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Developing a Model to Determine Natural Gas Utilization in Nigeria

Oloro J.

Delta State University, Abraka, Delta State.

Abstract

The prediction of the amount of natural gas utilized in Nigeria is a problem hence in this study a model was developed to solve the problem of prediction of gas utilized using multilinear regression techniques.
The model was developed using data obtained from the annual statistical bulletin of Nigeria National Petroleum corporation (NNPC).The data included the amount of gas produced, gas utilized, total gas utilized and gas flared annually for twelve years (2003-2012). The data was analyzed and plugged into the multi-linear regression equation to form the model. The Durbin Watson test for correlation was carried out to test for the validity of the model. The test suggests that the model developed was robust and reliable since the residual values (the difference between the estimated gas utilized and the actual gas utilized) were much different in value from one another, that is, it was negatively correlated.
The model was proven to be valid since at least one independent variable was linearly related to the dependent variable. model developed was validated for adequacy using Durbin Waston Model and it was okay.
This paper focuses on the use of an existing mathematical principle (linear regression) to develop a mathematical model which can be used to make relevant predictions to improve natural gas utilization in Nigeria.
The model developed was used to carryout prediction and optimization of natural gas utilized. The optimization result provided valuable managerial information about the sensitivity of the optimal solution.

Keywords: Regression, Utilization, Robust, Natural gas, correlation

1.0 Introduction

Natural gas which was once an unwanted by-product of crude oil production now provides about one-fifth of all the world's primary energy requirements. This remarkable development has taken place in a few years with increase in availability of gas resources of the countries. Natural gas is a subcategory of petroleum which is naturally occurring complex mixture of hydrocarbon with a minor amount of inorganic compounds. Since natural gas is petroleum in gaseous state, it is always accompanied with oil (liquid petroleum). There are three types of natural gas - non associated gas, associated gas and gas condensates. Non associated gas is gotten from reservoir with minimal oil, associated gas is gas dissolved in oil under natural conditions in the oil reservoirs while condensates refer to gas with a high content of liquid hydrocarbon at reduced pressures and temperatures [1].
The natural gas industry of today did not emerge until after World War II and the utilization of natural gas (either residential, commercial, industrial or power generation) has increased rapidly since then. This growth has resulted from several factors including development of new markets, replacement of coal as a fuel for providing space and industrial process heat, use of natural gas in making petrochemicals, fertilizers and strong demand for low sulfur fuel [2].
There is a business case for proper harnessing and adequate utilization of associated natural gas, as it can be a source of huge foreign exchange [3]. Offshore associated gas could be treated, recovered and economically utilized in power generation [4]. This view is supported by the outcome of the study by Abdulkareem and Odigure which suggests that substantial amount of money could be saved if conventional fuel and energy were to be substituted with natural gas [5].
The objective of this paper is to develop a model for the utilization of natural gas in Nigeria.

Corresponding author: Oloro, E-mail:joloroeng@yahoo.com , Tel.: +2348052756328

2.0 Research Design

In this project, the amount of natural gas produced, utilized and flared annually for twelve years (2003-2012) were analyzed. The regression parameters were substituted into the regression model to obtain the required equation. Thereafter, the model was tested for validity using the Durbin-Watson test (D.W).

3.0 Method of Data Collection

The data for this project was obtained from the 2012 annual statistical bulletin of Nigerian National Petroleum Corporation (NNPC) [6].The data is represented in Fig.1.

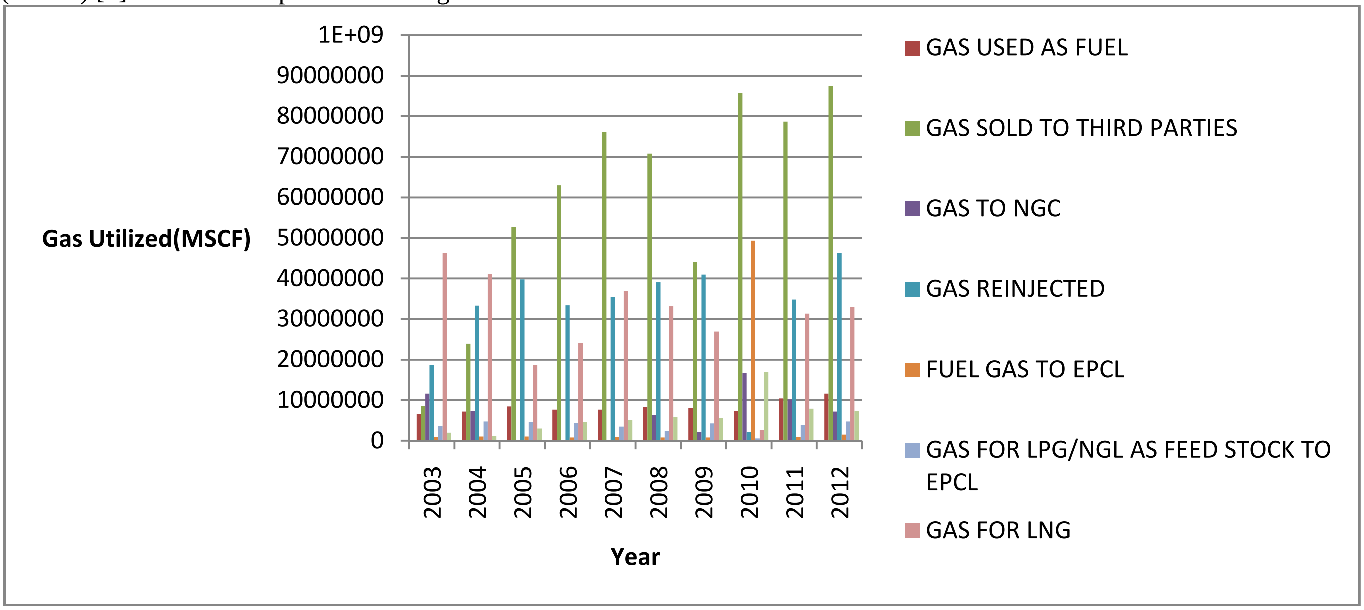

Fig.1: Gas Utilized in Nigeria

4.0 Method of Data Analysis

To analyze the data collected, a plot of total gas utilized (Y) is made against each variable representing the various uses of natural gas (X_1- X_8). This is used to know if the graph will be linear graph or not.

5.0 Model Development

In this paper, the dependent variable is Y, while the independent variables are x_1, x_2, x_3 …….., x_8.

NOTE:

Y = Total gas utilized, X_1 = Gas used as fuel, X_2 = Gas sold to third parties,
X_3 = Gas to Nigeria gas company (NGC), X_4 = Gas re-injected
X_5 = Fuel gas to EPCL, X_6 = Gas for LPG/NGL as feedstock to EPCL
X_7 = Gas for LNG, X_8 = Gas lift,

The equation of the study is given as equation (1):

$$Y = nb_o+b_1X_1+b_2X_2+b_3X_3+b_4X_4+b_5X_5+b_6X_6+b_7X_7+b_8X_8 \quad (1)$$

The normal equations to the equation (1) are:

$$\Sigma Y = nb_o+b_1\Sigma X_1+b_2\Sigma X_2+b_3\Sigma X_3+b_4\Sigma X_4+b_5\Sigma X_5+b_6\Sigma X_6+b_7\Sigma X_7+b_8\Sigma X_8 \quad (2)$$

$$\Sigma YX_1 = b_o\Sigma X_1+b_1\Sigma X_1^2+b_2\Sigma X_1X_2+b_3\Sigma X_1X_3+b_4\Sigma X_1X_4+b_5\Sigma X_1X_5+b_6\Sigma X_1X_6+b_7\Sigma X_1X_7+b_8\Sigma X_1X_8 \quad (3)$$

$$\Sigma YX_2 = b_o\Sigma X_2+b_1\Sigma X_1X_2+b_2\Sigma X_2^2+b_3\Sigma X_2X_3+b_4\Sigma X_2X_4+b_5\Sigma X_2X_5+b_6\Sigma X_2X_6+b_7\Sigma X_2X_7+b_8\Sigma X_2X_8 \quad (4)$$

$$\Sigma YX_3 = b_o\Sigma X_3+b_1\Sigma X_1X_3+b_2\Sigma X_2X_3+b_3\Sigma X_3^3+b_4\Sigma X_3X_4+b_5\Sigma X_3X_5+b_6\Sigma X_3X_6+b_7\Sigma X_3X_7+b_8\Sigma X_3X_8 \quad (5)$$

$$\Sigma YX_4 = b_o\Sigma X_4+b_1\Sigma X_1X_4+b_2\Sigma X_2X_4+b_3\Sigma X_3X_4+b_4\Sigma X_4^2+b_5\Sigma X_4X_5+b_6\Sigma X_4X_6+b_7\Sigma X_4X_7+b_8\Sigma X_4X_8 \quad (6)$$

$$\Sigma YX_5 = b_o\Sigma X_5+b_1\Sigma X_1X_5+b_2\Sigma X_2X_5+b_3\Sigma X_3X_5+b_4\Sigma X_4X_5+b_5\Sigma X_5^2+b_6\Sigma X_5X_6+b_7\Sigma X_5X_7+b_8\Sigma X_5X_8 \quad (7)$$

$$\Sigma YX_6 = b_o\Sigma X_6+b_1\Sigma X_1X_6+b_2\Sigma X_2X_6+b_3\Sigma X_3X_6+b_4\Sigma X_4X_6+b_5\Sigma X_5X_6+b_6\Sigma X_6^2+b_7\Sigma X_6X_7+b_8\Sigma X_6X_8 \quad (8)$$

$$\Sigma YX_7 = b_o\Sigma X_7+b_1\Sigma X_1X_7+b_2\Sigma X_2X_7+b_3\Sigma X_3X_7+b_4\Sigma X_4X_7+b_5\Sigma X_5X_7+b_6\Sigma X_6X_7+b_7\Sigma X_7^2+b_8\Sigma X_7X_8 \quad (9)$$

$$\Sigma YX_8 = b_o\Sigma X_8+b_1\Sigma X_1X_8+b_2\Sigma X_2X_8+b_3\Sigma X_3X_8+b_4\Sigma X_4X_8+b_5\Sigma X_5X_8+b_6\Sigma X_6X_8+b_7\Sigma X_7X_8+b_8\Sigma X_8^2 \quad (10)$$

6.0 Model Testing

The model developed was used to generate values given by Y. The residuals were computed and Durbin Watson test model was used to validate the model as shown in equation (11) [7].

$$D.W = \frac{\sum_{t-2}^{n}(e_t - e_{t-1})^2}{\sum_{t-1}^{n} e^2{}_t} \quad (11)$$

In equation (11)

e_t = residuals which is the difference between actual y value and that obtained with the model.

$(e_t - e_{t-1})$= difference between the residual and previous residual.

The Durbin-Watson test for significance was accepted at p<0.5 Significance level or probability.

7.0 Hypothesis

To test for adequacy of my model using the D.W Statistical model is unique since there is certain range of D.W values for which we can neither reject nor fail to reject. In this work, the hypothesis is

H_0: the null hypothesis which states that the errors are serially uncorrelated

H_i: Alternative hypothesis which indicates that errors are positively or negatively correlated.

The upper critical value (dU) and lower critical value (dL) have been have been tabulated for different values of k (the number of explanatory variables) and n (the sample size). They are found in a table called the Durbin Watson table of statistics [8].

If D.W < dL, we reject H_0: p=0

If D.W > dU, we do not reject H_0: p>0

If dL<D.W<dU, the test in inconclusive

From equations 2 through 11 the values of the regression parameters (b) computed are

b_0 = -0.75711151, b_1 = 0.99999825, b_2 = 1.000000013, b_3 = 1.000000039

b_4 = 1.000000015, b_5 = 1.000000001, b_6 = 1.000000104, b_7 = 0.999999995

b_8 = 0.999999969

These values are then plugged into the equation in equation 1 to obtain the multiple regression model given as;

$$Y = -7.54711151 + 0.999999825X_1 + 1.000000013X_2 + 1.000000039X_3 + 1.000000015X_4 + 1.000000001X_5 + 1.000000104X_6 + 0.999999995X_7 + 0.999999969X_{8.} \quad (12)$$

Equation (12) is the model to determine gas utilization in Nigeria.

Equation(12) is used to generate values for Y which is used for the Durbin Watson test in Table 1

Table 1: Durbin Watson test for auto correlation

YEAR	TOTAL GAS UTILIZED (Y)	ESTIMATED GAS UTILIZED (Ȳ)	RESIDUAL ℓt	ℓ_t^2	$(\ell_t - \ell_{t-1})$	$(\ell_t - \ell_{t-1})^2$
2003	983,562,969	983,562,957.8	11.2	125.44	0	0
2004	1,195,742,993	1,195,743,020	-27	729	-38.2	1,459.24
2005	1,282,313,082	1,282,393,076	6	36	33	1,089
2006	1,378,770,261	1,378,770,250	11	121	5	25
2007	1,655,960,315	1,655,960,301	14	196	3	9
2008	1,668,148,489	1,668,148,527	-38	1,444	-52	2,704
2009	1,327,926,402	1,327,926,395	7	49	48	2,025
2010	1,811,270,545	1,811,270,604	-59	3,481	-66	4,356
2011	1,781,370,022	1,781,370,023	-1	1	58	3364
2012	1,991,498,902	1,991,498,875	27	729	28	784
				6,862.44		15,815.24

From equation (12),

$$D.W = \frac{\sum_{t-2}^{n}(e_t - e_{t-1})^2}{\sum_{t-1}^{n} e^2{}_t} = \frac{15815 \ \ .24}{6862 \ \ .44}$$

D.W = 2.3046

From the Durbin Watson table of statistics, since d=2.3046

N (sample size) =10
K (number of explanatory variables) = 8
But D.W falls between dL = 0.15 and dU = 2.69 when k=5, n=10
Recall,
If D.W < dL, H_0 is rejected. But H_0 is not rejected since 2.3046(d) is greater than 0.15(dL)
If D.W > dU, H_0 is not rejected. But H_0 is rejected since 2.69(dU) is greater than 2.3046(d)
If dL< D.W < dU, the test is inconclusive.
The test can be said to be inconclusive since 0.15(dL) < 2.3046(d) < 2.69(dU)
From the above result, we see that the Durbin-Watson test is inconclusive. But according to Wikipedia the free encyclopedia, 2012. If D.W is less than 2 but greater than 1, there is evidence of positive autocorrelation which means that successive error terms are averagely close in value to one another. But if D.W is substantially less than 2, successive error terms are averagely much different in value from one another. That is, it is negatively correlated.
In this paper, the value of the calculated d shows that the error terms are negatively correlated.
Another statistical test for validity of model can be carried out by checking if there is at least one independent variable is linearly related to the dependent variable [9].
If at least one b is not equal to zero as is the case with the model in this study, the model is valid.
Therefore, there is sufficient evidence to reject the null hypothesis in favor of the alternative hypothesis because at least one b is not equal to zero. Thus the linear regression model is valid since at least one independent variable (X_1, X_2 -------X_8) is linearly related to the dependent variable (Y)
Therefore, the model developed is valid and it can be used to predict gas utilized in Nigeria.

8.0 Conclusion

From the results gotten and the Durbin Watson test for carried out, the model developed is robust and reliable.

9.0 References

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