Impact of Digital Infrastructure on Indian Economic Growth

Suman Makkar & Aarushi Rajpal

Digital Infrastructure has become a significant necessity for economic growth acting complementary to traditional social and economic infrastructure factors like health, education, power and roads. It lays down roots of connectivity, availability and affordability facilitating better distribution of resources. With strong technological development like high quality broadband, mobile connectivity and digitalization India aims to become a digitally empowered economy. The present study attempts to analyze role of Digital Infrastructure in contributing to Indian economic growth during 2001-2019 using Autoregressive Distributed Lag (ARDL) Bounds Testing Approach to Cointegration. It has been observed that Fixed Telephone Subscription has negative impact on economic growth while Mobile Cellular Subscription impacts it positively. Though Fixed Broadband Subscription impacts significantly in short run but has insignificant impact in the long run.

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Introduction

Advancement in Information and Communication Technology since the 20th century has given rise to global collaborations and expansions leading to rise in productivity and overall growth of nations. Digital Infrastructure comprises facilities which enable transparent integration and management of data, programs and equipment which facilitate functioning of Information and Communication Technology. With 5.07 billion people accessing internet according to Digital 2022 October Global Statshot Report[1], channelization, management and storage of data has become of utmost importance. In India, the focus is on development of infrastructure sector of the nation as a strong infrastructure will act as a multiplier of growth for the nation. In order to meet India's aim of reaching a US$ 5 trillion economy by 2025,

[1] https://datareportal.com/reports/digital-2022-october-global-statshot

government plans to spend US$ 1.4 trillion on infrastructure through 'National Infrastructure Pipeline' in the next five years.[2]. Along with economic and social infrastructure India also acknowledges the role of strong digital infrastructure to achieve economic growth and stand out in global economy.

Harnessing its digital potential, India with nearly half a billion internet users has taken the road to the development of strong digital infrastructure by introducing DIGITAL INDIA in 2015. Platforms like UMANG (Unified Mobile Application for New-age Governance), BHASHINI, BHIM (Bharat Interface for Money), AAROGYA SETU, Digi locker and various other digital services have flourished and helped India achieve its growth objectives and gain recognition globally. Chart 1 depicts components of Digital India program initiated on 1 July, 2015.

Chart 1 Components of Digital India Program

Source: https://cleartax.in/s/digital-india-scheme (Aug 24th, 2021) Chart computed by authors using data from website mentioned

According to neoclassical steady state Growth model of Meade, growth of output is determined by 3 factors; Marginal Productivity, Returns to Scale and Technological Progress. State of steady growth rate is attained at neutral technical progress, constant population growth rate and income growth rate. On similar grounds, Solow presented exogenous growth model drawing base from Harrod and Domar, by giving importance to invention of new technology to achieve growth beyond steady state. Various theories support the relation between growth of information and communication technology and economic growth.

[2] https://www.ibef.org/industry/infrastructure-presentation

Jorgenson and Vu (2007) revealed that IT investment has increased more in industrialized and developing economies than in other regions facilitating economic growth. Matambalya and Wolf (2001) revealed growing mobile phone usage, faxes and other digital tools have positive impact on economic development by using data from 150 companies between 1999 and 2000 in Kenya and Tanzania. The results depicted significant and positive influence of ICT on economic growth.

Review of Literature

Narayana, M. R. (2011) considered growth of postal and telecom services (both public and private), information and telecommunication services and found linkage between telecom services and economic growth in India by estimating changes in telecom GDP. However, Thompson and Garbacz (2011), based on analysis of 43 countries, concluded that mobile broadband has a positive and direct effect on GDP in both high and low income countries, but fixed broadband has an effect no different than zero due to increased reliance on mobile broadband. The study also presents impact of mobile broadband on GDP as depicted in Chart 2. Similarly, Erumban and Das (2016) documented economic growth being influenced both directly (investment) and indirectly (increased labor productivity and total factor productivity) by ICT.

Praharaj, Han and Hawken (2017) considering 100 cities of India concluded that extend of digital infrastructure availability enabled differentiated growth of cities to become Smart Cities. The study revealed that 1 in every 5 households in 100 cities owned a computer with domination in Delhi with 42.5 percent computer owners. Further, 9.8 percent of households in 100 cities have access to internet connection on computer at home. Similarly, Bulturbayevich and Jurayevich (2020) highlighted the importance of shifting to e-payments, creation of digital production to ensure quality, establishing data centers for efficiency resulting in economic growth and enhancement of labor productivity. Similarly, according to Goldbeck and Lindlacher (2021) internet availability leads to urbanization, transition from primary sectors of employment to secondary sectors i.e., contribution of manufacturing sector to be higher than agriculture in regions where strength of internet connectivity is greater. Overall, the study based on 10 Sub-Saharan African (SSA) countries concluded that availability of internet leads to rise in economic growth by 2 percent. Likewise, Mefteh (2021) considered GDP per capita (constant 2010 US$) and no. of individuals using internet as a percent of population and concluded that 1% rise in DI raises growth of economy by 0.159%

The study based on 10 Sub-Saharan African (SSA) countries concluded that availability of internet leads to rise in economic growth by 2 percent.

Therefore, the review of literature reveals that the relationship between digital infrastructure and economic growth exists but studies are inconclusive. With continuous advancement in technology old studies become of less relevance. Negligible number of studies have considered relevance of three advancing domains together; mobile cellular users, fixed telephone users and fixed broadband. Thus, in this context, the present study attempts to investigate the link between digital infrastructure and economic growth specifically focusing on Indian economy.

Data Sources & Methodology

The empirical analysis of the relationship between digital infrastructure and economic growth has been done using annual time series data for India for the period 2001-2019. Digital infrastructure is measured by fixed telephone subscriptions, mobile cellular subscriptions and fixed broadband subscriptions while real GDP (constant 2015 US$) is used to measure economic growth. Data for both is obtained from World Bank, World Development Indicators, 2022.

Natural log units of all variables are used for the study. The impact of digital infrastructure on economic growth is studied by using model 1, model 2 & model 3 :

Model 1: $\ln GDP_t = w_0 + w_1 \ln \text{Mobile Cellular} + w_2 \ln \text{Fixed Telephone} + \mu_{1t}$

Model 2: $\ln GDP_t = J_0 + J_1 \ln \text{Fixed Telephone} + J_2 \ln \text{Fixed Broadband} + \mu_{2t}$

Model 3: $\ln GDP_t = b_0 + b_1 \ln MobileCellular + b_2 \ln FixedTelephone + b_3 \ln FixedBroadband + \mu_{3t}$

Where $\ln GDP_t$ = Log of GDP; lnMobileCellular = log of mobile cellular subscriptions; lnFixedTelephone = log of fixed telephone subscriptions; ln Fixed Broadband = log of fixed broadband subscriptions

In order to examine the above model, initially stationarity of variables is authenticated using Augmented Dickey-Fuller (ADF), Phillips-Perron Test (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root tests. Besides this, the dependent variable has also been checked for structural break by applying the Augmented Dickey-Fuller (ADF) Breakpoint unit root test observed in year 2008. After confirmation of the order of integration of the variables, Autoregressive Distributed Lag (ARDL) approach is used to investigate the long-run relationship among them. The foremost step of the ARDL method involves checking the presence of cointegration

$$\Delta InGDP_t = \alpha_1 + \sum\omega_{1i}\Delta \ln GDP0_{t-i} + \sum\omega_{2i}\Delta \ln MobileCellular_{t-i} + \sum\omega_{3i} \ln FixedTelephone_{t-1} + \rho_1 \ln GDP_{t-1} + \rho_2 \ln MobileCellular_{t-1} + \rho 3 \ln Fixed\ Telephone_{t-1} + \varepsilon_{1t} \text{.........................(1)}$$

$$\Delta InGDP_t = \alpha_2 + \sum\delta_{1i}\Delta \ln GDP0_{t-i} + \sum\delta_{2i}\Delta \ln FixedTelephone_{t-i} + \sum\delta_{3i} \ln FixedBroadband_{t-1} + \varphi_1 \ln GDP_{t-1} + \varphi_2 \ln FixedTelephone_{t-1} + \varphi_3 \ln FixedBroadband_{t-1} + \varepsilon_{2t} \text{.........................(2)}$$

$$\Delta InGDP_t = \alpha_3 + \sum\gamma_{1i}\Delta \ln GDP0_{t-i} + \sum\gamma_{2i}\Delta \ln FixedTelephone_{t-i} + \sum\gamma_{3i} \ln FixedBroadband_{t-1} + \sum\gamma_{4i} \ln MobileCellular_{t-1} + \beta_1 \ln GDP_{t-1} + \beta_2 \ln FixedTelephone_{t-1} + \beta_3 \ln FixedBroadband_{t-1} + \beta_4 \ln MobileCellular_{t-1} + \varepsilon_{3t} \text{................(3)}$$

among the variables, in which the following equations are examined:

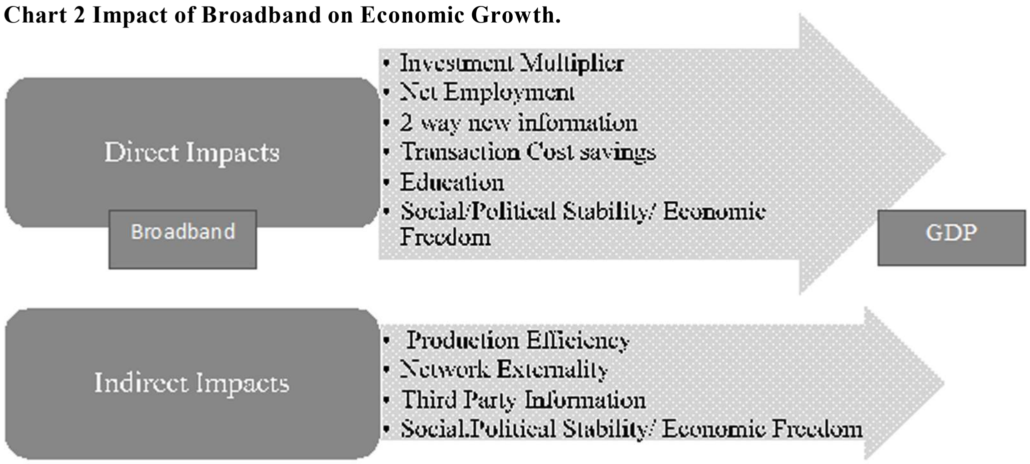
($\omega_{1i}\omega_{2i}\omega_{3i}\delta_{1i}\delta_{2i}\delta_{3i}\gamma_{1i}\gamma_{2i}\gamma_{3i}\gamma_{4i}$) are the short-run coefficients, and, ($\rho_{1i}\rho_{2i}\rho_{3i}\varphi_{1i}\varphi_{2i}\varphi_{3i}\beta_{1i}\beta_{2i}\beta_{3i}\beta_{4i}$) are the long-run coefficients. The presence of a long-run relationship among the variables is investigated by estimating the above equations by OLS and applying the ARDL F-bounds Test. Through the F-test, the null hypothesis that no-long run relationship exists among the variables (for equation 1, H_0:ρ_1=ρ_2= ρ_3=0; for equation 2, H_0:φ_1=φ_2 =φ_3=0; for equation 3, H_0:β_1=β_2=β_3=0) is tested against the alternative hypothesis that a long-run relationship exists among the variables (for equation 1, H_1:ρ_1=ρ_2=ρ_3=0 for equation 2, H_1:φ_1=φ_2=φ_3=0; for equation 3,H_1:β_1=β_2= β_3=0). The calculated value of F-statistic is used to make the decision, if the F-value is more than the upper bound critical value, then the long run cointegration exists, if the calculated F-value is less than the lower bound critical value, then no long run cointegration exists and if the F-value is between lower and upper bound critical value, then the test becomes inconclusive. We have used the upper bound and lower bound values provided by Narayan (2005) for a small sample size. On confirmation of long-run relationship among the variables, the long-run coefficients are estimated and thereafter, for the short-run relationship, an Error Correction Model (ECM) is estimated as follows:

$\Delta InGDP_t$=τ_0+$\Sigma\delta_{1i}\Delta lnGDP0_{t-i}$+$\Sigma\delta_{2i}\Delta lnMobileCellular_{t-i}$+$\Sigma\delta_{3i}$ $lnFixedTelephone_{t-1}$+ $\mu_1 ECT_{t-1}$+ε_{1t}..........(4)

$\Delta InGDP_t$=τ_1+$\Sigma\rho_{1i}\Delta lnGDP0_{t-i}$ +$\Sigma\rho_{2i}\Delta lnFixedTelephone_{t-i}$+$\Sigma\rho_{3i}$ lnFixed $Broadband_{t-1}$+ $\mu_2 ECT_{t-1}$+ε_{2t}........(5)

$\Delta InGDP_t$=τ_2+$\Sigma\varphi_{1i}\Delta lnGDP0_{t-i}$ +$\Sigma\varphi_{2i}\Delta lnFixedTelephone_{t-i}$+$\Sigma\varphi_{3i}$ lnFixed $Broadband_{t-1}$+$\Sigma\varphi_{4i}\Delta lnMobileCellular_{t-i}$+ $\mu_3 ECT_{t-1}$+ε_{3t}........(6)

Chart 2 Impact of Broadband on Economic Growth.



Source: Thompson & Garbacz (2011)

Table 1 Unit Root Analysis

I. Augmented Dickey-Fuller (ADF) Test						
Variables	At Level			At First Difference		
	WithConstantand Trend	With Constant	Without Constant and Trend	With Constant and Trend	With Constant	Without Constant and Trend
lnGDP	-3.1193(0.1332)	-0.4534(0.8794)	16.7466(0.9999)	-3.8311**(0.0405)	-3.8995***(0.0098)	-0.6285(0.4300)
lnMobile	-2.9488(0.1732)	-4.5222***(0.0029)	0.2651(0.7510)	-3.3940*(0.0854)	-1.4616(0.5279)	-1.7763*(0.0724)
lnTelephone	-3.4084*(0.0834)	0.7304(0.9892)	-2.0688**(0.0400)	2.5717(0.2952)	-3.0784*(0.0502)	-2.8409***(0.0074)
lnBroadband	-12.8071***(0.0000)	-3.8402**(0.0117)	0.9915(0.9072)	-3.6036*(0.0644)	-6.3604***(0.0002)	-0.7059***(0.0000)
II. Phillips-Perron (PP) Test						
Variables	At Level	At First Difference				
	With Constant and Trend	With Constant	Without Constant and Trend	With Constant and Trend	With Constant	Without Constant and Trend
lnGDP	-2.5741(0.2940)	-0.6600(0.8329)	22.6038(0.9999)	-3.9023**(0.0358)	-3.8971***(0.0098)	-0.4384(0.5092)
lnMobile	-2.7006(0.2473)	-9.1828***(0.0000)	2.1403(0.9888)	-3.3940*(0.0854)	-1.1569(0.6671)	-2.4666**(0.0171)
lnTelephone	-8.6934***(0.0000)	0.7304(0.9892)	1.9298*(0.0533)	-3.8895**(0.0366)	-3.7283**(0.0137)	-2.8230***(0.0077)
lnBroadband	-0.7131(0.9557)	-3.7623**(0.0121)	1.9996(0.9851)	-4.9772***(0.0053)	-2.3779(0.1617)	-1.7867*(0.0709)
III. Kwiatkowski-Phillips-Schmidt-Shin (KPSS) Test						
Variables	At Level	At First Difference				
	With Constant and Trend	With Constant	Without Constant and Trend	With Constant and Trend	With Constant	Without Constant and Trend
lnGDP	0.0901	0.5903***	N.A.	N.R.	N.R.	N.A.
lnMobile	0.1668**	0.5317**	N.A.	0.1431*	0.6559**	N.A.
lnTelephone	0.1495**	0.5384**	N.A.	0.1291*	0.3628*	N.A.
lnBroadband	0.1604**	0.5138**	N.A.	0.1152*	0.5234**	N.A.

Notes: (i) Figures in the parenthesis of the type ( ) are *p-values*. (ii) *, ** and *** denotes significance at 10%, 5% and 1% level of significance respectively. (iii) N.A. denotes Not Available; N.R. denotes Not Required.
Source: Authors' calculations.

($\delta_{1i}\delta_{2i}\rho_{1i}\rho_{2i}\varphi_{1i}\varphi_{2i}\varphi_{3i}\varphi_{4i}$) are the short-run coefficients, and the speed of adjustment parameters ($\mu_{1i}\mu_{2i}\mu_{3i}$) of lagged Error Correction Term, (ECT (-1) need to be negative and represent significant stability.

Empirical Results

In the initial step, the stationarity of the variables is checked by using the ADF, PP, KPSS unit root tests. The unit root analysis results are presented in Table 1, whereas the summary of the three tests is given in Table 2. The results show that GDP is stationary at first difference for both ADF and PP but stationary at level under KPSS whereas, mobile cellular, fixed broadband and fixed telephone are stationary at levels under both ADF and PP but stationary at first difference under KPSS. The variables (GDP, mobile subscription, fixed broadband and fixed telephone) are integrated of mixed order i.e. I(0) and I(1). So, Autoregressive Distributed Lag (ARDL) approach is used to examine the relationship among the variables. Further, a structural break in the dependent variables has also been checked using the ADF Breakpoint Test, and a break is found in the year 2008 in the GDP, for which a dummy variable is included in the analysis as D2008.

Table 2 Summary of Unit Root Analysis

	ADF	PP	KPSS
lnGDP	I(1)	I(1)	I(0)
lnMobile	I(0)	I(0)	I(1)
lnTelephone	I(0)	I(0)	I(1)
lnBroadband	I(0)	I(0)	I(1)

Note: I(0) and I(1) stands for order of integration at level and at first difference respectively.
Source: Authors Calculations.

This confirms the presence of long run relationship among the variables.

Further in the next step, the ARDL model is used to study the long run relationship among variables. Akaike Information Criterion (AIC) is used to decide the optimum lag length of the variables. According to the F-bounds test, for all the three models presented in Table 3, the calculated F-value is above the critical upper bound value, I_1(i.e. 11.1796, 16.8866, 14.2706 > 6.265 and 5.966) at 1 percent level of significance. This confirms the presence of long run relationship among the variables.

Before proceeding ahead, the models are checked for serial correlation and heteroscedasticity by using Breusch-Godfrey LM test and Breusch-Pagan-Godfrey test respectively to ensure validity. The results of diagnostic tests are represented in Table 4. All the models confirm the reliability as residuals are serially uncorrelated and models are homoscedastic cannot be rejected, as p-value is statistically insignificant in each case.

Further the long run and short run coefficients of models are examined and the results are presented in Table 4 and 5, respectively. They show that in model 1 if mobile cellular subscriptions increase by one percent, then GDP will increase by 0.32% in long run also having positive impact in short run and with one percent increase in fixed telephone users GDP will decline by 0.90% in long run and also having positive impact in short run. In model 2, if fixed telephone users increase by one percent GDP declines by 0.84% and if fixed broadband users increase by one percent GDP increases by0.16%. In Model 3, mobile cellular users affect GDP positively, fixed telephone users affect GDP negatively and fixed broadband becomes insignificant in long run.

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Table 3 F Bounds Test

Trend Specification: Restricted Constant & No Trend						
	Model 1 ARDL (1, 1,1)		Model 2 ARDL (1, 1, 2)		Model 3 ARDL (1, 0, 1, 1)	
Test Statistic	Value	K	Value	k	Value	K
F-statistic	11.1796	2	16.8866	2	14.2706	3

Note: (i) For models 1 & 2: Critical Values for Bounds Test: n=35 (I_0=4.948, I_1=6.028);n=30 (I_0=5.155, I_1=6.265) at 1% level of significance. (ii) For model 3: Critical Values for Bounds Test: n=35 (I_0=4.428, I_1=5.816);,n=30 (I_0=4.614,I_1=5.966) at 1% level of significance.
Source: Author's calculations.

Table 4 Long-Run Coefficients

Variables	Model 1	Model 2	Model 3
lnMobile	0.3227**(0.0215)	-	0.3160**(0.0210)
lnTelephone	-0.9030***(0.0001)	-0.8470***(0.0000)	-0.9814***(0.0000)
lnBroadband	-	0.1641***(0.0016)	-0.1074(0.1952)
Constant	37.9278***(0.0000)	40.6466***(0.0000)	40.7206***(0.0000)
Diagnostic Tests			
Serial Correlation	0.5456 (0.4601)	3.3471 (0.1876)	0.0392 (0.8916)
Heteroscedasticity	1.7927 (0.9377)	6.9300 (0.4362)	4.2473 (0.7509)

Notes: (i) Figures in the parenthesis of the type ( ) are *p-values*. (ii) ** and *** denotes significance at 5%and 1% level of significance, respectively.
Source: Author's calculations.

Further, the stability of long run models is checked by coefficient of lagged Error Correction Term, ECT (-1). The results presented in Table 5 show that for all the models, ECT (-1) is negative and significant at 1 percent significance level, thereby, confirming the stability of

Table 5 Short-Run Estimates

Variables	Model 1	Model 2	Model 3
D(lnMobile)	0.1020***(0.0000)	-	-
D(lnTelephone)	0.0448***(0.3651)	0.1340**(0.0367)	-0.2041***(0.0008)
D(lnTelephone(-1))	-	0.3032***(0.0013)	
D(lnBroadband)	-	0.0070(0.4558)	0.0173**(0.0373)
D2008	-0.0619***(0.0017)	-0.0937***(0.0001)	-0.0591***(0.0003)
ECT(-1)	-0.1465***(0.0000)	-0.3355***(0.0000)	-0.2925***(0.0000)

Notes: (i) Figures in the parenthesis of the type ( ) are *p-values*. (ii) ** and *** denotes significance at 5%and 1% level of significance, respectively.
Source: Author's calculations.

long run models, with speed of adjustment being 14.65 percent, 33.55 percent and 29.25 percent per annum in the case of model 1, 2 and 3 respectively. If disequilibrium occurs then in the case of model 1, adjustment will take place in 6.82 years approximately. In the case of model 2, it will take place in 2.98 years approximately and in the case of model 3, it will take place in 3.41 years approximately.

Fig. 1. Plot of CUSUM& CUSUMSQ for Model 1

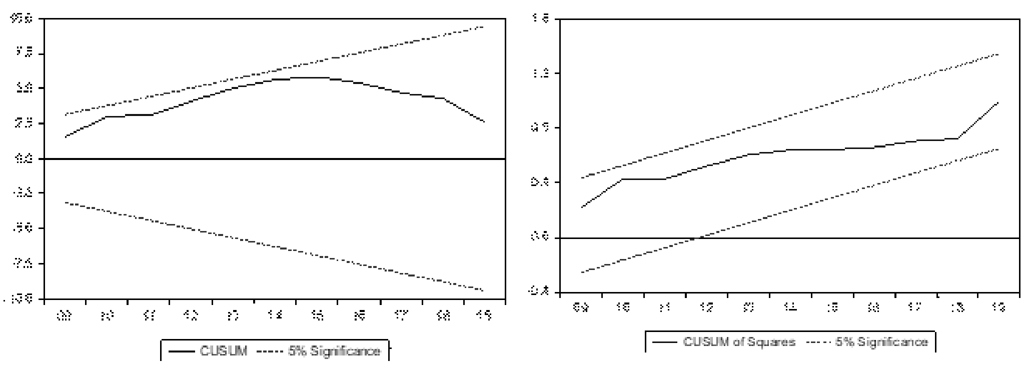


Fig. 2. Plot of CUSUM & CUSUMSQ for Model 2

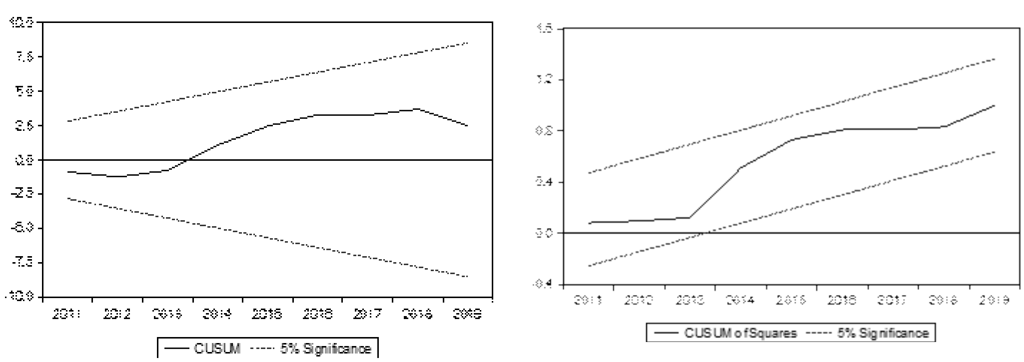
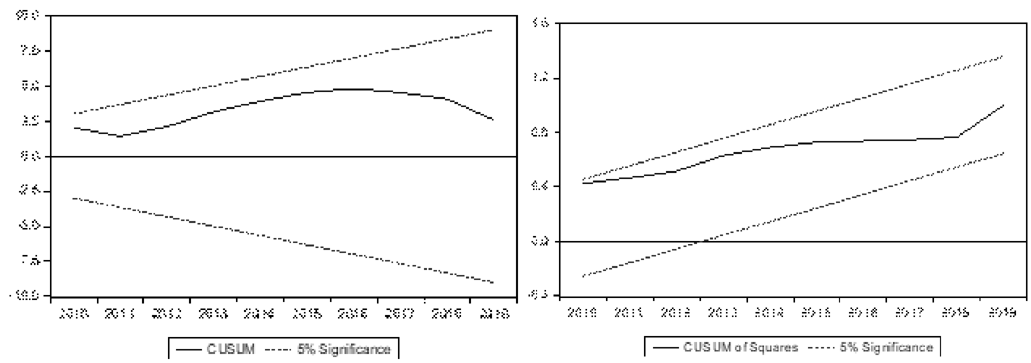


Fig. 3. Plot of CUSUM & CUSUMSQ for Model 3



Figs. 1, 2 and 3 present the stability of all the three models at 5% significance level.

Conclusion

The study concludes that growing reliance on mobiles affects growth positively whereas fixed broadband has momentary impact on growth. Also, usage of fixed telephones results in declining growth. The findings suggest rigorous investment in digital infrastructure in India to play a positive role in upgrading nation's economic sector and tapping on creation of latest opportunities to transform production procedures. Digital infrastructures act as a backbone to boost trade, transport and finances. Policy makers should focus on development of technology as transfer of technology globally is easier whereas mobilization of other factors of production requires greater effort and time. Therefore, ways should be paved for newer technologies for tapping growth potential.

References

Bulturbayevich, M. B. &Jurayevich, M. B. (2020),"The Impact of the Digital Economy on Economic Growth", *International Journal of Business, Law, and Education*, 1(1): 4-7.

Erumban, A. A. & Das, D. K. (2016),"Information and Communication Technology and Economic Growth in India", *Telecommunications Policy*, 40(5): 412-31.

Goldbeck, M. &Lindlacher, V. (2021), Digital Infrastructure and Local Economic Growth: Early Internet in Sub-Saharan Africa., Working Paper. International Monetary Fund. African Department. IMF website google ebooks https://books.google.co.in/books?hl=en&lr=&id=Hn67DwAAQBAJ&oi=fnd&pg=PT6&dq=Digital+connectivity+in+sub+saharan+africa+a+comparative+perspective+imf&ots=jr8J9lLtSG&sig=aODWuTXmVUVfx12gN9aAtk2FoVY&redir_esc=y#v=onepage&q=Digital%20connectivity%20in%20sub%20saharan%20africa%20a%20comparative%20perspective%20imf&f=false

https://www.niti.gov.in/role-digital-infrastructure-socio-economic-development

https://cleartax.in/s/digital-india-scheme

Jorgenson, D. W. & Vu, K. (2007),"Information Technology and the World Growth Resurgence", *German Economic Review*, 8(2): 125-45.

Mefteh, H. (2021),"The Impact of Digital Infrastructures and Transportation Services on Economic Growth: Recent Evidence from High-, Middle-And Low-Income Countries", *Oradea Journal of Business and Economics*, 6(2): 29-42.

Matambalya, F. & Wolf, S. (2001), The Role of ICT for the Performance of SMEs in East Africa: Empirical Evidence from Kenya and Tanzania (No. 42), ZEF Discussion Papers on Development Policy, ZEF Bonn Centre for Development Research, www.econstor.eu

Narayana, M. R. (2011), "Telecommunications Services and Economic Growth: Evidence from India", *Telecommunications Policy*, 35(2): 115-27

Praharaj, S., Han, J. H. & Hawken, S. (2017), "Innovative Civic Engagement and Digital Urban Infrastructure: Lessons from 100 Smart Cities Mission in India", *Procedia Engineering*, 180: 1423-32.

Thompson Jr, H. G. &Garbacz, C. (2011),"Economic Impacts of Mobile Versus Fixed Broadband", *Telecommunications Policy*, 35(11): 999-1009.