THE EFFECTS OF MOBILE BROADBAND ON ECONOMIC GROWTH IN NIGERIA

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ABSTRACT
This paper analyzes the effects of mobile broadband on economic growth between 2010 and 2020 in Nigeria. The paper set out two objectives to analyze the effects of mobile broadband on (1). Economic growth and on (2) employment in Nigeria. The rising mobile broadband penetration rates in the face of declining growth and the growing unemployment rates call for an investigation into its impact on the Nigerian economy. The review of the literature suggested that the impact of mobile broadband in the economy is positive while its effects on employment are both positive and negative. The paper employed structural equations and GMM techniques for the analysis. The findings of this paper revealed that mobile broadband influences economic growth and employment in Nigeria. But the results depended upon instrumental variables such as population growth, broadband speed, capital stock, financial deepening and prices of crude oil in the international market. Mobile broadband subscriptions showed the evidence of reducing unemployment and other labour market outcomes in Nigeria. The quality and speed of mobile broadband was instrumental to enhancing economic growth and employment in Nigeria. The paper concluded that the potentials of mobile broadband are yet to be fully utilized in the country. The paper recommends that the government should invest in unserved areas, deepens the financial system, and reduce the regulation of the social media platforms because they help reduce unemployment and improving mobile broadband penetration in Nigeria.
Key Words: Mobile broadband subscriptions, economic growth, employment, Nigeria.
JEL. Classification: C36; O33; O35; O55

1. INTRODUCTION

The emergence of digital technologies (such as artificial intelligence, robotics, automated cars, the internet of things, etc.) in the world has transformed production systems, the nature of work and learning outcomes in developed and developing countries. Most of the transformations in productive firms' workplaces in developing countries are aided by the access and use of broadband. According to Qiang, et al., (2009), broadband has been established to possess the ability to lower costs and raise productivity in large firms and Micro, Small and Medium Enterprises (MSMEs). It also enhances the efficiency of production, the development of a knowledge-based economy, and improves economic growth. Specifically, mobile telecommunication of recent has been the major diver of the revolution in broadband access and usage in many developing countries. The revolution carries with it new opportunities for the startup of new firms or MSMEs in Nigeria and several developing countries (Bardesi, 2020).

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For instance, mobile broadband usage is transforming people's lives through social network platforms, online shopping, digital marketing, distance learning and online investment platforms or opportunities and online employment prospects in Nigeria. These opportunities have enabled firms to reduce the cost of operation, raise productivity, enhance the competitiveness of firms and increase economic growth in Nigeria. Broadband generally has the essential feature of being able to stimulate research and development (R&D) activities at national, regional, global, firm or individual levels which are capable of encouraging economic growth in the country (Purnama, 2018). The current upsurge in the adoption of mobile technology and the rising penetration rate of mobile broadband in Nigeria has been due to massive investment in the Information and Communication Technology (ICT) sector, improved regulation and infrastructures and competition among the operators. Available data from Nigerian Communication Commission (2021) revealed that the global system of mobile telecommunication (GSM) constituted about 99.75% of total broadband technology's market share in Nigeria. However, the data also revealed that the broadband penetration rate had reduced from 45.02% in December 2020 to 39.98% in November 2021.[3] According to the Federal Government of Nigeria, (2020), the current download speed for mobile broadband in Nigeria lags behind other countries in Africa with a recent mobile average download speed of 2.7 Mbps as measured by the measurement-Lab (M-Lab) as against Kenya at 5 Mbps and South Africa at 4.1 Mbps respectively. As Lee, et al., (2011) put it, despite the overall growth in mobile broadband diffusion, many countries are still in the early stages of broadband deployment and are assessing policy strategies to promote faster broadband adoption. Success and Arike (2015) acknowledged that broadband deployment is still at its early stage of development in Nigeria.

Mobile Broadband penetration has also been linked to employment generation. Some researchers have argued that the effects of broadband (digital technologies) on employment is negative and disruptive. Apart from the penetration, large unemployment and underemployment rate exist in Nigeria. Broadband penetration to unserved areas may be critical to ensuring the delivery of quality internet services and provide access to enhanced economic and social opportunities such as financial inclusion, employment generation, and access to government services including security for every Nigerian (Federal Government of Nigeria, 2020).[4] According to the National Bureau of Statistics, (2020), about 27.1% and 28.6% of Nigeria's population are unemployed and underemployed respectively in 2020. This suggests a combined unemployment rate of about 55.7% which is an issue of great concern to policymakers in Nigeria. Empirical studies like Shideler, et al., (2007), Lehr, et al., (2006), Crandall, et al., (2007) and Kolko, (2010) have found broadband to be related to employment in the economy. Since the inception of the global economic recession in 2016 and the outbreak of COVID-19, Nigeria have experienced periods of low economic growth in real GDP. The real GDP growth rate decreased from 2.79% in 2015 to -1.58% in 2016. The real GDP growth rates increased to 0.82% and 2.27% in 2017 and 2019 respectively.[5] The outbreak of COVID-19 from December 2019 to date has disrupted the economy and the growth rate of GDP and employment levels may have changed further in 2020. Therefore, it becomes necessary to link mobile broadband to growth and employment in the Nigerian economy.

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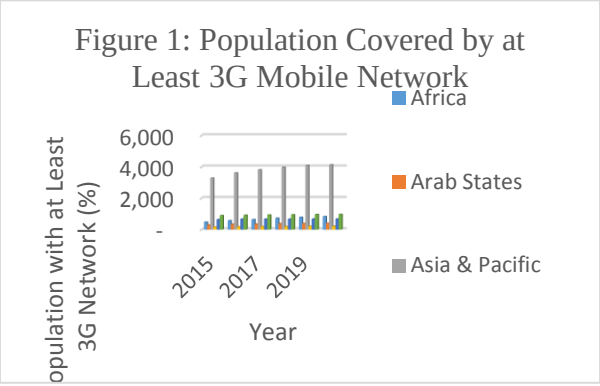
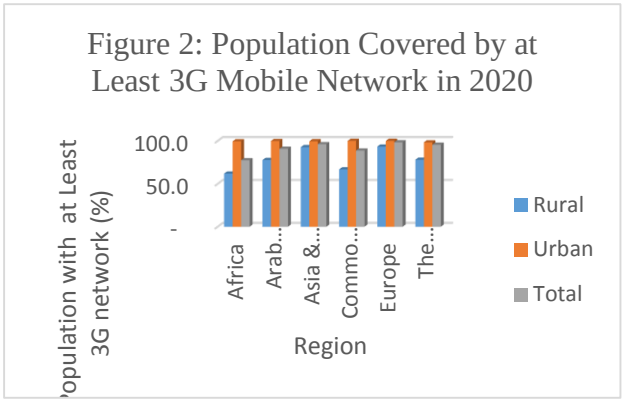
[3] The data from NCC were collected from their website www.ncc.gov.ng/statistics-report/industry

[4] According to the Nigerian National Broadband Plan 2020-2025 (Federal Government of Nigeria, 2020), Nigeria still has over 114 areas that are yet to be served with broadband internet or ICT network. Even in served communities, broadband access is low due to low per capita income in the country.

[5] See the CBN's Statistical Bulletin 2019 at www.cbn.gov.ng/statistical bulletin.

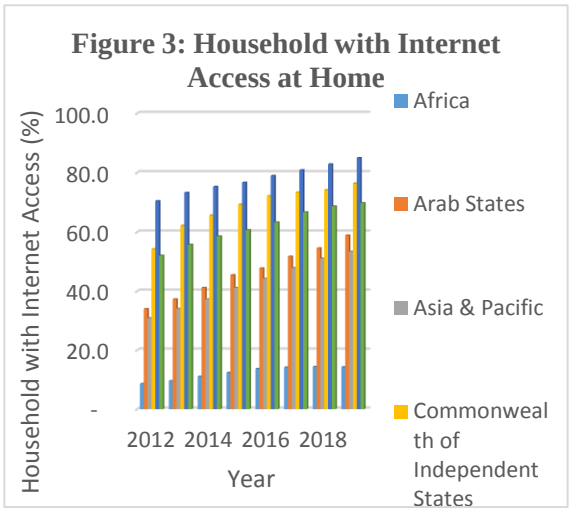
In Figure 1 and Figure 2, the population of people with at least 3G networks are presented. The figures showed that Africa is one of the continents with the least number of people with at least a 3G network in the world (ITU ICT indicators 2020), after the Commonwealth of Independent States (CIS) and the Arab States. Africa had the least rural and urban population with at least 3G networks in the world (see Figures 1 &2 for details).

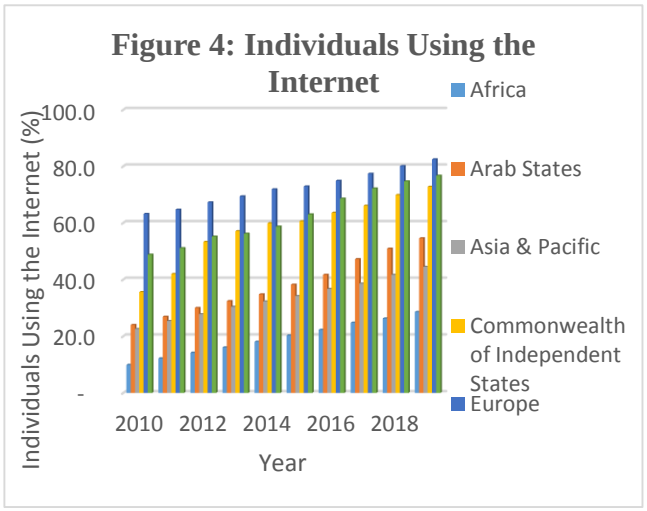




Source: ITU World Telecommunication/ICT Indicators (2020)

In Figure 3&4, the percentage of households with internet access at home and the percentage of individuals using the internet are the lowest in Africa. Although the number of people that are accessing and using the internet is rising globally, its impact in Africa is not fully utilized. People increasingly use broadband or the internet to acquire knowledge and skills to increase their productivity and employment opportunities (Khalil, et al 2009). However, broadband access supports the growth of firms by lowering costs and raising efficiency and productivity.



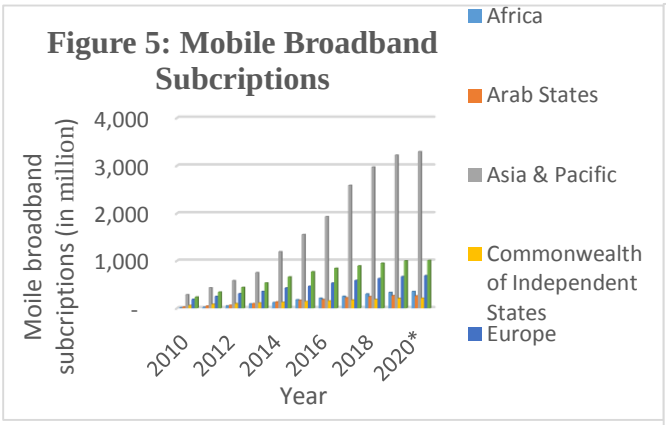


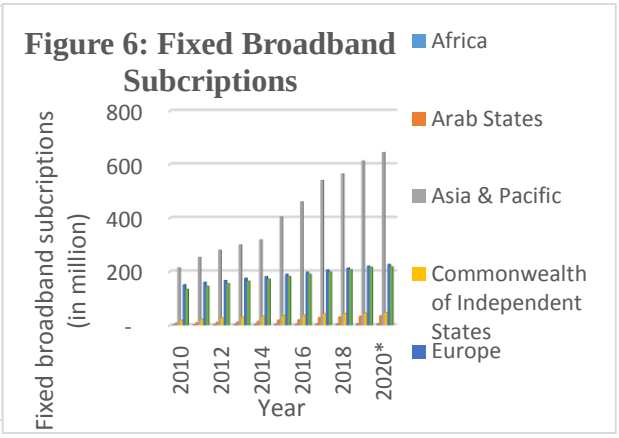
Source: ITU World Telecommunication/ICT Indicators (2020)

According to a report by the International Centre for Investigative Reporting (ICIR), research by Daisy Group in 2015 found that unreliable internet connections cost the United Kingdom economy £11 billion a year in lost productivity. Furthermore, TRAC research found that the average revenue loss was US$4,100 an hour of slowdown connections.[6] Mobile and fixed

[6] *https://www.icinigeria.org/still-loading-how-slow-internet-speed-under-develops-nigerians-economy-stifle-smes-growth/*

broadband subscriptions have been rising the world over. The rise is highest in Asia and the Pacific, followed by America, Europe, CIS, Arab States and Africa. Broadband plays a very significant role in the knowledge economy (see Figures 5&6). The number of mobile phones in the world surpassed the number of fixed telephone lines in 2002; by the end of 2008, there were an estimated 4 billion mobile phones globally. No technology has diffused quickly like the mobile phone (Khalil, et al., 2009).





Source: ITU World Telecommunication/ICT Indicators (2020)

The past decade or so has witnessed several attempts in both the academic circles as well as the policy circle toward understanding the impact of broadband on economic growth (Ghosh, 2016). Empirical studies such as Koutroumpis (2009; 2019), Oloja (2020), Qiang et al., (2009), Czernich (2009) and Crandall et al., (2007) to mention but a few, have reported that broadband influences economic growth positively in different countries. Evidence in the literature has also shown that broadband policies and infrastructures influence economic growth (Katz and Avila 2010; Ghosh 2016; and Badran, 2012). Gruber and Koutroumpis (2011) and Ghahabo and Ajuwon (2019) have however reported that mobile telecommunications influence economic development positively. Studies on the impact of mobile broadband on economic growth in Nigeria are scarcely available and still require a more robust approach given it relevance in the economy.

The channel of mobile broadband's impact on growth is through the combination of labour inputs, capital resources and information and ICTs. The technical combination of these inputs improves the productivity of labour, enhances marketing and sales, reduces the cost of production and increases economic growth in the country (Leo 2021). In Nigeria, benefits derived from mobile broadband penetration and diffusion of mobile technologies are still lagging. Some MSMEs and even large enterprises are not utilizing enough of the low-cost mobile technologies in productive activities. Some empirical studies have attempted to examine the effect of mobile broadband but it appears that the penetration of broadband is dwindling in Nigeria. The effects of broadband on growth and employment is not well known since there are many unserved communities in Nigeria (Federal Government of Nigeria 2020). Apart from unserved communities, a great part of output or GDP produced through mobile technologies is not accounted for in the national income. Therefore, the objective of this paper is to investigate the effects of mobile broadband on economic growth and employment in Nigeria.

2. LITERATURE REVIEW

The literature contains the different meanings of broadband depending on the country or institution in question. For instance, the International Telecommunication Union (ITU) (2020) defined broadband as a 4G or 5G equivalent connection that targets a population of people ten (10) years and above.[7] According to the Federal Government of Nigeria (2020), broadband is defined as any connectivity delivering a minimum download speed of 10 Mb/s in rural areas and a maximum of 25 Mb/s in urban areas to every Nigerian at an affordable price and quality by 2025. This paperwork is with the definition provided by the Federal Government of Nigeria because the 4G or 5G networks as suggested by ITU (2020) are scarcely available. Where they are available, the demand for such networks is still low due to low per capita income and high prices of broadband bundles in Nigeria. Therefore, mobile broadband refers to the connectivity with sufficient bandwidth to permit the combined provision of voice, data and video without using cables or fixed lines. Mobile broadband allows economies to acquire and share ideas, expertise, services and technologies locally, regionally and across the world (Khalil et al., 2009). It creates new opportunities for economic development, accelerates knowledge transfers and improves technological diffusion in the economy. Due to the important role being played by mobile broadband, mobile networks now constitute the world's largest distribution platforms and is creating major development opportunity in developing countries.

Economic theories have explained how technological innovations stimulate economic growth in a country. For instance, Joseph Schumpeter, Robert Solow and Paul Romer have demonstrated the role of technology in achieving economic growth and development. Empirical studies such as Roller and Waverman (2001), Koutroumpis (2009), Katz and Callorda, (2013) and Gordon (2012) have supported the theories propounded in economics. Roller and Waverman (2001) used simultaneous equations to examine the impacts of telecommunication infrastructures on economic development. They found evidence of a significant positive link effects between telecommunication infrastructures and economic development especially when a critical mass of telecommunication infrastructure is present. Using a structural equation approach, Koutroumpis (2009) reported that broadband penetration influences economic growth. The result suggests a significant causal positive link with the existence of a critical mass of broadband infrastructure in the economy. Katz and Callorda (2013) examined the economic impact of broadband deployment in Ecuador using structural models between 2008 and 2012. The results showed that fixed broadband had a significant positive effect on economic growth in Ecuador. For every 1% increase in broadband penetration, the average annual contribution to GDP growth was estimated at 0.052%. Still, Lehr, et al (2006) reported that in communities where broadband was available they found rapid employment growth, the number of businesses overall and businesses in IT-intensive sectors. They concluded that broadband access does enhance economic growth, the performance of businesses and its impacts can be measured. Broadband access tends to increase the number of businesses operating in the informal sector of the digital economy. Even large firms that operate in the formal sector find it cost-effective when they market their activities online or through the internet. Kolko (2010) reported that a positive relationship exists between broadband expansion

[7] *This definition of broadband by ITU is based on an average download speed of 10 Mb/s with a 4G or 5G network as the proxy for people who are ten years and above.*

and economic growth in the economy. The relationship is stronger in industries that rely more on information technology and in areas with lower population densities. He further found that broadband expansion is associated with employment growth that is as high as 6.4%. The study argued that although the relationship between broadband expansion and employment growth varies across industries, the positive relationship is especially larger for utilities, information, finance and insurance, professional, scientific and technical services, management of companies and enterprises and administrative and business support services.

In an ITU study, Katz (2012) argued that research aimed at investigating the economic impact of broadband on the economy has five main transmission mechanism which includes; broadband's impact on economic growth, its impact on productivity gains, impact on employment and output, impact on consumer's surplus and improvement of firm efficiency. This study does investigate all the transmission channels because our interest is in the impact of mobile broadband on economic growth and employment. Recent evidence from the literature has confirmed that the impact of broadband on economic growth is positive, however, other evidence has shown otherwise. Using a system Generalised method of moments (GMM) for 39 African countries, Solomon and Klyton (2020) reported that digital technologies (network readiness index) influences economic growth in Africa. Similarly, Adeleye and Eboagu, (2019) found that mobile subscriptions have the largest output elasticity in influencing economic growth in Africa. However, Feng (2016) showed that the development of the internet as a form of communication technology played a significant role in promoting economic growth in China.

Empirical studies have attempted to investigate the effects of high-speed broadband infrastructures on economic growth. For instance, Chatchai and Bohlin (2014) reported that broadband speed influences economic output in OECD countries. They further argued that the impact of broadband speed is greater in lower-income countries than in countries with high-income levels. Hakim (2014) has reported the determinants of household demand for mobile broadband in Indonesia to include age, gender, education level, income level, geographical location and number of internet users. The paper concluded that income plays a less important role in its effects on mobile broadband access than geographical area, suggesting that affordability is not an issue to further develop broadband. This paper argues that broadband speed does not directly influence economic output or growth but it is instrumental for achieving economic output or growth. The output level is influenced more by broadband penetration and subscriptions than by broadband speed. Broadband speed is the instrument or vehicle that facilitates labour to be more productive given the level of broadband subscriptions and penetration. The higher the mobile broadband subscriptions the more impact it may have on output or growth. Therefore, broadband speed is directly linked to labour productivity but indirectly linked to growth. Gruber and Koutroumpis (2011) examined the impact of mobile telecommunications on economic growth using annual panel data for 192 countries between 1990 and 2007. They reported that countries with low mobile penetration had the smallest impact in terms of economic growth. In low-income countries, mobile telecommunications contributed to annual GDP growth of 0.11% while it was 0.20% for high-income countries. The study further argued that the increasing returns from mobile telecommunications adoption are emerging when assessing the impact on productivity growth.

Andrianaivo and Kpodar (2011) examined ICT, financial inclusion and economic growth in some selected African countries using the Generalised Method of Moments (GMM) between 1988 and 2007. The paper reported that ICT (including mobile telephone development) influences economic growth in African countries. The paper argued that the effect of mobile telephone penetration on economic growth stems from greater financial inclusion and this further

consolidates the effects of financial inclusion on economic growth in many African countries. In Chile, Mexico and Venezuela, Katz and Avila (2010) examined the relationship between broadband policy and economic growth and found the factors that derive telecommunication policy development in Latin America are platform-based competition, institutional strength, the existence of government plans and freedom of foreign investment. These factors enhanced broadband development in Latin America. Using the co-integration techniques and the fully modified least squared, Adeoye and Alenoghena (2019) reported that internet usage is significantly influencing the economy positively in Nigeria. Similarly, Gbahabo and Ajuwon (2019), used the distributed lag model (ARDL) to examine the effects of mobile broadband technology on the Nigerian economy. They found that mobile broadband technology is influencing economic growth positively. Also, Bahia et al (2020) examined the welfare effects of mobile broadband in Nigeria using the panel data analysis (Fixed effect). They found that mobile broadband coverage had a positive and significant impact on consumption and poverty reduction in Nigeria. Mobile broadband coverage also reduces the proportion of households below the poverty line driven by higher food and non-food consumption in rural households in Nigeria.

3. METHODOLOGY AND THEORETICAL FRAMEWORK

The theoretical framework of this paper is derived from Katz and Callorda (2013). It was an applied endogenous growth model that has been used by Roller and Waverman (2001) and Koutroumpis (2009; 2019). The framework jointly estimates a micro-model for broadband investment with a macro production function that endogenized broadband investment in the economy.

3.1. The Model.

The aggregate production function specified economic growth as a function of labour, capital and broadband penetration in Nigeria. The technical combination of labour, capital and broadband can influence economic growth in the economy. i.e.

$$Y_t = \mathrm{F}(L_t, K_t, MBS_t) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

We rewrite equation one (1) in econometric form as in equation (2)

$$Y_t = \propto_0 + \propto_1 L_t + \propto_2 K_t + \propto_3 MBS_t + \varepsilon_t \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

A-priori expectation requires that $\propto_1 > 0, \propto_2 > 0 \; and \; \propto_3 > 0$. Where $Y_t =$ economic growth proxied by real GDP at current market prices, $L_t =$ Labour proxied by the labour force population, $K_t =$ Capital stock proxied by the gross capital formation, $MBS_t =$ mobile broadband subscriptions or penetration, $\varepsilon_t =$ error term, $\propto_0 =$ the intercept or constant term, $\propto_1, \propto_2 \; and \; \propto_3 =$ the slope of the explanatory variables L_t, K_t and MBS_t respectively.

The demand for the broadband model is expressed as a function of disposable income, mobile broadband price baskets and level of education proxied by secondary school enrollment and attendance rates, i.e.

$$MBS_t = \mathrm{F}\,(YD_t, MBP_t, LEDU_t) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

Similarly, we have re-written equation (3) in econometric forms as in equation (4)

$$MBS_t = \beta_0 + \beta_1 YD_t + \beta_2 MBP_t + \beta_3 LEDU_t + U_t \dots\dots\dots\dots\dots\dots\dots\dots\dots (4)$$

The a-priori expectation requires that $\beta_1 > 0, \beta_2 < 0, and \; \beta_3 > 0,$ Where; YD_t = disposable income of broadband users, MBP_t = mobile broadband price baskets, $LEDU_t$ = Level of education proxied by secondary school enrolment and attendance rates, β_0= intercept term,

$\beta_1, \beta_2\ and\ \beta_3,$ = slope of the explanatory variables YD_t, MBP_t and $LEDU_t$, respectively, U_t= error term.

The supply of broadband is specified as a function of one-quarter lagged mobile broadband price baskets, electricity generation as a proxy for infrastructures and disposable income of mobile broadband users, i.e.

$$MBR_t = \mathcal{F}(MBP_{t-1}, YD_t, EG_t) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (5)$$

Equation (5) is written in an econometric form as in equation (6)

$$MBR_t = \delta_0 + \delta_1 MBP_{t-1} + \delta_2 YD_t + \delta_3 EG_t + \epsilon_t \dots\dots\dots\dots\dots\dots\dots (6)$$

A-priori expectation requires that $\delta_1 < 0, \delta_2 > 0\ and\ \delta_3 > 0$. Where; MBR_t = mobile broadband sales revenues, EG_t = electricity generation as a proxy for infrastructure, δ_0 = intercept term, $\delta_1, \delta_2\ and\ \delta_3$ = slope of the explanatory variables MBP_{t-1}, YD_t, and EG_t respectively and ϵ_t = error term. The broadband output model is expressed as a function of mobile broadband sales revenue of operators, mobile broadband price baskets and R&D expenditures. i.e.

$$MBS_t = \text{F}\,(MBR_t, MBP_t, RD_t) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (7)$$

Equation (7) is transformed in econometric form as in equation (8)

$$MBS_t = \theta_0 + \theta_1 MBR_t + \theta_2 MBP_t + \theta_3 RD_t + \mu_t \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (8)$$

The a-priori expectation requires that $\theta_1 > 0, \theta_2 < 0\ and\ \theta_3 > 0$. Where; RD_t= research and development expenditures, θ_0= intercept term, $\theta_1, \theta_2\ and\ \theta_3$ = the slope or coefficient of the explanatory variables MBR_t, MBP_t and RD_t respectively and μ_t = error term.

3.1.1. The Employment Model

This paper specified the employment model in two components namely employment and unemployment models which are expressed as a function of mobile broadband penetration or subscription, growth of real GDP, inflation rates and research and development expenditures (Katz and Avila 2013). The employment model is presented in Equations 9 and 10 while the unemployment model is in Equations 11 and 12. The employment model determines the jobs created as a result of increased mobile broadband penetration in Nigeria. i.e.

$$EM_t = \mathcal{F}\,(MBS_t, RGG_{t-1}, RD_t) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (9)$$

Equations 9 can be presented in econometric form as shown in equation 10.

$$EM_t = \propto_0 + \propto_1 MBS_t + \propto_2 RGG_{t-1} + \propto_3 RD_t + \varepsilon_{1t} \dots\dots\dots\dots\dots\dots\dots\dots (10)$$

The a-priori expectation for equation 10 requires that $\propto_1 > 0, \propto_2 > 0,\ and\ \propto_3 > 0$. The unemployment model determines the impact of mobile broadband penetration on the reduction of the unemployment rate in Nigeria. The unemployment model is expressed as follows;

$$UE_t = \mathcal{F}\,(MBS_t, RGG_t, RD_{t-2}) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (11)$$

Equation 11 is also transformed into equation 12 as follows;

$$UE_t = \beta_0 + \beta_1 MBS_t + \beta_2 RGG_t + \beta_3 RD_{t-2} + \varepsilon_{2t} \dots\dots\dots\dots\dots\dots\dots\dots (12)$$

The a-priori expectation for equation 12, it is expected that $\beta_1 < 0,\ \beta_2 < 0\ and\ \beta_3 < 0$. Where; EM_t = employment level, RGG_t = growth rate of real GDP with one-quarter lagged in equation 10, UE_t = unemployment rate, RD_{t-2} = two-quarter lagged research and development expenditures $\varepsilon_{1t}\ and\ \varepsilon_{2t}$ = error terms in equations 10 and 12 respectively, $\propto_0\ and\ \beta_0$ = intercept terms of equations 10 and 12 respectively, $\propto_1, \propto_2, \propto_3\ and\ \beta_1, \beta_2, \beta_3$ = respective coefficients or parameters in equation 10 and 12 with i= 1, 2 and 3. In all the models the instrumental variables are population growth rate, broadband speed, financial deepening, crude oil prices, etc. The choice of instruments depended on the model specified and the number of variables in question.

3.2. Data and Estimation Techniques

The models specified imply that data were required on mobile broadband penetration, mobile broadband price baskets, broadband sales revenues, urban population growth rates, inflation rates, growth rates of real GDP, research and development expenditures, real GDP at current market prices, labour force, capital stock, level of education, population growth rates, financial deepening, crude oil prices, broadband speed, disposable income, inflows of foreign direct investments, electricity generation, employment rates and unemployment rate in Nigeria. the data range from 2010 to 2020. The data were collected from the Nigerian Communication Commission (NCC), Nigerian Bureau of Statistics (NBS), Central Bank of Nigeria (CBN), International Telecommunication Union (ITU), World Bank World Development Indicators, UNESCO Institute of Statistics (UIS) and United Nations Children's Education Fund (UNICEF). The paper made the best use of the data collected to make useful inferences.

The paper employed the generalized method of moments (GMM) techniques to estimate the models. The GMM technique does not require complete information on the data distribution like the maximum likelihood method. The error terms in equations 2, 4, 6, 8, 10 and 12 are allowed or assumed to be conditionally heteroskedastic as well as serially correlated.[8] The GMM estimators produce estimates that are stationary and efficient after correcting for autocorrelation and heteroskedasticity in the models. The GMM is a limited information estimator that has the advantage of recognizing the specification bias in the models and produces more efficient estimates if the model is identified (Koutroumpis 2009). The standard error and probability values will be used to make inferences and validate the estimates of the models. The descriptive statistics of the variables specified in the structural equations and employment models are presented in Table 1.

Table 1: Descriptive Statistics of Variables

Statistics	Y	L	K	MBS	MBP	BS	YD	COP
Mean	63,553.7	66.629	12,844.4	35,323,309	11.04	256.0	62,845.9	64.499
Median	55,469.4	65.170	9,591.1	37,915,495	3.940	256.0	54,612.3	61.235
Maximum	154,252.3	94.540	45,348.4	85,941,222	22.25	256.0	152,324.1	127.35
Minimum	7,062.8	42.370	2,409.1	0.000	2.700	256.0	6,990.6	24.500
Std. Dev.	46,707.1	14.824	11,051.3	28,531.201	8.980	0.000	46,189.4	30.606
Skewness	0.489	0.134	1.730	0.399	0.277	NA	0.490	0.4338
Kurtosis	2.039	2.267	5.388	2.027	1.159	NA	2.038	2.059
Jarque-Bera	1.648	0.534	15.467	0.725	1.386	NA	1.652	5.734
Probability	0.438	0.766	0.0004	0.696	0.500	NA	0.438	0.0569
Sum	1,334,628.0	1399.2	269,731.4	389.00	99.36	5376.0	1,319,763.	5417.9
Sum Sq. Dev.	43,600.00	4394.9	2,440.00	814,000.000	645.14	0.000	42,700,000.0	77749.0
Observations	21	21	21	11	9	21	21	84

Statistics	LEDU	MBR	EG	EM	UE	FD	RD	RGR
Mean	37.069	323.00	7,958.6	54.909	4.898	18.911	242.14	5.638
Median	39.233	271.00	3,531.3	57.530	3.820	21.35	230.02	6.220
Maximum	59.200	699.00	24,208.9	57.780	9.010	24.90	442.31	14.60
Minimum	0.0000	124.00	2,257.6	48.610	3.591	11.410	58.77	-1.920
Std. Dev.	15.339	157.00	7,894.4	3.508	1.981	4.786	101.21	3.991
Skewness	-1.1324	0.840	1.096	-0.626	1.275	-0.427	0.044	-0.0434
Kurtosis	4.0527	2.755	2.416	1.657	2.778	1.498	2.253	2.983
Jarque-Bera	5.4575	3.964	4.505	2.949	5.734	2.613	1.982	0.007
Probability	0.0653	0.138	0.105	0.229	0.057	0.271	0.371	0.997

[8] https://faculty.washington.edu/eziovot/econ583/gmm.pdf

Sum	778.465	1,060.00	167,131.8	1,153.1	102.86	397.13	20,340.0	118.4
Sum Sq. Dev.	4,706.24	790,000.0	1,250.00	246.06	78.464	458.16	850,245.7	318.6
Observations	21	33	21	21	21	21	84	21

Source: Author's computation

4. EMPIRICAL RESULTS AND ANALYSIS

4.1. Mobile Broadband and Economic Growth

The models in Table 2 were estimated using GMM techniques. One-quarter lagged was introduced on mobile broadband price in the supply of broadband model because the effects of mobile telecommunication technology may not be instantaneous but time-variant. The result in Table 2 revealed that the constant term (C) and the coefficient of labour in the aggregate production function are not significant but met the a-priori expectation of the model. However, the coefficient of capital stock was positive and significant at a 5% level. An increase or decrease in the country's capital stock by ₦1 billion, will increase or decreases economic growth by 0.6939 units in Nigeria. The effect is dependent on instruments such as population growth, broadband speed, consumer disposable income, financial deepening and the prices of crude oil in the international market. This suggests that capital stock influences economic growth in the presence of the mentioned instruments. Also, the coefficient of mobile broadband subscriptions or penetration was significant in influencing economic growth at a 5% level. This suggested that an increase or decrease in mobile broadband subscriptions by one unit will increase or decrease economic growth by 0.00018 units in Nigeria. Changes in mobile broadband subscriptions are associated with changes in economic growth especially when there is a rise in population growth, broadband speed, disposable income, financial deepening and prices of crude oil in the international market. The findings of the study support Katz and Callorda (2013) and Koutroumpis (2019) broadband penetration influences economic growth. The coefficient of determination (R^2) supports that about 94.2% of the variations in economic growth are explained by variations in labour, capital stock, and mobile broadband subscriptions in Nigeria.

In the demand for the broadband model, the coefficient of mobile broadband price baskets met the a-priori expectation of the model but was insignificant. This suggests that broadband price baskets do not significantly influence the demand for broadband in Nigeria. However, the coefficients of disposable income and level of education (proxied by secondary school enrollment and attendance rates) were significant at a 5% level in Nigeria. As consumer disposable income rises, the demand for broadband also rises in the country. Although the coefficient of the level of education did not meet the a-priori expectation of the model, it was however significant in influencing the demand for broadband in Nigeria. Experience suggests that the higher the level of education, the higher will be the demand for broadband but the evidence in this paper says the contrary in Nigeria. The instruments used in the demand for the broadband model are Population growth, broadband speed, capital stock, crude oil price and financial deepening. The supply of broadband model showed that the coefficient of disposable income did not meet the a-priori expectation and was not significant. The coefficient of mobile broadband price did not also meet the a-priori expectation of the model but was however significant at a 5% level. This suggests that mobile broadband price baskets influence the supply of broadband positively in Nigeria. This finding is contrary to the theory of demand and supply which propounded a negative relationship between price and quantity of broadband demanded and supplied. The coefficient of electricity generation met the a-priori expectation and was significant at a 5% level of significance. An increase or decrease in the level of infrastructure (electricity generation) by 1 unit will result in an increase or decrease in the supply of broadband by 1136364 units in Nigeria. Electricity generation

plays a very important role in the use of mobile broadband technology in Nigeria. The instruments used in the supply of broadband model are Population growth, broadband speed, financial deepening and crude oil price.

Table 2: Empirical Results on the effects of Mobile Broadband on Growth.

Variables	**Aggregate model (Y_t)**	**Demand for broadband model (MBS_t)**	**Supply of broadband model (MBR_t)**	**Broadband Output model (MBS_t)**
C	2853.81 (0.7542)	5002585 (0.9035)	-3.69×10^{9}** (0.0139)	-48131577** (0.0004)
L_t	173.14 (0.2044)			
K_t	0.6939** (0.0269)			
MBS_t	0.00018** (0.0013)			
YD_t		2428.69** (0.0155)	-14752.18 (0.5003)	
MBP_t		-537499.8 (0.4101)	29599649** (0.0129)	-1107545** (0.0012)
$LEDUC_t$		-527815.2*** (0.0840)		
EG_t			1136364** (0.0286)	
MBR_t				0.0669** (0.0000)
RD_t				287327.5** (0.0000)
R^2	0.9420	0.8857	0.3819	0.9339
D.W Stat	1.3624	0.7864	0.4935	1.5955
J-Stat.	6.7808** (0.0092)	3.9405** (0.0471)	- (0.0000)**	1.03×10^{15}** (0.0000)
Instruments	Population growth rate, broadband speed, crude oil price, financial deepening, and disposable income	Population growth, broadband speed, capital stock, crude oil price and financial deepening.	Population growth, broadband speed, financial deepening and crude oil price.	Population growth, broadband speed, financial deepening and crude oil price.

Note that: (1) the values in parenthesis are the probability values, (2) ** and * = significant at 5% and 10% level respectively**

The broadband output model showed that mobile broadband price baskets, mobile broadband sales revenue and research and development expenditures are significant determinants of broadband output in Nigeria. Research and development expenditures facilitate broadband use in knowledge creation and generation thereby leading to growth. Also, the lower the mobile broadband price basket, the higher the broadband output. Similarly, the higher the broadband sales revenue, the higher the broadband output in Nigeria. The coefficient of determination revealed that about 93.39% of the variations in broadband outputs are explained by variations in mobile broadband prices, mobile broadband sales revenues and research and development expenditures in Nigeria. The instruments on the broadband output models include Population growth, broadband speed, financial deepening and crude oil price.

4.2. Mobile Broadband and Employment

The employment and unemployment models in Table 3 were also estimated using the GMM technique. One-quarter lag was introduced on the real GDP growth rate in the employment

model while a two-quarter lag was placed on research and development expenditures in the unemployment model. The effects of mobile broadband subscription on employment or unemployment are time-variant. The result of the employment model showed that the coefficient of mobile broadband subscription did not meet the a-priori expectation but was significant at a 5% level. The finding does not support Katz and Callorda (2013) that found that broadband subscriptions are positively related to employment.

Table 3: Empirical results on the Effects of Mobile Broadband on Employment

Variables	Employment model (EM_t)	Unemployment model (UE_t)
C	45.108**	-0.4074
	(0.0000)	(0.8775)
MBS_t	-0.00001**	-0.0000000846**
	(0.0112)	(0.0460)
RGR_t	0.8077**	-0.8123**
	(0.0000)	(0.0011)
RD_t	0.0299**	0.0453**
	(0.0300	(0.0046)
R^2	0.8457	0.6289
D.W Stat	0.5357	0.6791
J-Stat	1.6986	69.1443**
	(0.4277)	(0.0000)
Instruments	Population growth, broadband speed, crude oil price, financial deepening, capital stock, and foreign direct investment.	Population growth, broadband speed, crude oil price and capital stock.

Note that: (1) the values in parenthesis are the probability values, (2) **&*= significant at 5% and 10% level respectively**

This suggests that mobile broadband subscriptions are reducing employment in Nigeria. The instruments in the employment model are population growth, broadband speed, crude oil price, financial deepening, capital stock, and foreign direct investment. However, the unemployment model revealed that mobile broadband subscriptions are reducing unemployment in Nigeria. An increase in mobile broadband subscriptions by one unit will reduce the unemployment rate by -0.0000000846 units in Nigeria. The finding however supports Katz and Callorda (2013) who found that mobile broadband subscriptions are negatively related to unemployment in Ecuador. Mobile broadband penetration is reducing unemployment by transforming people's lives through social network platforms, online shopping, digital marketing, distance learning and online investment platforms or opportunities and online employment prospects in Nigeria. The instruments in the unemployment model are Population growth, broadband speed, crude oil prices and capital stock. The coefficients of real GDP growth rate and R&D expenditures were significant in the employment and unemployment model.

5. CONCLUSION AND POLICY RECOMMENDATIONS

This paper analyzes the effects of mobile broadband on economic growth in Nigeria. The paper set out two objectives to analyze the effects of mobile broadband on (1). Economic growth and on (2) employment in Nigeria. The rising mobile broadband penetration rates in the face of declining growth and the growing unemployment rates call for an investigation into its impact on the Nigerian economy. The review of the literature suggest that the effect of mobile broadband on the economy has been found to be positive while its effects on employment are both positive and negative. The paper employed structural equations and GMM techniques for the analysis. The

findings of this paper showed that mobile broadband influences economic growth and employment in Nigeria. But this depended on instruments such as population growth, broadband speed, financial deepening and prices of crude oil in the international market. The results showed that mobile broadband subscriptions is reducing unemployment and other labour market outcomes in Nigeria. The quality and speed of mobile broadband are vital instruments in boosting employment and growth in Nigeria. This is because the Nigerian economy is endowed with abundant labour and capital resources that may improve production given the availability of technologies. According to Koutroumpis (2019), various technologies help the economy produce more by coordinating its activities, reducing communication costs and improving market conditions by increasing its capital and labour intensive margins. However, the income levels in Nigeria are low but still playing a significant role in improving mobile broadband subscriptions. Low-income levels are probably the reason for the poor results in the demand and supply of broadband models. However, electricity infrastructures, disposable income and low mobile broadband prices influence the demand and supply of broadband in Nigeria. Research and development expenditures, mobile broadband prices and mobile broadband sales revenue were significant in influencing mobile broadband output in Nigeria. The opportunities that come with mobile broadband are yet to be fully tapped in Nigeria.

The paper makes the following recommendations that will enhance broadband penetration in Nigeria. The government should improve broadband penetration through massive investment in the ICT sector, control mobile broadband prices to the lowest level to enhance the affordability of broadband services by the population, improve the collection of micro-level data at all levels of education to enhance research and development activities and diversity in the ICT sector in broadband access and usage. The Central Bank needs to deepen and diversify digital credit channels to improve access and usage of mobile broadband. The government should improve broadband penetration rates in unserved areas through the provision of broadband infrastructures in rural areas. Restricting the rights or freedom of expression or association, especially in social media is reducing mobile broadband usage and penetration rates in Nigeria. Government should concentrate on regulating and preventing abuses of the social media platforms in Nigeria rather than restricting what people say on the media.

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