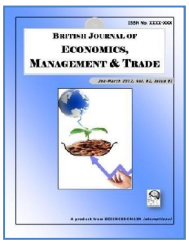

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Investment in Telecommunications Infrastructure and Economic Growth in Nigeria: A Multivariate Approach

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Authors' contributions

This work was carried out in collaboration between all authors. Author BOAO designed the study, performed the statistical analysis and wrote the first draft of the manuscript. Authors AST and MAO reviewed the entire study for quality and contribution to knowledge. All authors read and approved the final manuscript.

Research Article

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ABSTRACT

This paper attempts to investigate the impact of investment in telecommunications infrastructure on economic growth in Nigeria. A multivariate model of simultaneous equations was deployed. The paper also deploys 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.

Keywords: Investment; telecommunications infrastructure; causality; economic growth; macroeconometric model.

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1. INTRODUCTION

Telecommunications infrastructure has been identified as having both direct and indirect impact on the growth of an economy (Udjo et al., 2000). Ariyo and Jerome (2005) for example, argued 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. Okafor (2007) submits that telecommunications infrastructure becomes a crucial ingredient in the process of economic development in both the developing and the developed countries. This position is supported by Alleman et al. (1997) who explained that economic development policies in developed countries increasingly included telecommunications as an essential component of the economic infrastructure. In the opinion of Ndukwe (2005), the developed world had been able to transform not only their domestic economic growth but also increase their competitiveness in the world market, partly due to economic development policies predicated on telecommunications as an essential component of the economic infrastructure.

In Nigeria, there has been huge growth recorded in telecommunications teledensity and infrastructure but with an unimpressive impact on economic growth. The average annual growth rate of teledensity over the last two decade, specifically from 1986 to 2010 was 16.3 percent. On the other hand, the average rate of economic growth for the same period was 4.9 percent (National Bureau of Statistics, 2010; Central Bank of Nigeria, 2010). The mismatch in the performances of the telecommunications industry and that of the aggregate economy have put a big question mark on the role of telecommunications infrastructural investment in promoting economic growth. This also suggests that the importance of telecommunications infrastructure in the process of economic development may be exaggerated in the literature. It is equally possible that there may not be a direct impact of telecommunications infrastructural investment on economic growth.

Flowing from this, the paper is therefore to investigate the impact of telecommunications infrastructure on economic growth in Nigeria. The scope of the study which covers the period of thirty eight years (1970 to 2010) across cycles of economic buoyancy and recession provides an opportunity for a comprehensive assessment of the impact of telecommunications infrastructural investment on the Nigerian economy. These periods account for about 77 per cent of the life of the country, which attained political independence in 1960.

1.1 Overview of Telecommunications Industry in Nigeria

Telecommunications facilities in Nigeria were first established in 1886 by the colonial administration. At independence in 1960, with a population of roughly 40 million people, the country only had about 18,724 phone lines for use. Between 1960 and 1985, the telecommunications sector consisted of the Department of Post and Telecommunications (P&T) in charge of the internal network and a limited liability company and the Nigeria External Telecommunications (NET) Limited, responsible for the external telecommunications service providing the gateway to the outside world. The installed switching capacity at the end of 1985 was about 200,000 lines as against the planned target of about 460,000. All the Switching exchanges were analog systems. Telephone penetration remained poor equaling one telephone line to 440 inhabitants, well below the target of 1

telephone line to 100 inhabitants recommended by International Telecommunications Union (ITU) for developing countries.

The establishment of Nigeria Communication Commission (NCC) in 1992 removes the monopoly enjoyed by the government communication institution and by 2002 three GSM operators (MTEL Limited, ECONET Nigeria Ltd and MTN Communications Nigeria Ltd.) were licensed. This major achievement in telecommunication infrastructure increased the teledensity from 0.71 in 2001 to 63.11 in December 2010 (Nigeria Communication Commission, 2011). The major operators, the private investments as well as the growth teledensity of telecommunication in Nigeria are depicted in Table 1.

Table 1. Licensed operators and teledensity in Nigeria

National Carrier	Dec. 1999	June. 2006	Dec. 2010
	1	1	2
Number of licensed Mobile operators (GSM and CDMA)	1	10 (including operator with unified license)	9 (are operating actively) GSM [MTN, ETISALAT, CELTEL (now AIRTEL) MTEL, GLO] CDMA [STARCOMMS, VISAFONE, MULTILINKS and ZOOM]
Number of active licensed Fixed line operators	9	27	16
Private investment	$50m USD	$8,150m USD	$18,000m USD
Teledensity	0.41	23.79	63.11

Source: www.ncc.gov.ng/ industry statistics (Dec. 2011) and Author's compilations.

In Nigeria, the entrance of Global System for Mobile Communications (GSM) operators from 2001 has positive impact on the culture and life of Nigerians. It generated employment for many unemployed able persons. The industry currently directly employs about 10,000 professionals and is indirectly responsible for another 1,000,000 jobs (Tella et al., 2007). The industry received global acclaim as one of the fastest growing mobile markets in the world (Ndukwe, 2006) and has enhanced both foreign direct investment (FDI) and private investment in Nigeria, which account for at $18billion in December 2010 (NCC, 2011).

The contribution of the communications sector to economic growth is that GDP increased from an average of 0.4 percent between 1986 and 1989 to about an average of 5 percent between 2006 and 2010. The average annual growth rate of the GDP rose from about 3.7 percent average between 1986 and 1989 to about an average of 8 percent between 2006 and 2010 (National Bureau of Statistics, 1986, 2007; Central Bank of Nigeria, 2007, 2009) (Table 2). The big leap observed in the annual growth of telecommunications from 2000 (6 percent) and 2001 (30 percent) can be linked to the fact that most of the licenses were granted to the GSM providers around this period.

In spite of the performance shown in Table 2, the telecommunications sector is still plagued with some problems such as poor public power supply, poor security, vandalized infrastructure, high import duty, anti-competitive practice, finances and high operational costs. The world development indicators revealed that the per capita power consumption in Nigeria was estimated at 82 Kilowatts (KW) compared with an average of 456 KW in other

Sub–Saharan countries and 3,793KW in South Africa (The World Bank, 2004). The consequential effect of these problems contributes to the high cost of telecommunications service delivery and prices. This power problem poses major constraint in terms of maintenance of equipment and general cost of running telecommunications in the country.

Table 2. National GDP and telecommunications contribution to GDP (1986-2010)

Years	Average GDP at 1990 constant base prices =N= Million	Average telco contribution =N= Million	Telco contribution to GDP %	Average annual GDP growth rate %	Average annual telco growth rate %
1986-1989	267,847	1,073	0.38	3.71	1.17
1990-1993	334,270	1,171	0.35	3.89	2.77
1994-1997	360,731	1,340	0.37	2.49	4.24
1998-2001	406,423	1,757	0.43	3.41	11.57
2002-2005	509,075	5,423	1.05	6.82	37.37
2006-2010	775,400	35,400	4.6	7.9	34.6

Sources: National Bureau of Statistics and Central Bank of Nigeria Annual Report (2010). Growth rates calculated by Authors.

The remaining part of this paper is structured as follows. Section 2 focuses on the relevant literature while section 3 is on the methodology and model specification. Section 4 covers data analysis and discussion of the results. Section 5 summarizes the paper and offers some recommendations.

2. LITERATURE REVIEW

There is a plethora of evidence in both the empirical and theoretical literature on the relationship between telecommunications infrastructure and economic growth. Saunders, et al. (1994) cited by Ding and Haynes (2004) provide a positive relationship between telecommunications and economic growth. 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.

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. The study of Tella et al. (2007) on telecommunications infrastructure in Nigeria show that main landline and cell phone penetration had significant effects on economic growth, after controlling for the effects of capital and labour. The results also show that traditional economic factors like income and price helped explain demand for main land phones, but they do not explain demand for Cell phones. Osotimehin et al. (2010) study also

on Nigerian using OLS multiple regression technique upheld a close correlation between telecommunications and economic growth.

2.1. Conceptual Framework

The conceptual framework of the theoretical linkage between telecommunications infrastructural investment and economic growth is presented in Fig. 1.

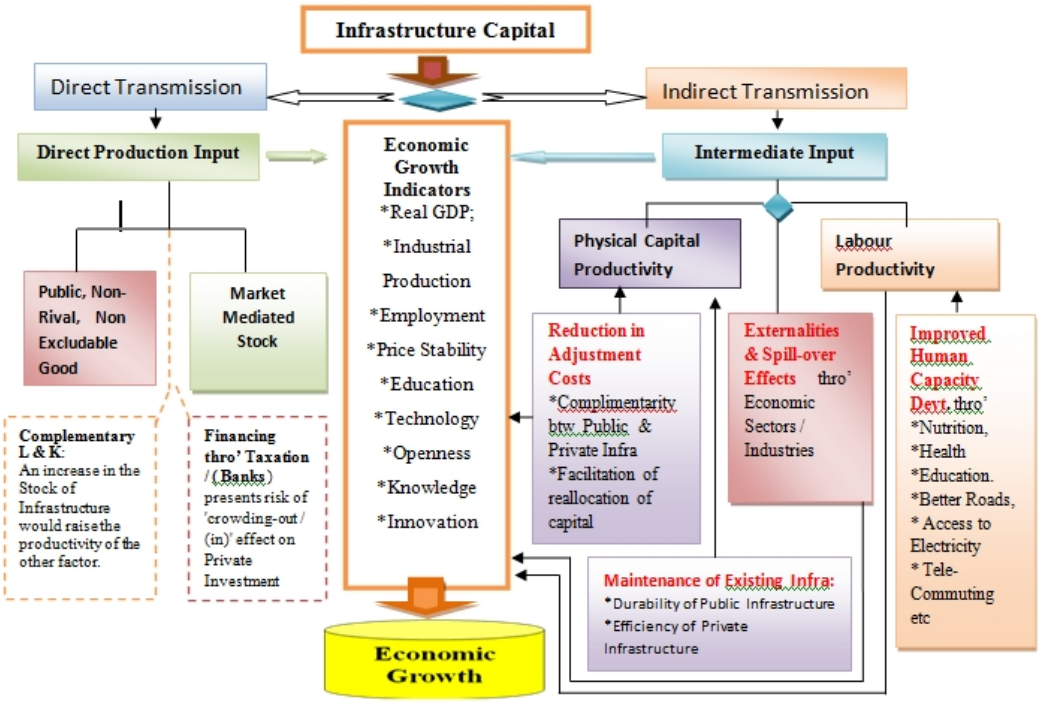

Fig. 1. Theoretical flow of the transmission channels through which telecommunications infrastructural investment affect economic growth
Source: Authors: 2012

The various channels of transmission are illustrated therein. The effect of infrastructure is transmitted directly and indirectly to economic growth. This effect is manifested only through the economic growth indicators which include real GDP, industrial production, employment, price stability, education, technology, openness, knowledge, innovation. The nature of transmission is determined by the role of infrastructure capital in the production function i.e. whether it is a direct or intermediate input. As a direct input, it can either be in its pure public good form or provided by the private investors, guided by market forces. The transmission channel in this case is said to be direct channels. Where infrastructure capital is an intermediate input in the production function, the consequential indirect transmission channel through which infrastructure affects growth is determined by three factors. These are productivity of physical capital which is in turn determined by reduction in adjustment costs and maintenance of existing infrastructure also derived from the facilitation of reallocation of capital. The second variable is higher labour productivity obtained from improved human capacity development. The transmission impact through human development can be

realized through improving health better nutrition, education, better Roads, access to electricity, telecommuting, etc. The third factor is the externalities which transmit key technological innovations to other sectors leading to involve lower costs, and spill-over effects on other firms and therefore, on the economy as a whole.

2.2 Summary of the Literature Review and Gap to Be Filled

Vast as the literature is, it is far from being conclusive on the effect of infrastructure on economic growth. There are those that have not been able to establish any significantly positive relationship and thereby suggest that there is little evidence of an effect of infrastructure on income growth (Garcia-Mila et al., 1996; Holtz-Eakin, 1994; Holtz-Eakin and Schwartz, 1995; Tatom, 1991, 1993a, 1993b). However, there is also the body of works that have found some limited positive impact of infrastructure on growth (see Aschauer, 1989; Barro, 1990; Canning and Pedroni, 2004; Easterly and Rebelo, 1993; Gramlich, 1994; Sanchez-Robles, 1998; The World Bank, 1994).

Some early studies measuring the returns from public infrastructure (e.g. Aschauer 1989) have suffered from simultaneity bias and spurious correlation. Some others have addressed this weakness by utilizing first differencing approaches or by moving to smaller data aggregation (e.g. Aaron, 1990; Hulten and Schwab, 1990). Others including Roeller and Waverman (2001), Waverman et al. (2005), Sridhar and Sridhar (2005, 2007) and Tella et al. (2007) have adopted the use of simultaneous equation models which endogenize telecommunications investment by incorporating supply, demand and output equations. These equations are thereafter estimated jointly with a macro production function to account for the simultaneity effects. The use of simultaneous equation is borne out of the need to disentangle the possible reverse causality effect between economic growths due to the increase in infrastructure on the one hand and the increase in the demand for telecommunication services due to higher economic output.

However, as this study shows, there is the need to address the spill-over effects and externalities generated by infrastructural investment which is transmitted throughout the economy. There is also the need to determine the inter-sectoral linkage impact of telecommunications infrastructure on the economy. This is under-scored by the fact that infrastructure, apart from serving as a direct input, can also be an intermediate input in the production process. Thus, activities of the real sector of the economy (manufacturing, agriculture, oil etc) and even those of services and monetary sectors are influenced by infrastructural investment and consequently their contributions to economic growth (e.g. Murty and Soumya, 2005, 2006). Theoretically, ignoring these sectoral multiplier effects, when in fact they exist, may lead to biased and inefficient results. In addition, the impact of infrastructure may be underestimated if these externalities are not factored into the estimation process (omitted variable bias). This study is an attempt to remove such biases.

The body of works on the role of infrastructure on economic growth has just started emerging in Nigeria. The most recent studies on Nigeria by Tella et al. (2007), Gold (2010) and Osotimehin, Akinkoye and Olasanmi (2010) did not consider the forms of effect which telecommunications infrastructure could have on economic growth. The studies by Ajiboye et al. (2007) and Anyasi and Otubu (2009) only examined the impact of mobile telephony. This research intends to fill this literature gap in Nigeria.

For this purpose, the study utilises a simultaneous system of equation model that captures the channels through which telecommunications infrastructure affects growth. In addition, it

employs the tool of an aggregative, structural, three-stage least squares method to estimate inter- linkages of various macroeconometric variables in order to simulate and forecast their impact on economic growth. Such macroeconometric model has not been used for the study of telecommunication infrastructural investment in Nigeria and therefore serves as the foundation for comprehensive, recursive and in-depth analysis of the impact of the investment in telecommunications infrastructure on the Nigerian economy.

The preceding discussions show the importance of telecommunications infrastructure and economic growth as indicated in both the empirical and theoretical literature. It is therefore expedient to examine the empirical relationship between telecommunication infrastructure and economic growth. The analysis also looks at the causal relationship between the phenomena. The next discussion thus focuses on the methodology and model specification.

3. METHODOLGY AND MODEL SPECIFICATIONS

3.1 Methodology

The paper deploys the three stage least squares (3SLS), an estimator which combines two-stage least squares (2SLS) with SURE (Seemingly Unrelated Regression). It generalizes the 2SLS method to take account of the correlations between equations in the same way that SURE generalizes OLS and is a more robust technique for estimating a hybrid simultaneous equation system (Zellner and Theil, 1962). The benefit of 3SLS is that its design takes care of any probable occurrence of non-stationarity and consequential possibility of spurious regressions. This is because 3SLS incorporates lag terms of both the dependent and independent variables in the estimation process. Thus, there is no need to test for stationarity.

In the estimated model of this study, the equations are all over-identified and 3SLS is therefore more appropriate. The 3SLS technique satisfies the over identification condition and in addition, resolved some simultaneity or endogeneity biases (for example between investment in telecommunications infrastructure and economic growth) which could have rendered the use of either OLS or ILS invalid. A number of post estimation tests to ascertain the reliability of the results obtained by conducting normality test and serial correlation tests were also conducted. The normality test is used to examine whether the disturbances are normally distributed or not (Jarque and Bera, 1980). The estimation of the model was carried out with the use of E- ViewsTM (version 6.1).

3.2 Model Specification

The model specification for the paper is of the simultaneous equation regression which has been recommended by many scholars including Roller and Waverman (2001), Belaid (2004), Herrera (2001) and Cadot et al., (2006). This method is considered appropriate especially when a dependent (endogenous) variable in one equation appears as explanatory variable in another equation which leads to a feedback distortion between the variables.

The structure of the macroeconometric model is fashioned after the national accounting identity. The theoretical foundation of the model is predicated upon the IS-LM-BOP model. However, infrastructure capital in the case of Nigeria is a function of the market size which determines the growth of the economy. The government was the major player in the provision of infrastructure prior to year 2001. When the market size expands, there is

pressure on the public infrastructure which forces the government to increase investments in this sector. The constraints in the capacity of the government to solely provide the economic infrastructure gave birth to the involvement of the private sector via the deregulation of the industry. The implication of this is that government spending is exogenous and not market-determined. Private sector involvement commenced only in the last decade and has not fully harnessed the opportunities available in the financial market but has contributed to the stock of telecommunications infrastructure. Even though most of the infrastructural inputs were imported and should have implications for the Balance of Payment, the funding for the equipment was derived from the government's annual budgetary appropriations for three quarters of the study period. Therefore, this study focuses on the IS portion of the IS-LM-BOP Model.

The model of the paper consists of four blocks: supply (Output); demand (Expenditure); Government and the external sectors. This reflects the inter-linkages between telecommunications infrastructure and the various sectors of the economy, as well as major variables within the economy. Flowing from the above, we specify the model, the description of the variables, which is presented in Appendix 1 as follows:

3.2.1 Supply block

The supply block given by equations (1) to (7) describes the basic macroeconomic components of the economy.

$$Y_{TIF} = a_1 + a_2 GCR_{TIF} + a_3 FDI_{TIF} + a_4 K_{TIF} + a_5 P_{TIF} + e_1 \quad (1)$$

$$Y_{OIF} = a_6 + a_7 GCR_{OIF} + a_8 FDI_{OIF} + a_9 K_{OIF} + a_{10} P_{OIF} + e_2 \quad (2)$$

$$Y_{MFG} = a11 + a_{12} GCR_{MFG} + a_{13} Y_{TIF} + a_{14} Y_{OIF} + a_{15} FDI_{MFG} + a_{16} K_{MFG} + a_{17} P_{MFG} + e_3 \quad (3)$$

$$Y_{AGRIC} = a_{18} + a_{19} GCR_{AGRIC} + a_{20} Y_{TIF} + a_{21} Y_{OIF} + a_{22} FDI_{AGRIC} + a_{23} K_{AGRIC} + a_{24} RAIN + a_{25} P_{AGRIC} + e_4 \quad (4)$$

$$Y_{OIL} = a_{26} + a_{27} GCR_{OIL} + a_{28} Y_{TIF} + a_{29} Y_{OIF} + a_{30} FDI_{OIL} + a_{31} K_{OIL} + a_{32} P_{OIL} + a_{33} OPEC + e_5 \quad (6)$$

$$Y_{SERV} = a_{34} + a_{35} Y_{TIF} + a_{36} Y_{OIF} + a_{37} FDI_{SERV} + a_{38} K_{SERV} + a_{39} P_{SERV} + e_6 \quad (7)$$

In this case, the inter-sectoral linkages among five identified economic sectors: infrastructure sector, manufacturing sector, agricultural sector, oil sector and services sector are described as equations 10 to 14. Infrastructure sector is further divided into telecommunications and other infrastructure in order to more carefully capture the effect of telecommunications infrastructure on economic activities in Nigeria.

3.2.2 Private demand block

In the demand (expenditure) block, two types of demand can be distinguished. These are private and government demand. Equations (8) to (18) provide the description of flows of interactions among variables for the private demand.

$$C_F = a_{40} + a_{41} P_F + a_{42} YDc + a_{43} IR + e_7 \quad (8)$$

$$C_{NF} = a_{44} + a_{45} P_{NF} + a_{46} YDc + a_{47} W + e_8 \quad (9)$$

$$INV_{TIF} = a_{48} + a_{49} Y_{TIF+a50} FDI_{TIF} + a_{51} GCR_{TIF} + a_{52} P_{TIF} + e_9 \quad (10)$$

$$INV_{OIF} = a_{53} + a_{54} Y_{OIF} + a_{55} FDI_{OIF} + a_{56} GCR_{OIF} + a_{57} P_{OIF} + e_{10} \quad (11)$$

$$INV_{MFG} = a_{58} + a_{59} Y_{MFG} + a_{60} INV_{IF} + a_{61} IR + a_{62} FDI_{MFG} + a_{63} GCR_{MFG} + a_{64} P_{MFG} + e_{11} \quad (12)$$

$$INV_{AGRIC} = a_{65} + a_{66} Y_{AGRIC} + INV_{IF} + a_{67} IR + a_{68} YD + a_{69} GCR_{AGRIC} + a_{70} P_{AGRIC} + e_{12} \quad (13)$$

$$INV_{OIL} = a_{71} + a_{72}Y_{OIL} + a_{73}\,INV_{IF+a74}\,FDI_{OIL} + a_{75}GCR_{OIL} + a_{76}\,P_{OIL} + e_{13} \quad (14)$$

$$INV_{SERV} = a_{77} + a_{78}Y_{SERV} + a_{79}INV_{IF} + a_{80}FDI_{SERV} + a_{81}GCR_{SERV} + a_{82}\,P_{SERV} + e_{14} \quad (15)$$

3.2.3 Government block

$$GE = a_{83} + a_{84}GRV + a_{85}(CG) + a_{86}EDS + a_{87}DDS + a88\,Y + a_{89}\,FD + e_{15} \quad (16)$$

$$GRV = a_{90} + a_{91}Y_{TIF} + a_{92}Y_{OIF} + a_{93}FDI + a_{94}\,NX + e_{16} \quad (17)$$

$$FDF = a_{95} + a_{96}FD + a_{97}\,NFA + a_{98}EXR + e_{17} \quad (18)$$

3.2.4 External block

The external sector block, which shows equilibrium between exports and imports, is given by equations (19) to (21).

$$X = a_{99} + a_{100}Y + a_{101}TOT + a_{102}EXR + e_{18} \quad (19)$$

$$M = a_{103} = a_{104}TAR + a_{105}Y + a_{106}\,TOTa_{107}EXR + e_{19} \quad (20)$$

$$RES = a_{108} + a_{109}Y + a_{110}NFA + a_{111}EXR + e_{20} \quad (21)$$

Finally, the system is closed by a set of identity equations listed as equations (22) to (32).

$$Y = Y_{IF} + Y_{NIF} \quad (22)$$

$$Y_{IF} = Y_{TIF} + Y_{OIF} \quad (23)$$

$$Y_{NIF} = Y_{MFG} + Y_{AGRIC} + Y_{OIL} + Y_{SERV} \quad (24)$$

$$INV_{NIF} = INV_{MFG} + INV_{AGRIC} + INV_{OIL} + INV_{SERV} \quad (25)$$

$$INV_{IF} = INV_{TIF} + INV_{OIF} \quad (26)$$

$$C = C_F + C_{NF} \quad (27)$$

$$INV = INV_{IF} + INV_{NIF} \quad (28)$$

$$NX = X - M \quad (29)$$

$$AGD = PDD + GE + NX \quad (30)$$

$$PDD = C + INV \quad (31)$$

$$GE = FDF + GRV \quad (32)$$

It is significant to note that the models as indicated provide for two main possible channels through which infrastructural investment can affect economic growth. First, it can affect output directly through the effect of capital stock in telecommunications infrastructure (K_{TIF}) on the output of telecommunications infrastructure (Y_{TIF}). Second, telecommunications infrastructure can affect economic performance indirectly through the effect of Y_{TIF} on the outputs of other economic sectors (manufacturing, agriculture, oil, and services). Thus, we use the supply (equation 1) demand block (equation 10) to estimate the causal relationship.

3.2.5 Sources of data

Time series data used for the estimation covers 1970 to 2008, were obtained from the Nigerian Bureau of Statistics (NBS, various issues), Central Bank of Nigeria (CBN, various issues), the Nigerian Communications Commission (NCC, various years), United States

Energy Information Administration Independent Statistics and Analysis (2010) (http://www.eia.doe.gov), Energy Information Administration, International Petroleum Monthly (http://www.eia.doe.gov), International Telecommunications Union (various years), Telecommunications Development Report (www.itu.int/itud/ict/)

4. DATA ANALYSIS AND DISCUSSION

The results are presented in three parts: Investment in telecommunications infrastructure and output; Output of telecommunications infrastructure and economic growth and Direction of the causality. The results are presented in Table 3.

4.1 Investment in Telecommunications Infrastructure and Economic Growth

The result of the output telecommunications infrastructural investment (Y_{TIF}) as the dependent variable is presented in Table 3. The adjusted coefficient of determination ($\overline{R^2}$) which is used to measure the goodness of fit or the explanatory power of a model technically gives the proportion or percentage of the total variation in the dependent variable explained by the regressors. The results show that the four explanatory variables in equation 3.27 account for 95% ($\overline{R^2}$ = 0.95) variation in the output of telecommunications infrastructure (Y_{TIF}). However, a high level value of adjusted coefficient of determination ($\overline{R^2}$) as in this case, may be symptomatic of a spurious result. The Durbin-Watson Statistics (DW) is recommended to validate the regression result (Greene, 2002). Since the DW (2.03) is greater than the $\overline{R^2}$ (0.95), the obtained result can be taken as valid and an attestation of a high degree of the model specifications.

Table 3. System Estimation Report: Investment in Telecommunications Infrastructure and Economic Growth

Dependent Variable	Explanatory Variables					Equation No
	Constant	***GCR_{TIF}***	***FDI_{TIF}***	***K_{TIF}***	***P_{TIF}***	
Y_{TIF}	1.2684 (2.43)	*0.2323* (4.66)[a]	0.0628 (0.55)	0.2801 (2.43)[b]	0.1233 (1.00)	10

R^2 = 0.96, $\overline{R^2}$ =0.95, SE =0.4658, Durbin Watson (DW) Statistics =2.03
Note: a, b, c imply 1%, 5% and 10% significance level respectively. t-statistic in parenthesis.

The result of the output telecommunications infrastructural investment (Y_{TIF}) as the dependent variable in Table 3 shows that the Capital Stock of telecommunications infrastructure (K_{TIF}) has a positive and significant relationship with output of the telecommunications infrastructure. K_{TIF} which is the main construct variable of the paper, serves as the proxy for Investment in telecommunications infrastructure (INV_{TIF}) The relationship is statistically significant with a t-value of (2.43) at 5 percent level. With a coefficient value of (0.28), a percentage increase in telecommunication capital stock would result in about 0.28 percent increase in the growth of telecommunication infrastructure output. Since the capital stock of telecommunications infrastructure ($K_{TIF)}$), is statistically significant in explaining the output of the telecommunications infrastructure (Y_{TIF}), the investment in telecommunications infrastructure has **direct** and significant impact on economic growth in Nigeria directly through the impact of its own industry's output.

4.2 Output of Telecommunications Infrastructure and Economic Growth

The results show that output of telecommunications infrastructure (Y_{TIF}) is statistically significant at 1 percent, 5 percent and 10 percent to the outputs of the oil, manufacturing and service sectors respectively. It is however not significant to the output of the agricultural sector. The estimated *t*-statistic values for the outputs of oil (Y_{OIL}), manufacturing (Y_{MFG}), services (Y_{SERV}) and agriculture (Y_{AGRIC}) are (3.31), (2.33), (18.07) and (1.27) respectively (Table 4).

Table 4. System estimation report: impact of the output of telecommunications infrastructure on other sectors

Dependent Variables	*Coefficient of Y_{TIF} as Explanatory* Variable	R^2	*Durbin-Watson Statistics*	*Equation No.*
Y_{MFG}	0.1830			3
	(2.33)[b]	0.96	1.09	
Y_{AGRIC}	0.0627			4
	(1.27)	0.98	1.66	
Y_{OIL}	0.2797			5
	(3.31)[a]	0.99	1.76	
Y_{SERV}	0.0866			6
	(18.07)[c]	0.99	1.34	
GRV	0.1078			7
	(1.00)	0.98	2.41	

Note: a, b, c imply 1 percent, 5 percent and 10 percent significance level respectively. T-statistic in parenthesis.

The estimation result of equation 3 shows that about 96 percent ($\overline{R^2}$ = 0.96) of the output of manufacturing (Y_{MFG}) is explained by the regressors. Also in equation 4 and 7, the dependent variables account for 98 percent each of the variation in the outputs of agriculture (Y_{AGRIC}) and government revenue (GRV) respectively. In the same vein, about 99 percent of the variations of in the outputs of oil and services are accounted for by the explanatory variables in equations 5 and 6. The high values of adjusted coefficient of determination ($\overline{R^2}$) although indicative of a specious result, can be considered valid in view of the fact that the Durbin-Watson Statistics (DW) for each of the regression is higher than the respective $\overline{R^2}$.

Since the outputs of all these sectors are positively related to the output of the telecommunications infrastructure, with three of the four sectors being significant, we can therefore, infer that the investment in telecommunications infrastructure through the output of telecommunications infrastructure indirectly impacts Nigeria's economic growth. This impact is channeled through the output of these other sectors.

Consequently, telecommunications infrastructural investment can be said have an **indirect** effect on economic growth. The non significance of the output of telecommunications infrastructure to the output of agriculture is supported by the findings of Jagun et al. (2008). Who reports that before the advent of the liberalisation of the telecommunications sector, Nigerian farmers had little access to telecommunications facilities. Pyramid Research (2010) also reports that the easier and faster access to up-to-date market and price information

assistance to farmers and rural-based traders through modern mobile telecommunications facilities was hitherto not available. The discussion has shown the direct and indirect impact of the investment in and output of telecommunications infrastructure economic growth.

The next discussion examines the causal relationship to know the extent of the predictive power of the relationship between telecommunications infrastructure and economic growth. This will provide the extent to which the impact of telecommunications infrastructure induces further investment demand.

4.3 Direction of Causality

The result of the estimation of the causal relationship between telecommunications infrastructural investment (Y_{TIF}) equation 10 and Investment in telecommunication infrastructure (INV_{TIF}) equation 17 is presented in Table 5.

Table 5. System estimation report: causal relationship between the impact of investments in and the output of telecommunications infrastructure

Dependent Variables	*Explanatory Variables*	R^2	*Durbin-Watson Statistics*	Equation No.
Y_{TIF}	0.2801 K_{TIF} (2.43)[b]	0.95	2.03	*3.27*
INV_{TIF}	0.2687 Y_{TIF} (5.59)[a]	0.97	1.34	*3.35*

Note: a and b imply 1% and 5% significance level respectively, t-statistic in parenthesis.

The results of equations 10 and 17 reveal that the regressors account for 95 percent and 97 percent ($\overline{R^2}$ = 0.95 and $\overline{R^2}$ = 0.97) respectively in explaining the variation in the both the output of telecommunications infrastructure (Y_{TIF}) and capital stock of telecommunications. Although the adjusted coefficients of determination ($\overline{R^2}$) are rather high, the Durbin-Watson Statistics (DW) test results are higher in both cases. Therefore, the results can be accepted as valid.

In the estimation of equation (17), the output of telecommunications infrastructure (Y_{TIF}) has a positive relationship with the capital stock in telecommunications infrastructure, K_{TIF} (serving as the proxy for investment in telecommunications infrastructure (INV_{TIF})). The output of telecommunications infrastructure (Y_{TIF}) is also related significantly at 1 percent level with t-statistic of (5.59) to the investment in telecommunications infrastructure (INV_{TIF}). With a coefficient of 0.27, one percent increase in the output of telecommunications infrastructure will cause a rise of 0.27 percent in telecommunications infrastructural investment. Please recall that in equation (10), the capital stock in telecommunications infrastructure (K_{TIF}) has a significant and positive relationship at 1 percent level with the output of telecommunications infrastructure (Y_{TIF}). A rise in the stock of telecommunications infrastructure has been reported to generate 0.28 upsurges in its investment. The combined effect of the estimation of equations (3.27) and (3.35) indicates that just as increase in investment in telecommunications infrastructure (INV_{TIF}) leads to increase in telecommunications infrastructure output (Y_{TIF}), a rise in the output of telecommunications (Y_{TIF}) also brings about a rise in investment in telecommunications infrastructure (INV_{TIF}).

Consequently, there is a bi-directional causality between telecommunications infrastructural investment and output of telecommunications infrastructure.

The preceding discussions indicate that investments in telecommunications infrastructure have both direct and indirect impact on Nigeria's economic growth. The discussion also shows a bi-directional relationship between the two variables. In addition, the result supports the endogenous growth theory which indicates that the stock of telecommunications infrastructure is determined endogenously within the model. The results further confirm the inter-sectoral linkage effects of telecommunications infrastructure in the economy hitherto omitted in the literature.

5. CONCLUSION AND RECOMMENDATIONS

The paper has reviewed the impact of telecommunication infrastructure on economic growth. The results of the paper are consistent with similar results in both the developing and developed nations. The study has established that investments in telecommunications infrastructure both directly and indirectly significantly affect economic growth in Nigeria. The research also shows a bi-directional relationship between the two variables. The output of the telecommunications industry is also considered an important determinant of output of other sectors with forward and backward linkages in the economy. The research paper further reports on the inter-sectoral linkage effects of telecommunications infrastructure in the economy hitherto omitted in the literature which is supported by the Romer's endogenous growth theory and the vintage capital theory.

The results of the study further show that government should provide non-monetary incentives including the funding of the development of other infrastructure particularly electricity. To reduce the operating cost of telecommunication business, the operators should consider the strategy of co-location and infrastructure sharing in addition to the out-sourcing its infrastructure logistics. In order to encourage rural telephony, the Nigerian government should consider providing further concessionary fiscal incentives to investors who are willing to commit resources to the marginally profitable areas. The development of rural telephony will greatly assist growth of employment and incomes.

In addition, the telecommunications companies should instal modern equipment technology that can provide a broader array of services, as this will have a greater impact than marginally expand existing network. This supports the Vintage theory Solow (1960) which posited that the higher the rate of embodied technical progress, the more productive will the new capital be compared to older capital.

The future of the communications industry will continue to be shaped by innovations in technology, adjustments in regulatory policy and social norms, and, more critically, the continued elaboration of demand for information goods and services. Although the structural character of the industry will surely change, there is little doubt that its economic importance will grow in the coming years. The outcome of our study shows that investment in telecommunications infrastructure have direct and indirect linkage to economic growth. This is corroborated by the works of Anyasi and Otubu (2009) and Osotimehin et al. (2010). Given the fact that telecommunications contributes less than 10% to Nigeria's income growth, the conclusion of this study is therefore not significantly different from that of Allerman et al. (1997) that neither infrastructure generally nor investment in telecommunications alone is sufficient to cause the economy to grow. Other conditions

including human and capital resources must be present, if the country is to obtain greater benefits from infrastructural investment.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX 1

Description of Variables and Identities

Notation	Definition	Type	Unit
Y_{TIF}	Output of telecommunication infrastructure	Endogenous	N/million
Y_{OIF}	Output of other infrastructure	Endogenous	N/million
Y_{MFG}	Output of manufacturing	Endogenous	N/million
Y_{AGRIC}	Output of Agriculture	Endogenous	N/million
Y_{OIL}	Output of Oil	Endogenous	N/million
Y_{SERV}	Output of Service	Endogenous	N/million
Y_{IF}	Output of infrastructure	Endogenous	N/million
Y_{NIF}	Output of non infrastructure	Endogenous	N/million
Y	Overall Output	Endogenous	N/million
C_F	Food Consumption	Endogenous	N/million
C_{NF}	Non –food Consumption	Endogenous	N/million
INV_{TIF}	Investment in telecommunication infrastructure	Endogenous	N/million
INV_{OIF}	Investment in other infrastructure	Endogenous	N/million
INV_{MFG}	Investment in manufacturing	Endogenous	N/million
INV_{AGRIC}	Investment in Agriculture	Endogenous	N/million
INV_{OIL}	Investment in Oil	Endogenous	N/million
INV_{SERV}	Investment in Service	Endogenous	N/million
INV_{IF}	Investment in infrastructure	Endogenous	N/million
INV_{NIF}	Investment in non-infrastructure	Endogenous	N/million
INV	Total Investment	Endogenous	N/million
C	Total Consumption	Endogenous	N/million
PDD	Private Deduction	Endogenous	N/million
NX	Net Export	Endogenous	N/million
AGD	Aggregate Demand	Endogenous	N/million
FDF	Fiscal deficit financed by the CBN	Endogenous	N/million
X	Export	Endogenous	N/million
M	Import	Endogenous	N/million
EXR	Exchange rate	Endogenous	Index
GRV	Government Revenue	Exogenous	N/million
GE	Total Government Expenditure	Exogenous	N/million
CREDIT	Credit to the government	Exogenous	N/million
EDS	External Debt Service	Exogenous	N/million
DDS	Domestic Debt Service	Exogenous	N/million
FD	Fiscal Deficit	Exogenous	N/million
FDI	Foreign Direct Investment	Exogenous	N/million
NFA	Net foreign Assets	Exogenous	N/million
TOT	Terms of Trade	Exogenous	Index
TAR	Implicit Tariff	Exogenous	Rate
GCR_{TIF}	Government Capital Exponential ratio in telecommunication infrastructure	Exogenous	Ratio
FDI_{TIF}	Foreign Direct Investment in telecommunication infrastructure	Exogenous	N/million
K_{TIF}	Capital Stock in telecommunication infrastructure	Exogenous	N/million
P_{TIF}	Average price of telecommunication infrastructure	Exogenous	N/million
GCR_{OIF}	Government capital expenditure in other infrastructure	Exogenous	Ratio
FDI_{OIF}	Foreign Direct Investment in other infrastructure	Exogenous	N/million
P_{OIF}	Price of other infrastructure	Exogenous	N/million
K_{OIF}	Capital Stock in telecommunication infrastructure	Exogenous	N/million
FDI_{MFG}	Foreign Direct Investment in manufacturing	Exogenous	N/million
Notation	Definition	Type	Unit

K_{MFG}	Capital Stock in manufacturing	Exogenous	N/million
P_{MFG}	Price of manufacturing	Exogenous	N/million
GCR_{AGRIC}	Government Capital Expenditure ratio in agriculture	Exogenous	Ratio
Notation	Definition	Type	Unit
FDI_{AGRIC}	Foreign Direct Investment in agriculture	Exogenous	N/million
K_{AGRIC}	Capital Stock in Agriculture	Exogenous	N/million
RAIN	Annual Rainfall	Exogenous	Millimetre
P_{AGRIC}	Price of Agriculture	Exogenous	index
GCR_{OIL}	Government capital expenditure ratio in oil	Exogenous	Ratio
FDI_{OIL}	Foreign Direct Investment in oil	Exogenous	N/million
K_{OIL}	Capital Stock in oil	Exogenous	N/million
P_{OIL}	Price of oil	Exogenous	N/million
OPEC	OPEC output	Exogenous	M/Barrels
FDI_{SERV}	Foreign Direct Investment in service	Exogenous	N/million
K_{SERV}	Capital stock in service	Exogenous	N/million
P_{SERV}	Average price of services	Exogenous	N/million
P_F	Food price	Exogenous	N/million
YD	Disposable income	Exogenous	N/million
IR	Interest rate	Exogenous	rate
P_{NF}	Price of non- food items	Exogenous	N/million
W	Wealth	Exogenous	N/million
FDI_{MFG}	Foreign Direct Investment in manufacturing	Exogenous	N/million
GCR_{MFG}	Government capital expenditure ratio in manufacturing	Exogenous	Ratio
P_{MFG}	Price of manufacturing	Exogenous	N/million
FDI_{AGRIC}	Foreign Direct Investment in agriculture	Exogenous	N/million
CREDIT	Credit to the Government	Exogenous	N/million
P_{AGRIC}	Price of agriculture	Exogenous	N/million
FDI_{OIL}	Foreign Direct Investment in oil	Exogenous	N/million
GCR_{SERV}	Government capital expenditure ratio in agriculture	Exogenous	Ratio

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