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Telecommunication Infrastructure and Economic Growth in Nigeria: New Evidence From ARDL Bound Testing Approach to Cointegration

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Abstract
This study investigates the relationship between telecommunication infrastructure and economic growth in Nigeria using time series quarterly data for the period of 2002 to 2014. A functional relationship was modeled between macroeconomic variables such as GDP growth rate, teledensity, number of mobile telephone subscribers, number of landline subscribers, degree of openness in the economy, gross domestic investment and foreign direct investment. This study adopted an autoregressive distributed lag model (ARDL) estimation techniques approach to cointegration test using bound test, stability test and others. The results from the analysis revealed the existence of long run relationship between telecommunication infrastructure and economic growth in Nigeria and concluded that, gross domestic investment, foreign direct investment and degree of openness in the country has improved the teledensity, number of mobile telephone subscribers as well as number of landline which facilitates or enhanced economic activities and in turn leads to increased economic growth. We therefore recommends that government should implement policies that will enhance the development of the telecommunications sectors and complementary factors such as electrification particularly in rural areas, pay more attention to measures that would increase mobile telephone penetration such as reduce tariffs on telecommunication components, as well as formulate policies that will enhance domestic savings and attract more foreign direct investment.
Keywords: Telecommunication Infrastructure, Teledensity, Gross domestic Investment, ARDL, Economic Growth,

1. Introduction

The overall success or failure of every economy is measured by the rate of their economic growth and development. This depends chiefly on the available resources such as capital, manpower, technology etc., there efficient and effective utilization as well as an enabling environment. Given the reasonable level of the understanding of the Nigerian economy and availability of resources, (Christy, et al. 2009), explained an enabling environment as a set of policies, institutions, support services and other conditions that collectively improve or create a general business setting where enterprises and business activities can start, develop and thrive. He maintained that, enabling environment is thus associated with a situation in which domestic and foreign firms can operate and grow as a result of the presence, interaction and capacity of the level of infrastructural facilities in the economy. Hence, infrastructure is an essential ingredient for enhancing the performance of the economy which in turn leads to economic growth and development.

Infrastructure is a heterogeneous term, including physical structures of various types used by many industries as inputs in the production of goods and services (Chan et al., 2009). This depiction incorporates two important key terms “social infrastructure” which can be schools and hospitals and “economic infrastructure” simply refers to as network utilities such as energy, water, transport, and digital communications etc (Stewart, 2010). It is a public goods and services that go into the production process as complementary inputs for traditional factors of production such as capital, labour and entrepreneur which helps to increase returns on investment by reducing production cost and improving transition efficiency.

On the importance of infrastructure on economic growth, (Pravakar, et al., 2010) maintained that, infrastructure development both in its economic and social terms is one of the major determinants of economic growth, particularly in developing countries. They explained that, direct investment on infrastructure creates production facilities and stimulates economic activities, as well as provides employment opportunities for the poor. While lack of infrastructure creates bottlenecks for sustainable growth and poverty reduction. Hence, among the components or forms of infrastructure, telecommunication infrastructure has been viewed to have pervasive economy-wide effects on the economy (Lei, and Kingsley, 2006).

Telecommunication Infrastructure has been identified as having both direct and indirect impact on the growth of an economy (Udjo et al., 2000). As supported by (Ariyo and Jerome, 2005), they maintained that telephone penetration has a positive impact on gross domestic product (GDP) because it provides a stimulant to economic growth and that as economies become more highly developed, they need more communications. It has the capacity to attract experienced radical technical and productivity change, large amounts of investment capital from both the public and private sectors and its rapid diffusion can propelled a sharply reduced costs and increased capacity (Nadiri and Nandi, 2003).

Nigeria's telecommunications system has shown an increasing rate of development in its infrastructure as it progresses over a decade ago through various stages of development from the primitive communications equipment in its colonial days to the enormous variety of technologies available today. With the most recent scenarios, the level of telecommunication infrastructure in Nigeria as at December 2000, resulted to an account of 450,000 connected fixed lines, no connected digital mobile line, 1 national career, 18 operating Internet Service Providers, 9 active licensed fixed-line operators, and 1 licensed mobile line operator with 200,000 internet users (Ndukwe, 2005). In March 2004, the figure grew to become 888,854 connected fixed lines, 3.8 million connected digital mobile lines, 2 national careers, 35 operating Internet Service Providers, 30 active licensed fixed-line operators, and 4 licensed mobile line operators with 1.5 million internet users. This is by all indication a reasonable level of telecommunication development given the nature of the economy in the country which was as a result of improved telecommunication infrastructures.

Hence, with the recorded high level of investment and development in telecommunication infrastructures, it is expected that, these should have translated to economic growth and development in the country given the relationship shown by empirical evidences in previous literatures. But the reality in the country revealed that, average annual growth rate of teledensity over the last two decade, specifically from 1986 to 2010 was 16.3 percent, while the average rate of economic growth for the same period was 4.9 percent (NBS, 2010; CBN, 2010). Given the above disparity in the performances of the telecommunications industry and that of the aggregate economy, one will be forced to raise questions that, is there any significant relationship between telecommunication infrastructure and the level of economic growth in Nigeria? If yes, is this relationship a direct or indirect one and what is the extent of this relationship or the contribution of telecommunication infrastructure on economic growth in Nigeria? Hence, the quest of providing answers to be questions raised above gave birth to the enthusiasm for embarking on this study.

Therefore, following the introduction above, the remaining part of this paper is structured as follows. Section II focuses on the relevant literature while section III is on the methodology and model specification. Section IV covers data analysis and discussion of the results. Section V conclusions the paper and offers some recommendations.

2. Literature Review

Continuous expansion in the telecommunication sector which facilities rapid increase in the telecommunication infrastructure has cut the interest of researchers on the aftermath effect of this development on the economic growth both developed and developing countries.

Jorgenson (2001) investigated the contribution of investment on information technology (IT) in United State economy and found out that investment in information technology (IT) contributed more than one-half of the recent increase in the US economic growth. The outcome of his finding was supported by that of Kraemer and Dedrick (2001) who, using data from 43 countries, upheld the view that the growth in IT investment is correlated with productivity growth.

In the same vein, Oulton (2001) in his study on United Kingdom economy revealed that in the beginning and later part of 1990s, Information and Communication Technology’s (ICT) contribution to GDP growth was 0.36% and 0.57% respectively. While, for a country like Beligium and Zandweghe, (2002) found that the accumulation of ICT capital has a significant impact on output growth and average labor productivity growth. CEPII (2003) study on France showed that in the early 1990s to the mid 1990s, ICT’s contribution to capital growth in increased from 0.25 percent to 0.45 percent.

In Asia, Seo and Lee, (2000) did a study on Korea and their finding showed a significant contribution from ICT investment while another study by the Australia National Office of Information in 2003, also confirmed that ICT and services have become pervasive, general-purpose enablers of economic and social transformation. They opined that given the enabling socio-economic environment, ICT would provide the platforms on which the growth in productivity, innovation and social well-being can be constructed. And using 12 Asia-Pacific countries and data from 1984 to 1990, Kraemer and Dedrick (1994) confirmed that IT investment is positively correlated with gross domestic product (GDP) and productivity growth.

Lei and Kingsley (2004) empirically investigated the role of telecommunication infrastructure on regional economic growth in China, for a sample of 29 regions in a 17 years’ period from 1986-2002. The results of the study revealed that telecommunication was both statistically significant and positively correlated to regional economic growth in real GDP per capita in China. The results were strong even after controlling investment, population growth, past levels of GDP per capita and lagged growth. The study further revealed that the telecommunication investment is subject to diminishing returns. However the study failed to establish a dual causality and could probably have given better results had the time period been extended.

Waverman, Meschi and Fuss (2005) conducted a study of mobile telecommunication impact on developing countries’ growth. The study considered the average growth rate of per capita GDP from 1980-2003 as the dependent variable. This was regressed on the average ratio of investment to GDP, the stock of telecoms in 1980, the proportion of the 15 years and above population that had completed primary schooling in 1980 and the average level of mobile penetration for the period (1996-2003). The initial level of telephone (fixed line) penetration was found to be insignificant. However, the average level of mobile telephone penetration was significant, implying that an increase in mobile penetration will increase economic growth.

Roller and Waverman (2001) examined the impact of investment in telecommunication infrastructure on the GDP of 21 OECD countries and 14 developing or newly-industrialized non-OECD countries between 1970 and 1990. They found that the impact may not have been linear. The impact was greater in OECD countries than it was in non-OECD countries and in countries that had reached critical mass (the number of main telephone lines exceeds 40 per 100 persons). The study highlighted various shortcomings. These included lack of data and statistical knowledge. The study further suggested the use of panel data to observe the specific country effects.

Chakraborty and Nandi (2003), in their study on privatization, telecommunication and economic growth in 12 developing countries in Asia found a bidirectional relationship. The study divided these countries into two groups, those with a high degree and those with low degree of privatization. There was a bidirectional relationship between teledensity and GDP both in the short run and long run. The causality was bidirectional for those countries with high degree of privatization. In the countries with a low degree of privatization, the causality ran from teledensity to GDP.

Cieslik and Kaniewsk (2004) in their study on impact of telecommunication infrastructure and income at the regional level in Poland found that there was a positive and statistically significant causal relationship between telecommunication and income at regional level. Further, the causality ran from the former to the latter.

Alleman et al. (1997) examined the relationship between investment in telecommunications infrastructural investment and economic growth with respect to the Southern African countries and concluded that investment in telecommunications and will take one period to manifest this impact. This is supported by Jain and Sridhar (2003) in the study of the non-OECD countries: Algeria, Argentina, Brazil, Chile, Costa Rica, Egypt, India, Indonesia, Korea, Malaysia, Mauritius, Mexico, Morocco and Tunisia. Ding and Haynes (2004) empirical investigation of a sample of 29 regions in China covering 1986 to 2002, confirms that fixed investment has a positive effect on economic growth and that telecommunications is both statistically significant and positively correlated to regional economic growth in real GDP per capita growth in China.

Saunders, et al. (1994) cited by Ding and Haynes (2004) provide a positive relationship between telecommunications and economic growth. While intensive review based on the works of (Canning, 1998; Cronin et al., 1991, 1993; Nadiri and Nandi, 1997; Wang, 1999; Schreyer, 2000; Yilmaz et al., 2001; International Telecommunications Union-ITU, 2003; Datta and Agarwal, 2004; Lam and Shiu, 2010) show a positive and significant causal link between telecommunications infrastructure and economic growth. However, even with the enormous literatures supporting positive relationship between telecommunication infrastructure and economic growth. We have those that have not been able to establish any significant positive relationship which thereby suggests little evidence of the effect of infrastructure on income growth (Holtz-Eakin, 1994). While some works also revealed limited positive impact of infrastructure on economic growth (see Aschauer, 1989; Barro, 1990; Canning and Pedroni, 2004; Easterly and Rebelo, 1993; The World Bank, 1994).

Considering the peculiarity of the economy of Nigeria and the recent emerging of interest in this subject matter, it can be deduced that several studies on the impact of telecommunication infrastructure on economic growth has shown a positive and significant relationship with the two given their various account as follows;

Tella, et. al. (2007), investigated the simultaneous relationship between telecommunications and the economic growth in Nigeria. A system of equations that endogenize economic growth and telecom penetration as well as telecom investment was estimated. The study found that main landline and cell phone penetration had significant effects on economic growth, when we control for the effects of capital and labour. Also traditional economic factors like income and price helped explain demand for main land phones, this was not the case with respect to demand for cell phones.

Gold, (2010) examined the effects of telecommunication infrastructural development on the Nigerian economy and examined the growth implication. Secondary data was used and was estimated using Ordinary Least Square (OLS) techniques. However, the findings revealed that telecoms have influenced the economy by increasing their market access and reduced distribution cost, which invariably affected the service provider cost. Also, the study revealed how GSM has enabled Nigerians to transact their businesses easily resulting in higher productivity; reduction in poverty level and prevalence through increase in income generating capacity and business expansion; improved living standard; boosted economic capacity, and stimulates the economy to achieve the desired macroeconomic policy targets.

Osotimehin, et. al. (2010) appraised the effects of investments in telecommunication infrastructure on economic growth of Nigeria measured by gross domestic product using a comprehensive national level data set in Nigeria for a sample period of 16 years (1992-2007). The data were analyzed through the pooled ordinary least squared

(OLS) regression methods. And the causal relationship between the likely interdependence of telecommunication and economic variables were tested using the time series data. The results showed that telecommunication infrastructure measured by teledensity and telecommunication employment is both statistically significant and positively correlated with economic growth. The study concluded that the stock of telecommunication infrastructure plays a role in determining growth and productivity in Nigeria and that there is the need to create a conducive and competitive climate for the growth of the telecommunication industry, encourage more investment in the sector through private participation, stable and transparent telecommunication policies so that the capital required for building telecommunication infrastructure can be met.

Adegbemi, et al (2012), investigated the impact of investment in telecommunications infrastructure on economic growth in Nigeria with a multivariate simultaneous model using three-stage least squares method to capture the transmission channels through which telecommunications infrastructure promotes growth. The finding shows that telecommunications infrastructural investment has a significant impact on output of the economy directly through its industrial output and indirectly through the output of other sectors such as agriculture, manufacturing, oil and other services. The results also show a bi-directional causal relationship between telecommunications infrastructure and economic growth. The paper recommends for more effective telecommunications infrastructure that will further impact economic growth in Nigeria.

Onakoya, et al, (2012), investigated the impact of investment in telecommunications infrastructure on economic growth in Nigeria using a multivariate model of simultaneous equations. With the three-stage least squares method whch captured the transmission channels through which telecommunications infrastructure promotes growth. The finding showed that telecommunications infrastructural investment has a significant impact on output of the economy directly through its industrial output and indirectly through the output of other sectors such as agriculture, manufacturing, oil and other services. They recommends for more effective telecommunications infrastructure that will further impact economic growth in Nigeria.

Akanbi, et al (2013) examined empirically the impact of telecommunication service expansion on economic growth in Nigeria using secondary data on Gross Domestic Product, Telecommunication contribution (GSM) and Private Investment (PI) which was regressed using pooled Ordinary Least Squared (OLS) regression methods. The study found that there exists a positive relationship between economic growth, proxied by real GDP, and telecommunication (GSM) variables (teledensity, telecommunication contribution to GDP, private investment in telecoms and mobile subscribers) in Nigeria. Having discovered that teledensity has a positive relationship with economic growth, the study recommends that policies that could lead to continual expansion in teledensity rate through the provision of supportive infrastructural base in the sector should be put in place.

Kawaljeet K. and Neena M. (2014), investigated the causal relationship between telecommunication development and GDP as well as various sectoral components of GDP in India. The results of the study revealed a long run relationship between growth of telecommunication and economic growth at aggregate level as well as at sectoral levels. The study indicated that there is causal relationship between telecommunication growth and growth of manufacturing sector as well as services sectors. Growth of FIRB services (Finance, Insurance, and Real estate and business services) is causing telecommunication growth in India while the causal relationship is other way round that is growth of SPC and TTHC is caused by telecommunication growth in India. The results show structural break in data in 1995 and 2005 which indicates strong impact of telecommunications on development of various sectors of the economy.

Hence, owning to the fact that Nigeria as a country within the last few years has been waxing cold in her telecommunication infrastructural development, recent research needs to be conducted on the subject matter to either validate or invalidate the previous stance. However, above this line of reasoning is the fact that, only few of the previous work on the impact of telecommunication infrastructure on economic growth for other countries was able to considered at the same time the long and short run relationship between telecommunication infrastructure and economic growth, while to the best of our knowledge, no research work in the context of the Nigeria economy has been able to tell us simultaneously the long run and short run impact of telecommunication infrastructure on the economic growth if significant relationship actually exist between them within the period of study which represent the gap this study want to fill.

3. Model Specification and Estimation Technique

3.1 Theoretical Framework

For the purpose of this study, we bring into play the neoclassical model developed by Solow and Swan (1956). The Solow model centers on four variables: output (Y), capital (K), Labour (L) and Knowledge or the effectiveness of labour (A). At any time, the economy has some amounts of capital, labour, and knowledge, and these are combined to produce output. The production function takes the form as presented in the below equation;

$$Y(t) = F\big(K(t), A(t), L(t)\big) \quad \ldots\ldots\ldots\ldots \quad (3.1)$$

Where, t denotes time.

The technology does not enter the model directly, but only through K, L, and A. That is output changes over time only if the inputs to production change. In particular, the amount of output obtained from given quantities of capital and labour rises over time. There is technological progress only if the amount of knowledge increases.
Observe also that A and L enters multiplicatively. AL is referred to as effective labour, also known as labour-augmenting or Harrod-neutral. The central assumption of the Solow model concerns the properties of the production function and the evolution of the three inputs into production over time. The model is set in continuous time and the initial levels of capital, labour, and knowledge are taken as given. Labour and knowledge grow at constant rates as shown in equation 3.2

$$\dot{L}(t) = nL(t) \quad (3.2)$$

$$\dot{A}(t) = gA(t) \quad (3.3)$$

Where *n* and *g* are exogenous parameters and where a dot over a variable denotes a derivative with respect time. The growth rate of a variable refers to its proportional rate of change which is represented as $\frac{\dot{X}(t)}{X(t)}$, thus equation (3.2) implies that the growth rate of L is constant and equal to *n*, and equation (3.3) implies that A's growth rate is constant and equal to *g*. Applying the result that a variable's growth rate equals the rate of change of its log to equations (3.2) and (3.3) shows that the rates of change of the logs of L and A are constant and that they are *n* and *g*, respectively. Thus

$$\ln L(t) = [\ln L(0)] + nt \quad (3.4)$$

$$\ln A(t) = [\ln A(0)] + gt \quad (3.5)$$

Where L(0) and A(0) are the values of L and A at time 0. Exponentiation both sides of the equation gives:

$$L(t) = L(0)e^{nt} \quad (3.6)$$

$$A(t) = A(0)e^{gt} \quad (3.7)$$

Thus the assumption is that both L and A grow exponentially.
Output is divided between consumption and investment. The fraction of output devoted to investment, s, is exogenous and constant. One unit of output devoted to investment yields one unit of new capital. In addition, existing capital depreciates at rate δ thus:

$$\dot{K}(t) = sY(t) - \delta K(t) \quad (3.8)$$

Because the economy may be growing over time, it turns out that it is easier to focus on the capital stock per unit of effective labour, k, than on the unadjusted capital stock, K.
Since $k = \frac{K}{AL}$, then using chain rule the equation becomes

$$\dot{k}(t) = \frac{\dot{K}(t)}{A(t)L(t)} - \frac{K(t)}{[A(t)L(t)]^2}[A(t)\dot{L}(t) + L(t)\dot{A}(t)] \quad (3.9)$$

$\frac{K}{AL}$ is the same as *k*. From equation (3.2) and (3.3), $\frac{\dot{L}}{L}$ and, $\frac{\dot{A}}{A}$ are *n* and *g* , respectively. $\dot{K}$ is given by equation (3.8). Substituting these facts into equation (3.9) yields

$\dot{k}(t) = \frac{sY(t) - \delta K(t)}{A(t)L(t)} - k(t)n - k(t)g$ which simplifies to

$$\dot{k}(t) = \frac{sY(t)}{A(t)L(t)} - \delta k(t) - nk(t) - gk(t) \quad (3.10a)$$

Using the fact that $\frac{Y}{AL}$ is given by *f(k)*, the equation thus becomes

$$\dot{k}(t) = sf(k(t)) - \delta k(t) - nk(t) - gk(t) \quad (3.10b)$$

Where, s denotes the propensity to save, $n > 0$ the exogenous rate of population growth and δ the rate of depreciation of physical capital and *g* is the growth rate in technology. The model implies that countries with similar production technologies as well as comparable savings and the population growth rates should converge to similar steady state levels of per capita income. This convergence property means that poor countries starting with relatively low standard of living and a lower capital/labour ratio will grow faster during transition as they catch up with rich countries. Intuitively according to Agenor (2005), convergence occurs because, with diminishing marginal returns, each increment in capital stock generates large additions to output when the capital stock is initially small.
According to Romer (2006), the neoclassical growth model led to "Sources of Growth" approach, a popular empirical methodology aimed at analyzing the determinants of changes in output. Considering equation 3.1 the study assumed that production function included labour-augmenting technological progress, and that the technology term *T(t)*, grows at constant rate *x*. Thus the condition for the change in the capital stock is:

$$\dot{K} = s.F[K, L.T(t)] - \delta K \quad (3.11)$$

Dividing equation 3.11 by *L* an expression for the change in time in *k* overtime becomes:

$$\dot{k} = s.F[k, T(t)] - (n + \delta).k \quad (3.12)$$

To compute per capita growth rate equation (3.12) is divided by *k* to yield

$$\frac{\dot{k}}{k} = s.\frac{F[k, T(t)]}{k} - (n + \delta) \quad (3.13)$$

Since *s*, *n* and *g* are constants, equation (3.13) implies that the average product of capital, $[\frac{F[k,T(t)]}{k}]$, is constant in the steady state. Because of constant returns to scale, the expression for average product equals $F[1,\frac{T(t)}{k}]$ and is therefore constant only *k* if and *T(t)* grow at the same rate. The output per capita is given by:

$$y = F[k,T(t)] = k.F[1,\frac{T(t)}{k}] \ldots\ldots (3.14)$$

The variable *k* is the quantity of capital per unit of effective labor and *y* is the quantity of output per unit of effective labour. Taking that technology *T (t)* grows at the rate *x* the dynamic equation for k becomes

$$\frac{\dot{k}}{k} = \frac{s.f(k)}{k} - (x + n + \delta) \ldots\ldots (3.14)$$

The technology incorporated is assumed to be as a result of investment in telecommunication infrastructure.

3.2 Model Specification

Subsequent to the theoretical framework above, the functional relationship between telecommunication infrastructure and economic growth emerges from equation 3.14 while we take into consideration other externalities linked with output growth. Note that output growth is a function of effective amount of labour. The study assumes that telecommunication infrastructure services contribute to the efficiency in labour. Therefore, the growth rate is a function of capital growth $(\dot{k})$ and technological progress *(T(t))*, while the externalities stated specifically by Barro (1991), Mankind et al. (1992) and Norton (1992) were incorporated and thus the equation as adapted from Martin (2012) is stated as follows;

$$GDPGR = f(GDI, LTL, TI, NMS, DOO, FDI) \ldots\ldots (3.16)$$

Where,

GDPGR = the gross domestic product growth rate which was measured by change in GDP at constant prices and presented in percentage.

GDI = gross domestic investment as a share of GDP and measured in percentage.

LTL = Number of landline (main telephone) telephone lines per 100 people.

TI = Telecommunication infrastructure (interaction between landline and mobile telephone) was represented by teledensity which is the number of telephone per 100 inhabitants including both fixed line and mobile subscribers.

NMS = Number of mobile telephone subscribers per 100 people,

DOO = Country's volume of trade measured by degree of Openness. It represents the share of trade in GDP.

FDI = Foreign direct investment which is the amount of investment from abroad.

Explicitly, equation 3.16 can be stated as follows;

$$GDPGR = \alpha + \beta1GDI + \beta2\,LTL + \beta3\,TI + \beta4\,NMS + \beta5DOO + \beta6FDI + \mu \ldots (3.17)$$

Where,

α is the constant,

β_1 - β_6 are the coefficients, and

μ is the error term.

3.3 Estimation Techniques

This study after taking into consideration all necessary rules governing econometric procedures and the purpose this study seeks to achieve, we employed ARDL bounds testing estimation techniques. "ARDL" stands for Autoregressive - Distributed Lag and it is a model that deals with single cointegration and is introduced originally by Pesaran and Shin (1999) and further extended by Pesaran et al. (2001). The ARDL approach has the advantage that it does not require all variables to be I(1) as the Johansen framework and it is still applicable if we have I(0) and I(1) variables in our set.

The bounds test method cointegration has certain econometric advantages in comparison to other methods of cointegration such as; it assumes that all variables of the model are endogenous, it can be used to test for cointegration, and estimate long-run and short-run dynamics, even when the variables in question and may include a mixture of stationary and non-stationary time-series.

The basic form of an ARDL regression model is given as;

$$\Delta GDPGR_t = \alpha_0 + \sum_{i-1}^{n}\alpha_{1i}\,\Delta GDPGR_{t-i} + \sum_{i-1}^{n}\alpha_{2i}\,\Delta GDI_{t-i} + \sum_{i-1}^{n}\alpha_{3i}\,\Delta LTL_{t-i} + \sum_{i-1}^{n}\alpha_{4i}\,\Delta TI_{t-i} + \sum_{i-1}^{n}\alpha_{5i}\,\Delta NMS_{t-i} + \sum_{i-1}^{n}\alpha_{6i}\,\Delta DOO_{t-i} + \sum_{i-1}^{n}\alpha_{7i}\,\Delta FDI_{t-i} + \beta_1 GDPGR_{t-i} + \beta_2 GDI_{t-i} + \beta_3 LTL_{t-i} + \beta_4 TI_{t-i} + \beta_5 NMS_{t-i} + \beta_6 DOO_{t-i} + \beta_7 FDI_{t-i} + \varepsilon_t \ldots\ldots (3.18)$$

Where,

Δ denotes the first difference operator,

α_0 is the drift component,

ε_t is the usual white noise residuals.
Equation 3.18 above connotes that, the terms with the summation signs represent the error correction dynamics i.e ($\alpha_1 - \alpha_7$) while the second part ($\beta_1 - \beta_7$) correspond to the long run relationship.
Hence, the investigation of the long-run relationship between telecommunication infrastructure and economic growth using the specified economic variables in this study requires Pesaran et al. (2001) bound testing procedure. The bound testing procedure is based on the F-test. The F-test is actually a test of the hypothesis of no coinetegration among the variables against the existence or presence of cointegration among the variables, represented as:
Ho: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = 0$ i.e., there is no cointegration among the variables.
H1: $\beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq \beta_6 \neq \beta_7 \neq 0$ i.e., there is cointegration among the variables.
The exact critical values for the F-test aren't available for an arbitrary mix of I(0) and I(1) variables. However, Pesaran et al. (2001) supply bounds on the critical values for the asymptotic distribution of the F-statistic. For various situations (*e.g*., different numbers of variables, (k + 1)), they give lower and upper bounds on the critical values. In each case, the lower bound is based on the assumption that all of the variables are I(0), and the upper bound is based on the assumption that all of the variables are I(1). In fact, the truth may be somewhere in between these two polar extremes. If the computed F-statistic falls below the lower bound we would conclude that the variables are I(0), so no cointegration is possible, by definition. If the F-statistic exceeds the upper bound, we conclude that we have cointegration. Finally, if the F-statistic falls between the bounds, the test is inconclusive.
Furthermore, Pesaran et al.(2001), maintained that equation (3.18) can be replicate to ARDL version of the error correction model relating to the variables equation (3.18) as thus:

$$\Delta GDPGR_t = \alpha_0 + \sum_{i-1}^{n} \alpha_{1i}\, \Delta GDPGR_{t-i} + \sum_{i-1}^{n} \alpha_{2i}\, \Delta GDI_{t-i} + \sum_{i-1}^{n} \alpha_{3i}\, \Delta LTL_{t-i} + \sum_{i-1}^{n} \alpha_{4i}\, \Delta TI_{t-i} + \sum_{i-1}^{n} \alpha_{5i}\, \Delta NMS_{t-i} + \sum_{i-1}^{n} \alpha_{6i}\, \Delta DOO_{t-i} + \sum_{i-1}^{n} \alpha_{7i}\, \Delta FDI_{t-i} + \delta ECM_{t-i} + \mu_t \quad \ldots\ldots (3.19)$$

Where, δ is the speed of adjustment parameter and ECM is the residuals that are obtained from the estimated cointegration model of equation (3.18).
Hence, this study relies on secondary quarterly data from 2002 – 2014 which was soured for from world development indicators (2014), Nigerian Communication Commission Data Base, the Central Bank of Nigeria Statistical Bulletin (2014) and National Bureau of Statistics Annual Abstract (2014).

4. Presentation of Results and Interpretation

4.1 Stationarity Test

It is important to note that, the ARDL approach to cointegration does not necessarily require unit roots pre testing but it is imperative to determine the maximum order of integration of the variables because a variable that is stationary at second difference, I(2), can not fit in the bounds testing. This is because the critical values are only available for I(0) and I(1) variables. To identify the order of integration of our variables, we employ two test approaches Augmented Dickey-Fuller and Phillip-Perron .
Result of unit root test using Augmented Dickey-Fuller and the Phillip-Perron are presented in the below table 1.

Table 1: ADF and PP Unit Root Test

VARIABLE		Augmented Dickey-Fuller (ADF) Test			Phillip-Perron (PP) Test		
		CONSTANT	CONSTANT & TREND	STATUS	CONSTANT	CONSTANT & TREND	STATUS
GDPGR		-3.367021**	-4.225389**	I(0)	-3.670211**	-5.595211*	I(0)
GDI		-1.040831	-2.266594		-1.037224	-1.507374	
Δ(GDI)		-4.314603*	4.727721**	I(1)	-4.198032*	4.184763**	I(1)
LTL		-1.936492	-1.580088		-1.936492	-1.037968	
Δ(LTL)		-3.316625**	-4.177173**	I(1)	-3.316625**	-5.866640*	I(1)
NMS		-3.955214**	-3.990779**	I(0)	-3.583669**	-6.354096*	I(0)
TL		-4.288481*	-4.624762**	I(0)	-4.354184*	-4.558006**	I(0)
DOO		-4.451304*	-4.602534**	I(0)	-4.629091*	-4.717289**	I(0)
FDI		-1.726406	1.837288		-1.772865	-2.524918	
Δ(FDI)		-5.852815*	-5.714786*	I(1)	-6.300564*	-15.27391*	I(1)
CRITICAL VALUE	1% 5% 10%	-4.121990 -3.144920 -2.713751	-4.992279 -3.875302 -3.388330		4.121990 -3.144920 -2.713751	-4.992279 -3.875302 -3.388330	

Source: Authors' Computation from E-views Output

Notes: * indicates stronger significant at one percent or a rejection of the null of no unit root at the one percent level

** indicates significant at five percent or a rejection of the null of no unit root at the five percent level.
Number of lags was selected using the AIC criterion

From the result presented in table 1 above, the GDPGR, NMS, TL and DOO were all stationary at level with both the ADF and PP unit root test with trend and without trend respectively which means they are integrated of order (0), while the GDI, LTL and FDI were not stationary at level which necessitated there differencing. Hence, for these variables after the first difference, it was observed that the null hypothesis of non-stationarity were rejected at 10%, 5% and some at 1% critical value for ADF and PP with and without trend respectively . This means that the variables are stationary at first difference and are integrated of order (1). Therefore, the appropriate techniques of analysis is that which can capture the characteristics of a mixture of I(0) and I(1) of the variables which according to Pesaran, et al. (2001) is the ARDL model.

4.2 Lag Length Selection

ARDL bound testing approach to long run level relationship among the variables requires the determination of the optimal lag for the cointegrating equation based on the assumption of serially uncorrelated residual. The lag length that minimizes the value of the AIC, SC, HQ and SBC and at which the model does not have autocorrelation is the optimal lag.

The Schwarz Information Criterion (SC) was used to select the optimal lag length. Based on the SIC, it was found that one lag was optimal. SC was used for model selection such as determining the lag length of a model, with smaller values of the information criterion being preferred. This is shown in the below table.

Table 2: VAR Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-2270.994	NA	5.66e+31	92.97935	93.24961	93.08188
1	-1995.547	460.9520*	5.60e+27*	83.73662*	85.89870*	84.55691*
2	-1982.603	17.96307	2.75e+28	85.20829	89.26219	86.74634
3	-1953.456	32.12131	8.70e+28	86.01861	91.96433	88.27441
* indicates lag order selected by the criterion						
LR: sequential modified LR test statistic (each test at 5% level)						
FPE: Final prediction error						
AIC: Akaike information criterion						
SC: Schwarz information criterion						
HQ: Hannan-Quinn information criterion						

Source: Authors' Computation from E-views Output

4.3 Estimation of Long Run Relationship

Equation 3.18 above is estimated to test the null hypothesis of no cointegration against the alternative hypothesis. The result obtain is presented in the table below.

The result presented above shows the existence of long run relationship among the variable given a negative and significant coefficient of the lag value of the gross domestic product growth rate (GDPGR) and its depicts that all the explanatory variables in their long and short run forms are in line with the apriori expectation and significant at 5% significance.

Also, the coefficient of determination (R^2) explains 70% of the variations in the dependent variable which is above 50% and even after taking into consideration the degree of freedom, the adjusted coefficient of determination (adjusted R^2) still explains 52% variation in the dependent variable. The F-statistic 112.06(0.0000) confirmed the fitness of the coefficient of determination and shows an overall significant level of the explanatory variables jointly in explaining the gross domestic product growth rate. Above all, the model is free from autocorrelation as shown by the Durbin-Watson value that is approximately equal to 2.

In the same vein, the outcome of this result can be tested using some diagnostic tests such as serial correlation test and stability test. These are presented and explained below respectively:

The result of the Breusch-Godfrey Serial Correlation LM test shows that, the Null hypothesis of no serial correlation cannot be rejected given the probability value of 0.6159 and that the alternative hypothesis that there exist serial correlation in the model can be rejected. Therefore, there is a plus to the reliability of the estimated model as it is free from serial correlation problem.

Table 3: ARDL Long Run Relationship Result

Dependent Variable: D(GDPGR)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	29.91279	14.62844	2.044844	0.0033
D(GDPGR(-1))	0.241289	0.272035	0.886977	0.3811
D(GDI(-1))	9.053897	0.004011	2.251267	0.0031
D(LTL(-1))	29.02768	11.71978	2.476811	0.0365
D(TL(-1))	2.826036	3.136940	2.900889	0.0138
D(NMS(-1))	1.97E-06	2.22E-06	0.888497	0.3803
D(DOO(-1))	0.473148	0.370137	1.278305	0.2096
D(FDI(-1))	2.66E-05	1.04E-05	2.565016	0.0257
GDPGR(-1)	-0.517341	0.146921	-3.521209	0.0012
GDI(-1)	0.001853	0.002374	0.780643	0.4403
LTL(-1)	8.240709	4.003633	2.058308	0.0445
TL(-1)	4.631664	2.104353	2.200992	0.0378
NMS(-1)	1.74E-06	1.49E-06	1.168764	0.2504
DOO(-1)	1.035474	0.285871	3.623314	0.0135
FDI(-1)	3.10E-05	8.13E-06	3.820043	0.0177
R-squared	0.699451	Mean dependent var		0.035134
Adjusted R-squared	0.519231	S.D. dependent var		5.613213
S.E. of regression	5.558977	Akaike info criterion		6.512030
Sum squared resid	1081.578	Schwarz criterion		7.085637
Log likelihood	-147.8008	Hannan-Quinn criter.		6.730463
F-statistic	112.0629	Durbin-Watson stat		1.983168
Prob(F-statistic)	0.000047			

Source: Authors' Computation from E-views Output

Table 4: Breusch-Godfrey Serial Correlation LM Test:

Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	2.012837	Prob. F(2,33)	0.0059
Obs*R-squared	13.35424	Prob. Chi-Square(2)	0.6013

Source: Authors' Computation from E-views Output

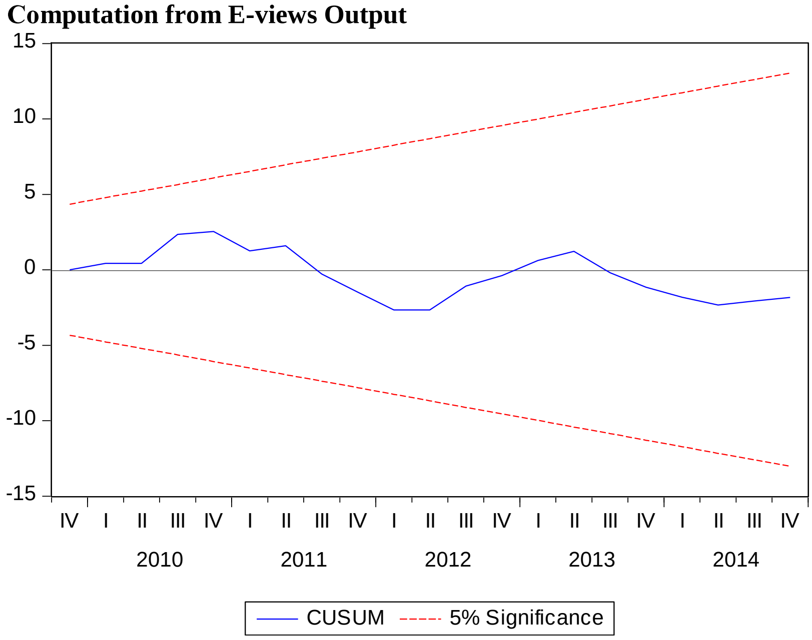

Fig. 1: Plot of Cumulative Sum of Recursive Residuals

For the stability test, CUSUM figure above shows that the CUSUM line is within the critical bounds of 5 percent which is an indication that the model is structurally stable.

4.4 Bound Test Approach to Cointegration

The long run relationship of the result presented above can be further affirmed by conducting a bound test. This is done by testing if the coefficients of β's are equal to zero in our estimated model or not. The F-Statistic value from the bound test as revealed by the Wald test presented in table 5 below will be compare with the critical value from the bound table (Pesaran et al., 2001).

Table 5: Wald Test

Test Statistic	Value	df	Probability
F-statistic	7.137175	(7, 35)	0.0651
Chi-square	19.96023	7	0.0005

Source: Authors' Computation from E-views Output

Table 6: F-statistics for Testing the Existence of Co-integration

Test Statistic	Value	Lag	Significance Level	Bound Critical Value(Unrestricted intercept and no trend)	
F-statistic	7.137175	1		I(0)	I(1)
			1%	2.57	2.91
			5%	2.86	3.22
			10%	3.43	3.82

Source: Authors' Computation from E-views Output

We can observed from table 6 above that estimated results of the F-statistics exceed the upper critical values at 1%, 5% and 10% significance level, and thus, inferring that there exists a co-integrating relationship among the time series in the level form, without considering whether they are I(0) or I(1).

4.5 Error Correction Representation of ARDL Model

Equation 3.19 above is estimated and the result is given in the below table.

Table 7: Error Correction Result of ARDL Model

Dependent Variable: D(GDPGR)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.724070	0.855809	2.014551	0.0385
D(GDPGR(-1))	0.495658	0.241230	2.054705	0.0377
D(GDI(-1))	7.780238	0.003568	2.180560	0.0376
D(LTL(-1))	4.596565	10.25718	2.448131	0.0264
D(TL(-1))	7.084747	2.846287	2.489119	0.0274
D(NMS(-1))	9.59E-07	2.01E-06	0.475692	0.6368
D(DOO(-1))	0.976523	0.327030	2.986036	0.0299
D(FDI(-1))	6.41E-06	9.12E-06	0.703192	0.4859
ECM(-1)	-0.513646	0.140811	-3.647760	0.0007
R-squared	0.745030	Mean dependent var		0.035134
Adjusted R-squared	0.697718	S.D. dependent var		5.613213
S.E. of regression	5.331907	Akaike info criterion		6.346844
Sum squared resid	1165.598	Schwarz criterion		6.691008
Log likelihood	-149.6711	Hannan-Quinn criter.		6.477904
F-statistic	101.6347	Durbin-Watson stat		2.000882
Prob(F-statistic)	0.000008			

Source: Authors' Computation from E-views Output

From the above table, ECM (–1) is one period lag value of error terms that is obtained from the long-run relationship. The coefficient of ECM (–1) indicates how much of the disequilibrium in the short-run will be fixed (eliminated) in the long-run. As expected, the error correction variable ECM (–1) has been found negative and also statistically significant. Hence, the coefficient of the ECM term suggests that adjustment process is on the average as 51 percent of the previous year's disequilibrium in the explanatory variables from its equilibrium path will be corrected in the current year.

5 Conclusion

This study examined if there is a long run relationship between telecommunication infrastructure and economic growth in Nigeria using the autoregressive distributed lag model (ARDL) estimation technique approach. Telecommunication Infrastructure has been identified as having both direct and indirect impact on the growth of an economy (Udjo et al., 2000). Nigeria's telecommunications system has shown an increasing rate of development in its infrastructure as it progresses over a decade ago through various stages of development from the primitive communications equipment in its colonial days to the enormous variety of technologies available today. This provides a stimulant to economic growth and that as economies become more highly developed, they need more communications which has the capacity to attract experienced technical and productivity change, large amounts of investment capital from both the public and private sectors and its rapid diffusion can propelled a sharply reduced costs and increased capacity (Nadiri and Nandi, 2003). The ARDL approach to cointegration test was conducted using bound test, stability test and others. The result from the analysis revealed the existence of long run relationship between telecommunication infrastructure and economic growth in Nigeria. Hence, increase in the gross domestic investment, foreign direct investment and degree of openness in the country has improved the teledensity, number of mobile telephone subscribers as well as number of landline which facilitates or enhanced economic activities and in turn leads to increased economic growth. It is therefore, it is imperative for the government to implement policies that will enhance the development of the telecommunications sectors, development of complementary factors such as electrification particularly in rural areas , pay more attention to measures that would increase mobile telephone penetration such as reduce tariffs on telecommunication components, allow more mobile telephone operators to bring competition to cover wider areas and restructure education and manpower training to include telecommunication as well as policies that will enhance domestic savings and attract more foreign direct investment.

However, the study suggests that, further study on the subject matter should considered looking at the casual relationship between telecommunication infrastructure and economic growth to ascertain if there is one or two ways relationship between the two and also look at the place of internet connectivity in enhancing economic growth in the country.

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