

Infrastructure Investment as a panacea for Sustainable Economic Growth in Nigeria: A Pairwise Granger Causality and Bounds Test Approaches.

Abstract

This paper conducted pairwise Granger causality tests between economic growth, infrastructure investment, and employment in Nigeria for the period 1960-2017 using bivariate vector autoregression (VAR) model with and without a structural break. The result indicates that there is a strong causality between infrastructure investment and GDP growth that runs in both directions implying that infrastructure investment drives the long-term economic growth in Nigeria while improved growth feeds back into more public infrastructure investments. We also found a strong two-way causal relationship between economic infrastructure investment and public sector employment reflecting the role of such investments on job creation through construction, maintenance and the actual operational activities, while increased employment could in turn contribute to further infrastructure investments indirectly through higher aggregate demand and economic growth. Further, there is a strong unidirectional causal link between economic growth and public sector employment that runs from the former to the latter; and a strong one-way causal link between private sector employment and economic growth that runs from the former to the latter. Economic growth appears to be one of the main drivers of public sector jobs but not the private sector ones and that while the private sector employment remains one of the key drivers of growth, the latter does not seem to have translated into more jobs, reflecting the much-criticized scenario of jobless growth in the economy. The pairwise causality test results were assessed further using autoregressive distributed lag (ARDL) or bounds testing approach for cointegration to assess both the short-and long-run relationships among the variables in question. The bounds test results indicate the presence of steady-state long-run equilibrium relationship between economic growth, economic infrastructure investment, formal employment, and exports and imports of goods and services providing a theoretical foundation for the empirical results of the pairwise Granger causality tests.

Keywords: Infrastructure Investments, Economic Growth, Granger causality, Private Sector Employment.

Introduction

The primary mechanism through which the Nigerian government aims to achieve this rapid economic growth and income redistribution is accelerated investment in infrastructure particularly for basic needs. According to a report by European Commission, good quality infrastructure is a key ingredient for sustainable development. All countries need efficient transport, sanitation, energy and communications systems if they are to prosper and provide a decent standard of living for their populations. Unfortunately, many developing countries possess poor infrastructure, which hampers their growth and ability to trade in the global economy (European Commission, 2010). By a developing country standard, Nigeria has lagged far behind infrastructure such as roads, educational institutions and health facilities and energy.

In addition to this, the bulk of the existing infrastructure such as roads, railways and ports need sizable investment on maintenance and upgrading.

The current level of infrastructure deficit in Nigeria has been identified by Sanusi (2012) as the major constraint towards achieving the nation's vision of becoming one of the 20 largest economies in 2020. He further proffered that about 70 percent of the 193,000 kilometres of roads in the country is in poor condition; that enterprise surveys show that the power outages the nation experiences amount to over 320 lost days a year, with over 60 percent of the population lacking access to electricity with over \$13 billion spent annually to fuel generators and that that Nigeria, which once had one of the most extensive railway systems in Africa, could now barely boast of a functional route either for passengers or freight. According to National Bureau of Statistics (NBS) over the last decade, Nigeria's infrastructure spending contributed a 1.9% (approximately \$4 billion) per annum to GDP. The recommendation of the Asian Development Bank in the KPMG report is that in order for a developing country to sustain growth and development, not less than 6% of GDP should be invested on infrastructure. Sanusi (2010), reports that Nigeria is currently investing about 7% of GDP on infrastructure, which is above the average for Sub-Saharan Africa. He however expressed the need to increase this figure to at least 12% of the GDP.

The objectives of the study examine the hypotheses, suitable econometric models are required. Since the objective of this research is to test the Granger-causality of two variables (pairwise Granger causality test),

The remaining part of the paper is organized as follows: section two provides an overview of the related literature followed by the description of the econometric methodology and data used in the analysis in section three. The empirical analyses including unit root and Granger causality tests are conducted in section four. Section five investigates the long run equilibrium relationship between economic growth and economic infrastructure investment, formal employment, and exports and imports of goods and services thereby providing a theoretical foundation to empirical pairwise Granger causality analysis. The final section concludes the paper.

2. Theoretical and empirical literature

The theoretical literature on infrastructure and growth has been substantially influenced by the work of Barro (1990). He shows that the benefits of infrastructure investments may be offset by the negative impact of additional distortionary taxes to finance them. The negative effect of public spending on growth arises from the distortions to choice and the disincentive effects (Helms, 1995; Mendoza et al., 1997).

Aschauer (1989) pioneered the research on the impact of the infrastructure investment on output and productivity growth. He found that relatively slower growth in public capital accumulation in the United States during the 1970s and 80s was largely responsible for the private sector productivity slowdown. He found that the private output elasticity with respect to public capital

was about 0.42 indicating a sizable level of sensitivity. Following Aschauer (1989), Lynde and Richmond (1993) also investigated the causes for the decline in the US output and productivity growth since the early 1970s. They found that the services of the public capital are an important part of the production process and that about 40% of the productivity decline in the United States was explained by the fall in public capital-labour ratio. Furthermore, Ford and Poret (1991) suggest that cross- country differences in productivity growth might also be explained partly by differences in levels of infrastructure spending.

Among the limited research in this area, Canning and Pedroni (1999) conducted Granger causality test between investments in three types of economic infrastructure i.e., kilometres of paved road, kilowatts of electricity generating capacity, and number of telephones based on data from a panel of 67 countries for the period 1960- 1990. They found strong evidence in favour of causality running in both directions between each of the three infrastructure variables and GDP among a significant number of the countries investigated.

Fedderke and Bogeti (2006) investigate the direct impact of infrastructure investment on labour productivity and the indirect impact of infrastructure on total factor productivity using the panel data analysis method and Pooled Mean Group (PMG) estimator of Pesaran, Shin and Smith (1999) employing unrestricted error correction ARDL model. They argue that growth and productivity impacts of infrastructure have been characterized by ambiguous results with little robustness. They offer a number of explanations for the contradictory findings including possible crowding-out of private by public sector investment, non-linearities generating the possibility of infrastructure overprovision, simultaneity between infrastructure provision and growth, and the possibility of multiple (hence indirect) channels of influence between infrastructure and productivity improvements. They investigate these possibilities utilizing panel data for South Africa over the 1970-2000 periods, and a range of 19 infrastructure measures. They demonstrate that controlling for potential endogeneity of infrastructure in estimation robustly eliminates virtually all evidence of ambiguous impacts of infrastructure, due for example to possible overinvestment in infrastructure. They conclude that controlling for the possibility of endogeneity in the infrastructure measures renders the impact of infrastructure capital not only positive, but of economically meaningful magnitudes.

Herranz-Loncán (2007) analyzed the impact of infrastructure investment on Spanish economic growth between 1850 and 1935. Using new infrastructure data and VAR techniques, he shows that the growth impact of local- scope infrastructure investment was positive, but returns to investment in large nation-wide networks were not significantly different from zero. He provides two complementary explanations for the latter result. On the one hand, public intervention and the application of non-efficiency investment criteria were very intense in large network construction while on the other hand, returns to new investment in large networks might have decreased dramatically once the basic links were constructed. Furthermore, statistical evidence for United States showed that there is a direct positive link between infrastructure investment and GDP. For instance, for the period 1950-79, growth in public infrastructure contributed almost

one-for-one to economic growth. During this period infrastructure investment in core areas such as transportation, water management and electricity generation grew at an average rate of 4% while the overall economic or GDP growth averaged 4.1% during the same period. On the other hand, during the period 1980-2007 growth in public infrastructure investment drastically fell to 2.3% while average annual GDP growth fell to 2.9 percent over the same period (Heintz et al. 2009).

In addition to the output and productivity effects, infrastructure investment is believed to create more jobs than other types of investment through direct, indirect and induced jobs. However, the size of indirect and induced effects depends on the magnitude of the infrastructure investment multiplier. A similar study was conducted in South Africa by Perkins, Fedderke and Luiz (2005). Using Pesaran, Shin and Smith's (1996, 2001) F-tests, these authors identified directions of association between economic infrastructure and economic growth. They identified long-run forcing relationships from public-sector economic infrastructure investment and fixed capital stock to gross domestic product (GDP), from roads to GDP and from GDP to a range of other types of infrastructure. They also found that the relationship between economic infrastructure and economic growth run in both directions.

The current study differs from the previous ones in two respects. First, the Fedderke and Bogeti (2006) and Perkins et al. (2005) study used the data from pre- 2005 period and hence their time series did not incorporate the accelerated economic infrastructure investment period of 2005-2009. In this respect, the current study updates their results. Secondly, their study did not investigate the causal relationships between economic infrastructure investment and public and private sector employment. Given the importance of the direct and indirect impacts of infrastructure investment on private sector employment, the investigation of the existence and the direction of causality among these variables are of paramount importance. The present study makes a unique contribution by investigating these causal relationships. Moreover, the main objective of Fedderke and Bogeti (2006) study was to measure the elasticities of the various infrastructure investments with respect to labour productivity and total factor productivity, instead of economic growth per se and as such our approaches are different. Thirdly, the present study extends the pairwise Granger causality tests to the analyses of the short-and long-run relationships between economic growth and economic infrastructure investment in an ARDL or bounds test framework from which the long-term elasticity of economic infrastructure investment with respect to economic growth was estimated. Our estimated economic infrastructure investment elasticity is found to be much smaller than those obtained by previous empirical studies that used the pre 2005 data.

3. Methodology and Data

Our approach follows Granger (1969) who proposed a time-series data based approach in order to determine causality between economic variables. A question that frequently arises in time series analysis is whether or not one economic variable can help forecast another economic variable. In the Granger-sense therefore, a time series x is a cause of y if it is useful in forecasting y . More precisely, variable X is said to Granger-cause another variable, Y , if the current value of Y (y_t) is conditional on the past values of X ($x_{t-1}, x_{t-2}, \dots, x_0$) and thus the history of X is likely to help predict Y (Konya, 2004). This refers to causality for one period ahead and is generalized by Dufour and Renault (1998) to causality h periods ahead, and to causality up to horizon h , where h is a positive integer that can be infinite. They show that in a bivariate system no-causality for one period ahead implies no-causality at, or up to, any horizon. The advantage of a bivariate system over a trivariate system, (X, Y, Z) is that in the latter case causality between X and Y can arise via the auxiliary variable which needs to be captured using an appropriate methodology. In the trivariate system, X might cause Z one period ahead, which in turn might cause Y at a subsequent period. This indirect, two-period ahead causality might exist even if there is no direct, one-period ahead causality between X and Y . However, if there is no causality between X and Y for two periods ahead then there is no causality between them at, or up to, longer horizons either. This difference between bivariate and trivariate systems implies that they require different strategies to test for causality at horizons beyond one period (Konya, 2004).

Foresti (2006) states that there are three different types of situations in which a Granger-causality test can be applied:

- a) In a simple Granger-causality test there are two variables and their lags;
- b) In a multivariate Granger-causality test more than two variables are included, because it is supposed that more than one variable can influence the results, and finally;
- c) Granger-causality can also be tested in a VAR framework; in this case the multivariate model is extended in order to test for the simultaneity of all included variables. The empirical results presented in this paper are based on a pairwise bivariate causality test between the four variables stated earlier. There are five sets of bidirectional hypotheses to be tested:
 - i. Infrastructure Investment Granger causes economic growth and vice versa;
 - ii. Infrastructure Investment Granger causes private employment and vice versa;
 - iii. Infrastructure Investment Granger causes Public employment and vice versa;
 - iv. Economic growth Granger causes private employment and vice versa;
 - v. Economic growth Granger causes public employment and vice versa;

In order to examine the hypotheses, suitable econometric models are required. Since the objective of this research is to test the Granger-causality of two variables (pairwise Granger causality test), the test should be based on the appropriate bivariate time series models i.e. either vector auto-regression (VAR) or vector error correction model (VECM).

Following Atmadja (2005), we use the following procedure to conduct Granger causality test. First, unit root test at levels and first differences are conducted to determine whether each variable is stationary (I(0)) or non-stationary (I(1)). Second, the Engle-Granger residual-based test is conducted to check for the existence of co-integration among the variables. Third, if a co-integration relationship does not exist, i.e. both series are determined to be I(1) but not co-integrated, VAR analysis in first difference is applied. However, when the series are co-integrated, we can use a vector error correction (VECM) model for multivariate system and a VAR model in levels for a bivariate system (Konya 2004).

Since we are dealing with the growth time series, all of the variables are found to be I(0) or stationary at levels. Therefore, we specified two VAR equations in levels for each of the 5 hypothesised relationships above. For Granger causality test between infrastructure investments growth (EINFIg) and output growth (GDPg), the following VAR equations can be specified:

$$(\text{GDPg})_t = a + \sum_{n=1}^m \beta_i (\text{GDPg})_{t-i} + \sum_{j=1}^n \gamma_j (\text{EINFIg})_{t-j} + u_t \quad (1)$$

And

$$(\text{EINFIg})_t = \theta + \sum_{j=1}^n \phi_i (\text{EINFIg})_{t-i} + \sum_{j=1}^n \psi_j (\text{GDPg})_{t-j} + \eta_t \quad (2)$$

where,

u_t and η_t are error terms for the two equations respectively.

The Nigerian time series data exhibit a major structural break due to a democratic transition from the military system. Thus equations (1) and (2) are re-specified to include a dummy variable with values of 0 for the military period and 1 for the post military period as follows:

$$(\text{GDPg})_t = a + \sum_{n=1}^m \beta_i (\text{GDPg})_{t-i} + \sum_{j=1}^n \gamma_j (\text{EINFIg})_{t-j} + \delta DUM + u_t \quad (3)$$

And

$$(\text{EINFIg})_t = \theta + \sum_{j=1}^p \phi_i (\text{EINFIg})_{t-i} + \sum_{j=1}^q \psi_j (\text{GDPg})_{t-j} + \lambda DUM + \eta_t \quad (4)$$

Where DUM = a dummy variable with the value of 0 for military period and 1 for post-military period as explained earlier. The process is repeated for each of the five sets of bidirectional causality hypotheses discussed at the beginning of this section.

Based on the estimated OLS coefficients for equations (1) and (2) and in line with Foresti (2007), four different hypotheses about the relationship between IEINFG and GDPg can be formulated:

1. Unidirectional Granger-causality from EINF_g to GDP_g. In this case investment in infrastructure increases the prediction of the economy but not vice versa. Thus $\gamma_j \neq 0$ for $j = 1, \dots, n$; and $\psi_j = 0$ for $j=1, \dots, q$. That is while the lagged coefficients of IEINFG are significantly different from zero that of GDPg are all insignificant.
2. Unidirectional Granger-causality from GDPg to EINF_g. In this case the growth rate of the economy increases the prediction of investment in economic infrastructure but not vice versa. Thus $\gamma_j = 0$ for $j=1, \dots, n$ and $\psi_j \neq 0$ for $j=1, \dots, q$. That is while the lagged coefficients of EINF_g are all zero that of GDPg are significantly different from zero.
3. Bidirectional (or feedback causality). In this case $\gamma_j \neq 0$ for $j = 1, \dots, n$; and $\psi_j \neq 0$ for $j=1, \dots, q$ so in this case the growth rate of the economy increases the prediction of investment in economic infrastructure and vice versa; and
4. Independence between EINF_g and GDPg. In this case there is no Granger-causality in any direction. Thus $\gamma_j = 0$ for $j=1, \dots, n$ and $\psi_j = 0$ for $j=1, \dots, q$. The same procedure is replicated for each of the five relationships stated above. In general, testing causality in the Granger sense, involves using F-tests to test whether lagged information on a variable Y provides any statistically significant information about a variable X in the presence of lagged X. If not, then "Y does not Granger-cause X".

The data used in the analysis is obtained from the Central Bank of Nigeria (CBN). GDP is measured by constant 2005 prices. EINF_g is the sum of the general government economic infrastructure investment and economic infrastructure investment by the public corporations and is also at constant 2005 prices. Both the private sector employment (PVTEMP) and public sector employment (PUBEMP) are index numbers with the base year 2000 =100. Growth rates for each variable were annual average percentage changes. Exports of goods and services (EX) and imports of goods and services (IMP) are also measured at 2005 constant prices. Total formal employment (LAB) refers to actual number of formal employees derived from the combined indices of public and private sector employment at base year (2000=100) and the actual number of formal sector employment for the base year period obtained from National Bureau of Statistics (NBS).

4. Empirical Analysis

4.1 Unit root tests

We conducted Augmented Dickey-Fuller (ADF) and Phillips-Perron unit root tests to determine if the variables depicts stationary time series. The unit root tests for all variables in levels

confirm that the series are indeed stationary at levels as most growth variables appear to be. The ADF and Phillips-Perron unit root tests results are presented in table 1 and table 2 respectively.

Table 1: ADF Unit Root test for Economic Infrastructure Investment, Economic Growth and Employment at levels.

Variable	T-statistic	ADF Critical Value 5%	ADF Critical Value 1%	Null Hypothesis Series has a unit root
EINFIg	-2.601*	-2.926	-3.578	Rejected
GDPg	-2.783*	-2.926	-3.578	Rejected
PUBEMPg	-2.577*	-2.924	-3.578	Rejected
PVTEMPg	-2.952**	-2.924	-3.578	Rejected

Source: Authors 'Computation. The symbol ** and * indicate rejection of the null hypothesis of unit root at 5% and 10% level of significance. Lag length is 2 for all variables except for PUBEMPg for which it is 1. For EINFIg and GDPg unit root test was done with a constant without trend while for the employment variables a constant and trend were included. For ADF unit root test, lag length was selected automatically using Schwartz information criterion (SIC) (with maxilag =10) which selected lag length between one and two.

Table 2: Phillips-Perron Unit Root test at levels

Variable	T-statistic	Critical Value 5%	Critical Value 1%	Null Hypothesis Series has a unit root
EINFIg	-4.223***	-2.923	-3.574	Rejected
GDPg	-3.826***	-2.923	-3.574	Rejected
PUBEMPg	-4.091***	-2.923	-3.574	Rejected
PVTEMPg	-5.343***	-2.923	-3.574	Rejected

Source: Authors 'Computation. The symbol *** indicates the rejection of the null hypothesis of the presence of unit root at 1% level of significance. Inclusion of constant only or constant and time did not make any difference on the results under Phillips-Perron unit root test. Therefore, only results with constant and no trends were reported.

The Phillips-Perron unit root test used Bartlett Kernel spectral estimation method with automatically selected Newey-West bandwidth ranging from 0 to 3. Both ADF and Phillips-Perron unit root tests indicate that the growth series are all stationary or follow an I(0) process. Since the variables are stationary in levels, the VAR model in levels can be applied to conduct the Granger causality test. This precludes the need for cointegration test required when the variables in levels appear to have unit roots.

4.3 Granger causality Tests

Both ADF and Phillips-Perron unit root tests indicated that the variables are $I(0)$. Hence we used VAR in levels to conduct Granger causality test, i.e. equations (1) and (2) are specified in levels for each of the five hypothesized bidirectional causality tests. We used lag length ($m = n = 4$) based on General-to-Specific (Gets) approach except for two hypotheses: (a) Economic infrastructure investment does not Granger cause GDP growth and (b) Economic infrastructure investment does not Granger cause public sector employment. For these two models, we used lag length ($m = 12$). The results of the test are reported in Table 3 below.

According to the Granger causality test result presented in table 3 below, we reject the null hypothesis that economic infrastructure investment (the sum of government and public corporation economic infrastructure investment) does not Granger cause GDP growth. We also reject the null hypothesis that GDP growth does not Granger cause economic infrastructure investment. Both hypotheses are rejected at 1% level of significance indicating that there are strong two way causal relationships between economic infrastructure investments and economic growth in Nigeria for the period 1960-2017. The reasons for bidirectional causality between economic growth and economic infrastructure investment are straightforward. With the increase in GDP, governments will be able to spend more on infrastructure. This will in turn increase the marginal productivity of capital and labour in the private sector encouraging more investment. On the other hand, more investments create more productive capacity, more opportunities for jobs and higher wages resulting in higher income boosting aggregate demand and economic growth. In Nigeria, infrastructure deficit has remained one of the major structural bottlenecks to economic growth. Increased public investment on economic infrastructure has therefore been instrumental in enhancing the private sector competitiveness and encouraging further investment. On the other hand, since consumption expenditure by households' accounts for about 60% of Nigeria's GDP, increased higher wages and household income arising from improved investment will directly translate into higher GDP growth.

Null Hypothesis	F-Stat	Critical F Value at 1%	Critical F Value at 5%	Critical F Value at 5%	Decision
EINFIg Does not Granger cause GDPg	4.94***	2.62(25,24)	1.96(25,24)	1.69(25,24)	Rejected at 1%
GDPg Does not Granger cause EINFIg	6.35***	4.57(9,40)	2.82(9,40)	2.23(9,40)	Rejected at 1%
EINFIg Does not Granger cause PUBEMPg	1.54	2.62(25,24)	2.62(25,24)	1.69(25,24)	Not rejected
PUBEMPg Does not Granger cause EINFIg	2.26*	4.57(9,40)	2.28(9,40)	2.23(9,40)	Rejected at 10%
EINFIg Does not Granger cause PVTEMPg	6.57***	4.57(9,40)	2.28(9,40)	2.23(9,40)	Rejected at 1%
PVTEMPg Does not Granger cause EINFIg	2.08	4.57(9,40)	2.28(9,40)	2.23(9,40)	Not rejected
GDPg Does not Granger cause PUBEMPg	2.03	4.57(9,40)	2.28(9,40)	2.23(9,40)	Not rejected
PUBEMPg Does not Granger	0.70	4.57(9,40)	2.28(9,40)	2.23(9,40)	Not

cause GDP					rejected
GDP Does not Granger cause PVTEMPg	0.41	4.57(9,40)	2.28(9,40)	2.23(9,40)	Not rejected
PVTEMPg Does not Granger cause GDP	0.48	4.57(9,40)	2.28(9,40)	2.23(9,40)	Not rejected

Source: Authors' Computation

*The symbols *** and * indicate the rejection of the null hypothesis that one series does not Granger cause another at 1% and 10% level of significance respectively. Values in brackets are lower and upper degrees of freedom (df) respectively. For all Models, DW statistic ranged between 1.81 and 2.24*

In addition to the above, we reject at 1% level of significance the null hypotheses that economic infrastructure investment does no Granger cause private sector employment. There is a strong causal link between economic infrastructure investment and the private sector employment generation in the country that runs from the former to the latter. The public economic infrastructure investment does not crowd-out the private sector investment. Instead, the well-developed economic infrastructure improves the competitiveness of the private sector and enhances its growth and expansion thereby creating more job opportunities.

On the other hand, we found a one way causal relationship between the economic infrastructure investment and public sector employment that runs from the latter to the former. This may imply that as the public sector employs more skilled workers its capacity to implement public infrastructure projects may increase leading to more economic infrastructure investments. We however did not find any causal relationship between private or public sector employment and economic growth. The null hypothesis that GDP growth does not Granger cause private sector employment is not rejected at any level of significance. There is no causal relationship between employment and economic growth in either direction. This result may reflect the scenario of growth without employment and it is what the Nigerian economy is typically criticized for.

The previous Granger causality analysis did not take into account a structural break in the Nigerian time series resulting from the political transition in 1999. We therefore reassessed causal links between economic infrastructure investment, economic growth and private and public sector employment using alternative equations (3) and (4). We used lag length ($m = n = 4$) based on General-to-Specific (Gets) approach except for hypotheses involving bidirectional causality between economic infrastructure investment and growth; and the former and public sector employment, for which we used lag length ($m = 2$). The results of the test are reported in Table 4 below.

The inclusion of a structural break in the Granger causality test improved the number of significant causal relationships from 7 out of 10 hypothesized relationships compared to 4 out of 10 without the inclusion of the structural break. However, the inclusion of the structural break in the model did not significantly alter the main findings of the analyses of the initial model. We

found that there exists a strong bidirectional causal links between public sector economic infrastructure investment and economic growth with or without the inclusion of a structural break in the estimated model. The null hypotheses that economic infrastructure investment does not Granger cause economic growth and vice versa have been rejected at 5% and 1% level of significance respectively based on the model with a structural break, while the same hypotheses have been rejected at 1% level for both hypotheses in the model without a structural break.

Table 4: Pairwise Granger Causality Tests between Economic Growth, Infrastructure Investment and Employment with a Structural Break.

Null Hypothesis	F-Stat	Critical F Value at 1%	Critical F Value at 5%	Critical F Value at 10%	Decision
EINFIg Does not Granger cause GDPg	3.06**	3.29(6,43)	2.33(6,43)	1.92(6,43)	Rejected at 1%
GDPg Does not Granger cause EINFIg	6.18***	3.29(6,43)	2.33(6,43)	1.92(6,43)	Rejected at 1%
EINFIg Does not Granger cause PUBEMPg	5.38	3.29(6,43)	2.33(6,43)	1.92(6,43)	Not rejected
PUBEMPg Does not Granger cause EINFIg	3.97***	3.29(6,43)	2.07(10,39)	1.92(6,43)	Rejected at 10%
EINFIg Does not Granger cause PVTEMPg	0.88	2.80(10,39)	2.07(9,39)	1.76(10,39)	Rejected at 1%
PVTEMPg Does not Granger cause EINFIg	2.26**	2.80(10,39)	2.07(9,40)	1.76 (9,40)	Not rejected
GDPg Does not Granger cause PUBEMPg	2.71**	2.80(10,39)	2.07(10,39)	1.76(10,39)	Not rejected
PUBEMPg Does not Granger cause GDP	1.53	2.80(10,39)	2.07(10,39)	1.76(10,39)	Not rejected
GDP Does not Granger cause PVTEMPg	1.28	2.80(10,39)	2.28(10,39)	1.76(10,39)	Not rejected
PVTEMPg Does not Granger cause GDP	2.44**	2.80(10,39)	2.07(10,39)	1.76(10,39)	Not rejected

Source: Authors 'Computation

The symbols ***, ** and * indicate the rejection of the null hypothesis that one series does not Granger cause another at 1%, 5% and 10% level of significance respectively. Values in brackets are lower and upper degrees of freedom (df) respectively. For all Models, DW statistic ranged between 1.81 and 2.24

A significant improvement in the result was obtained in relation to the causal link between economic infrastructure investment and public sector employment and public sector employment and GDP growth. In the revised model, we found that there is a strong two way causal relationship between economic infrastructure investment and public sector employment as opposed to a weak, one way causal link that runs from public sector employment to economic infrastructure investment in the initial model. This implies that an increased public sector investment in economic infrastructure generates more public sector jobs through the actual

construction, operation and maintenance while higher level of public sector employment leads to increased public economic infrastructure investment indirectly via its impact on the aggregate demand.

Other important results from the estimated revised model are that, first, there is a strong unidirectional causal link between economic growth and public sector employment that runs from the former to the latter, and second, there is a strong one way causal link between private sector employment and economic growth that runs from the former to the latter. In the first case, economic growth is seen as a driver of the growth in public sector employment, while in the second, the private sector employment remains one of the main contributors to economic growth but such growth is not seen translating into more private sector jobs. In a nutshell, therefore, the often disputed scenario of jobless growth particularly in the private sector for which the South African economy is often criticized for may be a valid argument after all.

4.2 Analysis of Causality from Bounds Test

4.2.1 Description of the Model

In order to validate the results obtained using bivariate VAR model in the preceding section; we employed autoregressive distributed lag (ARDL) model, or bounds testing approach, proposed by Pesaran et al. (2001). This method allows us to test both short- and long-run relationship between the dependent and the explanatory variables in a multivariate framework. The use of ARDL technique is based on three rationales: First, Pesaran et al (2001) advocated the use of the ARDL model for the estimation of level relationships because the model suggests that once the order of ARDL has been identified, the relationship can be estimated by OLS. That is, as opposed to popular multivariate cointegration techniques such as Johansen and Juselius methods, bounds test allows the cointegration relationship to be estimated by OLS once the lag order of the model is identified. Second, the ARDL model (bounds test) allows a mixture of $I(1)$, $I(0)$ or mutually cointegrated variable as regressors, that is, the order of integration of relevant variables may not be necessarily the same. Therefore, the ARDL model has the advantage of not requiring precise identification of the order of the underlying data. Third, this technique is appropriate for small or finite sample size (Pesaran et al, 2001). Moreover, where sample size is small (50 observations in our case), tests for order of integration of variables have little power. Therefore, the application of unit root tests may not provide a conclusive result regarding the order of integration of the variables of interest. However, the major limitation of the bounds test procedure is that it crashes in the presence of $I(2)$ series (Oteng-Abayie and Frimpong, 2006).

To examine the short- and long- run relationships between economic growth and infrastructure investment, following Pesaran et al. (2001), we constructed vector autoregression (VAR) of order p , denoted by VAR(p) for the following infrastructure investment-led growth function:

$$\pi_t = \mu + \sum_{n=1}^m \beta_n \pi_{t-n} + e_t \quad (5)$$

Where π_t is the vector of both explanatory variables x_t and dependent variable y_t defined as real GDP. The vector matrix representing a set of explanatory variables is defined as; $x_t = [EINFI_t, LAB_t, EX_t, IMP_t]$, where EINFI = investment in economic infrastructure; LAB = labour (total formal sector employment); EX= exports of goods and services; and IMP= imports of goods and services. The public sector and private sector employment is combined into one series: i.e., total formal sector employment in order to eliminate possible multicollinearity among the time series. The trade variables EX and IMP are included because international trade is inextricably linked with financing for development, and remains an engine of economic growth. For instance, export growth accounts for about 40% of the increase in gross domestic product (GDP) of both developing and developed countries, except the United States while the faster growth on average in output and trade in developing and transition economies, compared with the developed world, is matched by their increasing share of world trade, from 35% in 2000 to over 40% in 2007 (UN DPI, 2008). Non-inclusion of the trade variables could therefore result in misspecification of the ARDL growth model; $u_t = [u_y, u_x]$, t is time or trend variable, while β is the matrix of VAR parameters for lag i . In this model, we consider the actual values of the variables instead of their growth rates to enable us examine both the short-term and long-term causal relationships between the dependent and the explanatory variables. Moreover, according to Pesaran et al (2001), in the ARDL model, π_t must be an I(1) while the regressor can be either I(0) or I(1) (see Choong et al, 2005).

From equation (5) we further specify a Vector Error Correction Model (VECM) as follows:

$$\Delta \pi_t = \mu + \alpha t + \delta \pi_t + \sum_{i=1}^{p-1} \psi_i \Delta y_{t-i} + \sum_{i=1}^{p-1} \psi_i \Delta x_{t-i} + e_t \quad (6)$$

Where Δ is the first difference operator capturing the short-term component of the model; the long run multiplier matrix, δ , can be partitioned as follows:

$$\delta = \begin{bmatrix} \delta_{yy} & \delta_{yx} \\ \delta_{xy} & \delta_{xx} \end{bmatrix}$$

As discussed in the preceding paragraphs, the diagonal elements of the matrix are unrestricted, so that the selected series can be either I(0) or I(1). Thus, if $\delta_{yy} = 0$, then y is I(1). On the other hand, if $\delta_{yy} < 0$, then y is I(0). In this way, it is possible to test for the presence of at most one cointegrating vector between dependent variable and the set of explanatory variables described above.

Following the assumptions made by Pesaran et al. (2001) in case III, that is unrestricted intercepts and no trends, we impose the restriction $\delta_{xy} = 0$, $\mu = 0$, and $\alpha = 0$, in order to derive the preferred ARDL model. The preferred infrastructure investment-led growth function can be stated as the following unrestricted error correction model (UECM):

$$\begin{aligned} \Delta GDP_t = & \beta_0 + \beta_1 GDP_{t-1} + \beta_2 EINF L_{t-1} + \beta_3 LAB_{t-1} + \beta_4 EX_{t-1} + \beta_5 IMP_{t-1} \\ & + \sum_{i=1}^P \beta_6 \Delta GDP_{t-1} + \sum_{i=0}^q \beta_7 \Delta EINF L_{t-1} + \sum_{i=0}^l \beta_8 \Delta LAB_{t-1} + \sum_{i=0}^M \beta_9 \Delta EX_{t-1} \\ & + \sum_{i=0}^M \beta_{10} \Delta IMP_{t-1} + V_t \end{aligned} \quad (7)$$

Where V_t is a white noise disturbance term. The rest of the variables are expressed in natural logarithm. Equation (7) can also be described as an ARDL of order (p, q, l, m, n) and indicates that economic growth can be influenced and explained by its past values and past values of other variables. Since the data in South Africa exhibit a major structural break following the 1994 democratic transition from the Apartheid based political system, equation (7) was modified to capture economic shock that followed the transition. The dummy variables (DUM) with the value of zero before the 1994 democratic transition and a value of 1 after the transition have been included in the equation to measure the impact of the structural change. The modified equation is expressed as

$$\begin{aligned} \Delta GDP_t = & \beta_0 + \beta_1 GDP_{t-1} + \beta_2 EINF L_{t-1} + \beta_3 LAB_{t-1} + \beta_4 EX_{t-1} + \beta_5 IMP_{t-1} \\ & + \sum_{i=1}^P \beta_6 \Delta GDP_{t-1} + \sum_{i=0}^q \beta_7 \Delta EINF L_{t-1} + \sum_{i=0}^q \beta_8 \Delta LAB_{t-1} + \eta DUM + \sum_{i=0}^M \beta_9 \Delta EX_{t-1} \\ & + \sum_{i=0}^M \beta_{10} \Delta IMP_{t-1} + V_t \end{aligned} \quad (8)$$

The lag length for equation (8) is determined using the minimum of both Schwarz and Hannan-Quinn information criterion both of which selected lag length 1 while the Akaike information criterion selected lag order 2 (see Table 4).

Table 4 Lag Order Selection Criteria Endogenous variables: EINF EX GDP IMP LAB
Exogenous variables: C Sample: 1960 2014 Included observations: 51

Lag	AIG	SC	HQ
0	-3.052159	-2.853394	-2.977701
1	-15.63045	-14.43786*	-15.18370*
2	-15.98480*	-13.79838	-15.16576
3	-15.61485	-12.43460	-14.42351

4 -15.41161 -11.23754 -13.84798

* indicates lag order selected by the criterion

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

According to Bardsen (1989), from the estimated UECMs, the long run elasticities are the coefficient of one lagged explanatory variable (multiplied by negative sign) divided by the coefficient of the one lagged dependent variable. For instance, in equation (6) the long run elasticity of infrastructure investment is $\left(\frac{\beta_2}{\beta_1}\right)$ and so on, while the short run effects are captured by the coefficients of the first-difference variables in equation (6). A Wald test (F-statistic) is computed from the estimated equation (6) to determine the long run relationship between the variables in question. The Wald test is conducted by imposing restrictions on the estimated long run coefficients of real GDP, EINFI, LAB, EX and IMP. The null and alternative hypotheses tested in the analysis are: $H_0 : \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$ (variables are not co-integrated)

$H_0 : \beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 = 0$ (variables are co-integrated)

The computed F-statistic is compared with the critical values tabulated in Pesaran et al.(2001), Table CI(iii). Pesaran et al. (2001) stated that the lower bound critical values assumed that the explanatory variables are integrated of order zero, while the upper bound critical values assumed that the variables are integrated of order one. Accordingly, if the computed F-statistic is smaller than the lower bound critical value, then the null hypotheses of no co-integration between the variables is not rejected and we can concluded that economic infrastructure investment and other explanatory variables do not Granger cause economic growth. On the other hand, if the computed F-statistic is greater than the upper bound value, then economic growth and its determinants are co-integrated and we can conclude that investment in economic infrastructure and other explanatory variables Granger cause economic growth.

4.2.2 Estimation Results

Both Augmented Dickey-Fuller (ADF) and Phillips-Perron unit root tests were conducted to determine the order of integration of the variables used in the ARDL model. This is important because in the presence of unit roots in the time series data, none of the usual test statistics for the ordinary least square regressions have standard distributions. The results obtained are reported in Table (5). Both test criteria indicate that the 5 macroeconomic variables used in the model are non-stationary at levels with or without the inclusion of a time trend. Both tests also yielded similar results when the unit tests were conducted in first differences. Except for the export variable, both ADF and Phillips-Perron unit root tests strongly rejected the null hypothesis of the presence of unit roots after first differencing with constant and time or without the time trend. The export variable has a unit root after first differencing when the time trend is included

but it stationary when the trend variable is excluded under both tests. The variables in question therefore follow on I(1) process.

Table 5: Result of the Unit Root Test

PANEL A: LEVEL				
Variable	ADF		Phillip-Perron	
	Constant; No Trend	Constant; Trend	Constant; No Trend	Constant; Trend
Data Period:1960-2009				
GDP	-1.58108	-2.920635	-1.885513	-2.549566
EINFI	-0.944660	-1.286919		-1.136409
LAB	-2.253913	-2.300037		-1.929286
EX	-1.293143	-2.232165		-1.717712
IMP	-0.068677	-1.587005		-1.868109
PANAL B: FIRST DIFFERENCE				
Variable	ADF		Phillip-Perron	
	Constant; No Trend	Constant; Trend	Constant; No Trend	Constant; Trend
Data Period:1960-2009				
GDP	-3.826569***	-3.933256**	-4.293403***	-4.283705***
EINFI	-4.293403***	-4.283705***	-3.833635**	-3.933256**
LAB	-4.420745***	-4.602148***	-4.395407***	-4.594808***
EX	-3.117706**	-2.994752	-2.922566*	-2.871092
IMP	-4.536613***	-4.351444***	-4.478528***	-4.279842***

Key: EINFI= Economic infrastructure investment; LAB = Labour; EX= Exports of goods and services, IMP= Imports of goods and services. The rejection of the null hypothesis of for both ADF and Phillips-Perron unit root tests is based on the MacKinnon criticalvalues. The lag length for the unit tests was selected automatically by Swartz information criterion (SIC) criteria (maxlag=10), which range from lag one to lag four. *** Rejection of the null hypothesis of presence of unit root at 1% level; ** rejection of null hypothesis of unit root at 5% level; rejection of null hypothesis of unit root at 10% level

The estimation results of equation (8) using the ARDL model is reported in Table (6). The goodness of fit of the model remains high with the R-squared value of 0.70. The robustness of the model has also been confirmed by several diagnostic tests such as ARCH test; Jaque-Berra normality test, Ramsey RESET specification test and hetro test. All the diagnostic tests revealed that the model has the desired econometric properties, i.e. has correct functional form, its residuals are serially uncorrelated, normally distributed and homoscedastic; and hence the results reported are valid for economic inference.

Table 6: Estimated ARDL Model for the South African Economic Infrastructure Investment led Growth Equation (8): 1960-2017

I. Coefficients and Levels of Significance				
Variable	Coefficient	Standard Error	t-value	t-probability
β_0	1.903620	0.7140	2.67**	0.012
GDP_t	-0.39374	0.1263	-3.12***	0.004
$EINFL_{t-1}$	0.038942	0.0184	2.12**	0.042
EX_{t-1}	0.160238	0.0696	2.30**	0.028
EX_{t-1}	0.130872	0.0500	2.62**	0.013
IMP_{t-1}	0.027657	0.0131	2.11**	0.043
DUM_t	0.013245	0.0153	0.862	0.395
ΔGDP_{t-1}	0.302364	0.1844	1.64	0.111
$\Delta EINFL$	-0.00138	0.0274	-0.050	0.960
$\Delta EINFL_{t-1}$	-0.05585	0.0247	-2.26**	0.031
ΔLAB	-0.220693	0.0669	3.29***	0.002
ΔLAB_{t-1}	-0.04791	0.0752	-0.637	0.529
ΔEX	-0.05019	0.0732	-0.686	0.498
ΔEX_{t-1}	-0.06211	0.0957	-0.649	0.521
ΔIMP	0.030019	0.0427	0.702	0.488
ΔIMP_{t-1}	-0.08237	0.0474	-1.74	0.092
II Model Criteria/Goodness of fit				
R^2	0.70079		F-statistics	4.99[0.000]**
Log-likelihood	140.049		DW	2.17
III. Diagnostic Tests				
AR 1-2 test:	F(2,30)	3.8281	[0.0331]	
ARCH I-I test:	F(1,30)	0.2363	[0.6304]	
Normality test:	Chi ² (2)	5.2601	[0.0721]	
Hetero test	F(29,2)	0.0948	[0.9996]	
RESET test:	F(1,31)	5.4485	[0.0562]	

***, **, * indicate level of significance at 1%, 5% and 10% respectively.

The results of the bounds cointegration test in Table 6 show that the null hypothesis of: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$ against the alternative $\beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 = 0$ is easily rejected at 5% and 1% level of significance. The computed F-statistic of 4.997 is greater than the upper critical

bounds values of 4.01 at 5% level of significance in Pesaran et al. (2001) Table CI(iii) case III, unrestricted intercept, no trends providing a strong evidence for the existence of long-run cointegrating relationship among economic growth, economic infrastructure investment, formal employment, exports and imports. Therefore, the previous pairwise Granger causality test results are underpinned by theoretical causality and hence go beyond capturing “temporal causality”. Infrastructure investment Granger causes economic growth in Nigeria during the period under consideration. The bounds test result is presented in Table 7.

Table 7: Bounds test for Cointegration Analysis based on Equation (8)

Critical Value	Lower Bound Value	Upper Bound value
1%	3.74	5.06
5%	2.86	4.01
10%	2.45	3.52

Computed F-Statistic: 4.997(significant at 5% level) Critical values are from Pesaran et al. (2001), Table CI(iii) Case III: Unrestricted intercepts and no trend.

The long run elasticities of the variables in estimated UECM model from equation (8) are presented in Table 8:

Table 8: The long-run elasticities of the explanatory variables

Variable	Elasticity
EINFI	0.100
LAB	0.406
EX	0.332
IMP	0.070

The above result is in line with the previous empirical findings on the responsiveness of economic growth to public economic infrastructure investment, but the size of elasticity is found to be smaller compared to the previous empirical estimates. Fedderke and Garlick (2008) reported a summary of the previous public infrastructure elasticity estimates by three authors namely: Abedian & Van Seventer (1995); Coetzee & Le Roux (1998) and DBSA (1998) who employed econometric technique ranging from OLS to cointegration analysis and estimated

public economic infrastructure elasticity of between 0.15 to 0.33. The main difference between the current study and these studies is (a) the choice of the indicator of economic growth, and (b) the time period covered. While we used growth in real GDP, the previous studies employed growth in real GDP per capita, which might have led to relatively higher elasticities. Besides almost all studies stated earlier used data predominantly from the pre 1994 period while the current study included almost two decades of observation from the post 1994 period including the period of infrastructure investment boom beginning in 2005.

From the estimated ARDL equation reported in Table 6, the short run Granger causality results are, however, not clear. As indicated in the table, in the short run economic infrastructure investment is found to have a significant negative impact on economic growth, while growth in formal public sector employment has a significant positive impact on economic growth contradicting our earlier pairwise Granger causality test results which found no significant causal relationship between economic infrastructure investment and private and public sector employment. The unexpected result regarding the casual links between economic infrastructure investment and economic growth may be due to either or both of the following; (a) the different channels through which economic infrastructure investment impacts economic growth may take longer term to realize than the one period lag considered in the model, and (b) accelerated infrastructure investment to realized economic growth.

The rejection of the pairwise Granger causality test results for the relationship between infrastructure investment and employment by the estimated ARDL model may be due to the use of different employment measures: i.e. disaggregated data for pairwise Granger causality test and aggregated data for ARDL model.

6 Conclusion

Economic theory and empirical research suggest that investment in economic infrastructure spurs economic growth. It is also expected to generate employment directly through the actual construction, operation and maintenance requirements but also through indirect multiplier effects across the economy. Economic theory identifies five channels through which infrastructure can positively impact on economic growth: (i) as a direct input into the production process and hence as a factor of production; (ii) by complementing other inputs into the production process, in the sense of lowering or raising the cost of production (iii) stimulating factor accumulation through, for example, providing facilities for human capital development; (iv) boosting aggregate demand through increased expenditure during construction, and possibly during maintenance operations; and finally, (v) serving as a tool to guide industrial policy. Empirical evidence for South Africa, based on Granger causality tests with and without a structural break, indicates that there is a strong two way causal relationships between economic infrastructure investment and GDP growth for the period 1960-2017. Economic infrastructure investment drives economic growth while the latter feeds back into enhanced investment in the former. The empirical finding on the

long term causal relationship between economic infrastructure investment and economic growth by the current study is in line with previous empirical studies both for Nigeria and elsewhere.

We also found a strong two way causal relationship between economic infrastructure investment and public sector employment reflecting the role of such investments on job creation through construction, maintenance and the actual operational activities, while increased employment could in turn contribute to further infrastructure investments indirectly through the multiplier effects across the economy. Further, there is a strong unidirectional causal link between economic growth and public sector employment that runs from the former to the latter; and a strong one way causal link between private sector employment and economic growth that runs from the former to the latter. Economic growth appears to be one of the main drivers of public sector jobs but not the private sector ones and that while the private sector employment remains one of the key drivers of growth, the latter does not seem to have translated into more jobs, probably reflecting the much criticized scenario of jobless growth in the economy. Therefore, to achieve the objective of accelerated economic growth and halving the level of poverty by 2020, the Nigeria government needs to increase and sustain the level of economic infrastructure investment into many more years in the future. This is imperative to ensure sustained reduction in current inequalities in income distribution and high level of poverty and unemployment in the economy.

The preceding findings have been corroborated by the results of the estimated ARDL model or bounds test for long run equilibrium relationship between economic growth, infrastructure investment and the control variables. The estimated results provide a strong evidence of the existence of long-run cointegrating relationship among economic growth, economic infrastructure investment, formal employment, exports and imports of goods and services thereby providing a theoretical foundation for the empirical results of the pairwise Granger causality tests and confirming that the causality between the stated variables go beyond capturing “temporal causality”. While these results are in line with the previous empirical findings on the responsiveness of economic growth to public economic infrastructure investment, the size of estimated elasticity is found to be smaller compared to the previous empirical estimates due probably to the difference in the period of the analysis and choice of the indicator of economic growth.

On the other hand, the apparent lack of casual link running from economic growth to private sector employment implies that enhanced economic growth may not directly translate into more job creation in the private sector. The scenario of jobless growth has already been recognised in the economy and appropriate policies must be formulated to ensure that economic expansion is geared towards more labour intensive or inclusive growth than more capital intensive growth path.

The short run Granger causality test from the estimated ARDL equation is however not clear. In the short run, infrastructure investment is found to have a significant negative impact on

economic growth, while growth in formal public sector employment has a significant positive impact on economic growth contradicting our earlier pairwise Granger causality test results which found no significant causal relationship between infrastructure investment and private and public sector employment. This may be due to the different channels and lag periods through which infrastructure investment impact on growth; possible overinvestment relative to realized economic growth, and use of different measures of employment for the two models.

Although the results of the study are encouraging, they are not without caveat. The current study updated the previous empirical findings in this area with the most recent data; nevertheless, it focused on macroeconomic impact of aggregate public infrastructure investment on economic growth and employment. Infrastructure is heterogeneous in its nature and the various channels through which it impacts on growth and employment could be better captured by disaggregated micro and project level analysis. Future research in this area is encouraged to take this into consideration and build on the findings of the previous disaggregated empirical analyses.

Policy Recommendation

The major policy recommendation that we draw from this study is that to satisfy the increasing infrastructure needs in Nigeria, a sustainable strategy is to promote private investment in transport infrastructures particularly in roads. The presence of good transport infrastructure may raise the image and perception of the country, thereby attracting additional private investment. Government should play a role of facilitator and regulator of services provided by private sector. The private sector's participation in development and management of infrastructure and the provision of public services is indeed the only way to meet the growing infrastructure needs in Nigeria. The objective behind this policy is to exploit the benefits of private participation, as this would improve managerial efficiency as well as efficiency in the provision of services

Private participation in infrastructure besides accelerated investments in infrastructure freed governments from heavy administrative and fiscal burdens. Private participation can take the form of green-field projects, complete or partial privatization, management and lease contracts or concessions. Asian countries like China, India, Indonesia, Malaysia, Philippines and Thailand have long recognized the need to improve the quality and quantity of their physical infrastructure (telecommunication, transport, energy and water and sewage sectors); realizing the fact infrastructure plays a crucial role in facilitating economic growth and international competitiveness. Given financial constraints, they have changed their policies to create an environment conducive to sustainable private sector involvement in their infrastructure sectors. As a consequence, private participation in the transport sector has increased tremendously in these countries.

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