Regression Modeling of Gross Domestic Products

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Abstract
This research work is structured towards modeling the GDP of Nigeria basing on the major sectors of economy (Agriculture, Manufacturing Sector, Trade and Services) with a view to determine the contribution of different Sectors of Economy to the Nigeria Economic Growth .The multivariate regression model is used to determine relationship between dependent variable and explanatory variables .Global validation Test is adopted to diagnose the autocorrelation and multicollinearity and the Studentized Breusch-Pagan test is applied to diagnose the presence of heteroscedasticity and its remedies which leading to building a predictive model.
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1. Introduction

Oil and natural gas are the most important export products for Nigerian trade. The country exports approximately 2.327 million barrels per day, according to the 2007 figures.In terms of total oil exports, Nigeria ranks 8thin the world. As of 2009, Nigeria has approximately 36.2-billion-barrel oil reserves. Nigerian National Oil Corporation (NNOC) is the regulatory body for the oil andnatural gas sector. Prior to oil production,which surged after 1970, agriculturalproduction was the largest export sector for Nigeria[1,2]. Nonetheless, it provides employment to almost 70% of the total working population. According to the 2009 figures, the country's total export volumes stand at US$45.43 billion. Major items of export are oil products, cocoa, and timber. United Kingdom and United States are the largest trade partners for Nigerian exports. Due to high international oil prices, Nigeria'simport balances export volume. Ricardo (1817), in his famous theory of comparative advantage, showed that countries would benefit by producing goods with the lowest opportunity cost, enabling surplus tradedomestic demand, given appropriate exchange-rate[3]. Under this model, a country will quickly specialize in sectors, in which, ithas a comparative advantage. The literature isreplete with various studies on the impact of export on economic growth, with reference todeveloping economies, while only a few studies have specifically examined the determinants of aggregate imports in Nigeria.For instance, the early researchers in this area,[4,5] conducted some studies in Asian countries of Asia using time series data from1955-1982. This study showed that there is asignificant statistical association between export and economic growth. Similarly,Kruger and Ito analyzed the economicgrowth of East Asian countries from 1965- 1991 and found that export enabled the countries' economy to grow for about 4-8%. From this, [3]investigated the relationshipbetween export, domestic demand and economic growth in Nigeria using Granger causality and cointegration tests. The study results from Trace and Maximum Eigen Value test conducted showed that the variables do not have long-run relationship, but the Pair-wise Granger Causality test showed that economic growth Granger causes both export and domestic demand, while a bilateral causality exists between export and domestic demand. In a relatedstudy by[6] on Tanzania using Vector Autoregressive (VAR) technique to analyze annual data from 1980 to 2009 to determine the long-run relationship between exports trade and economic growth. [2,7]investigate foreign trade and economic growth in Nigeria between 1980 and 2010 using the ordinary least square method to analyze the data. The result shows that non-oil export value, non- oil import value and oil export value are positively related to GDP for the period underthe study. Since studying the pattern of growth of GDP greatly determines theeconomic growth of a country, this will havea significant impact on the country's concernsin terms of unemployment, standard of living, and cost of living. Several papers havesuggested that a robust regression model canbe used for predicting GDP, import, or exportvolumes. This provides a basis for deciding on the balance of payments or trade balance between Nigeria and other countries. This research work is structured towards modelingthe GDP of Nigeria based on the major sectors of the economy (Manufacturing, Agriculture, trade, and services) with a view to understanding the contributions of each sector of the economy to Nigeria's Economic growth. This will go a long way in determining the efficiency and consistency of the model to predict imports and exports as they affect the balance of trade, which in turn pose adverse effect on the GDP of Nigeria. Statistical methods/analysis is a widely used approach to gain valuable and evidenced-based insights from data across different disciplines[8-11]. In this work, extensive statistical analyses are used to arrive at robust regression model which is used to model and predict the pattern of GDP. We envision that this work provides a solid theoretical background for regression analysis, as well as diagnosing and remedying issues such as autocorrelation, heteroscedasticity, and multicollinearity.

2. Methodology

2.1 Sources of the Data

This work model GDP of Nigeria using the data extracted from CBN statistical bulletin using robust regression obtained via box-cox transformation of data with heteroscedasticity in order to allow arrive at consistent and efficient model that can be used to predict for the future values.

2.2 Ordinary Least Square (Ols) Regression

Ordinary least squares (**OLS**) or **linear least squares** is a method for estimating the unknown parameters in a linear regression model, with the goal of minimizing the sum of the squares of the differences between the observed responses (values of the variable being predicted) in the given dataset and those predicted by a linear function of a set of explanatory variables. Visually this is seen as the sum of the squared vertical distances between each data point in the set and the corresponding point on the regression line – the smaller the differences, the better the model fits the data. The resulting estimator can be expressed by a simple formula, especially in the case of a single regressor on the right-hand side. The OLS estimator is consistent when the regressors are exogenous, and optimal in the class of linear unbiased estimators when the errors are homoscedastic and serially uncorrelated. Under these conditions, the method of OLS provides minimum-variance mean-unbiased estimation when the errors have finite variances. Under the additional assumption that the errors are normally distributed, OLS is the maximum likelihood estimator[12,13].

2.3 OLS regression with multiple explanatory variables

The OLS regression model can be extended to include multiple explanatory variables by simply adding additional variables to the equation, but this time Y is predicted by multiple explanatory variables (X1 to X3). $Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3$ the interpretation of the parameters (α and β) from the above model is basically the same as for the simple regression model above, but the relationship cannot now be graphed on a single scatter plot. α indicates the value of Y when all vales of the explanatory variables are zero. Each β parameter indicates the average change in Y that is associated with a unit change inX, while controlling for the other explanatory variables in the model. Model-fit can be assessed through comparing deviance measures of nested models. For example, the effect of variable X3 on Y in the model above can be calculated by comparing the nested models $Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3$ $Y = \alpha + \beta_1 X_1 + \beta_2 X_2$ .The change in deviance between these models indicates the effect that X3 has on the prediction of Y when the effects of X_1 and X_2 have been accounted for (it is, therefore, the unique effect that X3 has on Y after taking into account X_1 and X_2). The overall effect of all three explanatory variables on Y can be assessed by comparing the models $Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3$ $Y = \alpha$. The significance of the change in the deviance scores can be assessed through the calculation of the F-statistic using the equation provided above. As with the simple OLS regression, it is a simple matter to compute the R-square statistics.

2.4 Analysis of Variance Approach to Test the Significance of Regression

The analysis of variance (ANOVA) is another method to test for the significance of regression. As the name implies, this approach uses the variance of the observed data to determine if a regression model can be applied to the observed data. The observed variance is partitioned into components that are then used in the test for significance of regression[14,15].

2.5.1 Studentized Breusch-Pagan Test

It tests whether the variance of the errors from a regression is dependent on the values of the independent variables. In that case, heteroskedasticity is present. Suppose that we estimate the regression model $\boldsymbol{\hat{Y} = \beta X}$and obtain from this fitted model a set of values for the residuals. Ordinary least squares constrains these so that their mean is 0 and so, given the assumption that their variance does not depend on the independent variables, an estimate of this variance can be obtained from the average of the squared values of the residuals. If the assumption is not held to be true, a simple model might be that the variance is linearly related to independent variables. Such a model can be examined by regressing the squared residuals on the independent variables, using an auxiliary regression equation of the form:

This is the basis of the Breusch–Pagan test. It is a chi-squared test: the test statistic is distributed with *k* degrees of freedom. If the test statistic has a p-value below an appropriate threshold (e.g. $p<0.05$) then the null hypothesis of homoskedasticity is rejected and heteroskedasticity assumed. If the Breusch–Pagan test shows that there is conditional heteroskedasticity, one could either use weighted least squares (if the source of heteroskedasticity is known) or use heteroscedasticity-consistent standard errors.

2.5.2 Goldfeld-Quandt Test

It checks for homoscedasticity in regression analyses. It does this by dividing a dataset into two parts or groups, and hence the test is sometimes called a two-group test. In the context of multiple regression (or univariate regression), the hypothesis to be tested is that the variances of the errors of the regression model are not constant, but instead are monotonically related to a pre-identified explanatory variable. For example, data on income and consumption may be gathered and consumption regressed against income. If the variance increases as levels of income increase, then income may be used as an explanatory variable. Otherwise, some third variable (e.g. wealth or last period income) may be chosen[16].

3 Result and discussion

3.1 Fitting Regression Model to GDP data

Table 1: The Parameter Estimate

Coeficients	Estimates	Std. Error	t.value	Pr(>|t|)
Intercept	-1.898e+07	2.166e+07	-0.876	0.3887
Investment(I)	5.541e+00	9.63e-01	5.751	4.08e-06
Government Expenditure(GE)	3.464e+05	3.82e+05	0.906	0.3729
Private Investment(PI)	1.264e+01	5.24e+00	2.413	0.0229

The regression model GDP = -1.898e+07 + 5.541I + 3.464e+05GE + 1.264e+01PI, represent the regression of GDP as a function of investment, private investment, and government expenditure. The p-value (0.3887) > α (0.05) and p-value (0.3729) > α (0.05) shows that the estimate of intercept and government expenditure are not statistically significant, see **Table 1**. Therefore, those parameters have no significant contribution to the model. The estimates of investment and private investment are statistically significant, because p-value (4.08e-06) < α (0.05) and p-value (0.0229) < α (0.05) for investment and private investment is statistically significant but those parameters are not statistically stable.

Table 2:Test for the Model Adequacy

Response	df	Sum Sq	Mean Sq	F-value	Pr(>|t|)
I	1	1.78e+15	1.7854e+15	99.5768	1.49e+10
GE	1	4.723e+13	4.7231e+13	2.6342	0.1162
PI	1	1.0437e+14	1.0437e+14	5.8206	0.0229
Residuals	27	4.8412e+12	1.7930e+13		

From **Table 2** above, there is no linearity in the regression model with respect to the entire explanatory variable under investigation. The estimate of government expenditure (GE) is not linearly related to the GDP because p-value (0.1162) > α (0.05). Since, there is no linearity between the variable, then the regression model is not adequate. The coefficient of determination) shows that about 43.16% of the factors affecting GDP can be attributed to government investment, government expenditure and private investment while the remaining 56.84% are unexplained variation. Since the unexplained variation is very large, then the model is not adequate to forecast and relying upon in evidence based decision making and prospective planning. The regression model GDP = 1.898e+075.541I + 3.464e+05GE + 1.264e+01PI, represent the regression of GDP as a function of investment, private investment and government expenditure. The p-value (0.3887) > α (0.05) and p-value (0.3729) > α (0.05) shows that the estimate of intercept and government expenditure are not statistically significant. Therefore, those parameters have no significant contribution to the model. The estimates of investment and private investment are statistically significant, because p-value (4.08e-06) < α (0.05) and p-value (0.0229) < α (0.05) for investment and private investment is statistically significant but those parameters are not statistically stable. There is no linearity in the regression model with respect to the entire explanatory variable under investigation. The estimate of government expenditure (GE) is not linearly related to the GDP because p-value (0.1162) > α (0.05). Since, there is no linearity between the variable, then the regression model is not adequate. The coefficient of determination) shows that about 43.16% of the factors affecting GDP can be attributed to government investment, government expenditure and private investment while the remaining 56.84% are unexplained variation. Since the unexplained variation is very large, then the model is not adequate to forecast and relying upon in evidence-based decision making and prospective planning. Also, the assumption of homogeneity of variance is not satisfied, this results to the problem of heteroscedasticity. This has affected the parameter of the model greatly, thereby making the estimate of model to lack reliability, stability and consistency thus rendering the model useless in extrapolating for future values of GDP.

Table 3: Global Validation Test

Test	Value	p-value	Decision
Global Stat	18.602	0.003902	Assumptions not Satisfied
Skewness	6.6732	0.024563	Assumptions not Satisfied
Kurtosis	1.8976	0.178549	Assumptions acceptable
Link Function	2.5643	0.134562	Assumptions acceptable
Heteroscedasticity	5.4562	0.022670	Assumptions not Satisfied

From Table 3 above, we can deduce that the assumption of homogeneity of variance is not satisfied, this results to the problem of heteroscedasticity. This has affected the parameter of the model greatly, thereby making the estimate of model to lack reliability, stability and consistency thus rendering the model useless in extrapolating for future values of GDP.

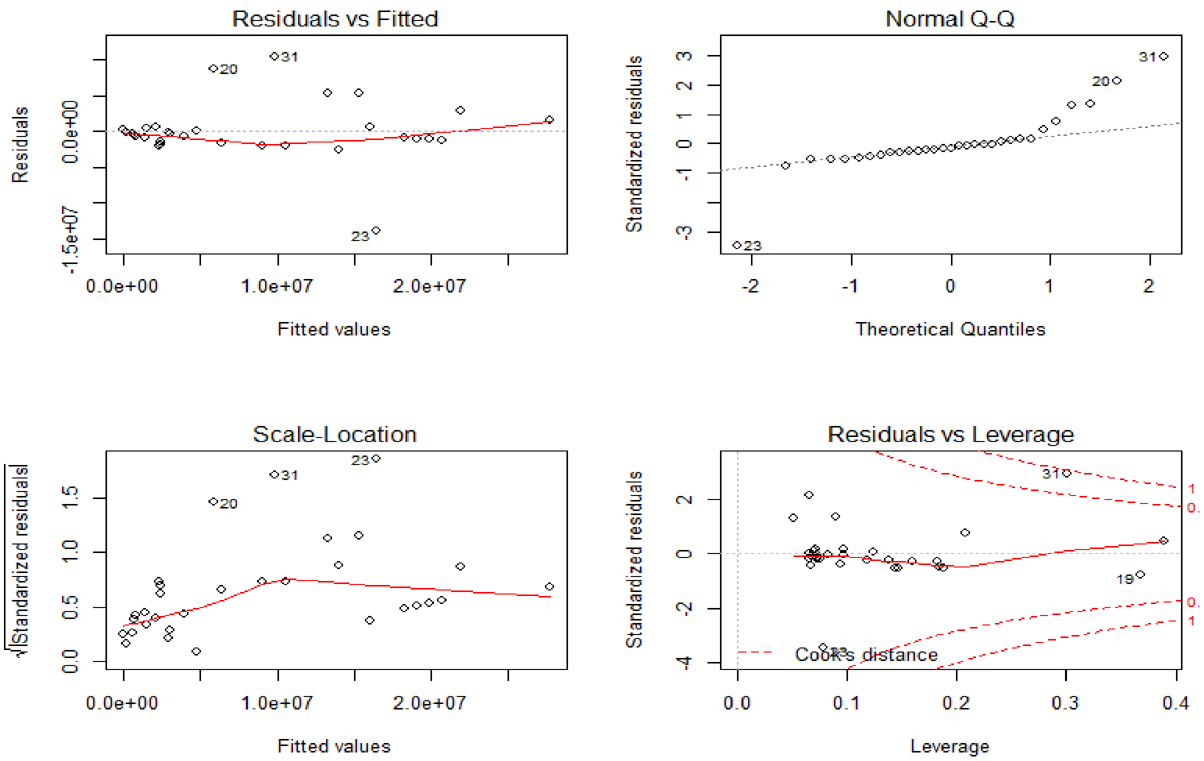

Figure 1: the graphical representation of global validation test.

From Figure 1 above, we can deduce that the chart at the top-left corner shows some fluctuation in the variance, and it is not completely random as suggested from the curvy smoothing line. The curvy red line as opposed the tiny doted black line signifies the presence of apparent errors in the model as a result of heteroscedasticity. Normal Q-Q plot is used to diagnose normality, and from the chart we can see that residuals are not normally distributed so also the data violated the assumption of normality of errors. Cook's distance in Residuals VS Leverage chart shows that there are some outliers in the data that produced the model. The presence of many outliers has caused the violation of the assumption of homoscedasticity.

3.2 Diagnosing Heteroscedasticity

Table 4: Test for Accessing Heteroscedasticity

Studentised Breusch-Pagan Test	Goldfeld-Quandt Test	Harvey-Collier Test
BP = 14.394	GQ = 88.74	HC = 0.014132
df = 3, p-value = 0.0163	df1 = 12, df2 = 11, p-value = 0.0590	df = 26, p-value = 0.9888

From **Table 4**, we used three different statistical testing approach, therefore, Studentized Breusch-Pagan, Goldfeld-Quandt and Harvey-Collier test. In Studentised Breusch-Pagan test ,the p-value (0.0163) < α (0.05), we have statistical reason not to accept H_0 and conclude that there exists heteroscedasticity in the data used. There is need to remove the heteroscedastic error in the model so as to make the model ample to forecast and thus increasing its reliability. Goldfeld-Quandt test, result into the p-value (0.0590) > α (0.05), statistically H_0 is to be rejected and we can conclude that the variance changes across different groups, thus making the model under investigation to contain heteroscedastic error. Hence, there is existence of heteroscedasticity. In the case of Harvey Collier test, p-value (0.9888) > α (0.05), statistical we can accept H_0 and conclude that there is no linearity.

3.2.1 Diagnosing Autocorrelation (Durbin Watson Test)

We further diagnose for autocorrelation in the data, we employed Durbin Watson test with DW = 1.213, p-value = 0.02213. Basically, If the Durbin Watson statistic (DW) is between 0 and 2, then we can conclude that there exists a positive autocorrelation. From the DW and the p-value obtained from the test, we can deduce that there exists a positive autocorrelation. Therefore, there is presence of serial correlation between the successive error terms. The problem of autocorrelation in the data has affected the parameter of the model greatly to the extent that it has rendered the model useless in using its estimate to make any evidence-based decision and prospective planning. Also, since p-value (0.02213) < α (0.05), then we can say there exist an autocorrelation in the data. To correct the heteroscedasticity box-Cox Transformation performed result into sample skewness of 0.616, and estimated lambda of 0.2. Based on these values, the estimated lambda can be used to correct the presence of heteroscedasticity in the model. The Box-Cox transformation was used to transform the data and the resulting regression model obtained using the transformed is represented by 0.2240076801I – 2.1003e-01GE + 0.56PI and it shows a gradual decrease in GDP with increasing government expenditure. With increase in both government investment and private investment, there will be corresponding increase in GDP. The estimate of government expenditure (GE) statistically significance because p-value (0.032876) < α (0.05). Since, the coefficient of investment and private investment are also statistically significant (p-values (0.003298, 0.000182) < α (0.05)), then the regression model is highly adequate to forecast and can be relied upon in evidence-based decision making and prospective planning. Also, there is linearity in the regression model with respect to the entire explanatory variable under investigation. The estimate of government expenditure (GE), investment and private investment are linearly related to the GDP because p-values (0.00335015), (7.006e-09) and (0.0001817) respectively are all > α (0.05). Since there is linearity between the variable, then the regression model is adequate. Then the model can be use to forecast and relying upon in evidence based decision making and prospective planning. The assumption of homoscedasticity has been satisfied and global validation has also been satisfied, then we can validate the reliability of the model as a function of consistency and stability of its estimates. This model can be used to make adequate accurate and consistent decision, thus making it adequate for making prospective planning.

3.2.2 Fitting regression to the transformed data

Table 5: Parameters Estimate

Coeficients	Estimates	Std. Error	t.value	Pr(>|t|)
Intercept	39.47	0.9018	10.38	0.014343**
Investment (I)	1.293	0.0041	13.22	0.003298***
Government Expenditure (GE)	-4.942	1.5910	9.311	0.032876**
Private Investment (PI)	9.456	2.182	8.335	0.000182***

From **Table 5** above, the regression model of the transformed data is represented by GDP = 39.47 + 1.293I-4.942GE + 9.456PI and it shows a gradual decrease in GDP with increasing government expenditure. With increase in both government investment and private investment, there will be corresponding increase in GDP. The estimate of government expenditure (GE) statistically significance because p-value (0.032876) < α (0.05). Since, the coefficient of investment and private investment are also statistically significant (p-values (0.003298, 0.000182) < α (0.05)), then the regression model is highly adequate. The coefficient of determination) shows that about 88.69% ($R^2 = 0.8869$) of the factors affecting GDP can be attributed to government investment, government expenditure and private investment while the remaining 11.31% are unexplained variation. Since the unexplained variation is significantly low as compared to the explained variation, then the model is adequate to forecast and can be relied upon in evidence-based decision making and prospective planning.

The model GDP = 39.47 + 1.293I - 4.942GE + 9.456PI is on a transformed predictor variable (GDP), But since this new variable is on a different scale compared to the original GDP we need to back-transform this variable by doing the opposite of box-cox transformation. The new predictive model is 0.2240076801I – 2.1003e-01GE + 0.56PI

Table 6:Test for the Model Adequacy

Response	**df**	**Sum Sq**	**Mean Sq**	**F-value**	**Pr(>|t|)**
I	1	21265.5	21265.5	68.4446	7.006e-09***
GE	1	56743.6	5743.6	18.4919	0.00335015**
PI	1	5837.7	5837.7	18.7890	0.0001817***
Residuals	27	8388.8	310.7		

From **Table 6** above, there is linearity in the regression model with respect to the entire explanatory variable under investigation. The estimate of government expenditure (GE), investment and private investment are linearly related to the GDP because p-values (0.00335015), (7.006e-09) and (0.0001817) respectively are all > α (0.05).

Since there is linearity between the variable, then the regression model is adequate. Then the model can be use to forecast and relying upon in evidence based decision making and prospective planning.

3.3 Global Validation Test for Testing the Presence of Heteroscedasticity in the new Model

Table 7: Global Validation Test

Test	Value	p-value	Decision
Global Stat	4.09831	0.50390	Assumptions acceptable
Skewness	3.12344	0.09456	Assumptions acceptabe
Kurtosis	0.10873	0.73519	Assumptions acceptable
Link Function	0.04512	0.94321	Assumptions acceptable
Heteroscedasticity	0.09203	0.08342	Assumptions acceptable

From the **Table 7** above, the assumption of homoscedasticity has been satisfied and global validation has also been satisfied, then we can validate the reliability of the model as a function of consistency and stability of its estimates. This model can be used to make adequate accurate and consistent decision, thus making it adequate for making prospective planning.

Table 8: Diagnosing Heteroscedasticity in the Model obtained after Cox Transformation

Studentised Breusch-Pagan Test	Goldfeld-Quandt Test	Harvey-Collier Test
BP = 1.8581	GQ = 7.8539	HC = 0.014132
df = 3, p-value = 0.6024	df1 = 12, df2 = 11, p-value = 0.0008761	df = 2.6988, p-value = 0.01207

From **Table 8** above, we can deduce from the p-value (0.6024) of the Breusch-Pagan Test that there is no heteroscedasticity in the model; this is because the p-value is less than α (0.05). Also, since the p-value(0.0008761) and p-value(0.01207) of Goldfeld-Quandt and Harvey-Collier test respectively are both less than α (0.05). we can say that there exist homogeneity of variance and the model is linear and adequate, thereby making the model to be consistent and efficient in predicting and quantitative planning.

Generally, we can say that the parameter of the first regression model is not stable or consistent because of the presence of heteroscedasticity that has greatly affected the stability of the estimates of the parameter. After using Box-Cox transformation to remove heteroscedasticity to arrive at a robust regression model which can be used to make better decision regarding GDP. Using the plot of global validation test, we can deduce that the chart at the top-left corner shows some fluctuation in the variance, and it is not completely random as suggested from the curvy smoothing line. The curvy red line as opposed the tiny doted black line signifies the presence of apparent errors in the model as a result of heteroscedasticity. Normal Q-Q plot is used to diagnose normality, and from the chart we can see that residuals are not normally distributed so also the data violated the assumption of normality of errors. Cook's distance in Residuals VS Leverage chart shows that there are some outliers in the data that produced the model. The presence of many outliers has caused the violation of the assumption of homoscedasticity.

Table 9: Durbin Watson to Invin Transformed data

Robust Model
Durbin-Watson statistic (original): DW = 1.213, p-value = 0.02213 (transformed): dw = 2.0015 , p-value: 0.90231

From Durbin Watson test above, we can deduce that the Durbin Watson values for the transformed data using Cochrane Orcutt showed that there is no auto correlation. This is because the value of Durbin Watson (dw=2) shows that there is no auto correlation in the transformed data. Then the model fit to this data will be statistically adequate, consistent, and statistically significant of its estimate. The estimate of this model can be relied upon in evidence-based decision making and prospective planning. Also, p-value (0.90231) > α (0.05) showed that there is no autocorrelation in the regression model, this means that Box-cox Transformation becomes efficient in case where we have multiple violation in the model. In this case, there is problem of Autocorrelation and Heteroscedasticity, and Box-cox transformation has corrected them, thus making our new regression model to be validated and it is efficient for prediction and making decision for quantitative planning and evidence based prospective planning.

4 Conclusion

Based on the result of the analysis, linear regression model provides a good basis for relying on the predictive efficiency of the model. The presence of heteroscedasticity affected the estimate of the model's parameters greatly to the extent that it renders the model useless when it comes to making prospective planning and evidence-based policy making. There regression model obtained after Box-Cox transforming the data so as to remove the presence of heteroscedasticity from the model is said to be sufficient, consistent, adequate with high reliability and stability of the model's parameter. This model is said to be adequate in making evidence-based decision and quantitative policy making. It is therefore advisable for researchers to carryout necessary diagnostic checking on the data at hand with a view to diagnosing the presence of heteroscedasticity, autocorrelation and muilticollinearity that might possible affect the adequacy, accuracy and stability of the model which possibly render the model useless in forecasting the future values.

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