Mobile Broadband and Economic Growth in Nigeria

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Abstract

Mobile internet broadband has been recognized by policymakers in governments and multilateral development agencies such as the World Bank and United Nations as having a transformational role in enabling social economic development across industrially developed and developing countries of the world. This growing recognition has given rise to an unprecedented rapid growth in Mobile wireless broadband deployment in most developing countries over the last few decades. The scale of diffusion of mobile wireless broadband technology and the its transformational effect across all sectors of the economy cannot be over emphasised. It enables the creation of new business processes/product innovation, thereby boosting job creation, as well as raising economic growth and productivity. This suggest that the mobile broadband is a general-purpose technology capable of producing a protracted critical mass effect at certain threshold of penetration. It is against this backdrop that this paper examines the relationship between mobile broadband and economic growth in Nigeria. Using the Endogenous Technological Change Growth Model, we employ ARDL Bounds testing approach to aggregate quarterly data from the first quarter of 2002 to the fourth quarter of 2016 to estimate the growth effect of mobile broadband. Data was collected from the Nigerian Communication, Central Bank of Nigeria and National Bureau of Statistics. The findings show that mobile broadband is impacting economic growth positively in the Nigerian economy, and therefore the welfare. Therefore, it is imperative for policymakers to makes policies designed to increase access to broadband infrastructure to both the unserved and underserved as well as enacting policies and regulations that can stimulate the economic impact of mobile broadband technology by strengthening the capacity of the economy to fully absorb the transformational benefits and make productive use of it as a General-Purpose Technology.

Keyword(s): Mobile Broadband, Economic Growth, ARDL model, Toda-Yamamoto Granger Causality test, Nigeria.

1.0 Introduction

There is a growing recognition of the transformational role mobile internet broadband play in enabling economic development among academics and policy makers around the world (World Bank, 2016; UN, 2016). The United Nations and the World Bank have both identified internet broadband as very crucial in empowering people, lifting people out of poverty through job creation, and creating conducive environment for business and technological innovation as well as enabling developing countries to achieve the targeted Strategic Development Goals. This growing recognition of the economic impact of broadband penetration has spurred massive investment and deployment of broadband infrastructure in both developed and developing countries over the last decade (Minges, 2015).

Mobile wireless broadband deployment in most developing countries have witnessed unprecedented rapid growth in the last decades largely due to a number of factors such as privatization and trade liberalization policies as well as advances in telecommunication technology giving rise to lower network installation cost and greater service affordability (GSMA, 2010; Minges, 2015). The scale of diffusion of mobile wireless broadband technology and the transformational effect it continues to have across all sectors of the economy in enabling the creation of new business processes/product innovation thereby boosting job creation, consumer surplus as well as raising economic growth and productivity suggest that the mobile broadband is a general purpose technology capable of producing a protracted critical mass effect at certain threshold of penetration (Bresnahan and Trajtenberg, 1995; Koutroumpis, 2009).

Investments in mobile wireless broadband infrastructure and its corresponding adoption has witnessed exponential growth rate in Nigeria over the last decade following the liberalisation policy reforms of the Nigerian Telecommunication industry in 2001.With the poor state of the fixed wire/wireless internet infrastructure deployment in Nigeria, mobile broadband continues to be a major source of internet access for a majority of the citizens accounting for over 95% of total internet connections in the country and estimated to have contributed over $6 billion to national GDP in 2016. The mobile broadband market grew from less than 400,000 active subscribers in 2001 to approximately 92 million active subscribers in the last quarter of 2016 accounting for a penetration rate of 48% of the total population of the country, which is well above the 20% threshold level that is required for countries to achieve critical mass that will enable them to reap the economic benefits of broadband investment (NCC, 2016).

Even though the social and economic importance of mobile broadband has now been recognized by policymakers and researchers, a thorough survey of extant literature reveals that there is paucity of empirical studies on the long-term effect of mobile broadband penetration on economic growth in Sub-Saharan Africa (Minges, 2015). Most of the existing studies have focused either on developed countries in the European Union and OECD (Waverman, Meschi and Fuss, 2005; Qiang and Rossotto, 2009; Koutroumpis, 2009 and Czernich et al., 2009) or developing countries in Latin America and the Caribbean (Zaballo and Lopez-Rivas, 2012). Out of the few studies that have investigated the long-term effect of mobile wireless broadband on economic growth in Sub-Saharan Africa, a great number of them have been panel growth econometric studies plagued with issues of oversimplification of heterogeneity across countries giving rise to biased coefficient estimates (Waverman, Meschi and Fuss, 2005; Deloitte 2011). Thus far, no country level aggregate time series empirical study has been carried out in Africa to understand the relationship between mobile wireless broadband penetration and economic growth. Therefore, this study attempts to fill this research gap.

The rest of the paper is structured as follows: Section two presents some stylized facts about the mobile wireless industry in Nigeria. The theoretical and empirical literature is discussed in section three. Section four presents the data and methodology employed. Discussions on the findings are presented in section five. The paper concludes with conclusion and policy implication in section six.

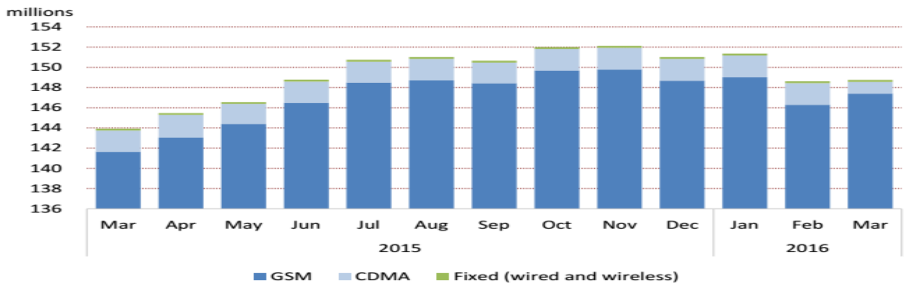
2.0 Overview of Mobile Telecommunication in Nigeria: Stylized facts

Nigeria has one of the largest mobile telecommunication industries in Africa which is worth over USD 60 billion, currently contributes an average of 8% of GDP over the last decade and estimated to contribute 25% of GDP by 2025 (NCC, 2016). The industry provides mobile voice and text message communication services on one hand and provides mobile wireless broadband services on the other hand. With rising but relatively low mobile voice and broadband penetration rates of 81.43% and 49.29% respectively, there is growth potential and thus the sector continue to attract considerable investment into the country (GSMA, 2010).

The aggregate investment into the Nigerian telecommunication industry grew from US$50 million in 2001 to US$ 68.2 billion in 2016. For instance, out of the total private investment flow into the telecommunication sector in Sub-Saharan Africa between 1998 and 2008, and estimated to be an average of US$ 5 billion a year, it was reported that Nigeria and South Africa alone accounted for over 60% of the total network investment, with the remaining 40% distributed among all the other countries in the sub region (World Bank, 2011). Indeed, over 75% of the Foreign Direct Investment capital stock invested in the Nigerian Telecommunication sector has concentrated in mobile network operations, although fixed-line networks have started to experience an upsurge in investments as well. It is also worthy to note that most of the investments have been green-field investments (i.e., fresh projects requiring a license without no existing business activity or assets) rather than acquisition of existing networks (Nigerian Bureau of Statistics, 2016).

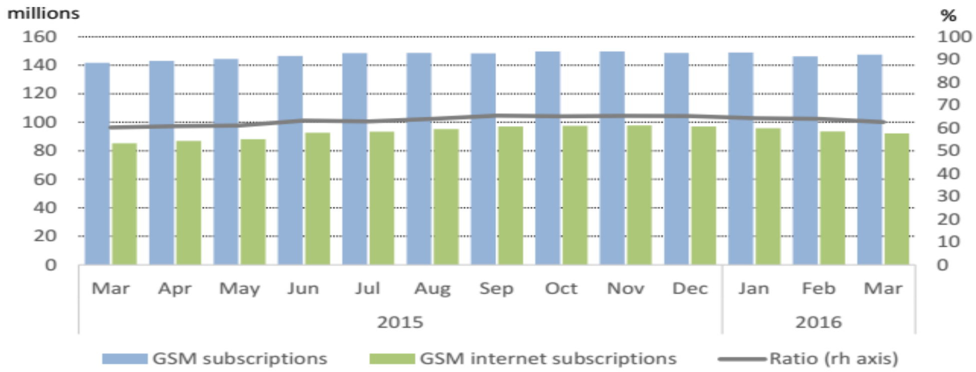
The mobile telecommunication sector in Nigeria is classified into two categories according to technology type; Global System for Mobile Communications Technology (GSM) and Core Division Multiple Access Technology (CDMA). GSM Mobile connections are by far the most dominant form of mobile subscriptions, and accounted for 99.09% of the total telecommunication subscribers in the country as at December 2015, up from 98.45% a year before, leaving CDMA with only a marginal share of the total telecom subscriptions. The share of GSM subscriber market continues to grow over the past year in contrast to a corresponding decline in the market share of CDMA from 1.46% of total subscriptions to 0.79% between March 2015 and March 2016. The dominance of GSM over CDMA is not unique to the Nigerian mobile telecom industry alone but it is rather due to the flexibility it offers subscribers to switch networks as well as roaming accessibility (Nigerian Communication Commission, 2016).

Figure 1: Monthly telecommunication subscription according to technology type, March, 2015-March 2016.



Source: Nigerian Bureau of Statistics, 2016.

Figure 2: GSM voice and broadband subscriptions, March, 2015- March 2016.



Source: Nigerian Bureau of Statistics, 2016.

3.**0 Literature Review**

3.1 Theoretical Framework: Endogenous Growth Model

More than any other theory, the endogenous growth model best explains the mobile broadband technology as a contributory factor to economic growth due to its emphasis on technological externalities or spill-over effects on the economy. The most important innovation in the endogenous growth model over the Solow model as presented by Paul Romer (1986) was not only the endogeneity of the productivity function and its implication on economic growth but also the ability of capital to enjoy an increasing return to scale according to the amount of net investment employed.

The model adopted for this theoretical framework is a simple AK endogenous growth model based on aggregate production function with technology,

$$Y_t = A(K_t)$$

Where Y_t represents real aggregate output of goods and services in the economy at a particular time, and $K_{t,}$ represents a broad aggregate measure of capital stock (physical capital, human capital and public infrastructure) in the economy at a given time, and A_t represents endogenous technical change at a particular time (A>0). Time is represented by subscript t. Capital (K_t = ∞) assumes an increasing return to scale depending on the level of net investment employed (Barro and Sala-i-Martin, 1991).

3.2. Conceptual Definitions

3.2.1 Mobile Broadband

The term mobile broadband refers to high speed internet data access available on wireless mobile devices especially through mobile phones including smartphones and feature phones, portable modems, and external USB dongles, tablet etc. Although mobile internet became available in 1993 and as part of the wave of second generation mobile telecommunication technology, it was not until 2001 that high speed mobile internet broadband access became largely available and was facilitated with the emergence of the third and fourth generation of wireless mobile telecommunication technology.

3.2.2 Economic growth

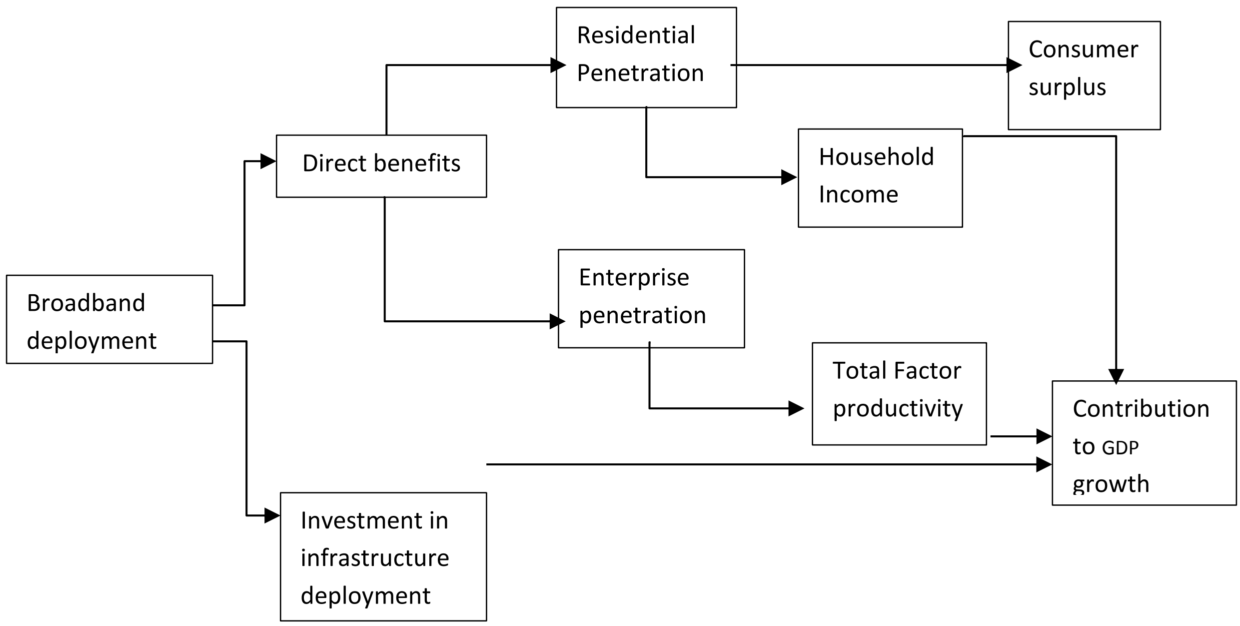
Economic growth is an increase in the production and consumption of goods and services. Because of the huge implications of economic growth on the living standards and income levels of the population, its pursuit has been the primary and perennial objective of most governments in many societies (Acemoglu, 2008). Aggregate economic growth is generally indicated by rising real gross domestic product (GDP) or real gross national product (GNP).

Inquiries into the determinants of economic growth and the factors of convergence across countries of the world are some of the most important research themes in the fields of social sciences (Barro, 1991; Barro and Sala-i-martin, 1992). Extant evidence on some of the determinants of economic growth is very robust and pretty much conclusive. Some of these factors include skilled and healthy human capital; strength of institutions; trade openness; accumulation of capital; well-developed financial system; public infrastructure such as roads, electricity and telecommunication networks, etc. as well as technological progress (Smith, 1776; Solow, 1957; North, 1990; Sachs, 1997; King and Levine, 1992).

3.3The Transmission Channels through which Mobile Broadband stimulates Growth

A brief review of relevant literature quickly reveals the transmission channels through which mobile wireless broadband penetration in an economy can lead to economic growth; Employment generation; Productivity gains; Consumer surplus; improved market efficiency and financial inclusion (World Bank, 2012; Gruber, Hatonen and Koutroumpis, 2014;).

Figure 3: The transmission channels through which broadband penetration stimulates economic growth.



Source: International Telecommunication Union, 2012.

3.4 Determinants of Mobile Broadband Diffusion

A wide range of conditions influence the rate of mobile phone diffusion in Sub-Saharan Africa as well as in many other developing regions of the world. The basic factors determining successful adoption of mobile broadband in a country is not restricted to the telecommunication sector only, but also applies to other sectors of the economy (World Bank, 2006). Some of these factors include improved liberalization and competition policies; technological advances; the standard of living or income per capita; the level of skilled human capital available; sound regulatory and institutional environment; the level of infrastructural development; geographic conditions such as land terrain, population dispersion, et cetera. (World Bank, 2006; OECD, 2008; ITU, 2013).

3.5 Empirical Literature

This section presents tabular empirical literature on the relationship between mobile broadband and economic growth. The literature will be organized according to level of aggregation as well as methodological approaches.

Table 1: Summary of Empirical Literature – Cross country Panel studies

Study	Countries Covered	Period Covered & Frequency	Estimation Method	Methodological Issues	Summary of Findings
Qiang and Rossotto (2009)	120 developed and developing countries	1980-2006, Annually	Cross sectional study using Endogenous Growth Framework	The study examines various ICT components including fixed broadband and mobile subscriptions.	The study concludes that a 10% rise in broadband penetration would lead to 1.38% increase in developing economies' GDP growth.
Koutroumpis, (2009)	22 OECD countries	2002-2007, Annually	Panel study using Simultaneous Equation Model	Model estimated effects of fixed broadband investment on GDP growth.	Significant positive effect at certain critical mass
Czernich, et al (2011)	25 OECD countries	1996-2007, Annually	Instrumental Variable Model	Instrumental variables parameters include existing telephone lines, cable television networks and diffusion speed.	Study found that 10% increase in broadband penetration leads to per capital growth of 0.9-1.5.
Thompson and Garbacz (2011)	Developed countries	2005-2009	Stochastic Frontier Analysis	Study measure the impact of fixed and mobile broadband on GDP per household	10% increase in fixed broadband penetration is linked to 0.77% increase in GDP per household. However 10% increase in mobile broadband penetration will shrink GDP per household by 0.55%
Zaballo and Lopez-Rivas(2012)	26 countries in Latin America and the Caribbean	2003-2009, Annually	Non-linear Multivariate regression	Model was used to estimate the impact of fixed broadband on growth.	Positive effect: a 10% increase in broadband penetration leads to 3.19% rise in GDP growth

Deloitte, 2012	96 Countries from both developed and developing countries	2008-2011	System GMM	Arellano-Bond estimator was used to control for endogeneity.	10% higher in 3G penetration leads to 0.15 growth rate of GDP per capita

Source: Computed by the authors

Table 2: Summary of Empirical Literature – Country specific studies

Study	Countries Covered	Period Covered & Frequency	Estimation Method	Methodological Issues	Summary of Findings
Crandall et al. (2007)	48 states in United States	2003-2005 Annually	System GMM	Panel study using GMM estimation.	Positive effect but statistically not significant.
Kattz et al (2010)	424 administrative units (*Landkreise)* Germany	2003-2006 Annually	Generalised Method of Moments model	Cross sectional study estimating the impact of fixed broadband on growth.	Positive effect: a 10% increase in broadband penetration leads to 0.255% rise in GDP growth
Katz and Koutroumpis (2012a)	Panama	2000-2010, Quarterly	Time series study using Production function	The study examines the economic impact of both fixed broadband penetration.	The study found that 10% increase in fixed broadband penetration would boost GDP growth by 0.45%.
Katz and Koutroumpis (2012b)	Philippines	2001-2010, Quarterly	Time series study using Production function	The study examines the economic impact of both fixed and mobile broadband penetration.	The study found no significant impact for fixed broadband however a 10% rise in mobile broadband penetration would lead to 0.32% increase in GDP growth.
Katz and Koutroumpis (2012c)	Senegal	2004-2011, Quarterly	Time series study using Production function.	The study examines the economic impact of both fixed and mobile broadband penetration.	Study found a negative but statistically insignificant effect for fixed broadband however 10% increase in a simple 2G mobile phone penetration has GDP growth effect of 0.44%.
Katz and Callorda (2013)	Ecuador	2009-2011	OLS	Study based on micro data obtained from household	The presence of broadband in a household would led to an increase

				survey with 24,028 individual observations	in annual income by 3.67%.
Feng and Ma (2013)	31 Provinces in China	2004-2009 Annually	Simultaneous equation Model	Panel Simultaneous equation model.	Positive effect: 10% increase in broadband leads to 2.14% GDP growth.

Source: Computed by the authors

Table 3: Summary of Empirical Literature – Micro and firm-specific studies

Study	Countries Covered	Period Covered & Frequency	Estimation Method	Methodological Issues	Summary of Findings
Qiang, Clarke and Halewood (2006)	The study sought to investigate the impact of ICT on firm performance	1999-2003	Comprising firms from 26 sectors in about 56 low- and middle-income countries in all regions.	Regression	Found that enterprises that used e-mail to communicate with their clients and suppliers grew by 3.4 percentage points faster per year in terms of sales and 1.2 percentage points faster in terms of employment than those that did not.
Clarke, Qiang and Xu (2015)	The study assessed the role of telecom services on economic performance amongst firms.	2006-2014	Medium, Small and Micro-enterprises across 100 countries	Regression Analysis	Found telecom services such as internet is highly correlated with firm performance. However both fixed and mobile services are robustly related to firm performance.

Source: Computed by the authors

4.0 Research Methodology: Data and Measurement

Table 4: Variables employed to measured Mobile Broadband Penetration impact on Economic Growth and sources.

Variable	Period: 2002Q1-2016Q4	Sources	Data frequency	Rationale	A priori expectation
Economic growth	Real Per capita GDP (constant LC)	Central Bank of Nigeria	Quarterly	Dependent variable	β>0
Mobile Broadband Penetration	Mobile Broadband Subscription per 100	Nigerian Communication Commission	Quarterly	Variable of interest	β>0
Mobile phone Penetration	Mobile Phone Subscription per 100	Nigerian Communication Commission	Quarterly	Variable of interest	β>0
Physical stock of capital	Gross fixed capital formation as a share of GDP	Nigerian Bureau of Statistics	Quarterly	Control variable	β>0
Labour stock	Labour force participation	Nigerian Bureau of Statistics	Quarterly	Control variable	β>0
Human Capital	Adult Literacy as a percentage ratio of total population	UNESCO Statistics	Quarterly	Control variable	β>0

Source: Computed by the authors

4.2 Model specification

4.2.1 The Endogenous Growth Model for Mobile phone penetration and growth

This study adopted a simple endogenous technical change model proposed by Barro (1991) to analyze the aggregate impact of mobile phone penetration on economic growth, as follows:

$$Y_{it} = f\left(K_{it,} L_{it}, Mbb_{it}, MobPen_{it}, X_{it,} t\right) \quad (1)$$

Where, Y is production output represented by change in economic growth (GDP per capita) i.e. $Y_{it} = (\Delta rgdppc_{it})$ (2)

Incorporating (2) into (1) gives the model specifications, hence:

$$Y_{it} = (\Delta rgdppc_{it}) = f\left(K_{it,} L_{it}, Mbb_{it}, MobPen_{it}, X_{it,} t\right) \quad (3)$$

Therefore, $Y_{it} = l_n[rgdppc_{it}] - l_n[rgdppc_{i,t-1}] = \propto_1 + \beta_1 l_n[\Delta rgdppc_{it-1}] + \beta_2\, l_n[\Delta Mbb_{it}] + \beta_3 l_n[\Delta MobPen_{it}] + \gamma X_{it} + \mu_i + \delta_t + \varepsilon_{it}$ (4)

Where,

Rgdppc = growth in real GDP per capita (dependent variable)

Mbb = growth in mobile broadband penetration (variable of interest)

Mobpen = growth in mobile phone penetration (variable of interest)

X is a set of growth determinants as control variables (aggregate investment, labour force, human capital).

εit denotes the error term in country *i* for period *t* respectively

5.0 Result Analysis

5.1 Descriptive Statistics

Table 5: Statistical Properties of the Variables

	MBB	MOBPEN	LNRGDPPC	LNADULTLIT	LNGFCF	LNLFPR	LNCPI
Mean	14.53332	39.51652	11.47022	4.133673	2.459842	4.099327	2.431143
Median	14.87370	42.82500	11.45513	4.118424	2.248857	4.018183	2.443210
Maximum	44.16902	84.58979	11.81485	4.348987	3.324676	4.315843	3.265759
Minimum	0.000000	0.067500	11.15072	4.004450	1.697449	4.003690	1.466337
Std. Dev.	13.04673	30.25706	0.141218	0.085345	0.497888	0.126516	0.382563
Skewness	0.530103	0.050129	0.173288	0.425192	0.335963	0.814030	-0.264215
Kurtosis	2.179333	1.511889	3.184434	2.854872	1.700971	1.706462	3.142248
Jarque-Bera	4.793412	5.932071	0.411018	1.984569	5.703894	11.53020	0.798592
Probability	0.091017	0.051507	0.814233	0.370729	0.057732	0.003135	0.670792
Sum	930.1322	2529.057	734.0939	264.5551	157.4299	262.3569	155.5932
Sum Sq. Dev.	10723.68	57675.85	1.256386	0.458879	15.61721	1.008404	9.220321
Observations	64	64	64	64	64	64	64

Source: Computed by the authors

It is evident from the results that the mean of the variables ranges between 2 and 40, while the median ranges between 2 and 42. In the case of their skewness, they are all positively skewed, with the exception of consumer price index. The skewness values of most of the variables are close to zero, while their mean values are far from zero. Hence, the variables are not standardised normal variables, because they violate the properties of a standardised normal distribution. Regarding kurtosis, that measures the peakness of the distribution of the variables, it can either be leptokurtic if its value is higher than 3, mesokurtic if equal to 3 or platykurtic if it is less than 3. From the descriptive statistic table, the kurtosis value for all the variables is less than 3, thus the variables are platykurtic, with the exception of GDP per capita and the consumer price index which has value greater than 3. These two variables are mesokurtic. Finally, the Jarque-Bera statistics and its probability value indicate the statistical significance of the variables. If the probability value is less than 5%, the variables are significant and vice versa. None of the variables have a value lower than 5%, with the exception of labour force participation rate.

4.3 The Analysis

Table 6: Stationarity test results

Variables	ADF	Philip-Peron	Decision
lnrgdppc	0.0481 -2.9287**	0.0024 -4.033	I(0)
lnMbb	0.0000 -7.2908***	0.0000 -7.2738***	I(1)
lnadultlit	0.0285 -3.1414**	0.0162 -3.3626**	I(1)
Lngfcf	0.0000 -5.6837***	0.0000 -5.6837***	I(1)
lncpi	0.0904 -3.2182*	0.0000 -6.7790***	I(0)

Source: Computed by the authors

The results of the stationarity test using the Augmented Dickey Fuller and Philip Peron test show that all the variables used in the analysis with the exception of GDP per capita and consumer price index were not stationary at level, but became stationary at First difference. Due to the presence of a stationarity problem, we decided to use ARDL since it allows the analysis of variables that became stationary at first difference and does not discriminate against the combination of I(0) and I(1). We are applying ARDL bounds testing approach to test the existence of cointegration among the variables for the establishment of a long run relationship.

In using ARDL, we start with the selection criteria in which final prediction error, Akaike information criteria and Hannan-Quinn information criteria chose maximum lag of 8. The result is presented in table7.

Table 7: ARDL Selection Criteria

VAR Lag Order Selection Criteria
Endogenous variables: LNRGDPC LNMBB LNADULTLIT LNGFCF LNCPI

Lag	LogL	LR	FPE	AIC	SC	HQ
0	10.74632	NA	5.60e-07	-0.205226	-0.024391	-0.135116
1	317.0234	546.9234	2.44e-11	-10.25084	-9.165827*	-9.830180
2	359.3588	68.03900	1.34e-11	-10.86996	-8.880772	-10.09875
3	385.0385	36.68529	1.39e-11	-10.89423	-8.000873	-9.772483
4	409.0104	29.96483	1.61e-11	-10.85751	-7.059979	-9.385217
5	460.2779	54.92955*	7.62e-12	-11.79564	-7.093931	-9.972798
6	494.9821	30.98584	7.38e-12	-12.14222	-6.536333	-9.968827
7	543.7267	34.81759	5.22e-12	-12.99024	-6.480180	-10.46630
8	599.7665	30.02132	3.88e-12*	-14.09880*	-6.684570	-11.22432*

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

With the selection criteria result, we move to ARDL estimation. Table 8 present the result of the ARDL bound test.

Table 8: ARDL bound test results

Test statistic	Value	K
F-statistic	4.5996	4
Critical Value Bounds		
Significance	I0 Bound	I1 Bound
10%	2.45	3.52***
5%	2.86	4.01
2.5%	3.25	4.49
1%	3.74	5.06

*** denote cointegration at the 1% significance level.
Source: Authors' computation

The F-statistic valued as depicted in the diagram, is compared to the upper I(1) and lower I(0) critical bound so as to determine the presence of cointegration among the variables. If the F-statistic is lower than the lower critical bound I(0), we can conclude that no presence of cointegration among the variables exists. In the same vein, if the F-statistic value is greater than the upper critical bound I(1), we conclude that the variables are co-integrated, and if the value falls between the lower I(0) and upper I(1) bound, the conclusion for cointegration is inconclusive and we may have to consider alternative measures to determine the presence of cointegration. Our analysis showed that the F-statistic value is greater than the upper critical bound at 1% level, and thus we concluded that a unique long-run relationship exists among the variables.
Our model is a good fit and satisfy the serial correlation test criteria at 0.694 which is above 0.05 value for non-hypothesis to be rejected.

We move on to the serial correlation test to satisfy that there is no serial correlation so as to avoid running a spurious regression, using Breusch-Godfrey serial correlation LM test.

Table 9: Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.156411	Prob. F(1,47)	0.6943
Obs*R-squared	0.202328	Prob. Chi-Square(1)	0.6528

The long- and short-run analysis using the ARDL cointegration model (1,0,1,3,0), selected automatically by applying Akaike Information Criterion (AIC) out of 6561 models are presented in table 10 and 11.

Table 10: ARDL Long Run Cointegration Result.
Dependent Variable: Real GDP Per Capita

Long Run Coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNMBB	0.155841	0.051763	3.010681	0.0041
LNADULTLIT	-0.158338	0.480947	-0.329220	0.7434
LNGFCF	-0.132678	0.094438	-1.404928	0.1665
LNCPI	-0.087515	0.063889	-1.369790	0.1771
@QUARTER=2	0.214753	0.098582	2.178425	0.0343
@QUARTER=3	0.385558	0.120793	3.191896	0.0025
@QUARTER=4	0.333734	0.094867	3.517919	0.0010
C	30.967724	1.954849	15.841494	0.0000

R-squared	0.843604	Mean dependent var	30.33792
Adjusted R-squared	0.804505	S.D. dependent var	0.183926
S.E. of regression	0.081323	Akaike info criterion	-1.994228
Sum squared resid	0.317442	Schwarz criterion	-1.544370
Log likelihood	73.82395	Hannan-Quinn criter.	-1.817924
F-statistic	21.57614	Durbin-Watson stat	1.846692
Prob(F-statistic)	0.000000		

*Note: p-values and any subsequent tests do not account for model selection.

Table 11: ARDL Short Run Cointegration Result.

Short Run Cointegrating Form

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNMBB)	0.079484	0.032191	2.469143	0.0172
D(LNADULTLIT)	0.923061	0.717334	1.286795	0.2043
D(LNGFCF)	0.025066	0.216727	0.115657	0.9084
D(LNGFCF(-1))	0.190601	0.305457	0.623988	0.5356
D(LNGFCF(-2))	-0.261937	0.203254	-1.288718	0.2037
D(LNCPI)	-0.044636	0.033775	-1.321550	0.1926
D(@QUARTER = 2)	0.109531	0.034708	3.155756	0.0028
D(@QUARTER = 3)	0.196648	0.032176	6.111667	0.0000
D(@QUARTER = 4)	0.170216	0.030212	5.634122	0.0000
CointEq(-1)	-0.510034	0.109993	-4.636971	0.0000

Cointeq = LNRGDPC - (0.1558*LNMBB -0.1583*LNADULTLIT -0.1327 *LNGFCF -0.0875*LNCPI + 0.2148*(@QUARTER=2) + 0.3856 *(@QUARTER=3) + 0.3337*(@QUARTER=4) + 30.9677)

Base on the long- and short-run ARDL analysis, the result shows that Mobile Broadband impacted economic growth positively in the Nigerian economy. For the long-run, a unit change in mobile broadband will lead to a corresponding 0.16 change in the GDP and it is significant at 1% level of significance. For the short-run analysis, a unit change in mobile broadband will lead to a corresponding 0.08 change in GDP, and it is significant at 5% level of significance. The rate of adjustment to the equilibrium for the short-run is 51%. The adjusted R-Squared of 0.81 shows that the model can explain 81% variation in the GDP. The Durbin-Watson statistics of 1.85 also confirm that there is no serial correlation in the model.

In order to capture the direction of causality between the variables, the Granger Causality/Block Exogeneity Wald Tests was carried out, using Toda Yamamoto. The result is presented in table 12.

Table 12: Granger Causality/Block Exogeneity Wald Tests

Dependent variable: LNRGDPC

Excluded	Chi-sq	df	Prob.
LNMBB	14.08817	8	0.0795
LNADULTLIT	14.16290	8	0.0776
LNGFCF	44.12819	8	0.0000
LNCPI	15.09859	8	0.0573
All	102.8498	32	0.0000

Dependent variable: LNMBB

Excluded	Chi-sq	df	Prob.
LNRGDPC	19.97733	8	0.0104
LNADULTLIT	16.42536	8	0.0367
LNGFCF	45.40619	8	0.0000
LNCPI	9.019224	8	0.3407
All	110.3699	32	0.0000

The result shows that there is two-way causality between mobile broadband and the GDP. At 105 level of significance, mobile broadband is granger causing GDP. Also, at 5% level of significance, GDP s granger causing mobile broadband.

5.0 Conclusion and Policy Implications

Though the transformational effect of mobile broadband penetration in enabling economic development has been recognised in the literature, very little has been explored empirically especially in Sub-Saharan Africa and certainly for Nigeria. This current study tries to fill that gap by way of investigating the effect of mobile broadband on economic growth. The result of this study indicates that mobile broadband penetration has a significantly positive effect on economic growth. The result also shows that there is both positive long and short run two-way causality between the economic growth and mobile broadband development.

In conclusion, it is imperative for policymakers to makes policies designed to increase access to broadband infrastructure to both the unserved and underserved as well as enacting policies and regulations that can stimulate the economic impact of mobile broadband technology by strengthening the capacity of the economy to fully absorb the transformational benefits and make productive use of it as a General-Purpose Technology.

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APENDIX

Null Hypothesis: Unit root (individual unit root process)
Series: LNRGDPC, LNMBB, LNADULTLIT, LNGFCF, LNCPI
Date: 08/22/17 Time: 16:48
Sample: 2001Q1 2016Q4
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 3
Total number of observations: 304
Cross-sections included: 5

Method	Statistic	Prob.**
Im, Pesaran and Shin W-stat	- 9.07464	0.0000

** Probabilities are computed assuming asympotic normality

Intermediate ADF test results

Series	t-Stat	Prob.	E(t)	E(Var)	Lag	Max Lag	Obs
D(LNRGDPC)	-3.5833	0.0090	-1.486	0.804	3	10	59
D(LNMBB)	-7.2908	0.0000	-1.520	0.746	0	10	62
D(LNADULTLIT)	-3.1431	0.0285	-1.520	0.746	0	10	62
D(LNGFCF)	-4.5091	0.0005	-1.486	0.804	3	10	59
D(LNCPI)	-6.8042	0.0000	-1.520	0.746	0	10	62
Average	-5.0661		-1.507	0.769			

Lag selection

VAR Lag Order Selection Criteria
Endogenous variables: LNRGDPC LNMBB LNADULTLIT LNGFCF LNCPI
Exogenous variables: C
Date: 08/22/17 Time: 16:53
Sample: 2001Q1 2016Q4
Included observations: 56

Lag	LogL	LR	FPE	AIC	SC	HQ
0	10.74632	NA	5.60e-07	-0.205226	-0.024391	-0.135116
1	317.0234	546.9234	2.44e-11	-10.25084	-9.165827*	-9.830180
2	359.3588	68.03900	1.34e-11	-10.86996	-8.880772	-10.09875
3	385.0385	36.68529	1.39e-11	-10.89423	-8.000873	-9.772483
4	409.0104	29.96483	1.61e-11	-10.85751	-7.059979	-9.385217
5	460.2779	54.92955*	7.62e-12	-11.79564	-7.093931	-9.972798
6	494.9821	30.98584	7.38e-12	-12.14222	-6.536333	-9.968827
7	543.7267	34.81759	5.22e-12	-12.99024	-6.480180	-10.46630
8	599.7665	30.02132	3.88e-12*	-14.09880*	-6.684570	-11.22432*

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

ARDL Model

Dependent Variable: LNRGDPC
Method: ARDL
Date: 08/22/17 Time: 16:58
Sample (adjusted): 2001Q4 2016Q4
Included observations: 61 after adjustments
Maximum dependent lags: 1 (Automatic selection)
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (8 lags, automatic): LNMBB LNADULTLIT LNGFCF LNCPI
Fixed regressors: @EXPAND(@QUARTER,@DROPFIRST) C
Number of models evalulated: 6561
Selected Model: ARDL(1, 0, 1, 3, 0)
Note: final equation sample is larger than selection sample

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LNRGDPC(-1)	0.489966	0.109993	4.454526	0.0001
LNMBB	0.079484	0.032191	2.469143	0.0172
LNADULTLIT	0.923061	0.717334	1.286795	0.2043
LNADULTLIT(-1)	-1.003819	0.817478	-1.227946	0.2255
LNGFCF	0.025066	0.216727	0.115657	0.9084
LNGFCF(-1)	-0.164072	0.302172	-0.542976	0.5897
LNGFCF(-2)	-0.190601	0.305457	-0.623988	0.5356
LNGFCF(-3)	0.261937	0.203254	1.288718	0.2037
LNCPI	-0.044636	0.033775	-1.321550	0.1926
@QUARTER=2	0.109531	0.034708	3.155756	0.0028
@QUARTER=3	0.196648	0.032176	6.111667	0.0000
@QUARTER=4	0.170216	0.030212	5.634122	0.0000
C	15.79459	3.447237	4.581811	0.0000

R-squared	0.843604	Mean dependent var	30.33792
Adjusted R-squared	0.804505	S.D. dependent var	0.183926
S.E. of regression	0.081323	Akaike info criterion	-1.994228
Sum squared resid	0.317442	Schwarz criterion	-1.544370
Log likelihood	73.82395	Hannan-Quinn criter.	-1.817924
F-statistic	21.57614	Durbin-Watson stat	1.846692
Prob(F-statistic)	0.000000		

*Note: p-values and any subsequent tests do not account for model selection.

VAR Granger Causality/Block Exogeneity Wald Tests
Date: 08/22/17 Time: 16:55
Sample: 2001Q1 2016Q4
Included observations: 55

Dependent variable: LNRGDPC

Excluded	Chi-sq	df	Prob.
LNMBB	14.08817	8	0.0795
LNADULTLIT	14.16290	8	0.0776
LNGFCF	44.12819	8	0.0000
LNCPI	15.09859	8	0.0573
All	102.8498	32	0.0000

Dependent variable: LNMBB

Excluded	Chi-sq	df	Prob.
LNRGDPC	19.97733	8	0.0104
LNADULTLIT	16.42536	8	0.0367
LNGFCF	45.40619	8	0.0000
LNCPI	9.019224	8	0.3407
All	110.3699	32	0.0000

Dependent variable: LNADULTLIT

Excluded	Chi-sq	df	Prob.
LNRGDPC	10.06517	8	0.2605
LNMBB	3.384608	8	0.9080
LNGFCF	9.380457	8	0.3112
LNCPI	12.72627	8	0.1216
All	53.86598	32	0.0091

Dependent variable: LNGFCF

Excluded	Chi-sq	df	Prob.
LNRGDPC	47.38092	8	0.0000
LNMBB	51.34648	8	0.0000
LNADULTLIT	20.31991	8	0.0092
LNCPI	35.91644	8	0.0000
All	153.4775	32	0.0000

Dependent variable: LNCPI

Excluded	Chi-sq	df	Prob.
LNRGDPC	6.650068	8	0.5748
LNMBB	5.672057	8	0.6839
LNADULTLIT	6.613176	8	0.5789
LNGFCF	4.775783	8	0.7812
All	37.84160	32	0.2200

ARDL Cointegrating And Long Run Form
Dependent Variable: LNRGDPC
Selected Model: ARDL(1, 0, 1, 3, 0)
Date: 08/22/17 Time: 17:01
Sample: 2001Q1 2016Q4
Included observations: 61

Cointegrating Form

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNMBB)	0.079484	0.032191	2.469143	0.0172
D(LNADULTLIT)	0.923061	0.717334	1.286795	0.2043
D(LNGFCF)	0.025066	0.216727	0.115657	0.9084
D(LNGFCF(-1))	0.190601	0.305457	0.623988	0.5356

D(LNGFCF(-2))	-0.261937	0.203254	-1.288718	0.2037
D(LNCPI)	-0.044636	0.033775	-1.321550	0.1926
D(@QUARTER = 2)	0.109531	0.034708	3.155756	0.0028
D(@QUARTER = 3)	0.196648	0.032176	6.111667	0.0000
D(@QUARTER = 4)	0.170216	0.030212	5.634122	0.0000
CointEq(-1)	-0.510034	0.109993	-4.636971	0.0000

Cointeq = LNRGDPC - (0.1558*LNMBB -0.1583*LNADULTLIT -0.1327
*LNGFCF -0.0875*LNCPI + 0.2148*(@QUARTER=2) + 0.3856
(@QUARTER=3) + 0.3337(@QUARTER=4) + 30.9677)

Long Run Coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNMBB	0.155841	0.051763	3.010681	0.0041
LNADULTLIT	-0.158338	0.480947	-0.329220	0.7434
LNGFCF	-0.132678	0.094438	-1.404928	0.1665
LNCPI	-0.087515	0.063889	-1.369790	0.1771
@QUARTER=2	0.214753	0.098582	2.178425	0.0343
@QUARTER=3	0.385558	0.120793	3.191896	0.0025
@QUARTER=4	0.333734	0.094867	3.517919	0.0010
C	30.967724	1.954849	15.841494	0.0000

ARDL Bounds Test
Date: 08/22/17 Time: 17:03
Sample: 2001Q4 2016Q4
Included observations: 61
Null Hypothesis: No long-run relationships exist

Test Statistic	Value	k
F-statistic	4.599550	4

Critical Value Bounds

Significance	I0 Bound	I1 Bound
10%	2.45	3.52
5%	2.86	4.01
2.5%	3.25	4.49
1%	3.74	5.06

Test Equation:
Dependent Variable: D(LNRGDPC)
Method: Least Squares
Date: 08/22/17 Time: 17:03
Sample: 2001Q4 2016Q4
Included observations: 61

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNADULTLIT)	0.928645	0.702930	1.321105	0.1927
D(LNGFCF)	0.008832	0.221571	0.039860	0.9684
D(LNGFCF(-1))	-0.091137	0.194451	-0.468688	0.6414
D(LNGFCF(-2))	-0.278277	0.204486	-1.360863	0.1799
@QUARTER=2	0.104734	0.035495	2.950692	0.0049

@QUARTER=3	0.185257	0.033255	5.570754	0.0000
@QUARTER=4	0.166511	0.030309	5.493719	0.0000
C	16.59600	3.679910	4.509892	0.0000
LNMBB(-1)	0.087730	0.033218	2.641016	0.0111
LNADULTLIT(-1)	-0.096355	0.225422	-0.427445	0.6710
LNGFCF(-1)	-0.085475	0.054050	-1.581413	0.1204
LNCPI(-1)	-0.044745	0.033634	-1.330336	0.1897
LNRGDPC(-1)	-0.533096	0.117368	-4.542079	0.0000

R-squared	0.682208	Mean dependent var	0.012049
Adjusted R-squared	0.602760	S.D. dependent var	0.129599
S.E. of regression	0.081683	Akaike info criterion	-1.985397
Sum squared resid	0.320258	Schwarz criterion	-1.535539
Log likelihood	73.55461	Hannan-Quinn criter.	-1.809093
F-statistic	8.586860	Durbin-Watson stat	1.860959
Prob(F-statistic)	0.000000		

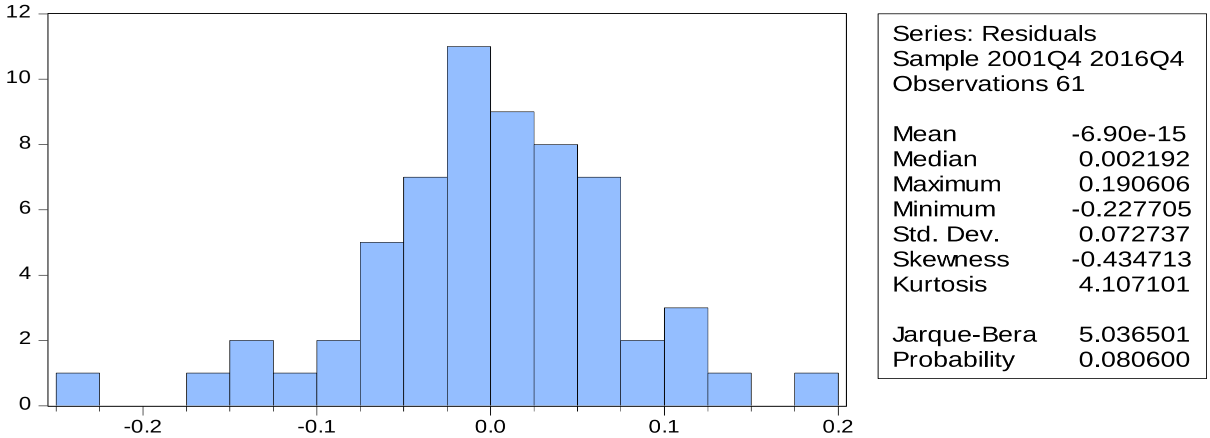
Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.156411	Prob. F(1,47)	0.6943
Obs*R-squared	0.202328	Prob. Chi-Square(1)	0.6528

Test Equation:
Dependent Variable: RESID
Method: ARDL
Date: 08/22/17 Time: 17:05
Sample: 2001Q4 2016Q4
Included observations: 61
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNRGDPC(-1)	-0.050801	0.169748	-0.299271	0.7661
LNMBB	0.006781	0.036726	0.184642	0.8543
LNADULTLIT	0.073286	0.747068	0.098098	0.9223
LNADULTLIT(-1)	-0.057240	0.837361	-0.068358	0.9458
LNGFCF	0.030702	0.232029	0.132319	0.8953
LNGFCF(-1)	-0.044971	0.325378	-0.138211	0.8907
LNGFCF(-2)	-0.007889	0.308822	-0.025546	0.9797
LNGFCF(-3)	0.017625	0.209850	0.083989	0.9334
LNCPI	-0.003574	0.035254	-0.101376	0.9197
@QUARTER=2	-0.008742	0.041411	-0.211112	0.8337
@QUARTER=3	-0.006021	0.035855	-0.167929	0.8674
@QUARTER=4	-0.001831	0.030830	-0.059386	0.9529
C	1.482793	5.114004	0.289948	0.7731
RESID(-1)	0.094414	0.238728	0.395489	0.6943

R-squared	0.003317	Mean dependent var	-6.90E-15
Adjusted R-squared	-0.272361	S.D. dependent var	0.072737
S.E. of regression	0.082047	Akaike info criterion	-1.964764
Sum squared resid	0.316389	Schwarz criterion	-1.480301
Log likelihood	73.92529	Hannan-Quinn criter.	-1.774898
F-statistic	0.012032	Durbin-Watson stat	1.889526
Prob(F-statistic)	1.000000		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Skewness -0.434713
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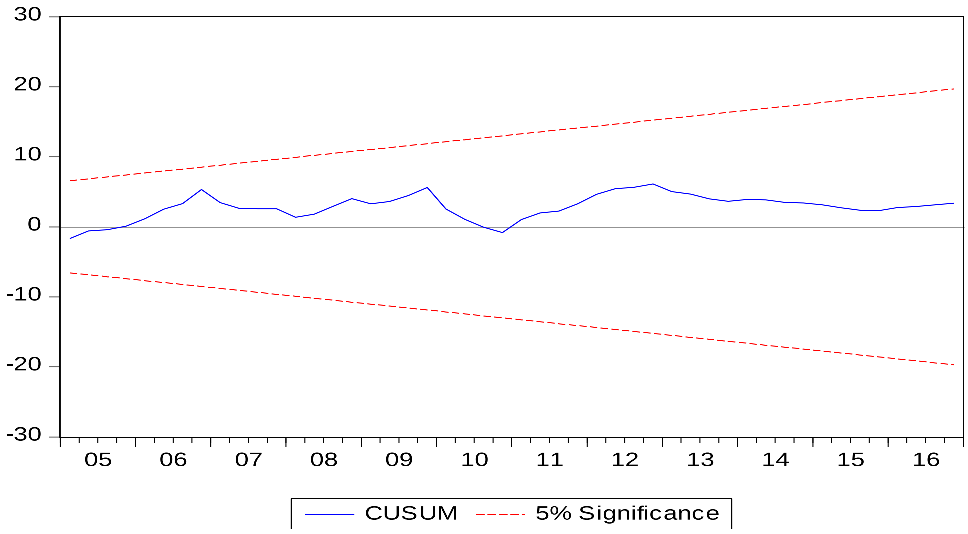
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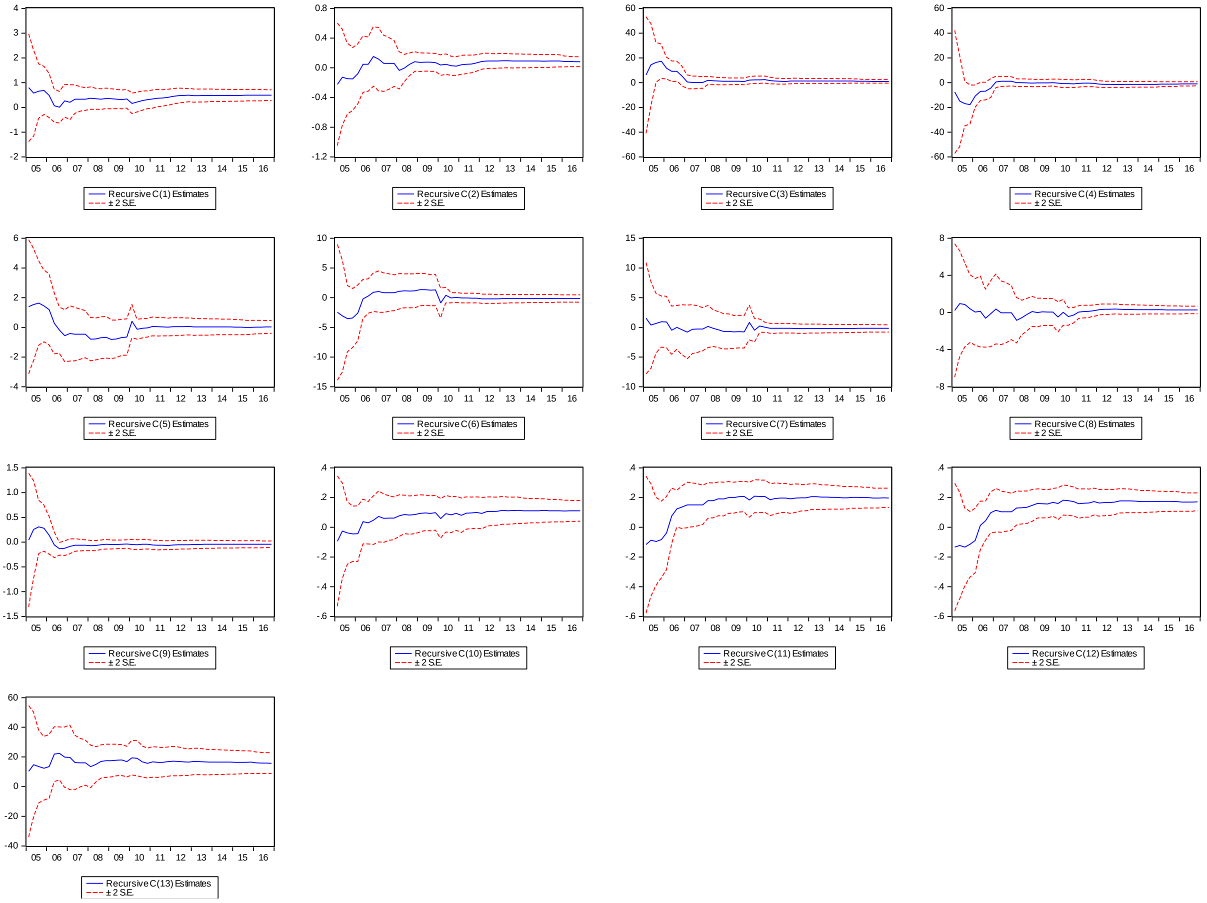
CUSUM
5% Significance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± 2 S.E.
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Recursive C(3) Estimates
± 2 S.E.
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± 2 S.E.
Recursive C(5) Estimates
± 2 S.E.
Recursive C(6) Estimates
± 2 S.E.
Recursive C(7) Estimates
± 2 S.E.
Recursive C(8) Estimates
± 2 S.E.
Recursive C(9) Estimates
± 2 S.E.
Recursive C(10) Estimates
± 2 S.E.
Recursive C(11) Estimates
± 2 S.E.
Recursive C(12) Estimates
± 2 S.E.
Recursive C(13) Estimates
± 2 S.E.