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APPLICATION OF RESTRICTED LEAST SQUARES TO ECONOMETRIC DATA

IBRAHEEM, A. G

LECTURER

DEPARTMENT OF MATHEMATICS AND STATISTICS

THE FEDERAL POLYTECHNIC

ADO-EKITI

ADEMUYIWA, J. A

SR. TECHNOLOGIST

DEPARTMENT OF MATHEMATICS AND STATISTICS

THE FEDERAL POLYTECHNIC

ADO-EKITI

ADETUNJI, A. A

LECTURER

DEPARTMENT OF MATHEMATICS AND STATISTICS

THE FEDERAL POLYTECHNIC

ADO-EKITI

ABSTRACT

Among numerous model misspecification problems in linear model is the one caused by the inclusion of unnecessary predictors in the model or by omitting the necessary ones out (Gujarati and Sangeetha, 2007). By applying standard results from restricted least squares estimation, insight can be gained about the behaviour of ordinary least squares estimates and associated tests when the restrictions imposed in the model are not true in the population (Esteban and O'Brien, 1992). This paper applies the "F-test" approach of Restricted Least Square (RLS) on Nigerian economy to find out if the linear restriction of Cobb-Douglas production function's parameters $(\beta + \theta) = 1$ is significant to Nigeria economy. The result of the research shows that the Nigerian economy is probably characterized by constant returns to scale over the reviewed period and therefore, using the restricted regression as stipulated by Cobb-Douglas function may not be misleading. Hence, if Capital/Labour ratio increased by 1 percent, on average, labour productivity went up by about 1 percent.

KEYWORDS

Restricted Least Square, Cobb-Douglas, Returns to Scale.

INTRODUCTION

In statistical inference, a critical component is the specification of the correct statistical model. Normal-theory linear modeling courses typically study the consequences of some forms of model misspecification. Among numerous model misspecification problems in linear model is the one caused by the inclusion of unnecessary predictors in the model or by omitting the necessary ones out. This research observes the original works of (Cobb and Douglas, 1928) and some other developmental works of different researchers by applying the F-test procedure of Restricted Least Squares on Econometric data. In economic, the Cobb-Douglas functional form of production is widely used to represent the relationship of output and two inputs. It was developed and tested against statistical evidence by Charles Cobb and Paul Douglas during 1900 – 1947, (Douglas, 1976). Earlier researchers like (Brown, 1966); (Sandelin, 1976); and (Samuelson, 1979) had indicated that the credit should have been given to Wicksell for its discovery since he started working on it in the 19th century. (Weber, 1998) notes that Wicksell employed the Cobb-Douglas functional form in production analysis, twenty years earlier. Weber also notes that Pareto used the Cobb-Douglas functional form to represent Utility in 1892. The estimation of the parameters of aggregate production functions is central to many of today's works on growth, technological change, productivity, and labour. Empirical estimates of aggregate production functions are essential tools of analysis in macroeconomics, and important theoretical constructs, such as potential output, technical change, or the demand for labour, are based on them, (Felipe and Adams, 2005).

In its most standard form for production of a single good (output) with two factors (inputs), the Cobb-Douglas function is: $Y = AL^\beta K^\theta$

Y = total production

A = Total factor productivity

L = Labour input

K = Capital input

β and θ = output elasticities of Labour and Capital respectively

Cobb and Douglas were influenced by statistical evidence that applied to show that labour and capital shares of total output were constant over time in developed countries. They explained this by statistically fitting least squares regression of their production function, (Gujarati and Sangeetha, 2007).

In stochastic form, Cobb-Douglas function becomes:

$$Y_i = \alpha X_{1i}^\beta X_{2i}^\theta e^{u_i} \quad (i)$$

PROPERTIES OF COBB-DOUGLAS PRODUCTION FUNCTION

β is the (partial) elasticity of output with respect to the labour input, that is, it measures the percentage change in output for, say, a 1% change in the labour input, holding the capital input constant.

θ is the (partial) elasticity of output with respect to the capital input, holding the labour input constant.

The sum $(\beta + \theta)$ gives information about the returns to scale, that is, the response of output to a proportionate change in the inputs.

If the sum is 1, then, there are constant returns to scale, that is, doubling the inputs will double the output, tripling the input will triple the output, and so on.

If the sum is less than 1, there are decreasing returns to scale – doubling the inputs will give less double the output.

If the sum is greater than 1, there are increasing returns to scale – doubling the inputs will give more double of the output.

Output elasticity measures the responsiveness of output to a change in levels of either labour or capital used in production, ceteris paribus. If $(\beta + \theta) = 1$, the production function has a constant returns to scale (i.e. the production output increases by a constant factor). This implies that doubling capital (K) and labour (L) will yield double output (Y). If $(\beta + \theta) < 1$, returns to scale are decreasing, and if $(\beta + \theta) > 1$, returns to scale are increasing.

LITERATURE REVIEW

(Greene and Seaks, 1991) obtained expressions for the restricted least squares estimator and its covariance matrix in the classical regression model when the matrix of regressors is not necessarily of full rank. The standard expressions for the restricted least squares estimator were not usable in the short rank case because they rely on the unrestricted estimator. But, in the presence of restrictions, their paper showed that the restricted least squares estimator may be computable even if the unrestricted estimator is not. The authors' derivation produces some additional, useful algebraic results for least squares computation (Kee, 2009) provides a consistent estimate of the bound of the marginal effect of an unobserved right-hand side variable on the dependent variable when only the sum of that variable with a positively correlated variable is available.

(Wan et al., 2007) said that traditional econometrics has long stressed the serious consequences of non-spherical disturbances for the estimation and testing procedures under the spherical disturbance setting, that is, the procedures become invalid and can give rise to misleading results. They opined that this is not unusual, however, to find that the parameter estimates do not change much after fitting the more general structure. This suggests that the usual procedures may well be robust to covariance misspecification. Their paper investigated the sensitivity of the restricted least squares estimator to covariance misspecification where the restrictions may or may not be correct.

(Haupt and Oberhofer, 2002) presented a comprehensive approach to estimation and hypothesis testing under a set of full restrictions, some of these arising from adding-up conditions on the endogenous variable. In contrast to the existing statistical literature, the paper used an argumentation style familiar from classical econometric textbooks, to provide an insightful, straightforward, and nevertheless rigorous exposition of the topic.

(O'Donnell, 2006) opined that Economic theory often provides information on the variables to be included in economic relationships (e.g., demands are functions of prices) and sometimes provides information on the signs and magnitudes of first- and second-order derivatives (e.g., homogeneity and concavity information) but this rarely provides information concerning functional forms. In the absence of this information, it is common to assume a specific functional form (e.g., translog) and subsume errors of approximation into a disturbance term. Unfortunately, the estimated parameters of these approximating relationships do not consistently estimate the economically-relevant characteristics of the true relationship unless the latter is of the approximating class (White, 1980). Practical econometric solutions to the problem are now becoming available. His paper discussed Kernel Regression (KR), Flexible Least Squares (FLS), Generalized Restricted Least Squares (GRLS) and Latent Class (LC) estimators. The empirical performance of all four estimators was assessed using an artificially-generated data set. Three of the estimators were then used to estimate characteristics of a labour demand function for US agriculture.

(Faliva and Zoia 2000): In this paper a novel partitioned inversion formula is obtained in terms of the orthogonal complements of off-diagonal blocks, with the emblematic matrix of unit-root econometrics springing up as the leading diagonal block of the inverse. On the one hand, the result paves the way to a stimulating reinterpretation of restricted least-squares estimation and, on the other, to a straightforward derivation of a key-result of time-series econometrics.

(Elias, 1992) in (Gujarati and Sangeetha, 2007) used Restricted Least Squares to observe Mexican Economy from 1955 – 1974. Using data on the country's Gross Domestic Product, Employment (labour), and Fixed capital, they found that Mexican economy was probably characterized by constant returns to scale over the sampled period and concluded that using Restricted Least Squares obtained for the data set could not be harmful. They also observed that increasing capital/employment ratio by 1 percent, on the average will increase the labour productivity by about 1 percent.

(Abidemi, 2010) examines productivity in the banking sector by way of estimating two major production functions known in the economic literature. The result obtained from the Ordinary Least Square (OLS) estimates shows that substitution parameters α and β (substitution parameters for capital and labour, respectively) confirms the a priori expectation that the duo of α and β are positive values of less than one. He found that the addition of the values of α and β is greater than one, which indicates that as the banking sector doubles its inputs in terms of capital and labour, the output in terms of deposit will be more than doubled. He also observes that the substitution parameters in the Constant Elasticity of Substitution Production Function were equally positive, which supports the theory. In his final analysis, his study supports economic theory on the specification of both Cobb-Douglas and Constant Elasticity of Substitution production functions.

(Liedholm, 1964) was the first work to be done on productivity in Nigeria by attempting to find out between labour and capital, which input contributed more to the output of major industries in Eastern Nigeria and it was found that labours' contribution to the output of the selected manufacturing industries was larger than that of capital. This position was confirmed by (Osagie and Odaro, 1975).

(Ekanem and Oyefusi, 2000) estimated the Cobb-Douglas and the Constant Elasticity of Substitution (CES) production functions for the manufacturing industry in Nigeria for the period 1980 – 1997, taking into consideration the phenomenon of idle capacity that has characterized the industry at the time. The results of the models when compared with the work of (Liedholm, 1964) and (Osagie and Odaro, 1975) gave satisfactory results in terms of goodness of fit. Of the two production functions estimated, the Cobb-Douglas Production Function performs better considering all the relevant econometric test criteria. This then showed that the Cobb-Douglas Production Function gives a better explanation of the aggregate production process in the manufacturing industry in Nigeria for the period studied.

MATERIALS AND METHOD

The dataset used for this research work obtained from World Bank data files (Total Labour Force of Nigeria 1990 – 2009) and Central Bank of Nigeria's Statistical Bulletin, 2011 (Real Gross Domestic Product and Capital expenditure)

Writing (i) in log form, the equation becomes:

$$\ln Y_i = \ln \alpha + \beta \ln X_{1i} + \theta \ln X_{2i} + u_i \quad (\text{ii})$$

X_1 is Labour, X_2 is Capital and Y is GDP

$$\ln Y_i = \varphi + \beta \ln X_{1i} + \theta \ln X_{2i} + u_i \quad (\ln \alpha = \varphi) \quad (\text{iii})$$

If there are constant returns to scale (equiproportional change in output for an equiproportional change in the input), economic theory suggests that $\beta + \theta = 1$. This is a form of linear equality restriction. In order to examine the validity of (ii), there are two possible approaches.

The F-Test Approach (Restricted Least Square, RLS)

The t-test approach is post-mortem in that it only finds out whether the linear restriction is satisfied after estimating the unrestricted regression. However, the F-test approach incorporates the linear equality restriction into the estimating procedure at the outset.

Since $\beta + \theta = 1$, hence $\beta = 1 - \theta$. Substituting $(1 - \theta)$ for β in (iii) gives:

$$\ln Y_i = \varphi + (1 - \theta) \ln X_{1i} + \theta \ln X_{2i} + u_i$$

$$\ln Y_i = \varphi + \ln X_{1i} - \theta \ln X_{1i} + \theta \ln X_{2i} + u_i$$

$$(\ln Y_i - \ln X_{1i}) = \varphi + \theta (\ln X_{2i} - \ln X_{1i}) + u_i$$

$$\ln(Y_i/X_{1i}) = \varphi + \theta \ln(X_{2i}/X_{1i}) + u_i \quad (\text{v})$$

Variables (Y_i/X_{1i}) and (X_{2i}/X_{1i}) are of great economic importance since (Y_i/X_{1i}) measures the ratio of the output with one of the inputs and (X_{2i}/X_{1i}) compares one of the input variables with the other. Once θ can be estimated from (v), β can be estimated using $\beta = 1 - \theta$.

The overall implication of this is that the procedure ensures that sum of the estimated coefficients of the two inputs equal 1 and hence, the name "Restricted Least Squares, RLS". The generalization of this procedure into more than one linear equality restriction is explained by (Theil, 1971).

Examining the validity of RLS

The validity of the Restricted Least Squares can be examined by applying F-test where

$$F_{cal} = \frac{(SSE_R - SSE_{UR})/a}{SSE_{UR}/(n-k)} \quad (\text{vi})$$

SSE_R is the sum of squares of error for restricted regression in (v)

SSE_{UR} is the sum of squares of error for unrestricted regression in (iii)

a is number of linear restriction ($a = 1$ in Cobb-Douglas function)

k is the number of estimated parameters in (iii)

n is the number of observations

The F_{cal} is compared with F_{table} with $[a, (n - k)]$ degree of freedom at specified level of significance with the null hypothesis, H_0 : The Restricted Least Squares (RLS) is not significant. If the RLS is not significant, the economy is probably characterized by constant returns to scale over the sampled period and hence, there may be no harm in using the restricted regression in (v).

RESULTS

Fitting the Cobb-Douglas production function to the data on Nigeria's Gross Domestic Product (GDP), Capital and total labour force from 1990 to 2009 gives:

$$\ln \widehat{GDP}_t = -129.439208 + 8.095468 \ln Labour_t + 0.253359 \ln Capital_t \quad (vii)$$

$$t = (-7.609275) \quad (7.644071) \quad (1.951656)$$

$$P\text{-value} = (0.000001) \quad (0.000001) \quad (0.067654)$$

$$Std\ Err. = (17.010715) \quad (1.059052) \quad (0.129817)$$

$$R^2 = 0.978207$$

$$RSS_{UR} = 38.525827$$

$$SSE_{UR} = 0.858280$$

The equation above (vii) shows that the output/labour elasticity is about 8.10 and the output/capital elasticity is about 0.25. if we add these coefficients, we obtain 8.36, indicating that the Nigeria economy has a very high increasing returns to scale. As high as this value, it is very essential to subject this finding to statistical hypothesis. Imposing the restriction of constant returns to scale gives the following result:

$$\ln(GDP/Labour)_t = 3.785507 + 1.190436 \ln(Capital/Labour)_t \quad (viii)$$

$$t = (6.845303) \quad (11.321751)$$

$$P\text{-value} = (0.000002) \quad (0.000000)$$

$$Std\ Err. = (0.553008) \quad (0.105146)$$

$$R^2 = 0.876866$$

$$RSS_R = 28.169922$$

$$SSE_R = 3.955770$$

* UR \rightarrow Unrestricted Regression $\wedge \rightarrow$ Restricted Regression

Since the independent variables in (vii) and (viii) differ, F_{cal} in (vi) is used to obtain F-value

$$F_{cal} = \frac{(SSE_R - SSE_{UR})/a}{SSE_{UR}/(n - k)} = \frac{(3.955770 - 0.858280)/1}{0.858280/17} = 3.60895$$

The F_{cal} follows the F -distribution with (1, 17) degree of freedom. Hence, F_{cal} is significant at both 1% (8.40) and 5% (4.45) level.

CONCLUSION

The conclusion then is that the Nigerian economy is probably characterized by constant returns to scale over the sample period and therefore, using the restricted regression as stipulated by Cobb-Douglas function may not be harmful. Hence, if Capital/Labour ratio increased by 1 percent, on average, labour productivity went up by about 1 percent over the sampled period.

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FIG. 1

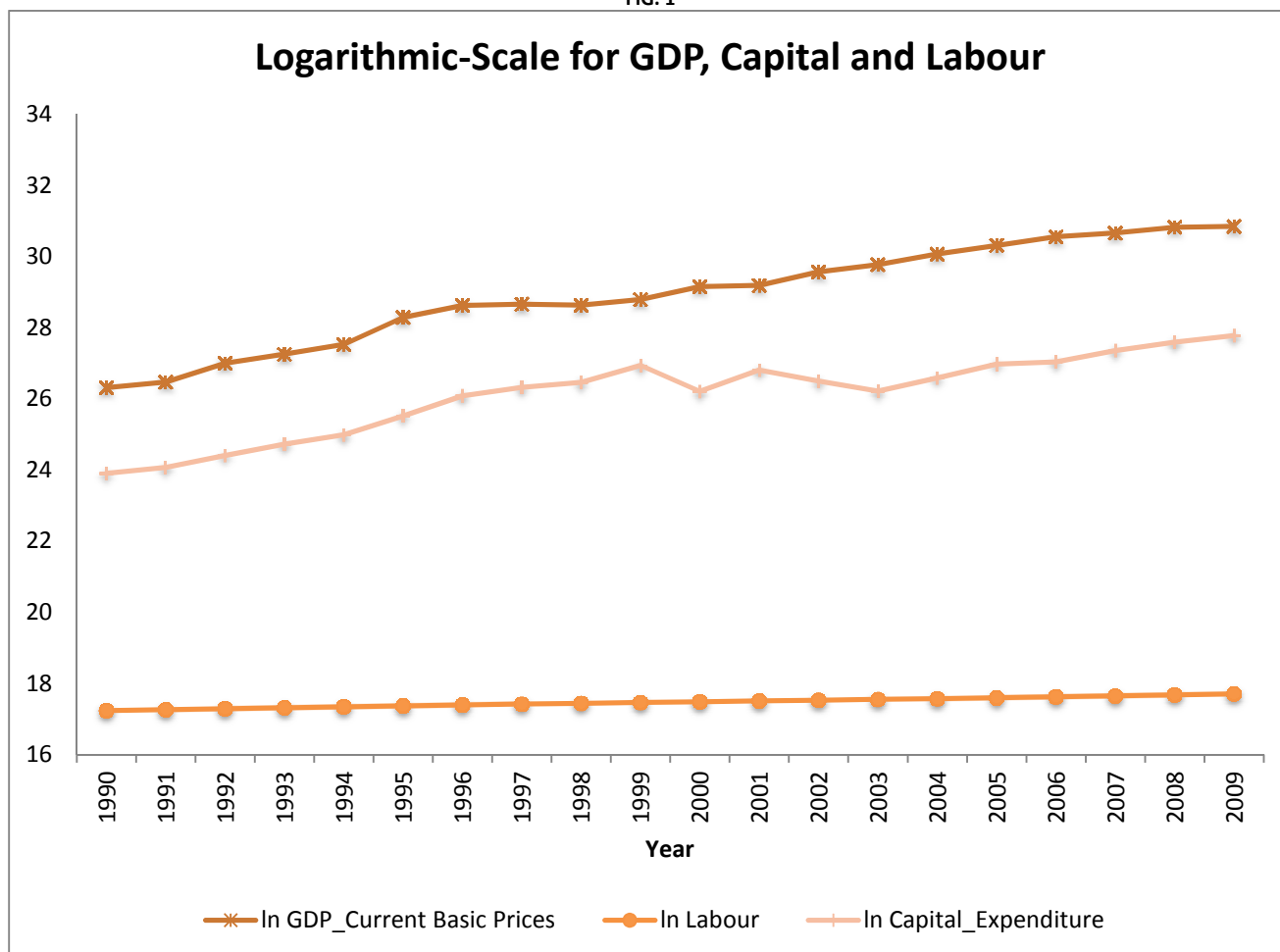
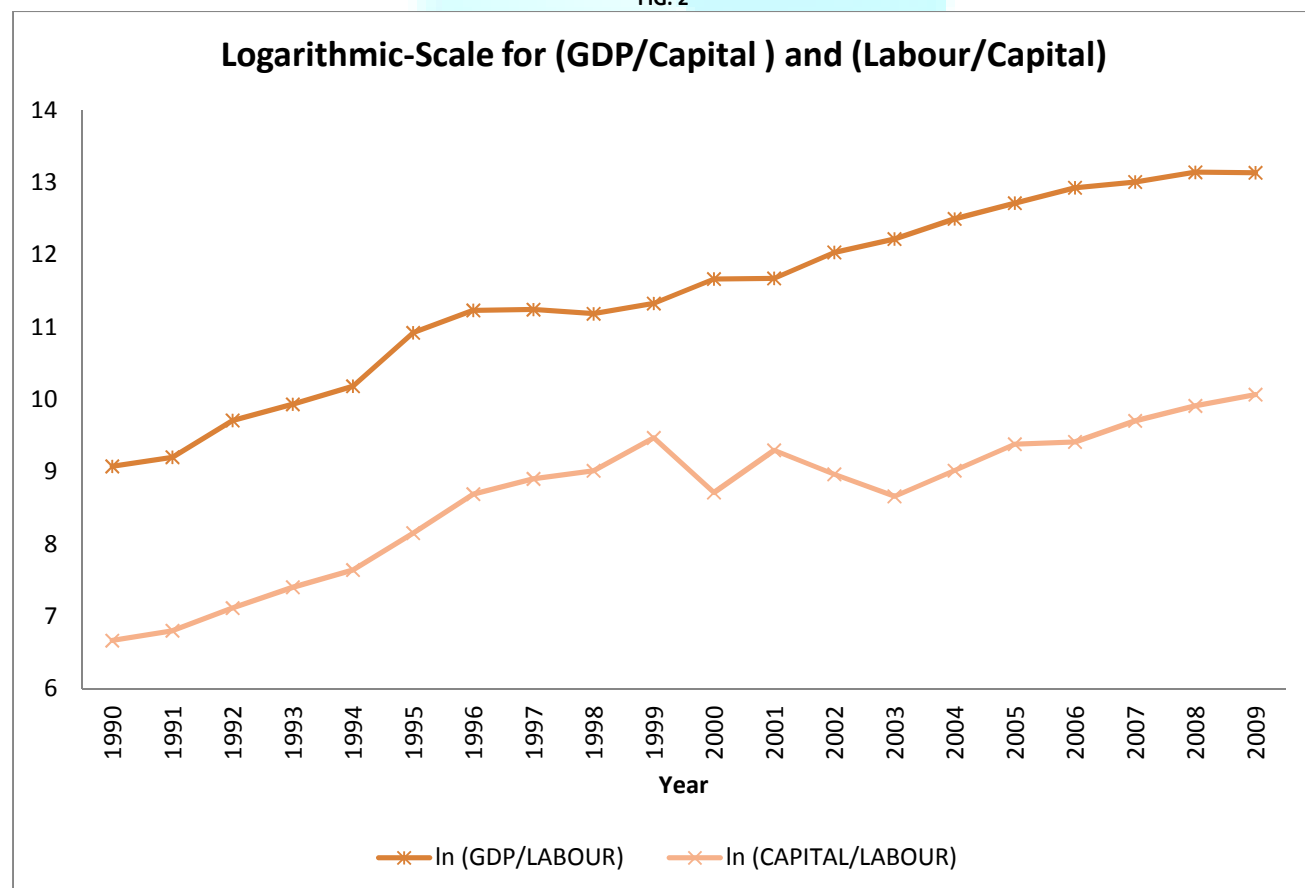


FIG. 2



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