Public Capital and Economic Growth Dynamics in Nigeria

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Abstract - **Using annual time series data covering the period 1981 to 2017, this paper investigates the relationship between public capital investment and economic growth in Nigeria using the General to Specific (GETS) approach. The empirical findings reveal that public capital and labour force have a detrimental impact on economic growth. The study also discovered that private capital and growth are positively related. The Granger causality tests, on the other hand, unveil that both bidirectional and unidirectional causal linkages. As a result, these findings suggest that infrastructure development should be emphasized through public-private partnerships and a favourable investment climate to stimulate private sector investment to sustain long-term economic growth should be improved.**

Keywords: Public capital; Private capital; Economic growth; Nigeria.

I. Introduction

Public capital is often regarded as a fiscal tool for stimulating economic growth and adjusting to economic downturns (Zhou, Raza and Sui, 2021). Transportation, energy, telecommunications, education, and health care facilities are all examples of infrastructure investment. These infrastructure facilities make up the majority of public capital investment that assist country's economy expand and develop sustainably (Tilahun, 2021). The World Bank underlined the importance of public capital investment, particularly in infrastructure development, which is the backbone, if not the engine of a nation's economic activity (Lechman and Popowska 2022; Romp and Haan, 2007; World Bank; 2004). There are several complex processes that link public capital with the economy. First, as a production intermediate, and second, infrastructure investment stimulates the production of other inputs (Kessides, 1992; Adenikinju, 2003). For that reason, public infrastructure projects are said to facilitate the development of private sector investment by increasing output growth (Chirinko, 1993; Aschauer, 1989a, b), but they take longer to pay off. Equally, the private sector can benefit from the spillovers of public sector capital both while and after the infrastructure project is completed. Well-developed roads and railway transportation systems, for example, reduce transportation costs and thus create an enabling environment for

economic activity. In the same way, investing in social services like education and health care facilities improves quality of human capital and life expectancy.

In developing countries, most infrastructure facilities are capital intensive and demand significant costs, and these countries especially in African have low-income and low savings, for that reason, investments in infrastructure projects have been facing serious obstacles in. As a result, the majority of infrastructure projects are funded through fiscal measures such as public debt or taxes (Barro, 1989; Zou et al., 2021; Islam et al., 2022). As a result, most countries rest on foreign interventions through foreign aid and borrowing to augment infrastructure deficit (Adamu, 2019).In addition, the long gestation period makes it unappealing to private sectors as a consequence limited private sectors are ready to engage in infrastructure investment to complement the public (Adenikinju, 2003; Adamu, 2016).For instance, Nigeria, as referred to "Giant of Africa" the state of public investment has been a long issue of concern due to inadequate funding and lack of proper maintenance of the existing ones. These created a wide infrastructure gaps and limit the development of private investment and long run economic growth (Adamu and Rasiah, 2016, Rasiah, Asirvatham and Adamu, 2017). Nigeria is looking into other alternatives to get over the infrastructure deficits since it is a single area that promotes economic activities and in turn lead to sustainable growth.

Although, understanding public capital investment in Nigeria is a difficult task because of the poor information from both public and private sector participation. However, as opposed to private sector investment, it is widely assumed that public investment in infrastructure development accounts for the majority of investment (Adamu and Rasiah, 2017; Adamu et al., 2021). According to World Bank (2017) Nigeria has recorded high investment rates in the early 1980s, indicating that Nigeria was able to benefit from infrastructure development from the oil revenue of the 1970s. Following the 1982 oil price crash and subsequent debt crisis, which mostly affected oil-rich countries, public investment as a percentage of GDP began to decline from 33% in 1981 to 12% in 1984. Furthermore, the 1986 government reform suggested an economic strategy known as the Structural Adjustment Program (SAP) targeted at reviving the economy through public and private sector investments. Regrettably, SAP failed, instead, the investment decline further from 15.6 per cent in 1986 to 7 per cent in 1995 and then picking up to 9.9, 11.8, and 11.4 per cent in 2003 and 2012 decrease a little and pick up to 11.8 per cent and 14.7 per cent in between 2013 and 2017. On the other hand, the trend of average annual GDP growth rate in Nigeria has been negative of about -5.6 per cent during the 1981 to 1984 period. However, the rate increased averagely to about 3.85 per cent during 1985 to 2002 periods. The rate later increased to an average of 7.4 per cent during 2003 to 2017 periods. The decline in public infrastructure has not been bounded to Nigeria. The majority of developing countries have experienced such challenges. Having looking at the trends, it is appropriate to determine whether or not public investment enhances output growth in Nigeria.

This paper seeks to investigate the impact of public capital investment on economic growth in a small open economy, Nigeria covering the period 1981 to 2017. The aim of this paper is to add to the current literature in three dimensions. First, while empirical studies on public capital-economic growth have been reviewed in the literature, there have been few studies on Nigeria. To the best of our knowledge, just a few researchers have acknowledged the importance of public capital in promoting economic growth. Ogun (2010) and Akinlabi et al., (2011) for example, are notable studies. These studies are similar to the current one, but their goals are different. They investigated the impact of public capital components on Nigeria's economic development, with a focus on poverty alleviation. In this study, output growth in Nigeria is explained using disaggregated investment and labor force data. Second, pioneer studies(see, for example, Aschauer (1989); Munnell, (1992) have been heavily criticized by Gramlich (1994); Sturm and de Haan, 1995; Garcia-Mila et al., (1996); Evans and Karras, 1994; and Sturm, 1998 for failing to account for the stochastic and deterministic trend in the series. To overcome this problem, this paper cross-examines the series to eliminate non-stationarity in the series. In addition, the unit root test developed by Zivot and Andrew (1992) is used to detect unexpected shifts that could result in a structural break in the series. Third, unlike the past studies, this paper employs newly cointegration modeling technique developed by Bayer and Hanck (2013) against the traditional cointegration test such as Engle and Granger (1987), Johansen and Juselius (1990) and ARDL bound test by Pesaran et al., (2001). The problem with Engle and Granger and Johansen and Juselius are that they provide biased empirical results due their low explanatory power properties (Ahmed et al., 2016). Equally, the ARDL single equation approach is unable to handle many cointegration relations simultaneously. For a robust result, Bayer-combined Hanck's cointegration technique employs many cointegration tests.

II.   Literature Review

Numerous theoretical and empirical viewpoints on the relationship between public capital and economic growth have been contested in recent times. For instance, neoclassical growth theory of Solow (1956) is built on technological relationship between output and production inputs. A rise in savings and investment rate of output growth may be temporarily while the steady state growth is determined by population growth and technological

progress. Similarly, a rise in public capital on growth may depend on the marginal productivity of public and private capital. Therefore, a raise in public capital will lead to a higher or lower return of economic growth (Aschauer, 1990). By employing a variety of financial plans, Arrow and Kurz (1970) contend that public capital plays an important role in promoting economic growth and welfare. According to them, public capital investment in human capital and infrastructure development constitutes a major part of the country's aggregate production function. However, neoclassical growth theory claims that an increase in public investment could harm economic growth because it can be achieved by directly raising taxes or by increasing public debt levels. If increased taxes were used to fund public investment, aggregate demand would fall and economic growth would dawdle or negatively affected (Barro 1989; Bah and Kpognon, 2021).

Figure 1 depicts the interaction of public capital and private capital stock with labour input as the conduits through which economic growth might be enhanced (Guild, 2000). For example, investment in public capital stock is an essential component of aggregate demand, it may be a major factor of growth and may not. As a result, its variations may have either positive or negative long term consequences on economic growth (Donwa and Agbontaen, 2010), although a solid institutional quality and macroeconomic policy framework may contribute to increased productivity. According to Ghali (1998) and Badawi (2003), increasing public capital investment might have three different outcomes. To begin with, productive public capital complements private capital; additionally, increased public capital investment supports output development. Second, raising public capital will raise private capital and output, improving private capital's marginal productivity relative to the real interest rate. Third, an increase in public capital boosts output by increasing labor productivity. The interplay between both inputs could result in a multiplier impact in the economy.
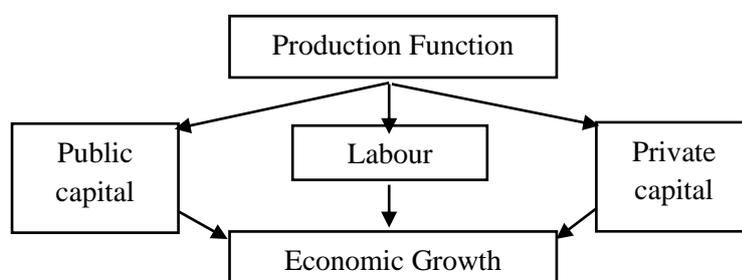

Figure 1: A schematic framework for Public capital and Economic growth

Studies on the relationship between public capital and economic growth have remained a source of controversy from an empirical standpoint, resulting in divergent viewpoints across countries and study periods. In a nutshell, reference should be made of numerous studies that are closely related with the present paper. At the point of departure, the paper begin with the pioneer empirical studies of Aschauer (1989a, b), which served as touchstone for all that postdated. In his study, Aschauer reveals a decline in U.S. output growth resulting from a decline in the public capital investment in the last decades. In their study, Munnell (1990, 1992) and Garcia-Mila and McGuire (1992) establish that a lower output growth, this is consistent with Aschauer's findings. Kamp (2005) examines the impact of public capital on production efficiency in 22 OECD countries from 1960 to 2001.Results indicate positive and significant effect of public capital on output of the OECD. Similarly, Batina (1998), Romp and de Haan (2007), Gufta et al., (2014), de frutos et al., (1998); Pereira and Roca-sageles (2003); Bottasso et al., (2013); Gupta et al., (2014); Arslanalp et al., (2010); Belloc and Vertova (2006) found positive effect of public capital on output growth. Furthermore, studies by Everaert and Heylen (2003)for Belgium; Ligthart (2000) for Portugal; Sahoo and Dash (2009) for India; Dalamagas (2000) for Greece; Fedderke et al., (2006) for South Africa; Sahoo and Dash (2009); Okoh and Ebi (2013) confirmed that public capital enhances output as well as causal relation between public capital to economic growth. Implying that public capital investment causes output growth or public capital depends on output growth.

In a related studies, Fedderke et al., (2006) for South Africa; Batina (1998) for U.S; de Frutos et al., (1998) for Spain; Kumo (2012) for South Africa; Uneze (2013) for 13 Sub-Saharan Africa found a positive relation as well as bi-directional (two-way) causality running in both directions simultaneously. This indicates both public capital and economic growth complement to each other i.e. feedback causality. Equally, few empirical studies have been found, concluding an inverse relation and non-causality between public capital, economic growth and population. These studies are in line with the findings by Ghali (1998) for Tunisia; Ibrahim (2000) for Malaysia, Dalamagas (2000) for Greece; Fosu *et al.*, (2012) for Sub-Saharan Africa; Herranz-Loncan (2007) for Spanish and Ma'in et al., (2018) among others. This denotes a null relationship between public capital and economic growth which do not produce a clear and satisfactory direction to assist the policy makers. Table 1 presents a meta-analysis of the studies according to countries, sample period, methodological approaches and their findings as widely acknowledged by Kamps (2005); Button (1998) among others.

Table 1: A Meta data set of some related empirical studies

Author (s)	Scope	Methodology	Causality	Effects
Single country case				
Aschauer (1989)	U.S. (1949-1985)	OLS	na	+
Munnell(1992)	7 OECD (1963-1988)	OLS	na	+
Ghali (1998)	Tunisia (1963-1993)	VECM, G & C	Kg ≠ Kp	**-**
Batina (1998)	U.S. (1948-1993)	VAR & VECM	Kg→Y	+
de Frutos et al., (1998)	Spain (1964-1992)	SVARMA	Na	+
Ligthart (2000)	Portugal (1965-1995)	VAR, G & C	na	+
Ibrahim (2000)	Malaysia (1961-1995)	OLS	na	-
Dalamagas (2000)	Greece (1956-1994)	AR and K-F	Kg ≠ Y	+
Everaert&Heylen (2003)	Belgium (1953-1996)	VECM, G & C	Kg→Y	+
Pereira & Roca-Sagales (2003)	Spain (1970-1995)	VAR	na	+
Fedderke et al., (2006)	S/Africa (1875-2	VAR, VECM, G & C	Kg ≠ Y	+
Herranz-Loncan (2007)	Spain (1850-1935)	VAR	Kg ≠ Y	+
Romp & de Haan (2007)	U.S. (1970-2004)	VAR	na	+
Sahoo& Dash (2009)	India (1970-2006)	G & C, OLS	Kg→Y	+
Kumo (2012)	South Africa (1960-2009)	ARDL	Kg↔Y	+
Okoh and Ebi (2013)	Nigeria	OLS, G & C	Kg↔Y	+
Nedozi et al., (2014)	Nigeria (1981-2013)	OLS	na	+
Bal et al., (2016)	India (1970-2012)	ARDL	na	+
Multi-country case				
Aschauer (1989b)	G7 Countries (1966-1985)	OLS	na	+
Munnell(1992)	7 OECD (1963-1988)	OLS	na	+
Kamps (2005)	22 OECD (1960-2001)	VECM	na	+
Belloc &Vertova (2006)	7 Countries (1970-1999)	VECM	na	+
Arslanalp et al., (2010)	48 OECD (1960-2001)	OLS	na	+
Fosu et al., (2012)	SSA countries (1967-2008)	GMM	Kg ≠ Y	+
Sahoo& Dash (2012)	S/Asia (1980-2005)	G & C	Kg↔Y	+
Bottasso et al., (2013	21 OECD (1975-2002)	OLS and Cup-FM	na	+
Uneze (2013)	13 SSA countries ()	G & C	Kg↔Y	+
Gupta et al., (2014)	71countries (2007-2010)	GMM	na	+

Note: Y = Output growth; KG = Public capital; KP = Private capital; L/N = Labour or employment; G = Government size/spending; M2 = Broad money; X = Export; M= Import; O = official exchange rate; VECM = Vector Error Correction Model; VAR = Vector Autoregressive Model; G & C = Granger Causality test; FM-OLS = Fully Modified Ordinary Least Square; 2SLS = Two-Stage Least Squares; GMM = Generalized Method Moments; K-F = Kalman-Filter test; ARDL = Autoregressive Distributed Lag; CUP-FM = Continuously Updated Fully Modified estimator; SVARMA = Structural Vector Autoregressive Moving Average; → = unidirectional; ↔ = bidirectional; ≠ = no causality.

III. Data and Methodology

Theoretical model and Data

For this study, we build our theoretical model base onthe standard production functionand mirrored the empirical works of Aschauer (1989);Munell (1990);Button (1998) and more importantly the recent study by Arslanalp et al., (2010).Consider the following neoclassical production function of the form:

$$Y_t = A_t LF_t^{\alpha} KG_t^{\beta} KP_t^{\delta} \varepsilon_t \qquad (1)$$

eqn. (1) expressed a production function where the physical output (Y_t) is solely depending on two homogeneous physical inputs, namely, labour and capital stock. The variable Y_t stands for the country's aggregate demand. A is the total factor productivity, LF_t is the stock of labour available in the economy, KG_t is the stock of public capital and KP_t is the stock of private capital which are substitutable in the production function as an extension of neoclassical growth model (see, Arrow andKurz;1970 and Barro, 1990),[1] and ε is the normal error term and t is the time period, α, β and δ are the expected coefficients to be estimated. Following Samuel (2013) the impacts of capital formation and other macroeconomic variables on real GDP growth could be measured through the changes in factor productivity, A component of Y_t. Thus, we assume that A is dependent on public capital and other relevant macroeconomic variables. Therefore, eqn. (1) can be re-written as:

$$A_t = f(LF_t, KG_t, KP_t) = LF_t^{\alpha} KG_t^{\beta} KP_t^{\delta} \qquad (2)$$

Rearranging the variables in order of priority from eqn. (2) gives an augmented growth equation in the form:

$$Y_t = c + \alpha KG_t + \beta KP_t + \delta LF_t^{'} + \varepsilon_t \qquad (3)$$

where a reduced form equation, eqn. (3) define the elasticity of output (Y_t) with respect to public capital formation (KG_t), β, α and δ are the basic component of production function to assess the input-output relations (Arslanalp et al., 2010). Assuming a factor markets is perfectly competitive, private capital (KP_t) and labour (LF_t) must be paid their marginal products, thus, $\alpha + \beta = 1$ respectively. Conversely, δ is expected to be positive, the model would generate increasing returns to scale ($\alpha + \beta + \delta$ >1). On the contrary, a constant returns to scale ($\alpha + \beta + \delta$ =1), then labour and private capital have to pay more than their marginal product (<1). This is exactly when public capital generates indirect income for labour and private capital, though it is not paid directly for its services (Arslanalp et al., 2010).By incorporating coefficients to the parameters and taking the natural logarithm of eqn. (3) gives as an empirical growth model in the form:

$$\ln(Y_t) = \beta_0 + \beta_1 \ln(KG_t) + \beta_2 \ln(KP_t) + \beta_3 \ln(LF_t)^{'} + \varepsilon_t \qquad (4)$$

The objective is to study the effect of public capital investment on economic growth. To achieve the stated objective, we employ annual time series data sets for Nigeria, from 1981through 2017. The data sets are chosen based on availability of data within the time frame. Real GDP per capita is measured in constant U.S. dollars base year 2000, and public capital investment is measured by the gross fixed capital formation as percentage of GDP. Indeed, due to insufficient data on private capital stock, we make use of foreign direct investment as percentage of GDP to proxy private capital investment, and lastly, labour force is measured by the total number of active labour force participation. All data were obtained from the World Development Indicators, World Bank (CD-ROM).

Integration and Cointegration test

We employ the Ng and Perron (2001) unit root test to examine the order of integration of the candidate variables, which outperforms the traditional unit root tests such the ADF (1981) and PP (1988) unit root tests. Where the root of the autoregressive polynomial is about but less than a unit, the ADF and PP unit root tests have inadequate explanatory power (Ng and Perron, 2001). Additionally, when the moving average polynomial of the first differenced series has a significant negative root, these traditional unit root tests indicate significant amount of bias (Ng and Perron, 2001). Zivot and Andrew (1992) unit root test is also employed to check for structural breaks caused by changes in economic policy or asymmetric shocks (John et al., 2007). This test derives information about a particular break point at a specific time endogenously from the series. For unit root testing, it also does not produce biased findings. Consider the model below, which takes pattern, intercept, and slope into account.

$$\Delta y_t = \psi + \gamma_1 y_{t-1} + \beta t + \pi_1 DU_t(\tau) + \eta_1 DT_t(\tau) + \sum_{j=1}^{p} \alpha_j \Delta y_{t-j} + \varepsilon_t \qquad (5)$$

where t = 1, 2, 3, 4,..., T, Δ is the first difference operator, y is the variables to be checked, and The dummy variable DU_t represents the mean shift occurring at the period *TB* (Time Break), whereas *DT* denotes the comparable dummy for the trend variable. If t >*TB*, DU_t equals to 1; otherwise, it equals to 0. $DT_t = t\text{-}TB$ if t is greater than *TB*, and Zero otherwise. Following that, the cointegrating relation between the variables must be estimated.

For the null of no cointegration relation, we employ Bayer and Hanch (2013) joint test statistics. Engle and Granger, Johansen, Peter Boswijk, and Banajee tests are encompassed in this new combined cointegration test. One of the benefits of this method is that it produces unique cointegration findings for each model. The Bayer-Hanck test estimated the level of significance of each cointegration equation using Fisher's formulas in the following form:

$$EG - JOH = -2[\ln(PEG) + (PJOH)] \tag{6}$$

$$EG - JOH - BO - BDM = -2[\ln(PEG) + (PJOH) + (PBO) + (PBDM)] \tag{7}$$

The probability values of different model cointegration tests are described by PEG, PJOH, PBO, and PBDM in eqn. (6) and (7). We may conclude that the null hypothesis of no cointegration is rejected if the approximate Fisher statistics is greater than the critical values established by Bayer and Hanck (2013). In a multivariate scheme, the Johansen cointegration test is used in addition to the Bayer and Hanck combine cointegration tests for robustness checks. The Johansen test is used to find out how many cointegrating vectors there are between variables. For a cointegration to occur there must be at least one cointegrating vector. The Johansen (1988) and Johansen and Juselius (1990) methods also take into account the calculation of all potential cointegrating vectors between the variables.

Parsimonious Vector Error Correction model

After the cointegration relationship, the next step is to establish the short run dynamic model by employing the vector error correction model (VECM). Thereupon, the VECM can be specified as:

$$\Delta Y_t = \sum_{j-1}^{p-1} \Pi_j \Delta_{t-j} + \delta \gamma Y_{t-p} + \vartheta + \varphi_t \tag{8}$$

where eq. (8) represents the vector error correction components with Y_t is a $k \, Y \, 1$ vector of the exogenous variables.

IV. Empirical results

Table 2 presents the descriptive statistics for the four series. Except labour force, the estimated Jaque-Bera statistics for economic growth, public capital and private capital are normally distributed. The mean and median values have no wide margin. This indicates the absence of high outliers. The standard deviation suggests that the variables exhibit a normal distribution. The next step is to observe the variables stationarity properties. Table 3 reports the output of the Ng-Perron unit root test in which economic growth, public capital, private capital and labour force are not stationary in their levels. After conducting the first difference test all the variables are found stationary. Thus, we conclude that all the variables have unique order of integration meaning there are integrated of order one, i.e. $I(1)$.

Table 2: Descriptive statistics

Variable	Mean	Median	Max	Min	Std. Dev.	Jarque-Bera
lnY_t	10.582	10.735	13.307	7.521	2.046	3.381 (0.184)
lnKG_t	3.454	3.599	4.492	2.651	0.539	1.501 (0.472)
lnKP_t	0.721	0.655	1.756	0.071	0.442	1.523 (0.466)
lnLF_t	3.997	4.006	4.022	3.952	0.022	7.684 (0.021)

Observations = 37; Sample = 1981 - 2017

Note: Figures in bracket (…) are *p*-values.

Table 3:Ng-PerronUnit root test

Variable	MZa	MZt	MSB	MPT
lnY_t	-8.573	-1.926	0.224	11.097
$lnKG_t$	-5.766	-1.639	0.284	15.688
$lnKP_t$	-3.788	-1.337	0.353	23.498
$lnLF_t$	-6.503	-1.788	0.275	14.014
ΔlnY_t	-12.298[*]	-2.467	0.200	7.477
$\Delta lnKG_t$	-17.363[**]	-2.943	0.169	5.266
$\Delta lnKP_t$	-26.914[***]	-3.668	0.136	3.386
$\Delta lnLF_t$	-17.404[**]	-2.949	0.169	5.236
Asymptotic critical values				
1 percent	-23.800	-3.420	0.143	4.030
5 percent	-17.300	-2.910	0.168	5.580
10 percent	-14.200	-2.620	0.185	6.670

Notes: ** and *** indicates 5% and 10% level of significance.Intercept and trend
are included in the test.

The Zivot and Andrew unit root test results are shown in Table 4. The presence of unit root is verified for economic growth, public capital, private capital, and labor force, but after the first difference, stationarity is reached, and the null hypothesis of unit root is rejected. However, the result reveals that 1989, 1990, 1994 and 1998 are the break points. These periods correspond with the Structural Adjustment Program (SAP) and rolling plans between 1986 and 1998. The SAP entails policy changes through total shifts from public sector based policy for private sector led growth. It was also aimed to align problems bedeviling the Nigerian economy following a decline in the oil revenues, increase fiscal and infrastructure deficits. Dismally, the ratio of public expenditure to GDP decreased since 1970, with the exception of some few years. For example, it was approximately 16, 10 and 6percent in 1980 to 1985, 1986 to 1990 and 1991 to 1996 periods. Indeed, from 1989 to 1996 the share of public investment to GDP averaged only 6 percent respectively (Ukah, 2007). The policy shifts in 1986 and the aftermath of economic uncertainty might have caused the decline in public capital.

Table 4:Zivot-Andrew unit root test with structural break

Variable	At level		At first difference		I(d)
	t_α	TB	t_α	TB	
lnY_t	-1.434 (2)	1999	-6.255 (3)[***]	1990	I(1)
$lnKG_t$	-2.827 (1)	1991	-6.854 (2)[***]	1989	I(1)
$lnKP_t$	-2.515 (0)	1991	-8.375 (3)[***]	1994	I(1)
$lnLF_t$	-2.198 (1)	1988	-6.893 (3)[***]	1998	I(1)

Note: *** indicate the rejection of unit root hypothesis at the 1 percent
level. Lags included are based on Akaike Information Criterion (AIC).

Table 5 reports the results of the cointegration test using the Akaike Information Criterion. The derived Fisher statistics for the EG-JOH and EG-JOH-BO-BDM for the four models - *lnY*, *lnKG*, *lnKP*, and *lnLF* - appear to be statistically significant for the EG-JOH and EG-JOH-BO-BDM at most 10% critical values. This

means that the EG-JOH and EG-JOH-BO-BDM tests statistics reject the null hypothesis that the variables have long run relationship. As a result, we conclude that public capital, private capital, labor force, and economic growthare cointegrated.

Table 5:Bayer and Hanckcombine cointegration test, 3 lag length

Model	EG-JOH	EG-JOH-BO-BDM	Inference
$lnY_t = f(lnKG_t, lnKP_t, lnLF_t)$	7.318	19.442[*]	Cointegration
$lnKG_t = f(lnY_t, lnKP_t, lnLF_t)$	21.916	29.761[**]	Cointegration
$lnKP_t = f(lnKG_t, lnY_t, lnLF_t)$	6.439	32.118[***]	Cointegration
$lnLF_t = f(lnY_t, lnKP_t, lnKG_t)$	24.667	38.429[***]	Cointegration
Level of significance	Bayer-HanckCritical values		
1 per cent level	16.25	31.16	
5 per cent level	10.63	20.48	
10 per cent level	8.36	16.09	

Note: [*], [**]and [***]indicates significance at 1%, 5% and 10% level respectively.

The presence of a long run cointegrating relationship among the variables necessitates the application of a dynamic short-run model that can be estimated and explores the impact of changes in each variable on economic growth. As a result, Engle and Granger (1987) Vector Error Correction Model (VECM) is defined as.

$$\Delta \ln(Y_t) = \beta_0 + \sum_{i=1}^{p}\beta_1\Delta\ln(Y_t) + \sum_{i=0}^{p}\beta_2\Delta\ln(KG_t) + \sum_{i=0}^{p}\beta_3\Delta\ln(KP_t) + \sum_{i=0}^{p}\beta_4\Delta\ln(LF_t) + \lambda_1(ect_{t-1}) + \varepsilon_{t,1} \quad (8)$$

$$\Delta \ln(KG_t) = \beta_0 + \sum_{i=1}^{p}\beta_1\Delta\ln(KG_t) + \sum_{i=0}^{p}\beta_2\Delta\ln(Y_t) + \sum_{i=0}^{p}\beta_3\Delta\ln(KP_t) + \sum_{i=0}^{p}\beta_4\Delta\ln(LF_t) + \lambda_1(ect_{t-1}) + \varepsilon_{t,2} \quad (9)$$

$$\Delta \ln(KP_t) = \beta_0 + \sum_{i=1}^{p}\beta_1\Delta\ln(KP_t) + \sum_{i=0}^{p}\beta_2\Delta\ln(Y_t) + \sum_{i=0}^{p}\beta_3\Delta\ln(KG_t) + \sum_{i=0}^{p}\beta_4\Delta\ln(LF_t) + \lambda_1(ect_{t-1}) + \varepsilon_{t,3} \quad (10)$$

$$\Delta \ln(LF_t) = \beta_0 + \sum_{i=1}^{p}\beta_1\Delta\ln(LF_t) + \sum_{i=0}^{p}\beta_2\Delta\ln(Y_t) + \sum_{i=0}^{p}\beta_3\Delta\ln(KG_t) + \sum_{i=0}^{p}\beta_4\Delta\ln(KP_t) + \lambda_1(ect_{t-1}) + \varepsilon_{t,4} \quad (11)$$

Where p is the lag length, Δ is the first difference operator and β_i are the coefficients of the variables in the short run dynamics model, and ect_{t-1} denotes the one lagged error correction term. T and ε are time dynamic and the Gaussian error term to capture unobserved variables in the model.

Panel A of Table 6 presents the estimated long run coefficients. It is note that the results reveal that the response of the public capital stock on economic growth is negative and significant at the 5 percent level, though a positive sign is expected. A 1% decrease in public capital reduces growth by 3.4percent. This implies that public capital has been counterproductive within the period under study. This is consistent with neoclassical growth theory, which claims that using public debt or taxes to finance public capital investment can have a negative impact on growth (Barro, 1989). It contradicts the findings of Aschauer (1989); Munnell (1990); Everaet and Heylen (2003); Ligthart (2000); Kumo (2012); Gupta et al., (2014), among others, but it is unswerving with Ibrahim (2000) and Ghali (2000) studies. At the 1% level, private capital is positive and significant. According to this, a 1% increase in private capital would enhance economic growth by 38%. At the 5% level, the labour force coefficient is negative and significant. This means that a 1% reduction in the labour force affects economic growth by 16%.

Panel B of Table 6 reports the coefficients of the short run dynamic model using general to specific approach (Hendry, 1986; 1987, and 1995; Shuaibu and Adamu, 2021). This method is flexible since it permits the re-run of the short run model by eliminating statistically insignificant lagged variables till a parsimonious error correction model is attained (see, for example, Odhiambo, 2008). Similarly, long-run results show that the coefficient of lagged public capital is negative and significant at most 5%. This implies that public capital and labour force adversely affects output growth respectively. We also found that the coefficient of private capital stock promotes economic growth as well.

Table 6: Long run and Short run coefficientsDependent variable: lnY_t

Variable	Coeff.	Std.error	t-stat.		Prob.
Panel A: Long run coefficients					
Intercept	-44.971	17.313	-2.597	*	0.013**
$lnKG_t$	-3.385	0.199	-16.983	*	0.000**
$lnKP_t$	0.382	0.208	1.836		0.075**
$lnLF_t$	16.764	4.242	3.951		0.000**
Panel B: Short run coefficients					
Intercept	0.104	0.029	3.555	*	0.001**
$\Delta lnKG_{t-1}$	-0.580	0.192	-3.018	*	0.006**
$\Delta lnKG_{t-3}$	-0.552	0.206	-2.671		0.014**
$\Delta lnKG_{t-4}$	-0.411	0.181	-2.268		0.034**
$\Delta lnKG_{t-5}$	-0.717	0.213	-3.367	*	0.002**
$\Delta lnKP_{t-1}$	0.131	0.038	3.383	*	0.002**
$\Delta lnKP_{t-2}$	0.146	0.042	3.403	*	0.002**
$\Delta lnKP_{t-3}$	0.102	0.038	2.699		0.013**
$\Delta lnLF_{t-2}$	-10.452	2.371	-4.495	*	0.000**
ect_{t-1}	-0.452	0.158	-2.860	*	0.009**
R^2	0.662				
DW	1.891				
F-test	4.570***				

Panel *C: Diagnostic test*	F-statistics [p-value]
$\chi^2 SERIAL$	(2,19) = 1.039 [0.372]
$\chi^2 NORMAL$	1.244 = [0.536]
$\chi^2 ARCH$	(1, 28) = 0.505 [0.482]
$\chi^2 RAMSEY$	(1, 20) = 1.516 [0.328]

Note: Notes: ***, ** and * indicate 1, 5 and 10 percent level of significance.

Moreover, as expected, the lagged error correction term (ect_{t-1}) is negative and statistically significant at the 1% level. This validated the cointegrating link between the public capital, private capital, labour force and economic growth, and it also means that the speed of adjustment from short run deviations to the long run deviations is adjusted by 45%.Though, the rate of speed to the long run equilibrium aftershock is moderate, but still confirmed that output growth is triggered by public capital and labour force in Nigeria. Additionally, the value of *R-squared* that measures the goodness of fit is 66%. This implies that the estimated model explain 66% goodness of fit, indicating a variation in economic growth as relates to independent variables. Similarly, Panel C of Table 6 reports the short run diagnostic tests such as serial correlation, Jaque-Bera (Normal), Ramsey RESET, ARCH for heterokedasticity have been examined and validated. This implies that the short run model is free from misspecification. To confirm the stability of the dynamic model, we employ the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) recursive residuals (Brown *et al.,*1975). Figure 2 reports the stability test which indicates that the bands are stable within the 5percent significance levels, which suggests that the model is stable and reliable to explain the variables relations.
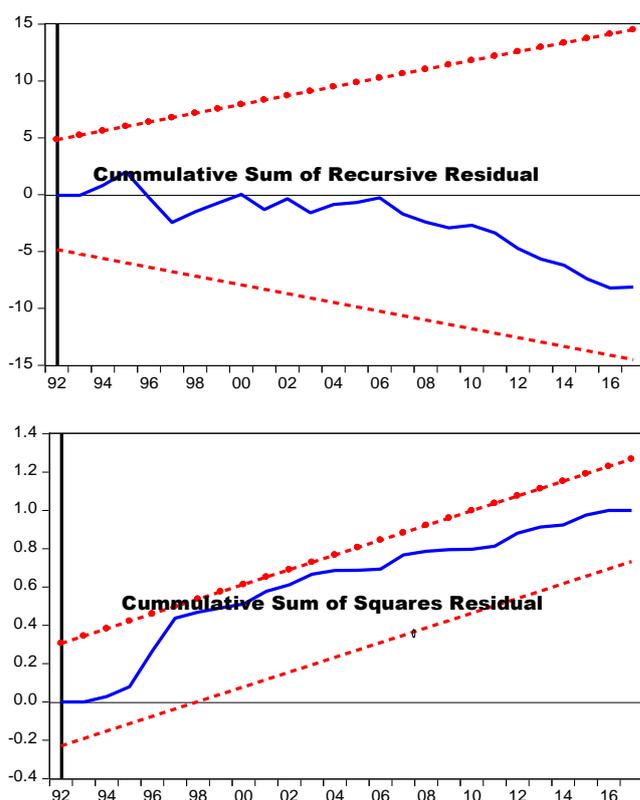
Figure 2: CUSUM and CUSUMSQ for model stability test

Nevertheless, causality test arises when there is cointegrating relationship amidst candidate variables, this implies that there must be at least one direction of causality (Granger, 1969; Galadima *et al.,* 2022).Equally, understanding the direction of causality between public capital and growth is that public capital might affect growth, and economic growth might also shape the demand and supply of public infrastructure (Romp and de Haan, 2007). Therefore, it is believed that results from the causality test would be a useful guide for policy making. Table 7 reports the VECM causality test using two lags length. Interestingly, the results coincide with the expected hypothesis and in line with previous findings in the literature. It is observed that there exists unidirectional causality from economic growth to public capital at10% significance level, which in turn granger causes private capital at 1% level. This implies that economic growth and private capital are simultaneously complementing each other and, private capital serves as an agent of influencing output growth over public capital. This is inconsistent with the findings of Dalamagas (2000); Fosu et al., (2012) and Feddereke et al., (2006) among others. The private capital does granger cause public capital and growth. This is contrary to the view of Ghali (1998), that increase in public capital may not be an agent of driving private capital investment.

Nevertheless, a unidirectional causality is also observed running from the labour force to output growth and public capital at the 1% level but no feedback causation. This suggests that decline in labour force affects economic growth negatively through public capital investment. Hence, it can be noted that there is no causality between private capital and economic growth, same with labour force which coincides with the works of Dalamagas (2000); Fosu et al., (2012) and Ma'in et al., (2018). This indicates that the Nigeria's investment climate does not support private sector investment; this may be due to uncertainties cause by high political risk, terrorism and poor macroeconomic policy leading to higher transaction cost in oil rich countries like Nigeria (Rasiah et al., 2010). Figure 3 shows a graphical representation of the Granger causality results.

Table 7**:** VECM Granger causality results

Dependent variable	Short run causality				Long run causality
	χ^2 statistics of lagged first difference term (*p*-value)				ect_{t-1}
	ΔlnY_t	$\Delta lnKG_t$	$\Delta lnKP_t$	$\Delta lnLF_t$	
ΔlnY_t		1.667 (0.782)	19.253 (0.001)***	11.943 (0.035)**	-1.506 [5.284]***
$\Delta lnKG_t$	10.127 (0.071)*		0.989 (0.963)	1.781 (0.878)	-0.187 [-0.375]
$\Delta lnKP_t$	14.670 (0.002)***	10.138 (0.071)*		12.950 (0.072)*	0.573 [2.345]**
$\Delta lnLF_t$	14.379 (0.003)***	11.856 (0.036)**	10.098 (0.072)*		-1.479 [-1.755]*

Note: ***, ** and * indicate 1, 5 and 10 percent significance level respectively. *p*-values in parenthesis (…) and the figure in square bracket […] indicate *t*-statistics.
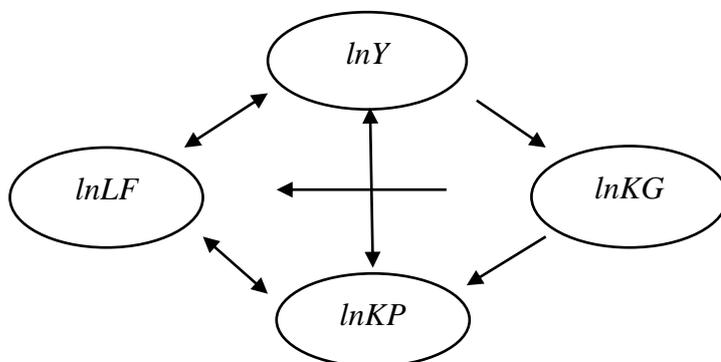

Figure 3. Schematic illustration of causality among Economic Growth, Public Capital, Private Capital and Labour Force

V.   Conclusions

This paper examines the relationship between public capital and economic growth in Nigeria using annual time series data for the Nigerian economy from 1981 to 2017. Vector Error Correction Model (VECM) is used for our findings. The novelty of our empirical results is contrary to the hypothesis that public capital investment promote economic growth (see for example, Aschauer, 1989; Ligthart, 2000; Kumo, 2012). As a result, there are three ways to look at our findings. First, both long run and short run results show that public capital investment and labour force declines economic growth in Nigeria. Based on the findings, it is reasonable to conclude that the poor economic growth in Nigeria throughout the period under study was due to insufficient government investment on public infrastructure. Private capital, on the other hand, promotes economic growth. Second, there is strong evidence of bidirectional causality between private capital investment, labour force, and economic growth, implying that all variables influence one another. Third, there is a one-way causality running from economic growth to public capital, public capital to the labour force, and private capital respectively. However, in the light of the foregoing, what are the policy implications for the Nigerian economy? First, to stimulate more growth-driven public investment, policymakers should promote public investment in Nigeria, which should be accompanied by improved governance, principally government effectiveness, rule of law as well as anti-corruption crusade. Second, to enhance infrastructure development while reducing government spending, government should embrace the concept of public-private partnerships. Besides, a favourable business climate is also required to attract private investment and enhances economic growth. Finally, in order to achieve long-term growth, greater focus should be placed on strengthening economic infrastructure projects as a crucial component of investment processes. This could be accomplished by implementing a comprehensive public policy framework that prioritizes activities that generate a higher economic return on investment.

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