

1 **Original Research Article**

2 **ESTIMATING NATURAL GAS DEMAND**
3 **ELASTICITIES IN NIGERIA**

4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

Comment [P1]: Check journal for amt for heading wheather all capital is suggested or not

8 **ABSTRACT**

9 *This study estimated natural gas demand elasticities in Nigeria. The objective of the study was to*
10 *examine the responsiveness of natural gas demand to changes in price of natural gas, income*
11 *and prices of other energy products. The study adopted the bound testing approach to*
12 *cointegration within the framework of autoregressive distributed lag (ARDL) to estimate annual*
13 *time series data over a period of 33 years (1984 – 2016). It was discovered that elasticity of nat-*
14 *ural gas demand is relatively price inelastic in both short and long run; cross-price elasticity of*
15 *gas demand revealed that automotive gas oil (diesel) and liquefied petroleum gas (LPG) are*
16 *substitute energy products for natural gas in Nigeria; while the estimate of income elasticity of*
17 *demand is not statistically significant in the short and long run.*

18 **Keywords:** Natural gas demand, elasticity, power supply, gas price, ARDL, bound test, Nigeria

19 **Word Count:**130
20
21
22

Comment [P2]: It is an abbreviatiob

Comment [P3]: Write abbreviations for repeated words so that the paper length reduces considerably

1. INTRODUCTION

Natural gas is an important energy resource that is crucial to the growth and development of every economy. Due to its growing demand, the issue of natural gas demand elasticities has been in the front line in recent times. Numerous studies have been conducted by researchers on natural gas demand and several methodologies have been adopted to estimate natural gas demand elasticities in different countries of the world. For example, Khan and Ahmed [1] estimated natural gas demand in Pakistan and adopted the Johansen (1988) and Johansen and Juselius (1990) cointegration techniques to estimate annual time series data from 1972-2007. The income elasticity of natural gas demand suggests that natural gas is a luxury good in Pakistan.

Erdogdu [2] examined natural gas demand in Turkey using the ARIMA model, Partial Adjustment model (PAM) and OLS estimation techniques. The study found that price elasticity of natural gas demand is perfectly inelastic, while, natural gas is a luxury good in the long run; and there is no relationship between natural gas demand and price and income in the short run. Similarly, Göncü *et al.* [3] proposed a framework to forecast future daily residential and commercial natural gas consumption in Turkey. The study employed ordinary least square (OLS) technique to estimate a formulated demand model. The study concluded that natural gas prices in Turkey have little or no explanatory power on changes in natural gas demand because the price of gas is highly regulated.

Arora [4] estimated price elasticities of natural gas demand and supply in the United States for three different time periods comprising weekly, monthly and quarterly time series data from 1993 to 2013. The study adopted vector autoregression (VAR) model in estimating price elasticity of natural gas demand in the US. The result of the monthly and quarterly analysis shows that natural gas demand is price inelastic in both short and long run. However, when shale gas was added to the model, the quantity of natural gas demand became less responsive to price in the short and long run.

Wadud *et al.* [5] conducted a study on modeling and forecasting natural gas demand in Bangladesh using the partial adjustment model (PAM) and OLS estimation techniques to estimate annual time series data spanning 1981-2008. The study revealed that natural gas in Bangladesh is a necessity good in the short run, while it is a luxury good in the long run. However, the result of price elasticity of natural gas demand is statistically insignificant in both short and long run.

Comment [P4]: Take this to abbreviations

53 Burke and Yang [6] examined the elasticities of natural gas demand in 44 countries using three
54 estimators to estimate panel data, which are: between estimator, pooled OLS and fixed-effects
55 estimators. The result of the analysis shows that natural gas demand in the 44 countries is price
56 inelastic for pooled OLS and fixed-effect estimator, while price elasticity of demand is perfectly
57 inelastic in the between estimator in the long run. Further, between estimators and pooled OLS
58 revealed that natural gas is a luxury good in these countries, while the outcome of the field-effect
59 estimator suggests that natural gas is a necessity good.

Comment [P5]: abbreviations

60 Some studies have also been conducted on natural gas demand elasticities in Africa. For exam-
61 ple, the study conducted by Ackah [7] on the determinants of natural gas demand in Ghana, ex-
62 amined the effect of economic and non-economic factors affecting demand using the underlying
63 energy demand trend (UEDT) within the framework of structural time series model (STSM) to
64 estimate annual time series data spanning 1989 – 2009. The study discovered that residential gas
65 demand in Ghana is price inelastic in the short run, while it is perfectly inelastic in the long run.
66 Income elasticity of demand reveals that natural gas is a necessity good in the short run, but a
67 luxury good in the long run. In the same vein, Abdullahi [8] modeled petroleum products [LPG
68 and others] demand in Nigeria using the UEDT within the framework of STSM and ARDL mod-
69 el. The outcome of the study revealed that LPG demand is price inelastic, while the result of in-
70 come elasticity of demand shows that natural gas is a necessity good in Nigeria in the long run.
71 However, the price of LPG and income do not have significant relationships with LPG demand
72 in Nigeria in the short run.

Comment [P6]: Abbreviation

Comment [P7]: abbreviations

Comment [P8]:

73 Despite adopting several methodologies for estimating natural gas demand elasticities, none of
74 the studies has adopted bound testing approach to cointegration within the framework of ARDL
75 in estimating natural gas demand elasticities in Nigeria. In other words, there is no study that has
76 adopted the ARDL approach to estimate natural gas demand elasticities in Nigeria. This study
77 aims to fill this gap that exists in literature. Thus, the objective of this study, is to estimate the
78 short-run and long-run price, income and cross price elasticities of natural gas demand in Nige-
79 ria. The outcome of this study will serve as a framework for policy formulation for inducing in-
80 vestments in gas utilization projects.

Comment [P9]: why this is highlighted

81 The remaining part of this study is divided into four sections. Section 2 examines natural gas uti-
82 lization and the Nigerian economy, while section 3 contains the theoretical framework and meth-
83 odology adopted in this study. Presentation and discussion of results are carried out in section 4,
84 while the conclusion and recommendations are expressed in section 5.

85 2. NATURAL GAS UTILIZATION AND THE NIGERIAN ECONOMY

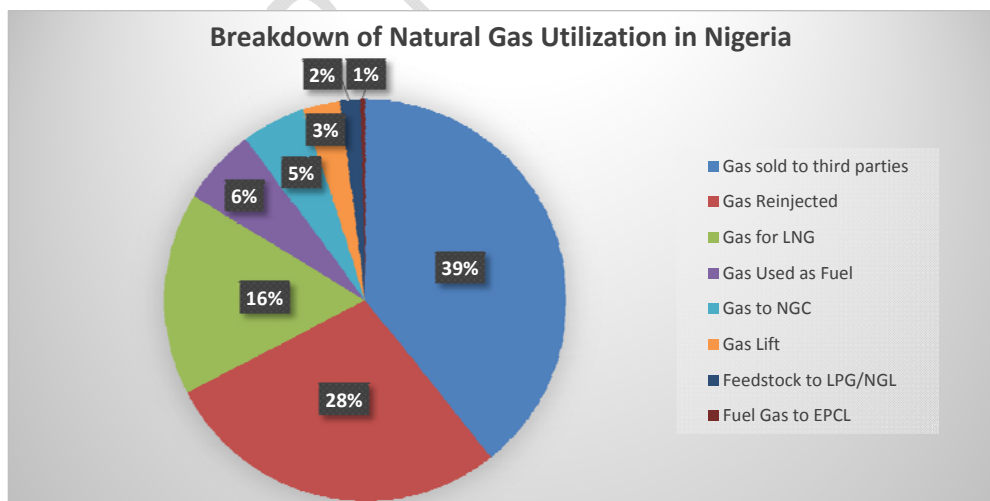
Comment [P10]: sub heading why capital

86 2.1 Natural Gas Utilization in Nigeria

Comment [P11]: introduce under the same or desperate heading introduction

87 Nigeria is estimated to have the largest proven natural gas reserves in Africa and the 9th largest in
88 the world; having an estimated proven gas reserve of 5,627bcm, which is 37% of the total gas
89 reserves in Africa [9]. There are several gas utilization projects in Nigeria. These projects utilize
90 natural gas for power generation, process operations, as feedstock and for export purposes.

91 The country exports pipeline gas to some West African countries (Benin Republic, Togo and
92 Ghana) through the West Africa Gas Pipeline (WAGP) and also exports LNG to Asia Pacific,
93 North America (Mexico), South and Central America, Europe and the Middle East [10]. The total
94 export of LNG from Nigeria in 2015 was 25.3bcm, which represents 7.59 percent of the total
95 LNG traded globally; however, it increased to 27.76bcm in 2017 [10]. This rank the country as
96 the 4th largest exporter of LNG in the world. The breakdown of natural gas demand by each of
97 the gas utilization projects is shown in figure 1.

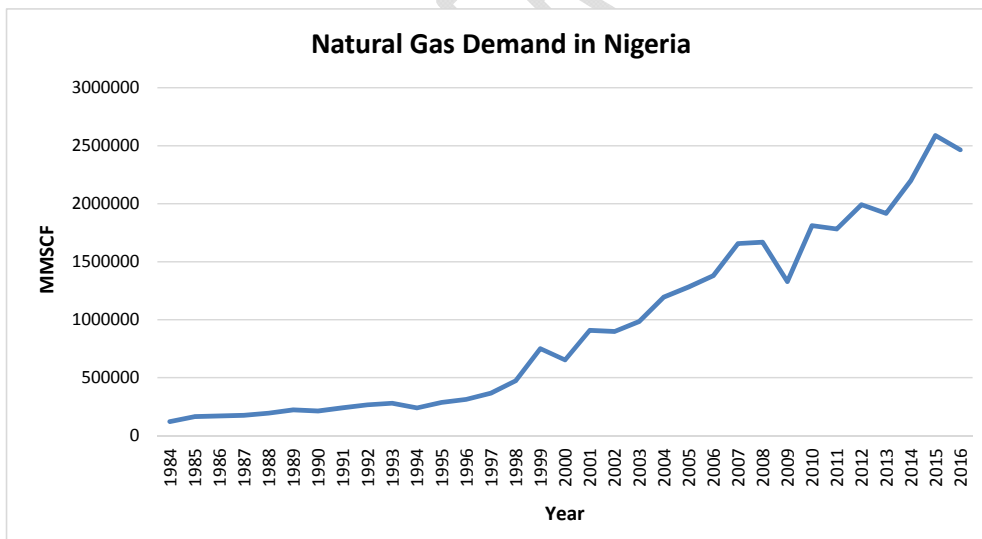


98 Figure 1 Natural Gas Utilization in Nigeria in 2015, NNPC Annual Statistical Bulletin, 2016.
99

100 Figure 1 shows that 39 percent of total gas utilized in 2015 was allocated to third parties who uti-
 101 lize gas for industrial heating and as feedstock for producing fertilizers, petrochemicals, etc.,
 102 which makes it the largest consumer of natural gas in Nigeria, while natural gas reinjected had
 103 28 percent of total gas utilized, making it the second largest consumer. However, fuel gas to
 104 EPCL and feedstock to LPG/NGL had 1 percent and 2 percent of total gas utilized respectively
 105 thereby making them the lowest consumers of Nigeria’s natural gas.

106 The trend of natural gas utilization from 1984 – 2016 is shown in figure 2. The total natural gas
 107 utilized in 1984 was 121.41bscf. Gas utilization experienced slow growth up until 1999 when it
 108 increased to 751Bcf largely as a result of the commencement of operations of Nigeria’s first
 109 LNG project – NLNG. Growth became much faster after this as the export project, which be-
 110 came and remains the largest gas utilization centre in Nigeria, added additional LNG trains. Gas
 111 demand was also boosted in the domestic market through the implementation of the Nigerian
 112 Gas Master Plan (NGMP) which increased demand from about 300MMcf/d to the current
 113 1.2bcf/d.

Comment [P12]: Y axis in the fig below units are to be written

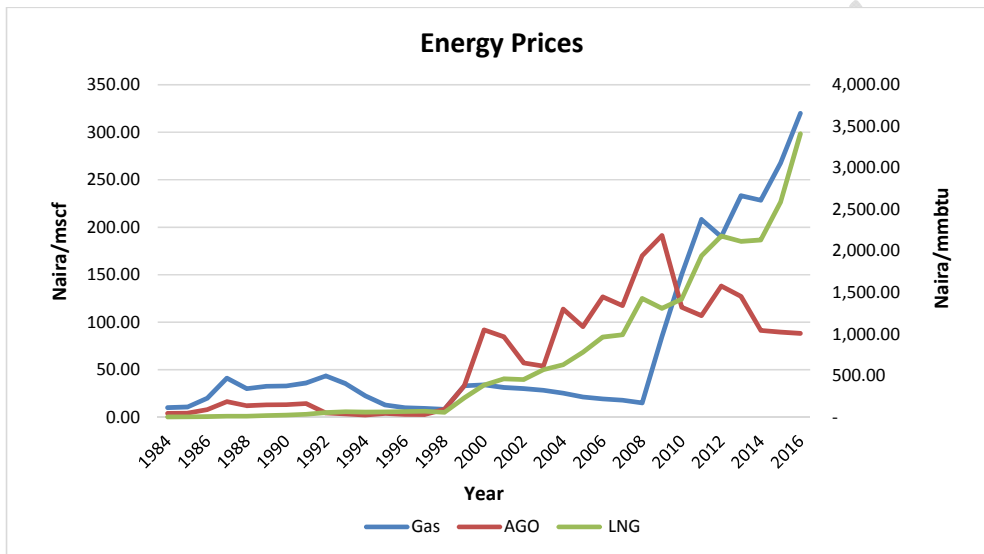


114 Figure 2 Natural Gas Demand in Nigeria 1984 – 2016, NNPC Annual Statistical Bulletin, 2016.
 115

116 **2.2 Energy Prices**

117 Gas utilization in Nigeria is in two folds: gas for domestic consumption – domestic market; and
 118 gas for export – international market. These two markets have different pricing frameworks

119 which is based on different factors. The Nigerian government through the National Domestic
 120 Gas Supply and Pricing Policy (2008) has grouped the country's gas demand sectors into three:
 121 the strategic power sector, the strategic industrial sector and the commercial/wholesale sector.
 122 This study adopted the price of natural gas in the strategic power sector, which is regulated. The
 123 trend of natural gas price is presented in figure 3.



Comment [P13]: Mscf long form and take to abbreviations

Comment [P14]:

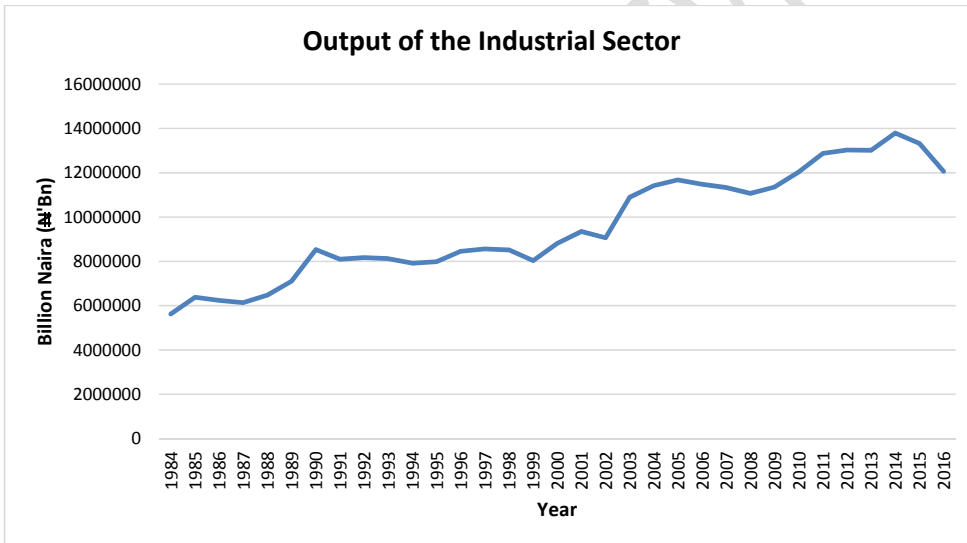
124
 125 **Figure 3 Energy Prices 1984 – 2016, NNPC (2016); World Bank (2016); BP (2018)**

126 Domestic natural gas price maintained a fairly stable trend from 1984 to 2008. This is attributa-
 127 ble to the adoption a fixed price regime for natural gas. The national gas pricing policy of 2008,
 128 however, led to the rise in gas price in 2009 until it reached a high of ₦208.22/mscf in 2011, be-
 129 fore rising to ₦233.19/mscf in 2013 [11]. Gas prices increased in the following year and has
 130 since maintained an upward movement.

131 In order to estimate the cross elasticity of natural gas demand, this study adopted the price of au-
 132 tomated gas oil (AGO) and LNG prices. These are presented in figure 4. The price of AGO wit-
 133 nessed a steady trend from 1984 to 1998 before experiencing an increase in 1999.AGO price
 134 however, experienced an undulating trend until it reached a peak in 2009 before declining [12].
 135 The international price of LNG maintained a steady pace from 1984 to 1999 before increasing in
 136 year 2000 [10]. It has since been experiencing an upward trend.

137 **2.3 Overview of Nigeria’s Industrial Sector**

138 In spite of abundant natural gas resources, output of the industrial sector of the Nigerian econo-
139 my that utilizes Nigeria’s natural gas, has been low. This is shown in figure 4. The output has an
140 undulating trend from 1984 to 2016. The output in 1984 was ₦5,621.18bn; it increased to
141 ₦8,531.59bn in 1990 as a result of the International Monetary Fund (IMF) loan obtained by Ni-
142 geria in 1985, before declining in 1991 [13]. The output trend was fairly stable from 1992 till
143 2002 before rising to ₦11,674.74bn in 2005. Output experienced a slight decline in 2006 till
144 2008 before experiencing an upward movement in 2009 till it reached an all-time peak at
145 ₦13,791.24bn in 2014 due to the positive effect of the National gas pricing policy of 2008.
146 However, output fell the following year and declined further in 2016.



147 Figure 4 Output of the Industrial Sector of Nigeria 1984 – 2016, Ministry of Finance, 2016.
148

149 **3. THEORETICAL FRAMEWORK AND MODEL SPECIFICATION**

150 **3.1 Theoretical Framework**

151 The theory adopted in this study is the theory of consumer choice (optimal choice of consumer).
152 This theory states that consumer problem is a utility maximization problem and as such, the con-
153 sumer puts together the theory of preferences and the budget set and also assumes differentiable
154 preferences and convex budget set [14].

$$Max U = U(g) \text{ ----- (1)}$$

$$155 \text{ Subject to } B = \{g \text{ in } G; \bar{p}.g \leq \bar{Y}\} \text{ ----- (2)}$$

156 In equations 1 and 2 above, g stands for natural gas, p represents price of natural gas and Y denotes real output of the manufacturing sector of the economy. It is worthy of note that p and Y are fixed.

159 Solving the consumers' choice problem using calculus of optimization-method of Lagrange multipliers yields the individual demand functions which are also called Marshallian demand functions. In the Marshallian demand function below, GD denotes natural gas demand, GP stands for gas price, $PLNG$ stands for price of LNG, DP stands for diesel price, $ELECT$ stands for electricity consumption per capita (which serves as a control variable), while Y is the same as explained above.

$$165 \text{ } GD = g(GP, PLNG, Y, DP, ELECT) \text{ where } GD = (g_1, g_2, g_3, \dots, g_n) \text{ ----- (3)}$$

166 In order to estimate the equation above, a mathematical form is needed, therefore this study adopts log-linear demand equation as adopted by Erdogdu [2] and Medlock [15] in setting up the econometric model. This equation, Medlock [15] posits, is often used in modeling energy [natural gas] demand in empirical studies. Equation 3 can then be written as:

$$\ln GD_t = \beta_1 + \beta_2 \ln GP_t + \beta_3 \ln PLNG_t + \beta_4 \ln Y_t + \beta_5 \ln DP_t + \beta_6 \ln ELECT_t + \varepsilon_t \text{ -----(4)}$$

170 The log of natural gas demand is equal to the explanatory variables, also expressed in \log . ε_t is the error term, while β_i are the parameters to be estimated; these parameters represent elasticities.

172 According to the standard demand theory, there is a negative relationship between price and quantity demanded of every product. This means that an increase in the price of natural gas will lead to a fall in quantity demanded ($\beta_2 < 0$). Conversely, an increase in real output of the manufacturing sector will lead to a rise in demand for natural gas. Therefore, there is a positive relationship between real output and natural gas demand ($\beta_4 > 0$). LNG is one of the many gas utilization projects in Nigeria. By implication, its availability largely depends on the availability of natural gas. It is expected that an increase in the international price of LNG will lead to an increase in Nigeria's natural gas demand ($\beta_3 > 0$). AGO is a substitute good for natural gas when an increase

180 in its price leads to an increase in the demand for natural gas ($\beta_5 > 0$). On the other hand, AGO is
181 regarded as a complementary good to natural gas if an increase in its price leads to a decrease in
182 the demand for natural gas ($\beta_5 < 0$). Since natural gas is used in generating over 80 percent of Ni-
183 geria's electricity, it is expected that an increase in electricity consumption per capita will lead to
184 an increase in natural gas demand ($\beta_6 > 0$).

185 3.2 Model Specification

186 This study adopts the Auto-Regressive Distributed Lag (ARDL) bound testing approach to
187 cointegration developed by Pesaran *et al.* [16] and adopted by Shahbaz *et al.* [17], Marbuah [18],
188 Belloumi [19] and Onolemhemhen *et al.* [20]. The choice of this methodology is influenced by
189 three factors: First, this approach has better small sample properties [21]. In other words, it is the
190 best approach for analyzing model with a small sample size. Secondly, it can be used to analyze
191 any model irrespective of the order of integration of the series of data [18]. In other words, no
192 pre-testing is required as it can be applied to any series with either I (0) or I (1) qualities. Third-
193 ly, the true or unbiased estimate of the long-run model is obtained by applying the ARDL tech-
194 nique. In this approach, dynamic models are estimated by adding the lag of the dependent varia-
195 ble as well as the lagged and contemporaneous values of the independent variables [18].

Comment [P15]: Why this is yellow check the previous reports of reviewer suggestions

196 3.2.1 Formulation of the Estimated Model

197 The error correction model is specified as:

$$\Delta \ln GD_t = \beta_1 + \beta_2 \Delta \ln GP_t + \beta_3 \Delta \ln PLNG_t + \beta_4 \Delta \ln Y_t + \beta_5 \Delta \ln DP_t + \beta_6 \Delta \ln ELECT_t + EC_{t-1} + \varepsilon_t \quad (5)$$

198 In this case, the parameters $\beta_2, \beta_3, \beta_4, \beta_5$ and β_6 would be interpreted as short-run effects, while
199 Δ represents the difference operator. The deviation from equilibrium in the previous period, that
200 is, the error, is responsible for the change in natural gas consumption in the next period. This de-
201 viation, as denoted by EC_{t-1} , is the error that is to be adjusted in the next period [21].

202 Model 6 is therefore specified as an ARDL model by "including lags of the dependent variable
203 and of the potentially non-stationary explanatory variables on the right-hand side" [21]. Further-
204 more, replace the error correction term, EC_{t-1} in equation (5) by its components from the long

205 run relationship in equation (7) instead of adopting a two-step process to estimate the model.
 206 This is expressed as:

$$EC_{t-1} = \varepsilon_{t-1} = (\ln GD_{t-1} - \beta_1 - \beta_2 \ln GP_{t-1} - \beta_3 \ln PLNG_{t-1} - \beta_4 \ln Y_{t-1} - \beta_5 \ln DP_{t-1} - \beta_6 \ln ELECT_{t-1}) \dots \dots \dots (6)$$

207 And this yields the unrestricted error correction model (UECM) with the form:

$$\begin{aligned} \Delta \ln GD_t = & \beta_1^* + \beta_{1A}^t + \sum_{i=1}^p \beta_{2i} \Delta \ln GP_{t-i} + \sum_{j=0}^q \beta_{3j} \Delta \ln PLNG_{t-j} + \sum_{k=0}^r \beta_{4k} \Delta \ln Y_{t-k} \\ & + \sum_{l=0}^s \beta_5 \Delta \ln DP_{t-l} + \sum_{m=0}^t \beta_6 \Delta \ln ELECT_{t-m} + \beta_7^* \ln GD_{t-1} + \beta_8^* \ln GP_{t-1} \\ & + \beta_9^* \ln PLNG_{t-1} + \beta_{10}^* \ln Y_{t-1} + \beta_{11}^* \ln DP_{t-1} + \beta_{12}^* \ln ELECT_{t-1} + \varepsilon_t \dots \dots (7) \end{aligned}$$

208 The UECM above is estimated as part of the ARDL framework in equation (4). $\beta_2, \beta_3, \beta_4, \beta_5$ and
 209 β_6 are parameters representing the short-run effects while $\beta_7^*, \beta_8^*, \beta_9^*, \beta_{10}^*, \beta_{11}^*$, and β_{12}^* denote
 210 the long-run elasticities.

211 3.2.2 Estimation Method for the Model

212 In equation 7 above, the variables GD, GP, PLNG, Y, DP and ELECT would each be subjected
 213 to unit root test. This is to investigate if the order of integration of the series are integrated of order
 214 2, that is, if it has I(2) properties. Estimation of the model is done and the test of hypothesis
 215 that $H_0: \beta_7^* = \beta_8^* = \beta_9^* = \beta_{10}^* = \beta_{11}^* = \beta_{12}^* = 0$ which is the null hypothesis, and/or $H_1:$
 216 $\beta_7^* \neq \beta_8^* \neq \beta_9^* \neq \beta_{10}^* \neq \beta_{11}^* \neq \beta_{12}^* \neq 0$ which is the alternative hypothesis is carried out using a
 217 standard F-statistic, although this F-test has a non-standard distribution. The critical value that
 218 enables a bounds test to be conducted is provided by Pesaran *et al.* [16].

219 The decision rule, therefore, is that if the calculated F falls below the lower bound at some sig-
 220 nificance level, the null hypothesis is accepted and this means that there is no cointegration
 221 among the variables. On the other hand, if the F statistic exceeds the upper critical bound at some
 222 significance level, we reject the null hypothesis. This means that there is cointegration among the
 223 variables. Lastly, if the F statistic falls between the upper and lower bounds, the result is incon-

224 clusive and the knowledge of the order of integration of the variables involved would be the
225 resolution of this uncertainty.

226 3.3 Description of Data

227 Empirical analysis is carried out on time series data covering the period 1984 – 2016 (33 years).
228 This period was adopted because of availability of data. Time series data on natural gas con-
229 sumption in Nigeria was sourced from [11]. It is measured in million standard cubic feet
230 (mmscf). The source of time series data on real output (Y) of the industrial sector is [13]. The
231 data on real output (Y) of the manufacturing sector was extracted from GDP at 2010 constant
232 basic prices and is expressed in million Naira (₦ Million).

233 The time series data on gas price was obtained from [11]. It was specified in United States' dol-
234 lars. However, for the purpose of this study, the price was converted to the Nigerian Naira (₦),
235 and was further deflated by Nigeria's Consumer Price Index (CPI) (2010 = 100) in order to get
236 the real price of gas. The same process was applied to price of diesel and the international price
237 of LNG in order to obtain their real prices in Naira terms; though the time series data on LNG
238 price was obtained by taking the average price of LNG in two markets (Japan and Germany) be-
239 fore its conversion to the Nigerian Naira. The time series data of price of diesel was sourced
240 from [12], while the price of LNG was sourced from [10]. The price of AGO is measured in
241 ₦/litre while the LNG price is measured in ₦/mmbtu. Electricity consumption per capita was
242 obtained from [22] and is expressed in kWh.

243 4. DISCUSSION OF RESULTS

244 4.1 Unit Root Test

245 Augmented Dickey-Fuller (ADF) test was conducted to ascertain the order of integration of the
246 time series data. It was discovered after the test that none of the variables was integrated of order
247 2, and none of the variables adopted is stationary at level. In other words, all the variables have
248 unit roots. However, all the variables became stationary at first (1st) difference. This is shown in
249 table 1.

250
251
252
253
254

255 **Table 1 Unit Root Test**

Variable	Level	1 st Difference
GD	-2.193931	-7.725809***
GP	-1.404493	-4.460467***
PLNG	-2.734929	-4.265754**
Y	-2.564917	-5.230566***
DP	-2.166937	-3.983713**
ELECT	-2.412257	-6.463673***

256 Note: ***, denote rejection of the null hypothesis at 1%, 5% and 10% level of significance

257 **, denote acceptance of null hypothesis at 1% level of significance but rejection at 5% and 10% level

258 **4.2 Results of Cointegration Test**

259 Results of the bounds test are presented in table 2. The cointegration test was carried out on gas
 260 demand and all the independent variables. The F-statistic of the cointegration test was 4.45. This
 261 result is higher than the upper critical bounds at only 10 percent and 5 percent levels of signifi-
 262 cance, and this indicates that there is cointegration among the variables at both 10 percent and 5
 263 percent levels of significance; hence, there is a long run relationship between gas demand, gas
 264 price, price of LNG, real output of the industrial sector, price of AGO and electricity consump-
 265 tion per capita. However, the value of the bounds test falls in between the lower and upper
 266 bounds at 2.5 percent and 1 percent significance levels.

267 **Table 2 Bounds Test for Cointegration**

Variable	F-Statistics	Critical Bounds			
		5%		10%	
		I(0)	I(1)	I(0)	I(1)
$F_{gd}(gd gp, plng, y, dp, elect)$	4.45**	3.12	4.25	2.75	3.79

268 NOTE: ***, denote rejection of null hypothesis at 1%, 5% and 10% level of significance, while ** denote rejec-
269 tion of hypothesis at 5% and 10% level of significance270 **4.3 Estimated Short-Run and Long-Run Results**

271 The error correction term has the correct sign (negative) and is statistically significant as shown
 272 in table 3. The error correction term of -1.295843 is similar to the error correction term obtained
 273 by Narayan and Smyth [23]. Narayan and Smyth [23] posit that this value “implies that instead
 274 of monotonically converging to the equilibrium path directly, the error correction process fluctu-
 275 ates around the long-run value in a dampening manner.” The economy returns rapidly to equilib-
 276 rium once the process is complete. Additionally, with an R^2 of 0.801913, the results show that 80
 277 percent variation in natural gas demand in Nigeria is explained by the independent variables. The
 278 residuals of the short-run models were subjected to a diagnostic test and it shows that they are
 279 well behaved with respect to serial correlation, heteroskedasticity, normality as well as constant

280 variances. Lastly, the parameters were subjected to stability tests using the cumulative sum of
281 recursive residuals (CUSUM) and cumulative sum of squares of residuals (CUSUMQ) devel-
282 oped by Brown *et al.* (1975). In the estimated models, CUSUM and CUSUMQ tests indicate that
283 the parameter stability falls within the 5% critical bounds; hence, they are stable. This is shown
284 in table 5.

285 The short run estimate is shown in table 3, while the long run estimate is presented in table 4.
286 The estimate of the short run price elasticity of demand is -0.15 and is statistically significant.
287 This means that, in the short run, natural gas demand in Nigeria is relatively price inelastic. In
288 other words, a 1 percent increase in the price of gas will lead to 0.15 percent decrease in the
289 quantity demanded of natural gas and vice versa, *ceteris paribus*. In the long run, the estimate of
290 price elasticity of natural gas demand is -0.089 and is statistically significant. This means that
291 elasticity of natural gas demand in Nigeria in the long run is also relatively price inelastic just
292 like the short run; but as we approach the long run, price elasticity shrinks from 0.15 percent to
293 0.09 percent. Therefore, if there is a 1 percent increase in the price of natural gas in the long run,
294 the quantity demanded for gas would fall by 0.09 percent and vice versa, *ceteris paribus*. The
295 short run and long run estimates follow our apriori expectation.

296 The price elasticity of demand of the international price of LNG in the short run is 0.311573.
297 This estimate is positive and is statistically significant. The estimate indicates that a 1 percent
298 increase in the international price of LNG will lead to a 0.31 percent increase in Nigeria's natural
299 gas demand and vice versa, *ceteris paribus*. In the same vein, the long run estimate of the inter-
300 national price of LNG is 0.101994, which is positive and is statistically significant. The result
301 reveals that a 1 percent increase in the international price of LNG will lead to an increase of 0.10
302 percent in Nigeria's natural gas demand in the long run and vice versa, *ceteris paribus*. This re-
303 sult follows our a-priori expectation.

304 The estimate of income elasticity of demand in the short-run and long-run are not statistically
305 significant.

306 The cross-price elasticity of demand of AGO in the short run is 0.101363. The elasticity obtained
307 is positive and is statistically significant. This means that, in the short run, AGO is a substitute
308 product for natural gas in Nigeria. Hence, a 1 percent increase in the price of AGO will lead to a

309 0.10 percent increase in demand for natural gas and vice versa, *ceteris paribus*. In the same vein,
 310 the long run estimate of price of AGO is 0.097945. This means that AGO is a substitute energy
 311 product for natural gas in Nigeria. Therefore, a 1 percent increase in the price of diesel will lead
 312 to a 0.09 percent increase in natural gas demand in Nigeria and vice versa, *ceteris paribus*.

313 Lastly, the short run estimate of electricity consumption per capita is positive and is statistically
 314 significant, while its long run estimate is not statistically significant. The short run estimate of
 315 0.471537 indicates that natural gas demand increases by 0.47 percent when there is a 1 percent
 316 increase in Nigeria's electricity consumption per capita and vice versa, *ceteris paribus*. This re-
 317 sult follows our a-priori expectation.

318 **Table 3** Error Correction Representation for the Selected ARDL Model ARDL (1, 0, 1, 0, 0,
 319 2) Selected based on Schwarz Criterion (SIC) 1984 – 2016

Explanatory Variables	Dependent Variable is GD
$\Delta GD (-1)$	-0.496123*** (-2.261794)
ΔGP	-0.149683*** (-4.293318)
$\Delta PLNG$	0.311573*** (5.562112)
ΔY	0.126850 (0.614177)
ΔDP	0.101363*** (3.341430)
$\Delta ELECT$	0.471537*** (3.900847)
ΔC	0.141812*** (8.706127)
$\Delta ECM(-1)$	-1.295843*** (-8.900937)

320 NOTE: ***, denote the rejection of null hypothesis at 1%, 5% and 10% level of significance
 321 The figures in brackets represent t-statistic

322
 323
 324
 325
 326
 327
 328
 329
 330

331 **Table 4 Estimated Long-Run Coefficients Using the ARDL Approach ARDL (1, 0, 1, 0, 0,**
 332 **2) Selected based on Schwarz Criterion (SIC) 1984 – 2016**

Explanatory Variables	Dependent Variable is GD
Constant	10.932110*** (4.517216)
LGP	-0.089228*** (-5.344379)
LPLNG	0.101994*** (2.423419)
LY	0.043753 (0.266551)
LDP	0.097945*** (5.944668)
LELECT	-0.116009 (-1.209397)

333 NOTE: ***, denote the rejection of null hypothesis at 1%, 5% and 10% level of significance
 334 The figures in brackets represent t-statistic

335 **Table 5 Regression Statistics and Diagnostic Tests**

R – Square	0.801913
Adjusted R – Square	0.754373
F – Statistic	16.86790 (0.000000)
Durbin – Watson Statistic	2.034899
Serial Correlation	0.697320 (0.5081)
Normality	1.254495 (0.534060)
Heteroscedasticity	0.842740 (0.5491)
CUSUM	Stable
CUSUMQ	Stable

Comment [P16]: Is the table formatting is as per journal

Comment [P17]:

336 5 CONCLUSION

337 The results of the analysis conducted in this study suggest that domestic gas price, price of AGO,
 338 international price of LNG and electricity consumption per capita are important determinants of
 339 Nigeria’s natural gas demand. Furthermore, the international price of LNG has a positive rela-
 340 tionship with Nigeria’s natural gas demand; hence, an increase in the international price of LNG
 341 will lead to an increase in natural gas demand. Secondly, the result of the cross elasticity of de-
 342 mand reveals that the demand for natural gas increases as a result of an increase in the price of
 343 AGO. In other words, AGO is a substitute energy product for natural gas in the Nigerian econo-
 344 my. Thirdly, an increase in Nigeria’s electricity consumption per capita leads to an increase in
 345 natural gas demand in the short run. Lastly, the elasticity of natural gas demand in Nigeria is rel-
 346 atively price inelastic. Thus, a fall in the price of natural gas will lead to an increase in the quan-

Comment [P18]: Conclude things in small paragraphs and include your mathematical formula in one conclusion. To give better clarity in the form of bullets.

347 tity demanded of natural gas by less than the percentage decrease in price. This study concludes
348 that natural gas price is a major determinant of the quantity demanded of natural gas in Nigeria.

349 This study therefore recommends that policy makers should adopt natural gas price as a tool for
350 increasing the quantity demanded of natural gas in Nigeria. Thus, there should be a downward
351 review of gas price in the national gas pricing framework. A downward review of gas price is
352 important, because, a lower domestic gas price will lead to an increase in quantity of natural gas
353 demanded by power plants, commercial centres and industries. Cheap and affordable gas would
354 reduce the cost of electricity generation; production of glass, steel, paper, etc.; and, production of
355 fertilizer, petrochemical, etc.

356 However, gas producers have argued that the current gas price is low and uneconomic. In es-
357 sence, it is difficult to make a reasonable profit from harnessing associated gas and selling same
358 at the prevailing market price. This is attributable to high cost of harnessing and converting asso-
359 ciated gas into usable gas. This claim is consistent with the law of supply. Therefore, in order to
360 ascertain the equilibrium gas price, further studies should be conducted to estimate natural gas
361 supply elasticities in Nigeria. The major limitation of this study is the inaccessibility of monthly
362 or quarterly time series data. This led to the adoption of annual time series data.

Comment [P19]: spelling

Comment [P20]: why this is highlighted in yellow

363 6 ACKNOWLEDGEMENT

364 My sincere appreciation goes to Professor Akin Iwayemi, Engr. Fisoye Delano, Dr. Lilian
365 Idiaghe, Mr. Banjo Onasanya, Mr. Oludele Folarin and Mr. Ayodeji Ladeinde for their immense
366 contributions towards the completion of this study.

367 **COMPETING INTERESTS DISCLAIMER:**

368 **Authors have declared that no competing interests exist. The products used for this re-**
369 **search are commonly and predominantly use products in our area of research and coun-**
370 **try. There is absolutely no conflict of interest between the authors and producers of the**
371 **products because we do not intend to use these products as an avenue for any litigation**
372 **but for the advancement of knowledge. Also, the research was not funded by the produc-**
373 **ing company rather it was funded by personal efforts of the authors.**

374 REFERENCES

375 [1] Khan MA, Ahmed U (2009); *Energy Demand in Pakistan: A Disaggregate Analysis*; Paki-
376 stan Institute of Development Economics Islamabad Pakistan 2009 MPRA Paper No. 15056,
377 posted 7. May 2009 00:11 UTC Munich Personal RePEc Archive. Available: [http://mpra.ub.uni-](http://mpra.ub.uni-muenchen.de/15056/)
378 [muenchen.de/15056/](http://mpra.ub.uni-muenchen.de/15056/). Accessed 21 January 2016.

- 379 [2] Erdogdu E (2009); *Natural Gas Demand in Turkey*; Energy Regulatory Authority, Republic
380 of Turkey. MPRA Paper No. 19091, posted 22. December 2009 06:04 UTC Available:
381 <http://mpra.ub.uni-muenchen.de/19091/>. Accessed 21 January 2016.
- 382 [3] Göncü A, Karahan MO, Kuzubaş TU (2013); *Forecasting Daily Residential Natural Gas*
383 *Consumption: A Dynamic Temperature Modelling Approach*; April 13 2013. Accessed 21 Janu-
384 ary 2016.
- 385 [4] Arora V (2014); *Estimates of the Price Elasticities of Natural Gas Supply and Demand in the*
386 *United States*; 6 March 2014 MPRA Paper No. 54232, posted 8. March 2014 14:44 UTC. Avail-
387 able: <http://mpra.ub.uni-muenchen.de/54232/>. Accessed 20 January 2016.
- 388 [5] Wadud Z, Dey HS, Kabir MA, et al. (2011); *Modeling and forecasting natural gas demand in*
389 *Bangladesh*; Energy Policy, 39 (11). 7372 - 7380. ISSN 0301-4215. Available:
390 <https://doi.org/10.1016/j.enpol.2011.08.066>. Accessed 22 September 2018.
- 391 [6] Burke PJ, Yang H (2016); *The price and income elasticities of natural gas demand: Interna-*
392 *tional evidence*; Arndt-Corden Department of Economics Crawford School of Public Policy,
393 ANU College of Asia and the Pacific. Working Paper No. 2016/14. Available:
394 <http://www.crawford.anu.edu.au/acde/publications/>. Accessed 22 September 2018.
- 395 [7] Ackah I (2014); *Determinants of Natural Gas Demand in Ghana*; UK MPRA Paper No.
396 59214 posted 15 October 2014 19:19 UTC. Available: <http://mpra.ub.uni-muenchen.de/59214/>.
397 Accessed 20 January 2016.
- 398 [8] Abdullahi AB (2014); *Modeling petroleum product demand in Nigeria using Structural Time*
399 *Series Model (STSM) approach*; International Journal of Energy Economics and Policy Vol. 4,
400 No. 3, 2014, pp.427-441 ISSN: 2146-4553. Available: www.econjournals.com. Accessed 3 July
401 2016
- 402 [9] Organization of the Petroleum Exporting Countries (2018), *OPEC Annual Statistical Bulletin*
403 *2018*, Organization of the Petroleum Exporting Countries. Available: <http://www.opec.org>
- 404 [10] BP (2018), *BP Statistical Review of World Energy June 2018*, BP. Available:
405 bp.com/statisticalreview
- 406 [11] Nigerian National Petroleum Corporation (2016), *2016 Annual Statistical Bulletin*, Nigerian
407 National Petroleum Corporation (NNPC). Available: nnpcgroup.com
- 408 [12] World Development Indicators (2016), *Pump Price for Diesel Fuel (US\$ per litre)*, World
409 Bank Data. Available:
410 [http://databank.worldbank.org/data/reports.aspx?source=2&series=EP.PMP.DESL.CD&country](http://databank.worldbank.org/data/reports.aspx?source=2&series=EP.PMP.DESL.CD&country=NGA)
411 [=NGA](http://databank.worldbank.org/data/reports.aspx?source=2&series=EP.PMP.DESL.CD&country=NGA)

412 [13] Ministry of Finance (2016), *2016 Statistical Bulletin: Real Sector Statistics*, Ministry of Fi-
413 nance.

Comment [P21]: page no

414 [14] Iwayemi A (2015); *Theory of Consumer Choice*; Topic 2, Lecture 1 2015, Centre for Petro-
415 leum, Energy Economics and Law, University of Ibadan, Ibadan, Nigeria.

Comment [P22]: lecture notes can be replacd
with a concrete reference
it should be available

416 [15] Medlock KB (2011); *Energy Demand Theory*; In: Evans J, Hunt LC, editors. *International*
417 *Handbook on the Economics of Energy*. pp. 89-111.

418 [16] Pesaran MH, Shin Y, Smith RJ (2001); *Bounds testing approaches to the analysis of level*
419 *relationships*; *Journal of Applied Econometrics* J. Appl Econ16: pp. 289–326
420 <https://doi.org/10.1002/jae.616>

Comment [P23]:

421 [17] Shahbaz M, Chandran VGR, Azeem P (2011); *Natural gas consumption and economic*
422 *growth: cointegration, causality and forecast error variance decomposition tests for Pakistan*;
423 MPRA Paper No. 35103, posted 30 November 2011 12:24. Available: [https://mpra.ub.uni-](https://mpra.ub.uni-muenchen.de/35103/)
424 [muenchen.de/35103/](https://mpra.ub.uni-muenchen.de/35103/). Accessed 20 June 2016.

Comment [P24]:

425 [18] Marbuah G (2013); *Understanding Crude Oil Import Demand Behaviour in Ghana*; De-
426 partment of Economics, Swedish University of Agricultural Sciences, P.O. Box 7013, 750 07
427 Uppsala, Sweden.

Comment [P25]: incomplete rference

428 [19] Belloumi M (2014); *The relationship between Trade, FDI and Economic growth in Tunisia:*
429 *An application of autoregressive distributed lag model*; Faculty of Economics and Management
430 of Sousse, University of Sousse City Erriadh 4023 Sousse Tunisia.

Comment [P26]: incomplete reference

431 [20] Onolemhemen RU, Laniran TJ, Isehunwa SO, Adenikinju A (2017); *An evaluation of do-*
432 *mestic gas utilization on the Nigerian economy*; *British Journal of Economics, Management &*
433 *Trade* 16(1): 1-13, 2017; Article no. BJEMT.30438 ISSN: 2278-098X. Available:
434 www.sciencedomain.org. Accessed 26 June 2017.

435 [21] Ryan DL, Plourde A (2011); *Empirical modeling of energy demand*; In: Evans J, Hunt LC,
436 editors. *International Handbook on the Economics of Energy*. pp. 112-143.

Comment [P27]: publisher

437 [22] World Bank Development Indicators (2016), *Electric power consumption (kWh per capita)*,
438 World Bank Development Indicators

439 [23] Narayan PK, Smyth R (2006); *What determines migration flows from low-income to high-*
440 *income countries? An empirical investigation of Fiji-US migration 1972 – 2001*; *Contemporary*
441 *Economic Policy* (ISSN 1074-3529); 332–342. <https://doi.org/10.1093/cep/byj019>

442

443

444

445 **APPENDIX**

