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Research Paper

Mobile Telecommunication and Economic Growth: Evidence from ARDL Modeling

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Abstract

This study examines the impact of mobile telephone on economic growth in Nigeria using ARDL (Autoregressive distributed lag) as methodology, with data from 2001-2017. The study reveals that mobile penetration had a positive impact on real GDP per capita. Which means as more people get access to mobile phones, GDP per capita is expected to grow. 10% increase in mobile penetration will lead to a 0.5 % increase in average annual GDP per capita. The study concludes that mobile telephony can aid sustainable economic development when used appropriately, with the full participation of all stakeholders, especially in a country like Nigeria. The intrinsic value of telecommunications lies not in easing communications and information, but in enabling growth and development. The study recommends that Consumer protection policies are needed to protect consumers from unfair calls and mobile data charges will ensure consumers get the value for their money, which will lead to increased consumption and investment in the industry.

Keywords *Telecommunication, Economic Growth, ARDL Model*

INTRODUCTION

Over the past three decades, the global telecommunications industry has experienced exponential growth in many different nations (Oladipo and Wynand, 2020; Leila, 2019: Amavilah, Asongu, and Andres, 2017). Economic growth has seen both direct and indirect benefits from telecommunications expansion (WDI, 2018; Sajjad, 2017 NCC 2014; Mohsin, Khan & Malik, 2012). In 2015 the estimated global number of people with mobile phones was 4.7 billion, and the number of active mobile devices was 7.6 billion, which was more than the global human population, owing to the fact that some people have more than one mobile device. During the period, the industry generated US$1.1 trillion in revenues, paid US$430 billion in tax, employed 17 million people directly and 15 million indirectly, was responsible for 4.2% of global GDP, and global 4G connection passed 1 billion people across 151 countries according to GSMA (2016).

Global system for mobile communication (GSM) plays a vital part domestically in supporting the various government communications initiatives and thereby linking all the sectors of the country together in order to achieve a common goal. Additionally, it offers a quick and effective solution to meet the communication requirements necessary to advance and promote trade between Nigeria and its international partners. Most significantly, it encourages investment, which in turn fosters long-term employment possibilities. The GSM's remarkable contribution to the country's Gross domestic product in 2003 was 53% at the microeconomic level (GDP). The final quarter of 2015 saw the GSM Market and other telecommunications industry segments contribute 1,645 82 billion nairas, or 8.8%, to the country's GDP.

Mobile telecommunication services are an integral part of economic activities, so it continues to offer unequalled chances for economic growth, especially in an emerging market,

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according to Lloyd and Fenio (2017). It has reduced the globe into a village through reduction of time and space.

Until recently, when deregulation and competition were implemented, mobile communications services in Nigeria were directly under the jurisdiction of the government since it believes them to be so important to the country's interests and economic development (Akinwale, Sanusi, Surujlal, 2018; Mamoun and Talib 2017 Lee, 2003). The development of information sharing as a vital resource for the economy's passage to post-industrial and information-technology-driven economic growth has been made possible by these advancements in mobile telecommunication technology.

Nigeria is witnessing a period of rapid growth in the use of mobile phones and mobile internet services, which has led to an increase in the share of disposable income spent on mobile services. Whether this is for business or social interaction, the tremendous impact on economic growth and the potential for further growth cannot be ignored anymore. According to data from the National Bureau of Statistics (NBS), services now make up 52% of the GDP as of 2015, and information and communications technology (ICT) is a key driver of growth. The Nigerian Communications Commission (NCC) reports that Nigeria has grown to be the biggest telecoms industry in Africa and the Middle East, with more than 140 million active telecoms subscribers in 2015 and more than 4 million phones entering the country each month. On the African continent, Nigeria accounts for 29% of all internet usage, and this percentage is projected to increase.

Nigerians spent over US$1.2 billion on 21 million mobile phones in 2012 (according to venture Africa), which means, on average, Nigerians spent N8,000 purchasing mobile phones. In contrast, the total expenditure on agricultural products in that year was below US$2 billion, which is very close to the amount spent on purchasing phones; this is truly amazing because Nigeria is a net importer of agricultural produce, which means Nigerians spent an almost equal amount of money on food and mobile phones. So what government policies have been put in place to reap the huge benefits from the mobile phone market? What impact does the expenditure on a mobile phone have on household income and business in Nigeria? According to the (NCC); Nigeria has 150 million active lines. When we calculate the number of active lines and the current average revenue per user (ARPU) benchmark of US$8 (N2516), then we can assume that Nigerians spend a total of N380 billion on their lines monthly which adds up to about N4.5 trillion annually. A study by Sridhar and Sridhar (2004) found that the impact of telecommunications penetration on total output is significantly higher for developing countries than for OECD countries. So, what is the impact of the huge expenditure on telecom services on the economy? Has the expenditure facilitated economic activities and increased economic growth? Or has it been just a mere expenditure on a luxury item? These constitute the problem of interest for this research.

The objective of the research is to examine the impact of mobile telephony on economic growth in Nigeria. The study intends to cover a span of 17 years (2001-2017) because GSM was introduced in Nigeria in 2001. This range was chosen to ensure the availability of data and for the analysis to be meaningful and aid in the achievement of the objectives work.

LITERATURE REVIEW

Oxford dictionary refers to mobile telephony as simply the operation or use of mobile phones. It is a term used for telephone services provided to phones that may move around rather than stay in a fixed position. In a nutshell, all services provided to mobile phones, primarily calls, SMS, internet, and apps, are referred to as mobile telephony. In Nigeria, they are two main digital mobile telephony systems which are GSM and CDMA. The NCC reports that there are about 139,486,832 GSM subscribers and 217,566 CDMA subscribers in Nigeria as of September 2021.

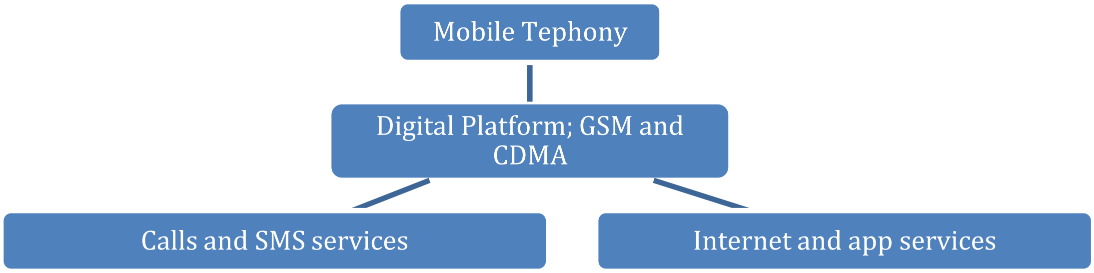

Figure 1. Basic structure of mobile telephony

Global Satellite (GSM)

GSM is a second-generation digital network for phones and tablets that was created by the European Telecommunications Standards Institute (ETSI). GSM is the most popular mobile platform in Nigeria (as in table 1 below). Some examples are MTN, Airtel, Glo, and 9mobile.

Code Division Multiple Access (CDMA)

CDMA is also a second-generation digital network, but it uses code division, unlike GSM. The platform is very popular in Nigeria (table 1 below), although it had a very good start with STARCOM. Some of the CDMA service providers still in business are MULTILINKS and VISAFONE.

One radio channel can accommodate several phone calls or Internet connections using GSM and CDMA. In terms of network quality, they can both provide a good network or a bad network, so network quality is dependent on the service provider. The most important distinguishing factor as far as the consumers are concerned is that; GSM service providers usually store the data of their subscribers on removable sim cards, which makes it easier for customers to transfer their sims from one phone to another while the customer data on CDMA is stored on the phone giving the service providers greater ownership of the device.

Table 1. Market share for technology

Year	**Technology**	**Mobile (GSM)**	**Mobile (CDMA)**	**Fixed (Wireless/Wired)**	**VoIP**
2017	Percentage	99.70%	0.15%	0.10%	0.03%

Source: NCC (2017)

The deregulation of the telecom industry in Nigeria in 2001 created exponential growth in the GSM market, which grew from barely less than a million subscribers to over 140 million subscribers as of 2017.

Table 2. Telecom contribution to GDP

Year	**2017**	**2016**	**2015**	**2014**	**2013**
Percentage	9.50%	9.13%	8.50%	7.60%	7.40%

Source: NCC (2017)

The Mobile Ecosystem in Nigeria

A very unique mobile ecosystem has evolved in Nigeria, which has the telecom service providers or mobile operators (MTN, Airtel, GLO & 9Mobile) in the middle of it. A report by GSMA (2012) defines the mobile ecosystem as follows:

1. **Providers of support services**, including those in the legal, advertising, and accounting fields.
2. **Creators of mobile applications**, where they develop applications for mobile phones. BudgIT, Traclis, Jobs in Nigeria, Genii games, and others.
3. **Handset importers and dealers**, on its own is a multibillion-dollar sector; some of the players here include importers of mobile devices, sellers of mobile devices, and new local producers like SOLO Devices.
4. **Computer equipment, automobiles, furniture, and other capital goods suppliers complete the list.**
5. **Suppliers of network equipment**, include regional infrastructure, upkeep companies, and foreign companies with local operations in Nigeria, including Nokia, Alcatel, Ericsson, Ericsson, Huawei, and Aviat.

Telecommunication services in Nigeria

E-Services and Mobile telephony

Mobile telephony is the backbone of e-services in Nigeria. E-services are just a medium of bringing goods and services to customers via electronic devices. It is vital to collect information about user needs and preferences to guide the producer's decision-making. Some examples of e-services from different sectors include.

E-Government

Information and communication technologies (ICTs) are used in e-Government to enhance the operations of public sector organizations. Oyeneka (2013) refers to it as the mobile government, which extends the concept of government further with the delivery of information and services to the doorsteps of the citizens in a personalized way via what they already have, the mobile phone.

E-Health

E-health is the application of ICTs (information and communication technologies) to health interventions. Applications like the Smart Health app concentrate on offering reliable sources of information about HIV/AIDS, TB, and malaria.

E-Commerce

Buying, selling, transferring, or exchanging goods, services, and/or information over electronic networks while also giving clients contact information is known as e-commerce. Most established businesses have a website where they attend to the needs of customers. SMEs and individual can sell their product on social media.

Empirical Literature

Minges (2015) examined the impact of diverse ICTs as well as fixed and mobile broadband services using cross-sectional analysis for 120 developing and developed countries during the period 1980-2006, and the framework of the analysis is based on an endogenous growth model. According to the study, a 10% rise in fixed broadband coverage would boost GDP growth by 1.21 percent in affluent nations and 1.38 percent in developing ones. However, whereas the coefficient was significant for developed economies at the 1% level, it was only significant for emerging economies at the 10% level.

A report by Deloitte for GSM Association (GSMA) in 2012 measured the effect of new mobile services on economic expansion, which essentially calculated the effect of mobile data usage on expansion. The report used Panel Data from several countries and econometrics analysis to measure the impact of mobile telephony on economic growth.

Zhang (2021) examines the relationship between broadband and economic growth in China during the COVID-19 pandemic period (March 2020, April 2020, March 2019, and April 2019) anchored under the Cobb-Douglas production function. The study used regression analysis, and findings reveal that broadband penetration limited the effect of the pandemic on China's economic growth, given the positive and significant relationship established with the variables. Maneejuk and Yamaka (2020) carried out an analysis of the impacts of telecommunications technology and innovation on economic growth in developed and developing economies using the time-series kink regression of Hansen (2017) and Panel kink regression of Zhang et al. (2017) and Tibprasorn et al. (2017). According to empirical research, developing nations are more significantly impacted by telecommunications innovation and technology than developed nations are. Using Panel Vector Auto regression analysis to examine the nexus between telecommunication infrastructures, economic growth, and development in 46 Africa from 2000 to 2015 (David, 2019). The researcher used the human development index, as well as data on mobile, fixed, and internet access penetration and the outcome shows that there is a long-term, bidirectional relationship between telecommunications infrastructures, economic development, and growth. Haftu looked into the effects of communications infrastructure improvement on the economic growth of 40 sub-Saharan African countries using panel data for the years 2006–15. (2019). The study's conclusions show that the per capita income of the area will have a beneficial impact on an increase in ICT in the form of mobile phone customers over the selected time period.

Okyere, Poku-Boansi, and Adarkwa (2018) examine the relationship between the telecommunication and transport sector in Ghana using Spearman's rank correlation technique. Empirical findings establish that telegraph, fiber optic networks, and telephone facilities, as components of telecommunication, exhibit a bidirectional relationship with the transport sector in Ghana. Similarly, a study by Enowbi (2015) adopted the methodology of Datta and Agarwal (2004) to examine telecommunication and economic growth nexus across 44 African countries for the period 1990–2010. Findings demonstrate that investments in telecommunications are subject to increasing returns and that telecommunications (fixed and mobile lines) contribute significantly to economic development. Another study by Cleeve and Yiheyis (2014) used Ad hoc structural analysis to examine telecommunication and economic growth in 36 African countries from 1995–2010. The findings show that higher mobile penetration influences GDP growth. In the research done by Jung (2020), institutions and telecommunications investment were examined for a sample of 13 European nations from 2007 to 2015. The study employs panel regression, and the findings supported the hypothesis that institutional quality and telecommunication investment levels are positively correlated. In terms of development and digital connectivity, research also indicated that institutional quality was more important for the majority of underdeveloped countries.

Usman, Ozturk, Hassan, Maria, and Ullah (2020) examined the effects of ICT on energy consumption and economic growth in Bangladesh, India, Pakistan, and Sri Lanka between 1990 and 2018 using a limits testing approach of cointegration and error correction modeling. Findings support the idea that ICT only has a long-term, beneficial impact on India's economic growth while having the opposite effect on other economies. The study, which compares 1980 to 2014 data from 25 countries in Sub-Saharan Africa, uses the Generalized Method of Moments technique to examine how information and communication technology (ICT) affects value added across industries (Asongu, Rahman, Nnanna & Haffar, 2020). Researchers' findings indicate that while there is a direct impact on value added in the service sector, the prevalence of mobile phones and the internet have indirect effects on value added in the agricultural and manufacturing sectors. The study by Solomon and van Klyton (2020) was carried out in 39 African countries from 2012 to 2016 to investigate the impact of digital technology usage on economic growth using the GMM estimator.

ICT use by individuals was found to be positively related to growth.

However, analyzing data from 192 countries between 1990 and 2007, Gruber and Koutroumpis (2010) discovered strong beneficial benefits of mobile telecommunications diffusion on GDP and productivity growth. Vu (2013) finds that the level of ICT use in Singapore has a significant positive relationship with value-added and economic growth, particularly in the manufacturing sector, utilizing econometrics and growth accounting. Results from a study by Commander, Harrison, and Menezes-Filho (2011) indicated a correlation between ICT capital and Brazilian and Indian business productivity. ICT works as GPT (general purpose technology), which is an enabling technology for further innovations that affect economic growth and productivity beyond the effect of conventional capital goods, in accordance with Cardona et al. (2013). Bertschek et al. (2015) survey research revealed a positive link between broadband internet and economic growth using broadband internet as a stand-in for telecommunications.

Koutroumpis and Pantelis 2009 conducted a study covering 15 European Union countries for the period 2003-2006. Using panel data analysis with GDP, working population, mobile penetration, and tertiary education per 1000. Two alternative regression analysis methods—Generalized Method Moment (GMM) and Three Stage Least Square (3SLS)—were used, along with two control factors (random and fixed effects). According to their data, there is a considerable influence on GDP growth ranging from 0.26 percent to 0.85 percent for each 10%-point rise in mobile penetration.

In a study on the relationship between the telecommunications sector and economic growth, Badran et al. (2012) argued that the telecom sector is one of the most significant sources of income for national treasuries in many emerging countries. Graber and Venkata (2013) claimed that the revenue of the communications business, which was earned from offering various services, is responsible for two to three percent of the overall GDP based on an empirical study in Egypt, Saudi Arabia, and India. Zhang (2013) and Bowles (2012) both made the case that Australia's economy is constantly changing due to the internet's presence, with the percentage of internet users rising from 73% in 2007 to 87% in 2009. In a different study based on the internet consumption model, Zhang (2013) and Song (2015) discovered a highly positive association between internet diffusion and GDP per capita.

Magaji & Eke (2015) examined the relationships between per capita income, trade and financial indicators, and education and freedom indicators using data from 16 West African nations. Internet, broadband, and mobile phone subscribers are among the rest. Access to Safe Drinking Water and Fresh Water Supply are both considered benchmarks for private sector-led water resource management performance indicators and public sector-led water resource management performance indicators, respectively. The findings indicate that government trade policies, ICT, and wealth levels have an impact on how effectively cross-country water resources are managed. Freedom factors have a significant impact on performance metrics for water resource management (WRMPI). More specifically, there is a positive correlation between WRMPI and Internet users, broadband subscribers, and mobile phone subscribers. Contrary to popular belief, schooling has little impact on WRMPI.

Although there is available empirical literature on mobile telecommunication and economic growth, a gap is created as Nigeria is not well-researched regarding telecommunication and economic growth, which this study intends to undertake.

Theoretical Framework

Endogenous Growth Theory

The sources, forms, and effects of economic growth have always been an important topic of discussion throughout all the economic schools of thought. What are the sources of growth, what are the forms of growth, and how does growth affect individual households and macro-economic activities at large. Economists argue whether economic growth is an end in itself or merely a means to an end (the end being economic development). But one fact they all agree on is that economic growth is an important prerequisite in achieving economic development.

In an effort to demonstrate that capital investment, innovation, and knowledge are major drivers of economic growth, the endogenous growth theory, also known as the new growth theory, was created in response to the shortcomings of the neoclassical (exogenous) growth theory. Romer first proposed his endogenous growth theory in 1986, which includes knowledge as an input into the production function. The hypothesis attempted to explain long-term growth by endogenizing technological advancement or productivity increase. Romer thinks that because technological change is endogenous to the growth model, it was created through regular economic activity. It also gives emphasis on knowledge and information shift within industries, which he considered as a public good and that firms should promote learning by investing. From Equation 1, the Romer model introduces technology augmenting capital.

$$Y = f(A^t K^a L^{1-a}) \ldots (\mathbf{1})$$

A is a constant that is >0 and represents technological change and if $a = 1$ then $Y = A^t K^a L^{1-a}$. An unsolved neoclassical model theory of economic growth and the idea that telecommunications infrastructure improvement alone is insufficient to stimulate economic growth are two limitations of the prior literature on this study. So, we take a look at some potential theoretical arguments against the hypothesis. Most growth is attributed to exogenous factors, such as technological advancements. For this reason, the neoclassical model's presumption of constant exogenous technology change need not present a problem.

RESEARCH METHOD

Sources of Data

The sources of data for this study will be secondary data from International Telecomm Union and World Bank. The period for the data will range from 2001 to 2017 because Mobile telephone services started in 2000, and data for the industry became available from 2001.

Technique of data analysis

The Augmented Dickey-Fuller (ADF) test from 1979, the Phillips-Perron (PP) test from 1988, and the Kwiatkowski-Phillips-Shin-Schmidt (KPSS) test were all used in the study to explore the associations between the variables (1992). The study also uses Pesaran et al. (2001)'s the autoregressive distributed lag model (ARDL) for error correction (short run) analysis and cointegration examination (time series data). The short-run dynamic relationships are investigated using the ECM version of the modified ARDL. All of this will be accomplished using the Ordinary Least Square (OLS) method and the ECM (Error Correction Mechanism). The Error Correction Term (ect), which is created using the long-run model, is used to calculate how quickly the model will change to reach long-run equilibrium. Stability test and diagnostic test.

Model Specification

The standard endogenous growth model employed in this study is adopted and modified in a manner similar to that of Andrainavo and Kpodar (2011) and Lee, Levendis, and Quteirrez (2009). The model by Andrainavo and Kpodar is the most elaborate model in the study of mobile telephony because it includes mobile penetration as the endogenous determinant of growth. And since this study adopts an endogenous growth model framework, the study intends to keep mobile penetration as a determinant of growth. GSMA (2013) used 3G penetration as a determinant variable, but since there are no concrete data on 3G penetration in Nigeria, the study intends to replace these variables with mobile penetration. The addition of mobile internet penetration means the study is not studying a particular kind of GSM technology (edge, 2G, or 3G) but the entire mobile internet usage, notwithstanding the kind of mobile platform. Also, the Andrainavo and Kpodar model is a panel model but would be modified into a time series model as we are concerned only about Nigeria in this study. The modified model is as follows.

$$gdp_t = \alpha gdp_{t-1} + \beta X_t + e_t \ldots \mathbf{(2)}$$

Where,

$X_t \quad = (gov, inv, trade, mobnet, mobpen)$

$E[e_{jt}] = 0$

GDP is the same as GDP per capita in the growth calculation above. The model considers a dynamic process in which the current value of the dependent variable may be influenced by past ones; hence the lagged value of GDP is added as a controlled variable on the right-hand side. The annual share of a country's investment to GDP serves as a proxy for the degree to which a country is open to international commerce. Trade is a country's annual trade volume as a percentage of its GDP. The government's annual consumption of goods and services as a percentage of GDP is known as Gov. mobPen is the level of mobile penetration measured by the number of mobile phones per 100 population, and mobnet is mobile internet penetration as a measure the number of people using mobile internet data per 100 population. From growth literature, the aprior expectation for the magnitude of the coefficient of each Xit is positive. Therefore:

GDP	=	Real GDP per capita
Gov	=	Government expenditure as a share of GDP
Inv	=	Investment expenditure as a share of GDP
Trade	=	Trade expenditure as a share of GDP (Openness of the economy)
Mobpen	=	Mobile penetration
Monet	=	Mobile internet penetration

E- Error Term

From equation (1), when we take the natural log of the equation. we derive the following.

$$\boldsymbol{\ln(gdp) = \alpha \ln(gdp_{t-1}) + \beta_1 \ln(gov_t) + \beta_2 \ln(inv_t) + \beta_3 \ln(trade_t) + \beta_4 \ln(mobnet_t) + \beta_5 \ln(mobpen_t) + e_t \ldots \quad (3)}$$

Following Pesaran et al., (2001), the ARDL representation of the model is expressed as,

Δlngdpt $= \beta_0 + \beta_1$*lngdpt*$-_1 + \beta_2$*lngovt*$-_1 + \beta_3$*lninvt*$-_1 + \beta_4$*lnmobnet t*$-_1 + \beta_5$*lnmobpen t*$-_1$ +

$$\sum_{i=1}^{p} \phi^1 \, \Delta lngdp_{t-i} + \sum_{i=1}^{p} \phi^2 \, \Delta lngov_{t-i} + \sum_{i=1}^{p} \phi^3 \, \Delta lninv_{t-i} + \sum_{i=1}^{p} \phi^4 \, \Delta lnmobnet_{t-i} + \sum_{i=1}^{p} \phi 5 \, \Delta lnmobpen_{t-i} + \mu_t \ldots (\mathbf{4})$$

Equation 5 represents the long run form of the model

$$\ln(gdp) = \alpha \ln(gdp_{t-1}) + \beta_1 \ln(gov_t) + \beta_2 \ln(inv_t) + \beta_3 \ln(trade_t) + \beta_4 \ln(mobnet_t) + \beta_6 \ln(mobpen_t) + e_t \ldots (\mathbf{5})$$

An error correction model (ECM) with the following specifications is used to estimate the short-run dynamics:

$$\Delta lngdpt = \phi_0 + \sum_{i=1}^{p} \phi^1 \, \Delta lngdp_{t-i} + \sum_{i=1}^{p} \phi^2 \, \Delta lngov_{t-i} + \sum_{i=1}^{p} \phi^3 \, \Delta lninv_{t-i} + \sum_{i=1}^{p} \phi^4 \, \Delta lnmobnet_{t-i} + \sum_{i=1}^{p} \phi^5 \, \Delta lnmobpen_{t-i} + \delta ECT_{t-1} \ldots (\mathbf{6})$$

Δ is the difference operator; β_0 is the constant term; and β_1 - β_4 are the long-run elasticities (coefficients of the explanatory variables); ϕ_1- ϕ_4 are the short-run elasticities (coefficients of the differenced explanatory variables); *Ln* is natural logarithm; *P* is the lag length; δ is the speed of adjustment parameter, *ECT* is error correction term lagged for one period, In the long-run model, the a prior expectation is that the coefficient on all the explanatory variables is positive.

Justification of the inclusion of variable

The study measured the impact mobile telephony has had on the economic growth of Nigeria. Since we are not measuring the impact of telecom in general but the impact of mobile telephony in specifics, our model contains two variables that would serve as good indicators for the impact mobile telephony has had on growth. First is mobile penetration, which measures the number of mobile phone subscriptions per 100 population, which is indicative of how common and regular the use of mobile devices is in the country. The source of the data is International Telecom Union (ITU). Secondly is mobile internet penetration, which means the number of mobile internet users per 100 population; this variable is unique to the study and is from International Telecom Union (ITU).

Other variables included in the model are all standard determinants of economic growth; government expenditure as a share of GDP has included the effect of government consumption of goods and services in economic growth as a measure of the degree of openness of the economy, which has an enormous impact on growth the model includes trade expenditure as a share of GDP and investment expenditure as a share of GDP would capture the effect of ever-changing investment expenditure on growth. All the above data are sourced from the World Bank.

Finally, GDP per capita would serve as a measure of economic growth. From the model, we have GDP per capita as the dependent variable and a lag value of GDP per capita as an independent variable. The reason for having a lag of GDP per capita on the right side of the equation is that we assume that growth from one year influences growth from the next year, and the data is from World Bank.

DISCUSSION

Unit Root Test Result Augmented Dickey-Fuller Test

The test findings demonstrate that none of the series tested (GDP, GOV, INV, MOBNET, and TRADE) is stationary at the level since each of their test statistics is below the 5% critical value of -3.478305 for rejecting the unit root hypothesis. However, the null hypothesis of non-stationarity is consistently rejected for all of them when they are given in first differences, showing that they are all integrated of order one (I(1)). Results with an intercept and a trend are those that are reported. However, there was no discernible difference between the results with and without a trend.
Test statistics with intercept and trend for the variable MOBPEN are smaller than the critical value of -3.478305 at 1%,5%, and 10%, both at the level and first difference, suggesting that the series in I(2).

Table 3. ADF Test results (with Intercept and Trend)

Variable	Test Statistics	Critical Value	Probability	Decision
With Intercept and Trend				
LNGDP	-1.275897**	-3.478305	0.8853	I(1)
D(LNGDP)	-8.986386**	-3.479367	0	
LNGOV	-1.369394**	-3.482763	0.8605	I(1)
D(LNGOV)	-7.726507**	-3.48397	0	
LNINV	-3.12646**	-3.478305	0.1087	I(1)
D(LNINV)	-7.998141**	-3.479367	0	
LNMOBNET	-1.559144**	-3.482763	0.7979	I(1)
D(LNMOBNET)	-3.721933**	-3.482763	0.028	
LNTRADE	-1.999457**	-3.482763	0.5902	I(1)
D(LNTRADE)	-8.014179**	-3.48397	0	
LNMOBPEN	-2.91173**	-3.24657	0.0221	I(0)
D(LNMOBPEN)	-1.417993**	-3.487845	0.8455	

Source: Author's computation using E-views 9.0
D indicates the 1st difference of the variable. **, indicates 5% level of significance

Since all of the test statistics fall below the 5% crucial value of -3.478305 for rejecting the hypothesis of a unit root, none of the series tested (GDP, GOV, INV, MOBNET, TRADE) are shown to be stable at the level. However, the null hypothesis of non-stationarity is consistently rejected for all 10 of them when they are given in initial differences, indicating that they are all integrated of order one (I(1)). Results with an intercept and a trend are those that are reported. However, there was no discernible difference between the results with and without a trend. Test statistics with intercept and trend for the variable MOBPEN are smaller than the critical value of -3.478305 at 1%,5%, and 10%, both at the level and first difference, suggesting that the series in I(2).

Philip-Perron Test

The variable has a unit root, which is the null hypothesis for the Philip-Perron (PP) test, while the alternative is that it does not. Intercept and trend were used to run the PP test. The Newey-west bandwidth is used for the bandwidth, and the default Bartlett kernel is used for spectral estimation in EViews. The test statistics are less than the critical values (5% level of significance) at level but more than the critical values (5% level of significance) at the first difference for all the variables. This means the variables are stationary at order 1, making them all I(1) processes.

Table 4. **Phillip-Perron Test**

Variable	Test Statistics	Critical Value	Probability	Decision
With Intercept and Trend				
LNGDP	-0.973793**	-3.478305	0.9404	I(1)
D(LNGDP)	-10.48629**	-3.479367		
LNGOV	-1.394228	-3.482763	0.8533	I(1)
D(LNGOV)	-7.726507	-3.48397	0	
LNINV	-3.324411	-3.478305	0.0711	I(1)
D(LNINV)	-7.998137	-3.479367	0	
LNMOBNET	-1.313268	-3.478305	0.8761	I(1)
D(LNMOBNET)	-15.35246	-3.479367	0.0001	
LNTRADE	-2.028279	-3.482763	0.5747	I(1)
D(LNTRADE)	-8.026641	-3.48397	0	
LNMOBPEN	-2.831394	-3.478305	0.1916	I(1)
D(LNMOBPEN)	-11.24646	-3.479367	0	

Source: Author's computation using E-views 9.0
D indicates the 1st difference of the variable. **, indicates 5% level of significance

Kwiatkowski-Philips-Schmidt-Shin Test

The Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test determines if a time series is non-stationary because of a unit root or stationery around a mean or linear trend. The null hypothesis is rejected, and the series is non-stationary if the LM statistic is higher than the critical value. The ADF test suggests that all variables are I(1) aside from MOBPEN, which is I(0). In the PP test, all the variables are I(1) and KPSS unit root test suggests that the variables are a mixture of I(0) and I(1) processes. So, according to Nkoro and Uko (2016), since the series is a mixture of I(0) and I(1) processes, Pesaran and Shin (1999) and Pesaran et al. (1996b) proposed Autoregressive Distributed Lag (ARDL) approach to cointegration or bound procedure for a long-run relationship will be appropriate.

Table 5. KPSS test result

Variable	Test Statistics	Decision (5% critical value = 0.146000)
LNGDP	0.23922	I(1) **
D(LNGDP)	0.100263	
LNGOV	0.190292	I(1) **
D(LNGOV)	0.100613	
LNINV	0.092249	I(0) **
D(LNINV)	0.272895	
LNMOBNET	0.272895	I(1) **
D(LNMOBNET)	0.138327	
LNTRADE	0.201180	I(1) **
D(LNTRADE)	0.048277	
LNMOBPEN	0.259018	I(1) **
D(LNMOBPEN)	0.136249	

Source: Author's computation using E-views 9.0
D indicates the 1st difference of the variable. **, indicates 5% level of significance. 5% critical value = 0.146000

ARDL Model Cointegration Test

Table 6. Bound Test

Critical Value Bounds		
Significance	**I0 Bound**	**I1 Bound**
10%	**2.26**	**3.35**
5%	**2.62**	**3.79**
2.5%	**2.96**	**4.18**
1%	**3.41**	**4.68**

Source: Authors computation using E-views 9.0, F statistics=15.06016, K=5, Prob(F-Statistics) = 0

The table above shows the bound test computation of the ARDL model at different levels of significance (1%, 2.5%, 5%, 10%). The Null hypothesis for the test is 'no cointegration'. We reject the null hypothesis since the F statistics is more than the I(0) and I(1) bounds (15.060), indicating that there is a long-term link between the variables. This justifies the utilization of an error correction model (ECM).

Estimated using ARDL

Table 7. ARDL Model Cointegration form (Short run)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNGDP(-1))	0.219605	0.10844	2.025124	0.051
D(LNGDP(-2))	0.219605	0.10844	2.025124	0.051
D(LNGDP(-3))	0.219605	0.10844	2.025124	0.051
D(LNGOV)	-0.106138	0.046264	-2.294186	0.0283
D(LNGOV(-1))	0	0.037091	0	1
D(LNGOV(-2))	0	0.037091	0	1
D(LNGOV(-3))	0.160336	0.043601	3.677347	0.0008
D(LNINV)	0.226359	0.077855	2.907426	0.0065
D(LNINV(-1))	0	0.045673	0	1
D(LNINV(-2))	0	0.045673	0	1
D(LNINV(-3))	-0.076135	0.048247	-1.578025	0.1241
D(LNTRADE)	-0.034716	0.023276	-1.491496	0.1453
D(LNTRADE(-1))	0	0.029717	0	1
D(LNTRADE(-2))	0	0.029717	0	1
D(LNTRADE(-3))	-0.114728	0.030092	-3.812503	0.0006
D(LNMOBNET)	0.149968	0.047407	3.16345	0.0033
D(LNMOBNET(-1))	0	0.013395	0	1
D(LNMOBNET(-2))	0	0.013395	0	1
D(LNMOBNET(-3))	0.072522	0.021101	3.436822	0.0016
D(LNMOBPEN)	0.140941	0.035911	3.924666	0.0004
CointEq(-1)	-0.942882	0.118468	-7.95895	0

Source: Authors computation using E-views 9.0

Table 7 shows the short run cointegration form of the ARDL model, and the significance is at 5% level. The coefficient of the variable CointEq is the speed of adjustment in the ARDL, which implies that the model moves towards long-run equilibrium at the speed of 94%. The bound test, however, indicated that our variables are cointegrated; therefore, we next estimated an error correction model (ECM).

Long Run Estimates

Table 8 presents the long-run model. The error correction term is generated via this process. The coefficient of LNGDP lag is positive and significant, which agrees with a prior expectation and economic theory, which says economic growth from one year has an impact on economic growth for the next year. With a probability of 0, LNGDP has a statistically significant coefficient of 0.434. The variable LNGOV is also positive and significant, implying that government spending has a positive impact on GDP per capita. The significant coefficient of government spending as a ratio to GDP, implies that a 10% increase in Government spending will lead to a 0.7 percent annual growth rate of GDP per capita.

Table 8. Long Run Estimates

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.349429	0.71401	6.091549	0
LNGDP(-1)	0.489486	0.083744	5.845019	0
LNGOV	0.072142	0.027126	2.65951	0.0102
LNINV	-0.1157	0.044586	-2.594934	0.0121
LNTRADE	-0.05381	0.021296	-2.526988	0.0144
LNMOBNET	0.000469	0.017327	0.027042	0.9785
LNMOBPEN	0.047178	0.015608	3.022726	0.0038
R-squared	0.984309	F-statistic		585.5029
Adjusted R-squared	0.982628	Prob(F-statistic)		0

Source: Authors computation using E-views 9.0
Estimated using the Least square method

The coefficients of LNINV and LNTRADE, -0.115 and -0.05, respectively, are both negative and significant, which is contrary to a prior expectation. A look at the individual observations of the variables showed that as real GDP per capita grew, the ratio of investment to GDP fell, and the ratio of trade to GDP fell as well. LNMOBNET has a coefficient of 0.000469, which is not statistically significant at a 5% level of significance. This means that mobile internet penetration doesn't have a significant contribution to GDP per capita.

For a certain level of mobile penetration, an increase in mobile penetration of 10% would result in an additional 0.5%-point increase in the annual growth rate of GDP per capita, according to the coefficient of the variable LNMOBPEN (0.05). The model has a nice fit as the R-square is 0.98, which implies that 98% percent of the variations in LNGDP are explained by the independent variables.

Short Run Dynamics

The coefficient of the ECT must be negative. It is the speed of adjustment of the system and the system's ability to return to long-term equilibrium quickly.

Table 9. Error Correction Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.005443	0.005984	0.909661	0.3689
D(LNGDP(-1))	0.484504	0.3078	1.574088	0.124
D(LNGOV(-1))	-0.018452	0.054305	-0.339784	0.7359
D(LNINV(-1))	0.032927	0.072414	0.454709	0.652

D(LNTRADE(-1))	0.007143	0.03751	0.190428	0.85
D(LNMOBNET(-1))	-0.026224	0.049387	-0.530981	0.5986
D(LNMOBPEN(-1))	-0.00416	0.048425	-0.085901	0.932
D(LNGDP(-2))	0.132978	0.162803	0.816802	0.4193
D(LNGOV(-2))	-0.016341	0.047504	-0.344003	0.7328
D(LNINV(-2))	0.029484	0.059098	0.498898	0.6208
D(LNTRADE(-2))	0.007356	0.037406	0.196653	0.8452
D(LNMOBNET(-2))	-0.030055	0.022072	-1.361715	0.1815
D(LNGDP(-3))	0.132978	0.162803	0.816802	0.4193
D(LNGOV(-3))	-0.016341	0.047504	-0.344003	0.7328
D(LNINV(-3))	0.029484	0.059098	0.498898	0.6208
D(LNTRADE(-3))	0.007356	0.037406	0.196653	0.8452
D(LNMOBNET(-3))	-0.030055	0.022072	-1.361715	0.1815
D(LNGDP(-4))	0.531142	0.162803	3.262482	0.0024
D(LNGOV(-4))	-0.198957	0.047504	-4.18823	0.0002
D(LNINV(-4))	0.042803	0.059098	0.724274	0.4735
D(LNTRADE(-4))	0.167724	0.037406	4.483849	0.0001
D(LNMOBNET(-4))	0.035972	0.022072	1.629804	0.1116
ECT(-1)	-0.706775	0.368675	-1.917068	0.063
R-squared	*0.625626*	***Durbin-Watson stat***		*2.039204*
Adjusted R-squared	0.403025	**F-statistic**		2.810529
		Prob(F-statistic)		0.002686

Source: Authors computation using E-views 9.0
Estimated using the least square method

In the ECM the system is getting adjusted at the speed of 71% towards long-run equilibrium. This also implies that about 71% departure from long-run equilibrium are corrected each period. The probability of the Error correction term (ect) is 0.063, which is slightly greater than 5% level of significance; the model is significant at 10% level of significance. Therefore, the ect results, although suggestive of an association, did not achieve statistical significance (P = 0.06).

The R-squared coefficient (0.62) implies that the fit of the model is good i.e. 62% of the variations in LNGDP is explained by the variations in the explanatory variables. The probability of the F-statistics (0.0026) confirms the statistical significance of the regression line at 5 per cent significance level. The R-squared was also found to be less than the Durbin-Watson statistics to further confirm that there is no evidence of spurious regression.

Model Diagnostics Result

The Breusch-Godfrey serial correlation LM test's null hypothesis is that there is "no serial correlation." Given that the residuals are not serially correlated and that the F-statistics value is 0.102 and the p-value is 0.9025, the test rejects the null hypothesis that there is no serial correlation.

Table 10. Residual Diagnostic Result

Residual test	**F-Statistic**	**Prob.**
Serial Correlation F(2,35)	0.102872	0.9025
Heteroskedasticity F(22,37)	1.356046	0.2021

For the Breusch-Godfrey heteroskedasticity LM test, the null hypothesis is that the errors are homoskedasticity, while the alternative is the errors are heteroskedasticity. The F-statistics (1.356) at a probability of 0.202, which is greater than the threshold ($p<0.05$); therefore, we reject the null hypothesis, which means the errors of the model are heteroskedastic.

Stability Test

At a 5% significance level, the CUSUM and CUSUMSQ plots in Figure 2 and Figure 3, respectively, are between the critical boundaries. This suggests that we are unable to disprove the null hypothesis and confirm the stability of the model coefficients during the sample period. Thus, there is no structural instability in the model's parameters.

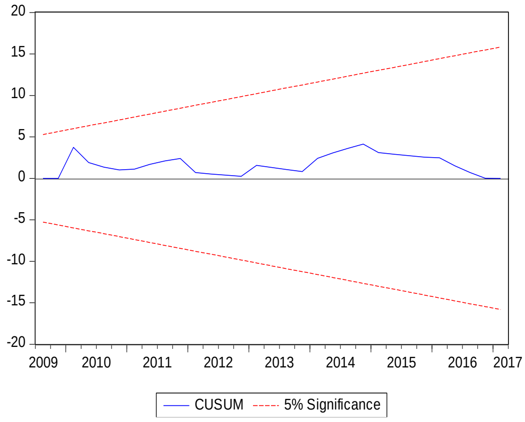

Figure 2. CUSUM Result

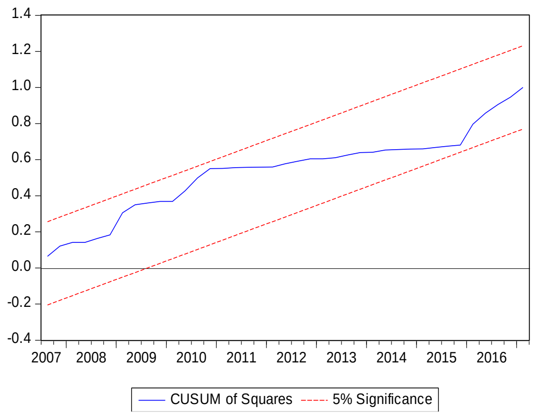

Figure 3. CUSUMSQres

CONCLUSIONS

The study concluded that mobile telephony has a beneficial impact on Nigeria's economic growth, and it draws the conclusion that, when used properly and with the involvement of all stakeholders, particularly in a nation like Nigeria, mobile telephony may contribute to sustainable economic development. The essential value of telecommunications is in facilitating growth and development, not in facilitating communication and information.

Better Telecom regulations will foster growth in the mobile phone industry which the study has found to have a positive impact on economic growth. Consumer protection policies that protect consumers from unfair calls and mobile data charges will ensure consumers get the value for their money which will lead to consumption and investment in the industry. Mobile service providers as well have to be protected from damage to facilities, angry communities, bandits, etc. Also, laws that protect intellectual properties would be hugely beneficial to software developers, App developers, and everybody that provides intellectual content in the mobile telephony ecosystem.

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