Durbin-Watson Stat	2.45	

Figure 1: Installed capacity and actual generation capacity of hydroelectricity in Nigeria (1981 to 2018)



Source: Author's computation using data from PHCN (2019)

Figure 2: Manufacturing sector output in Nigeria (1981 to 2018)



Source: Author's computation using data from CBN (2019)

approximately 79% which implied that the various energy sources included in the model explained about 79% variation in the manufacturing output. This is an indication that the regression equation (line) had a good fit, telling us that less than 21% of the variation the dependent variable (manufacturing output) was explained by the variables not included in the model. The adjusted R-squared, which was the adjusted multiple coefficient of determination was equally high, being 75%. The Durbin-Watson statistical value of 2.45 indicated that there was no problem of serial correlation among the variables of the model.

5. CONCLUSION AND POLICY RECOMMENDATION

The results from both the long run and short run ARDL models showed that hydroelectricity, coal and gas are positively related with manufacturing output, giving the impression that if these energy sources are more well developed and supplied, manufacturing production will be enhanced. The negative relationship between the other energy sources (diesel and petrol) and manufacturing output suggests their not being popularly used in the manufacturing sector of Nigerian economy either on account of their higher prices (as the two constitute the most highly deregulated energy sources) or because of their little relevance in the systemic mechanical composition of the activity of the manufacturing firms which does not require them as their major energy inputs.More so, findings from the study indicated that the energy sources altogether Granger caused manufacturing output. These findings imply that the government, firms and individuals should strive hard to improve the energy situation in the country through maximum development of these energy sources, especially coal which has been neglected overtime. Also emanating from the study is the potential positive role of renewable energy sources, such as solar, wind, biomass and nuclear energy on manufacturing output production. Thus their inclusion in the energy mix option will greatly increase energy supply not only for manufacturing sector consumption (production) but also for domestic uses. It is therefore recommended that government and firms should intensify their efforts at developing these new and cheaper renewable energy sources in Nigeria in order to meet the manufacturing energy need for higher manufacturing production and even for domestic uses by setting ambitious targets and high incentives for potential investors in renewable energy to optimize manufacturing production.

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