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THE ASYMMETRIC EFFECT OF CAPITAL ON PRODUCTIVITY IN NIGERIA BASED ON COBB-DOUGLAS PRODUCTION FUNCTION

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Abstract
This paper examined the asymmetric (non-linear) effect of capital on productivity in Nigeria using Non-Linear Autoregressive Distributed Lag Model over the years 1991 to 2022. The findings confirmed the existence of long run and non-linear relationship on the concerned variables. Furthermore, the results revealed that both the positive and negative effect of capital, in the short run, are not significant in influencing the productivity in Nigeria, but labor has a significant and a direct effect on productivity in the country. Also, long run is reached in less than two short run periods as more than eighty percent is corrected from short run toward long run equilibrium. When the long-run is reached, the positive shocks of capital has no significant-influence on productivity but the negative shock of capital has a positive influence on productivity in Nigeria. Similarly, labor has a direct linear effect on productivity of the country. Hence, the policymakers and entrepreneurs are advised to utilize labor intensive methods of production, for the purpose of improving their productivity in Nigeria.

Keywords: Asymmetry, Capital, Labor, NARDL, Nigeria, Productivity.

1. Introduction

There is no country that does not aim at continuous growth of its economy (Danlami, 2024 [a]; Zubair & Danlami, 2022). Nations pursue this aim for the sole purpose of becoming one of the developed nations (Danlami, 2024[a & b]; 2020; 2019). Development is seldom attained without economic growth. The surest and quickest way of achieving higher economic growth is through constant and continuous improvement on productivity by any nation (Danlami, 2017[a, b & c]; Danlami *et al*., 2018 [a & b]).

Continuous improvement in productivity is the major and simplest way to achieve higher economic growth. There are several influencers that can be improved for the purpose of improving the productivity of a nation (Musa *et al*.,2019 [a & b]; Danlami *et al*.,2018). The most noticeable of those elements are labor and capital (Danlami *et al*., 2018)). Studies on what could improve productivity, of any nation, will not be completed without studying the effect of labor and capital on productivity.

Nigeria is among the numerous developing states that constantly change policies to improve productivity. Many empirical studies exist on the effect of capital and labor on productivity. Among

them are Onyinye *et al*. (2017), Danlami *et al*., (2018) and others, but such studies concentrated on investigating the linear effect without attention on the non-linear or asymmetric effect of the major variables on productivity. This study aimed at investigating the asymmetric effect of capital on productivity in Nigeria. The study consists five sections: section one is introduction; it proposes the major issues and objective of the study. Section two of the paper reviews the related literature to the study. The third section explains the methodology utilized by the study. Section four presents and discusses the study results and findings. Finally, the last section, which is Section five, concludes the study.

2. Review of Related Literature

Most definitions of productivity point towards the total output produced within the territorial boundary of a nation, usually in a period of one year. When a total productivity is averaged based on the total number of labor in a country, it is referred to as labor productivity (i.e. average productivity of labor). If it is divided by capital, it is referred to as capital productivity (average productivity of capital).

2.2 Empirical Studies

A number of studies that analyze the effect of capital on productivity exist, but such studies mostly concentrated on the linear effect neglecting the asymmetric influence. For instant, Ajose and Oyedokun (2018) investigated the influence of capital accumulation on productivity (economic growth) in Nigeria. The research showed that there is inverse but insignificant association among the variables. Similarly, Onyinye *et al.*, (2017), empirically investigated the influence of capital formation on productivity (economic growth) in Nigeria. Their conclusion was that there exists insignificant positive influence of capital formation on productivity.

Furthermore, Danlami (2017[a, b & c]), Zubair and Danlami (2022), and Danlami *et al*. (2018) all discovered positive influence of capital on labor productivity in Nigeria based on Cobb-Douglas production function. Similarly, Nikoloski *et al.,* (2015) studied the impacts of capital on productivity in developing nations separate from developed countries and compare their findings. They reported in their study that there is significant but direct influence of capital on productivity in the duo groups. To them, the impact of capital on productivity is lower in developed states compared to the developing nations.

Nevertheless, Ekpung and Uchenna (2013) analyzed the effect of the entire capital market on productivity (economic growth) in Nigeria. Their analysis revealed that capital positively and significantly influences the productivity of the state. Meanwhile, in his investigation, Onuora (2019) examined the impact of capital market on Nigerian productivity, and reported mixed findings. The study reported insignificant but direct effect of some indices of capital on productivity, transportation and capital market revenue, as well as GDP growth rate and capital market revenue.

The findings further that there is positive and significant relationship between adequate security and capital market revenue.

Similarly, Onyinye *at al.* (2017) analyzed the influence of capital formation on productivity in Nigeria using VECM. The research uncovered a negative but insignificant influence of capital on productivity of the country. Though Yadirichukwu and Chigbu (2014) examined the influence of capital market on productivity in Nigeria, the research revealed that some indices of capital could positively influence productivity, some had significant effect while some had insignificant effect.

Mixed finding were reported by various studies such as Gbenga and Eleh (2023) and Adewunmi (2019). They examined the influence of capital formation on Nigerian productivity, and reported that the gross fixed capital formation and the foreign direct investment have no significant effect on productivity in the country. However, national savings recorded a positive significant influence on productivity of the nation. Meanwhile, the gross national savings and gross capital formation have no significant effect on productivity in Nigeria (Akinola & Omolade, 2013).

Among the recent studies on a similar issue are Azimi (2022), Jiang and Wang (2023), Kabrt and Bruna (2022), Luqman and Soytas (2022), MacCarthy *et al*. (2022), and Matousek and Tzeremes (2021). Luqman and Soytas (2022) maintained that 'Human capital and trade liberalization' have become key elements in modern growth theories. Notwithstanding, the relationship between these factors and economic growth remains uncertain due to mixed evidence from previous research. This study addressed the debate by examining the asymmetric relationships between human capital, trade liberalization, and economic growth, incorporating labor and capital within the context of Pakistan's economy. Their analysis employed 'a nonlinear autoregressive distributed lag (NARDL) model'. Findings revealed that the positive and negative asymmetric effects of trade liberalization and human capital on growth differ significantly in both the short and long run. Specifically, greater trade liberalization negatively impacts economic growth over the long term, whereas human capital shows only a slight positive effect in both time horizons. These results offered important insights for economists and policymakers seeking to enhance the role of human capital and trade liberalization in Pakistan's economic development.

Similarly, the research conducted by Kabrt and Bruna (2022) empirically examined the varied impacts of foreign capital inflows on income distribution measured by the Gini index across Post-China 16 (PC16) countries from 1995 to 2017. The primary analysis employed fixed-effects and random-effects models, while an alternative approach applies a dynamic panel framework using the Arellano–Bond estimator alongside an autoregressive distributed lag (ARDL) model. The study evaluated both aggregate foreign capital inflows and their components including foreign direct investment (FDI), portfolio investment, and other investments, which further distinguishes between equity and debt categories. The findings indicated that foreign capital inflows primarily benefit certain income groups within PC16 countries. While FDI shows no significant effect on income inequality, portfolio investment tends to increase income disparities, whereas other investments

help narrow them. Additionally, debt-related FDI and portfolio debt inflows contribute to rising income inequality, though their short-term effects diminish substantially. Furthermore, debt-type FDI exacerbates inequality more in countries with higher GDP and Human Development Index scores, whereas the poorest and least developed nations utilize portfolio debt inflows in ways that further widen income gaps.

Furthermore, Matousek and Tzeremes (2021) revisited the impact of human capital on the economic growth trajectories of nations, with attention to its significance and the asymmetric influence it exerts. Using a sample of 100 countries from 1970 to 2014, the analysis employed both nonparametric and semiparametric methods. It examined potential nonlinear effects of human capital on economic growth through two different human capital stock indices, while considering the scenarios of both perfect and imperfect substitutability between skilled and unskilled labor. The findings indicated that human capital positively and significantly influences economic growth levels across countries. Moreover, the results provided strong evidence of a nonlinear relationship between human capital and economic growth. Notably, the asymmetric patterns in human capital's impact are more pronounced in cases of perfect substitutability between skilled and unskilled workers.

MacCarthy *et al*. (2022) examined the impact of capital flight on economic growth in Ghana. Using quarterly time series data from 1976 to 2020, the research evaluated three hypotheses. The analysis employed a nonlinear autoregressive distributed lag (NARDL) approach, which incorporated unit root, cointegration, and Wald tests to capture the asymmetric relationships among the variables. Findings indicated that both positive and negative shifts in capital flight significantly influence economic growth. Additionally, capital flight, along with other macroeconomic factors, accounts for approximately 75.28% of the variation in economic growth. The model also demonstrates that short-run imbalances adjust toward long-run equilibrium at a rate of 35.6%. Based on these results, the study advised policymakers to enhance economic stability and investor confidence to discourage capital outflows. Furthermore, it emphasized the need for strategies that would recover illicit funds held abroad by corrupt officials and reinvest them domestically to stimulate economic growth.

Azimi (2022) investigated how capital and money market indicators influence economic growth in China by applying nonlinear autoregressive distributed lag (NARDL) and dynamic multiplier approaches. The use of asymmetric techniques stemmed from the assumption that financial impacts on growth may not be linear. The findings confirmed the presence of asymmetric relationships and long-run linkages among these variables. Specifically, positive shocks in money market rates tend to reduce economic growth, while negative shocks enhance it. Conversely, negative shocks in real interest rates and total liquidity boost growth, whereas positive shocks dampen it in the short run. Furthermore, both positive and negative shocks in market capitalization and stock market turnover contribute to growth, while shocks in total stock traded negatively affect growth in both the short and long term. The error-correction results indicated a consistent adjustment speed from short-run

asymmetries toward long-run equilibrium, which suggests that stronger financial systems foster productive financial projects, and by extension, promote sustainable long-term growth. Based on these insights, the study offered relevant policy recommendations.

Jiang and Wang (2023) maintained that human health capital plays a crucial role in influencing a nation's economic development. This study investigated the nonlinear impact of human health capital on economic growth and evaluated its asymmetry over time. Using annual data from 1978 to 2021 for China, the analysis applied the nonlinear autoregressive distributed lag (NARDL) model to assess both short- and long-term effects of positive and negative shocks in health capital on economic growth. Human health capital was represented by personal health expenditure (PHE), government health expenditure (GHE), and social service expenditure (SSE). The findings revealed that a one-unit decrease in short-term private health expenditure reduces GDP per capita by 7.48%, while an increase in PHE raises GDP per capita by 3.51%. In the long run, the positive and negative coefficients for changes in PHE are 1.31 and 3.87, respectively. Similarly, a reduction in short-term government health spending leads to a 10.99% drop in GDP per capita, while the corresponding long-run coefficients are –4.33 (positive) and 1.99 (negative). For social service expenditure, a one-unit decrease in the short term results in a 5.56% decline in GDP per capita, whereas an increase boosts it by 5.97%. The long-run coefficients are 5.76 (positive) and 4.62 (negative). The results indicated significant asymmetry in the short- and long-term effects of both private and government health expenditures on economic growth. Thus, proper allocation of human health capital can substantially promote economic development.

2.3 The Major Gap

The review vindicates that mixed findings exist on studies on the influence of capital on productivity, and hence, generalization could not be done without empirical evidence. Also, such mixed findings could be the result of the asymmetry that might exist on the influence of capital on productivity; hence, it is essential to explore the non-linear effect of capital on productivity through more research in the relevant area.

2.4 Theoretical Framework

The research is anchored on the arguments and usage of Cobb-Douglas production function. This therefore informs the theoretical basis of the research.

3. Methodology

3.1 Data

Table 1 describes the variables in the data. The timeframe of the data from the world development indicators (WDI) of World Bank is from 1991 – 2022.. Year 2022 was the most recent data obtainable during the sourcing and estimation. Hence, it is the availability of data that informs the selection of the period.

To unify the measurements of the data, the researchers converted them into a logarithm, and interpreted them in percentages.

Table 1: Variables names, their description and measurements

Variable	Description
Productivity (GDP)	GDP (current LCU) is the sum of gross value added by all resident producers in Nigeria. It is the total value of commodities produces in Nigeria, annually.
Capital (Gross Capital Formation)	Gross capital formation (formerly gross domestic investment) consist all the assets in Nigeria that could be considered as capital. The value is measured annually by WDI
Labor	Labor force consists the population part ages 15 & above, who supply labor for the production of commodities, in a year

Source: Created by the Authors. Data and their descriptions are sourced from WDI.

3.2 Method of Estimation

The study utilized Non-linear Autoregressive Distributed Lag (NARDL) Model considering its benefits above other models of estimations, such as VAR, VECM, OLS and other. NARDL can estimate asymmetric effect as against the other models; it can also accommodate mix stationary variables. Also, the estimations using NARDL is valid even if small sample is used (Jalil *et al*., 2013).

3.3 The Model

Drawing insights from Danlami (2017)[a & b], Palomba (2004), and Pesaran *et al*. (1999; 2001), the model (NARDL) for this research is presented in the following Equations:

LGDP = f(LGCF, LBR)…….[1]

Where: LGDP is productivity of the nation, LGCF is Gross Capital Formation (the Capital), and LBR is the labor.

Transforming Equation 1 in an Econometric form it will become:

$$LGDP_t = \beta_0 + \beta_1 LGCF_t + \beta_2 LBR_t + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [\,2\,]$$

Where: β_0 is the constant (intercept) of the Equation, β_{is} are the coefficients of the variables, ε_t is

the error term and subscript t reflects the data as time series, and the rest of the constituents are as defined in the previous Equations.

Taking into cognizance, Pesaran *et al*., (1999, 2001) Equation [2] can be transformed into NARDL model as presented as follows:

The General Model of the NARDL:

$$\Delta LGDP_t = \beta_0 + \sum_{k=1}^{p} \beta_1 \Delta LGDP_{t-k} + \sum_{k=0}^{q} \beta_2^* \Delta LGCF_{t-k} + \sum_{k=0}^{q} \beta_3^* \Delta LBR_{t-k} + \beta_4 LGCF_t + \beta_5 LBR_t + \varepsilon_t \quad \ldots [3]$$

Where: Δ is the difference operator, the superscript * segregates the effect of positive shocks from that of negative shock (if asymmetry exist), otherwise it falls back to linear effect with value of unity (one).
Equation 3, (which is the general modeling) can be further separated into short-run and long-run Equations as follows:

Short Run Equation:

$$\Delta LGDP_t = \alpha_0 + \sum_{k=1}^{p} \alpha_1 \Delta LGDP_{t-k} + \sum_{k=0}^{q} \alpha_2^* \Delta LGCF_{t-k} + \sum_{k=0}^{q} \alpha_3^* \Delta LBR_{t-k} + \mathrm{v}_1 ECT_{t-1} + \varepsilon_t \quad [4]$$

Where: v is the speed of adjustment towards long run Equilibrium, ECT is the error correction term, and the rest of the constituents are as defined from the previous Equations.

Long Run Equation:

$$LGDP_t = \alpha_0 + \sum_{k=1}^{p} \alpha_1 LGDP_{t-k} + \sum_{k=0}^{q} \alpha_2^* LGCF_{t-k} + \sum_{k=0}^{q} \alpha_3^* LBR_{t-k} + \varepsilon_t \quad [5]$$

Where: All the variables are as defined in the previous Equations.

4. Results Presentations and Discussions

The descriptive statistics (presented in Table 2 below) is shows that the research variables are clustered around their average and the average values are greater than their respective standard deviations.

Table 2; Variables of the study' Descriptive Statistics

	GCPL	GDPL	LBRL
Average	24.48	30.61	17.73
Median	24.79	31.04	17.73
Maximum	25.73	32.80	18.12
Minimum	23.24	27.10	17.32
Std. Dev.	0.70	1.67	0.24
Skewness	-0.09	-0.48	-0.07
Kurtosis	1.78	2.07	1.81
Jarque-Bera	1.96	2.34	1.85
Probability	0.37	0.31	0.40
Sum	758.89	948.91	549.53
Sum Sq. Dev.	14.58	84.12	1.73
Observations	31	31	31

Source: Computed by the Authors, 2025

Table 3 presents the correlation analysis, which implies that the research variables are toughly positively correlated and significant. Hence, it is essential for a robust methodology such as NARDL to estimate the model. This would ensure that multicolinearity is excluded from the independent variables. However, multicolinearity is not a major problem in both ARDL and NARDL estimations (Jalil *et. al* 2013, Pesaran *et al*., 1999; 2001)

Correlation Probability	GCPL	GDPL	LBRL
GCPL	1.00		

GDPL	0.93	1.00	
	(0.0000)	-----	
LBRL	0.94	0.99	1.000000
	(0.0000)	(0.0000)	-----

Source: Computed by the Authors, 2025

4.1 Test of Stationary

This study also conducted the tests using Augmented Dickey-Fuller and Philips Peron, and their results displayed that all the research variables are stationary at first difference as offered in Table 4.

Table 4; Unit Root Test Results

-	ADF	ADF	PP	PP
VRBLES	**Level**	**1st Difference**	**Level**	**1st Difference**
GDPL	**-2.04 (0.5548)**	**-4.06** (0.0172)**	**-2.42 (0.3624)**	**-4.53** (0.0057)**
GCPL	**0.19 (0.9677)**	**-4.26** (0.0024)**	**0.21 (0.9690)**	**-4.20** (0.0028)**
LBRL	**-1.32 (0.6097)**	**-3.03** (0.0437)**	**-1.25 (0.6400)**	**-2.44* (0.0526)**

Source: Authors' 2025; Notes: '' '**' '***' represents statistically significant at 1, 5 & 10 percent levels, respectively. Figures in parenthesis represent probability. ADF is Augmented Dickey Fuller and PP represents Philips Peron.*

4.2 General Modeling of NARDL

Table 5 below offers the general modeling of the NARDL Akaike Criterion was used to account for the number of years/lag of years; hence, NARD (2, 0, 1, 0) was chosen on the bases of the selected criteria. The study utilized the general modeling to conduct both the bounds test of co-integration and the test of asymmetry.

Table 5: Results of the NARDL (2. 0, 1, 0) Estimation

VRBLES	Coefficient	Std. Error	t-Statistic	probabilities
GDPL(-1)	0.76*	0.09	8.28	0.0000
GCPL_POS	0.23	0.14	1.66	0.1097
GCPL_POS(-1)	-0.24	0.14	-1.67	0.1089
GCPL_NEG	0.34	0.21	1.67	0.1077
LBRL	1.69**	0.88	1.92	0.0662
C	-21.97	13.03	-1.69	0.1047

Source: Authors' 2025, Notes: '' '**' '***' represents statistically significant at 1, 5 & 10 percent levels, respectively.*

4.3 Co-integration (Bounds) Test

Bounds test of co-integration was conducted on the grounds of the general modeling results. The test revealed that long run relationships exist among the study variables, having F-statistic value of approximately 6.29. This is above the critical value of 4.59 and 5.61 of I(0) and I(1) at one percent level of significant, as presented in Table 6 below.

Table 6: Results of Bounds Test of Co-integration

Test Statistic	Value	K
F-statistic	6.287601	3

Critical Value Bounds

Significance	I0 Bound	I1 Bound
10%	2.72	3.77
5%	3.23	4.35
2.5%	3.69	4.89
1%	4.29	5.61

Source: Computed by the Authors, 2025

4.4 Test of Asymmetry

Existence of asymmetry or non-linear influence among the research variables is confirmed by this test as the F-statistic is found to be approximately 3.06 with the corresponding probability value of approximately 0.07. Hence, the asymmetric relationship exists at ten percent level of significance.

Table 7: Results of Test of Asymmetry

Test Type	Value	DF	Prob
F-statistic	3.056056	(2, 24)	0.0657
Chi-square	6.112111	2	0.0471

Source: Computed by the Authors, 2025

4.5 The Short Run and the Long Run Results

Table 8 below presents both Short-Run (SR) and Long-Run (LR) results of the estimated NARDL model. Note that S.R is Short Run while L.R is Long Run.

Table 8: Short Run and Long Run Results

Variables	Coefficients	STD Errors	t-Statistics	Prob
		S.R Regressors		
D(GCPL_POS)	0.23	0.14	1.66	0.1097
D(GCPL_NEG)	0.34	0.21	1.67	0.1077
D(LBRL)	1.69***	0.88	1.92	0.0662
CointEq(-1)	-0.24**	0.09	-2.69	0.0129
		L.R Regressors		
GCPL_POS	-0.01	0.44	-0.03	0.9760
GCPL_NEG	1.40**	0.55	2.54	0.0181
LBRL	6.88**	1.92	3.59	0.0015
C	-89.68**	33.36	-2.69	0.0129

Source: Authors' 2025, Notes: '' '**' '***' represents statistically significant at 1, 5 & 10 percent levels, respectively.*

4.6 Discussions of Findings

The short-run (SR Regressors) and long-run (LR Regressors) results are offered in Table 8. The results during the SR session indicated that positive and negative shocks of capital have insignificant influence on productivity. Meanwhile, labor records a linear significant effect on productivity during the session. In fact, a one percent increases in labor results in 1.69 increases in productivity in Nigeria (significant at 10 percent level). The speed of adjustment towards long run equilibrium is about 89.68 percent. This means that the LR period is reached in less than two years (less than two SR periods) as 89.68 percent is corrected towards the LR at every SR period. It is significant at five percent.

During the LR period, the positive shock of capital is insignificant in influencing productivity in the country despite having inverse influence. The negative shock of capital is significant in influencing the productivity in the country at five percent level. In fact, one percent reduction in capital in the LR period results in the increase in productivity by 1.4 percent, ceteris paribus. Meanwhile, labor is also significant at five percent level and can positively influence the country's productivity. Changes in labor by one percent leads to similar change in productivity by 6.88 percent in the same direction (increase in productivity as a result of increased labor, decrease in productivity due to reduction in labor) ceteris paribus.

4.7 Post Estimation Diagnostic Checks

The checks were carried out to certify the fitness of the estimated model; and their results are as follows:

Autocorrelation Test

Serial Correlation LM test was conducted (based on Breusch Godfrey).The F-statistic is 0.81, and a probability of 0.4583 signifies that autocorrelation is absence in the estimated model.

Heteroskedasticity Test

Breusch Pagan-Godfrey test of heteroskedasticity was conducted.The F-statistic is 1.19, and a probability of 0.3417 indicates the variance of the errors to be homoskedastic, not heteroskedastic.

Normality Test

The result of Jarque-Bera statistics (with a value of 9.61 and probability 0.0082) indicated that the estimated model's error terms are not normally distributed, but this is not an issue in the ARDL and NARDL model (Jalil *et al.,* 2013).

Specification Test

The specification test, the Ramsey reset test has an F-statistic value of 0.31, and probability value of 0.7581 implies that there is no specification error in the estimated model.

Table 9: Post Estimation Diagnostic Checks

Tests	F-statistics	Probability	Outcomes
Breusch-Pagan Test.	1.19	0.3417	No Heteroskedasticity
Breusch-Godfrey Test	0.81	0.4583	No Serial Correlation
Jarque-Bera	9.61	0.0082	Normally Distributed
Ransey Reset	0.31	0.7581	No Specification Error

Source: Authors' 2025

Dynamic Stability

Similarly, the estimated models are dynamically stable based on the estimated CUSUM and CUSUM of Squares. The estimated model falls amid the upper and lower ridge line of the tests as shown in Figure 1 and Figure 2.

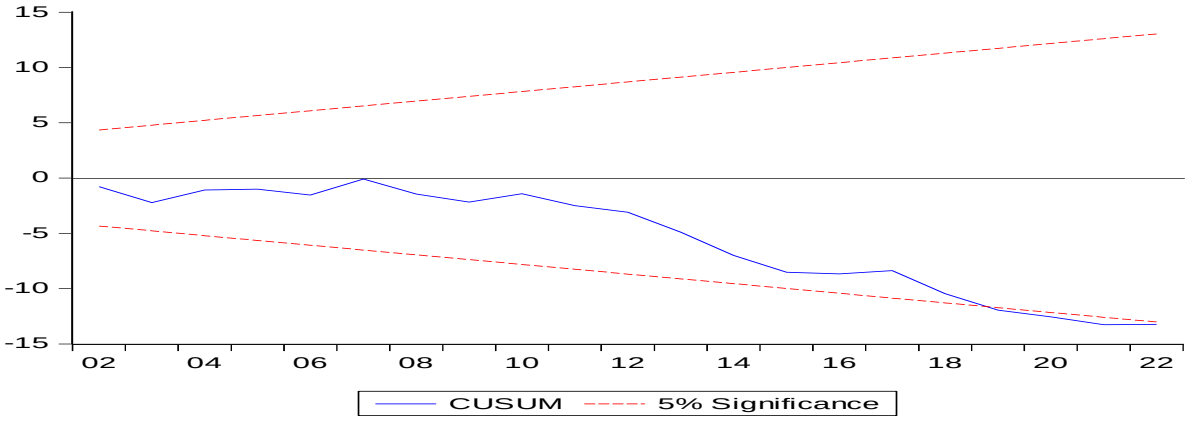

Figure 1: CUSUM of the Model

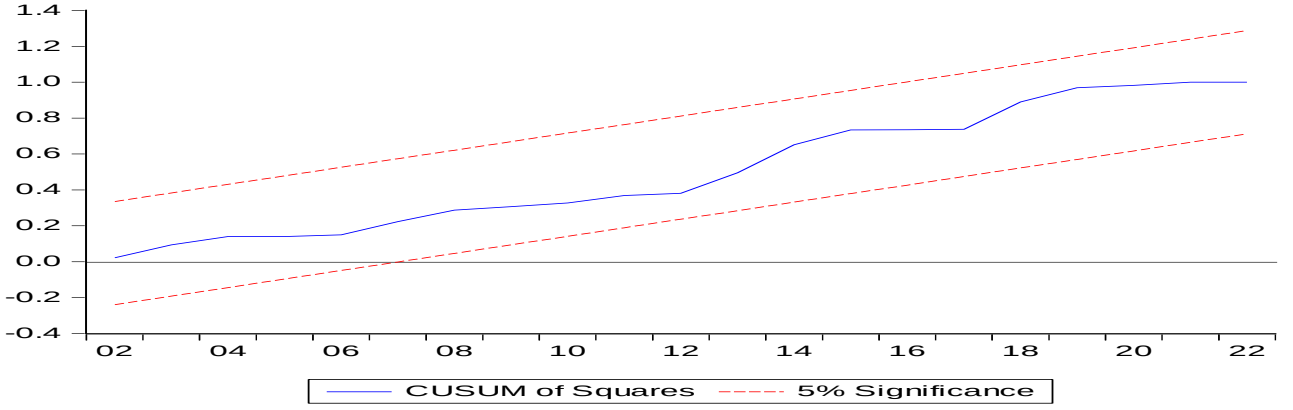

Figure 2: CUSUMSQ of the Model

5. Conclusion

This study was conducted to purposively check and analyze the asymmetric effect capital on productivity in Nigeria using NARDL model. First, tests of stationary were conducted, and it showed that the variables are all stationary at first difference, while Bounds test also showed the presence of long run relationships. Meanwhile, test of asymmetry showed the presence of non-linear effect of capital on productivity during the period of the study. During the SR period, both positive and negative shocks of capital were insignificant in affecting the productivity of the nation though, and labor was significant and could influence productivity based on linear effect. The LR period was reached in less than two SR periods and it was considered to the fast. In the LR, the positive shock of capital was insignificant in influencing the productivity in the country. Meanwhile, the negative shock could significantly influence productivity positively. Labor could also influence productivity positively. The implication of this study is that the country considering its vast and high population, is encouraged to adopt labor intensive technique, and utilize more of its labor in the production process. This can increase and influence productivity positively in Nigeria. However, the findings of this research are limited to Nigeria whose data were used based on the methodology applied (NARDL) and the period utilized.

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