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Broadband India Forum

GROWTH DIVIDENDS OF DIGITAL COMMUNICATIONS

The Case for India

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Acknowledgements

We are grateful to our sponsors, Broadband India Forum and the Asian Development Bank Institute for giving us the opportunity to undertake this project that reflects on the growth imperatives of India's digital ecosystem. This paper is the first part of a two-part study on the nature and magnitudes of telecom spillovers in South and South East Asia. A study of this kind would not have been possible without the help and support of numerous stakeholders who have engaged with us over years. The power of a good example is massive and the case studies which add immense value to the study are the result of insights provided by several organizations. Colleagues, as always, were generous with both time and wisdom making ICRIER a delightful place to reflect on such an engaging and stimulating area of research. All errors of course remain our own.

Executive Summary

The near ubiquitous diffusion and use of modern digital communications is an expression of its indispensability in contemporary economic and social existence. Much like the spread of roads and electricity, telecom infrastructure is now globalizing markets, reducing transactions costs, expanding productivity, and thus promoting economic growth. With rudimentary systems now being replaced by versatile networks, communications infrastructure has rightly acquired the tag of a General Purpose Technology (GPT) with Internet and mobile based communications generating significant and wide-ranging spillover benefits for the rest of the economy. High speed Internet is increasingly viewed as an enabler of economic integration allowing further tradability of many services as well as creating new kinds of tradable services. This technological dynamism has paved the way for continuous innovation and knowledge creation that has enormous potential to enhance efficiency.

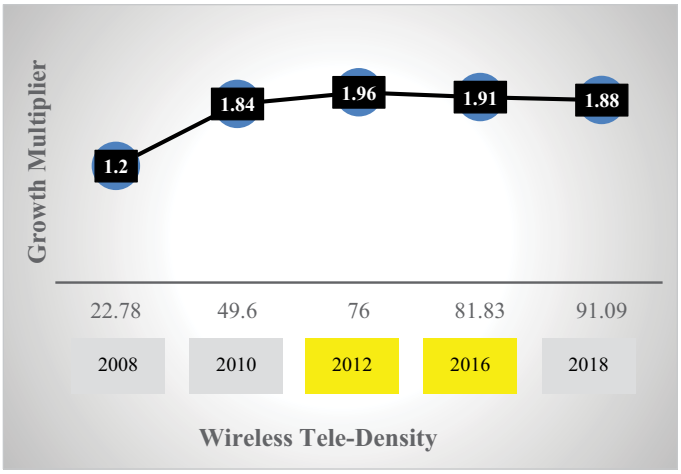
Since the global financial crisis of 2008, many countries have invested millions of dollars in communications infrastructure with the objective of reaping direct and indirect benefits of the Keynesian multipliers associated with that investment. The empirical literature on digital technologies provides adequate evidence of the role communications, in particular the Internet, has had on economic growth.

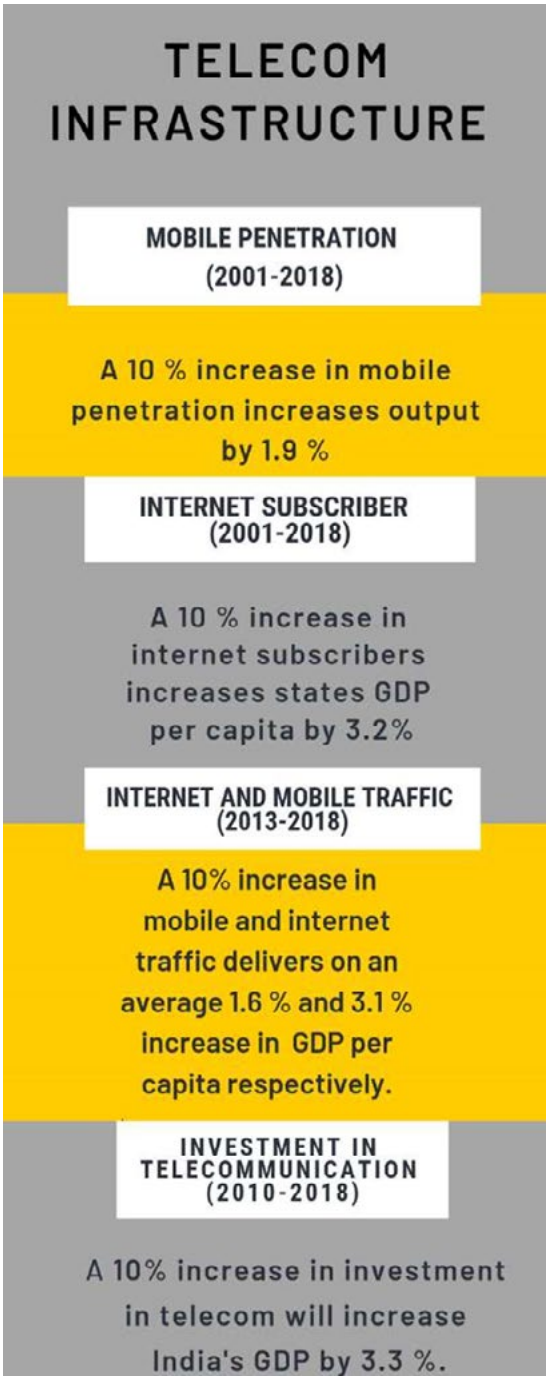
Economic effects of fixed, Mobile, Internet and Broadband		
	High Income	Low Income
Fixed	0.43	0.73
Mobile	0.60	0.81
Internet	0.77	1.12
Broadband	1.21	1.38
Source: Qiang 2009		

A new genre of studies estimate the opportunity cost of depriving access to the Internet. A study by Brookings in 2016 found that Internet shutdowns cost countries $2.4 billion dollars during the period July 2015 and June 2016. A parallel study titled "The Anatomy of an Internet Blackout: Measuring the Economic Impact of Internet Shutdowns in India" found that a 16,315 hours of Internet shutdown in India cost the economy approximately $3.04 billion during the period 2012 to 2017.

For the first time in 2009, ICRIER **estimated the impact of mobile penetration** exploiting the geographical diversity between Indian states. The model used Roller-Waverman's (2001) framework to estimate the growth dividends from mobile penetration in India. The study found that *a 10 percent*

increase in mobile penetration resulted in a 1.2 percent increase in the rate of State GDP growth. This study revisits the model first estimated in 2009 with minor modifications using a larger panel from 2001 to 2018. The model consists of three equations - an output equation, a demand equation and a supply equation all estimated together to account for the two-way causation between telecommunications and growth. The result is both positive and significant and shows that *a 10 percent increase in mobile penetration delivers, on average a 1.9 percent increase in output.* Segregating the sample between developed and developing states and by penetration rates shows a discernible return to higher diffusion. For states with above average teledensity, the results show that 10 percent increase in mobile penetration swells the growth dividend to 2.6.





The temporal analysis of growth dividends for mobile penetration shows a gradual moderation in impacts with rising levels of penetration. The model estimates growth coefficients for the period 2000 to 2010, 2000 to 2012, 2000 to 2016 and 2000 to 2018. Interestingly there is a decline in growth dividends after 2012 when teledensity had crossed 75% at the all India level. Keeping in mind that overall teledensity in India is about 50% overestimated because of multiple sims and dual sim handsets, the inflection point indicated by the analysis is likely to lie between a teledensity of 76 and 82, or 38 and 41 for unique subscribers.

Using an adaptation of Barro's endogenous growth model (1991), ICRIER first presented the estimates for impact of Internet in India in 2012. *The study found that a 10 percent increase in Internet subscribers delivers, on average 1.08% increase in output.* With current penetration levels at 38.02, this study re-estimates the model to gauge the changing magnitude of Internet impacts. A standard instrumental variable technique with fixed effects on panel data is employed for the period 2001 to 2018. It is important to note that the estimations are based on data for fixed line Internet subscribers. While they form a miniscule proportion of total Internet subscribers, a bulk of the Internet traffic flows through fixed infrastructure. The results show that growth dividends from Internet have increased over time. *According to the new estimates a 10% increase in Internet subscribers results in a 3.2 percent increase in rate of growth of state per capita GDP.*

With over 90 percent subscribers accessing the Internet on mobile, India is rightly classified as a mobile first economy. Although Internet use on mobile has increased

dramatically in the last few years, according to Cisco data, it continues to contribute less than 10% to global Internet traffic. The proportion of mobile Internet traffic to total Internet traffic in India is much higher than the global average, estimated at 22.9% in 2016. Estimating growth dividends based on Internet usage instead of penetration shows that *a 10 percent increase in India's total Internet traffic, delivers on average a 3.1 percent increase in GDP per capita, and a 10 percent increase in India's mobile Internet traffic, delivers on average a 1.6 percent increase in India's GDP.*

While calibration of impacts for technology type is important, in a converged world it is also meaningful to capture impacts for the overall telecom industry (excluding broadcasting). This is possible by developing an index that appropriately captures impacts in a technology neutral manner such as using investment data for the sector.. Investments in telecommunications increased at a compounded annual growth rate (CAGR) of 16.3% during the period 2010-11 to 2017-18. The cumulative investment during this period was Rs. 7, 47,652.8 crore amounting to 2.5% of the total gross fixed capital formation for India through those years. The customary instrumental variable technique used for the estimation of data over this period finds that a 10 percent increase in India's investment in telecommunications has the potential to deliver on average a 3.3 percent increase in India's GDP. The USD 100 billion investment envisioned in the National Digital Communications Policy, 2018 could cumulatively add USD 1.21 trillion to India's income over time.

The meteoric rise of telecoms in India also manifests in impacts at the micro level not often captured in data because it is hard to translate grass root impacts into a numerical figure. Financial services, health care, education, retail and e-governance services have especially benefitted from technology interventions. Case studies, an integral part of the narrative, collectively showcase a host of technology applications that are helping individuals and businesses. The benefits are captured in four broad categories. These are (i) improved access to services and information, (ii) improved efficiency and accountability, (iii) improved income and standard of living and (iv) employment generation. Each case study generates one or more of the above-mentioned impacts and is ranked on a scale of 1 to 4; with 1 highlighting the most direct impact generated by the intervention and 4 the least direct.

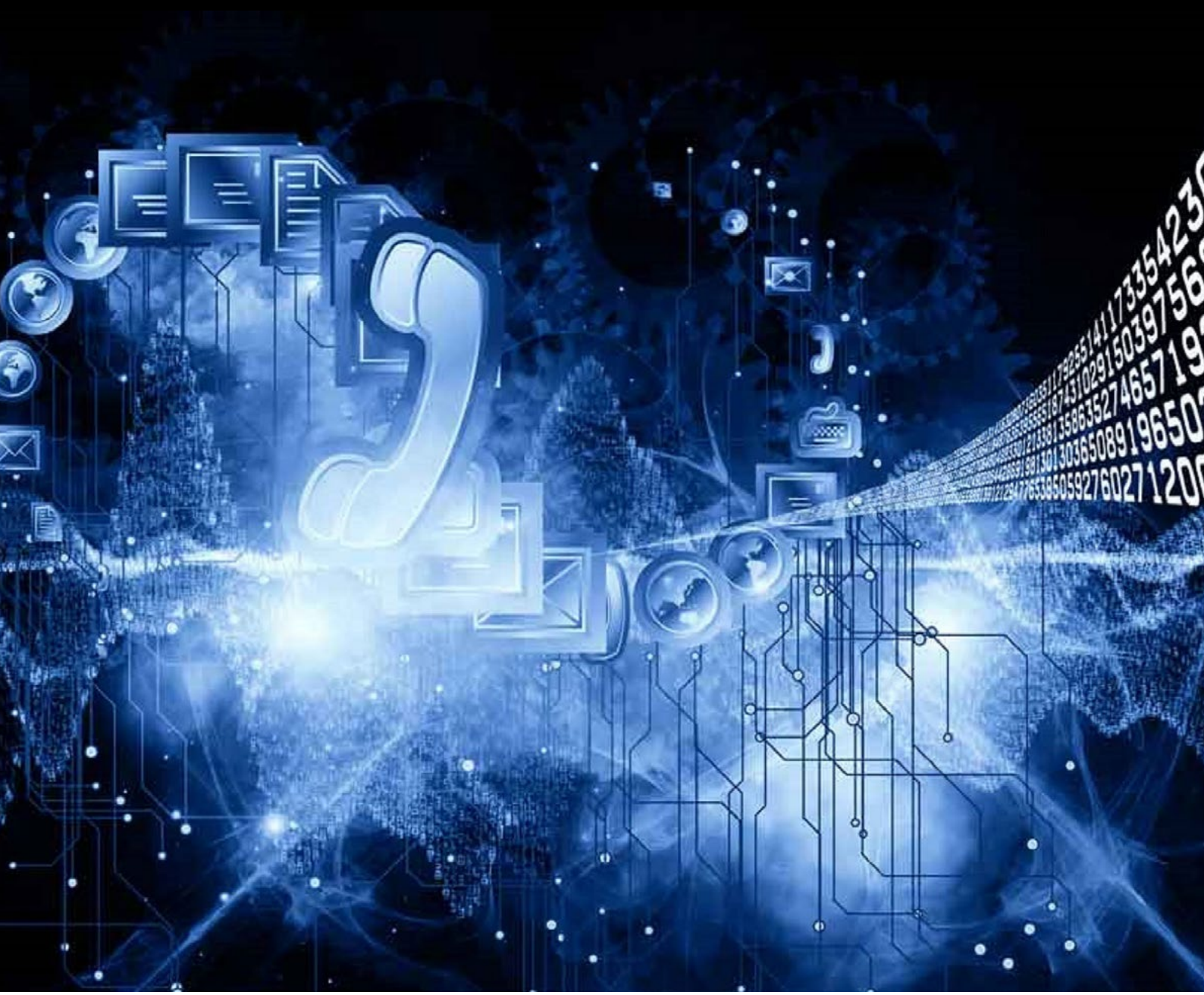
Framework for Case Studies Analysis

Case Study	Communication Technology	Sector	Impact			
			Access to Services and Information	Efficiency and Accountability	Income and Standard of Living	Employment Generation
GIS@School			1	1	2	3
Big Basket			1	1	2	2
HawkEye			1	1	2	4
Kilkari			2	4	1	1
Shipsy			1	1	4	4
IRCTC Next-Generation E-ticketing system			1	1	4	4
Ola			1	2	1	1
Byju's			1	1	2	3
GoBolt			2	1	2	2
Zomato			1	2	1	1
MakeMyTrip			1	2	1	3
Chennai Flood Map			1	1	3	4
Practo			1	2	1	3
Paytm			1	2	1	3

Communications Technology: Wireless Voice; Internet; IoT/M2M

Sector Health Education Agriculture E-Governance Women Empowerment Financial Services; E-Commerce Transport/ Logistics/Urban Services Security

The results capture the changing nature and magnitudes of digital communications spillovers for India. A key insight is the hierarchy in estimated impacts of various communication technologies, with data dominating voice as expected. Thus, the growth dividends from Internet are significantly higher than mobile (voice). Moreover, while impacts of mobile may have begun to moderate, the impact of Internet is still on the rise. This is because of increasing use of the internet in improving existing business models and notably creating newer ones. Another insight is that states and regions in India that lag ought to be fast tracked in use of Internet to capture the vast spill-over benefits that await remembering that the opportunity cost of inadequate and deficient access to the Internet are growing all the time.



1. Introduction

The near ubiquitous diffusion and use of modern digital communications is an expression of its indispensability in contemporary economic and social existence. Much like the spread of roads and electricity, digital communications is now globalizing markets, reducing transactions costs, expanding productivity, and thus promoting economic growth. With rudimentary systems now being replaced by versatile networks, communications has rightly acquired the tag of a General Purpose Technology (GPT)[1] with Internet and mobile based communications generating significant and wide-ranging spillover benefits for the rest of the economy. High speed Internet is increasingly viewed as an enabler of economic integration allowing further tradability of many services as well as creating new kinds of tradable services. This technological dynamism has paved the way for continuous innovation and knowledge creation that has enormous potential to enhance efficiency.

1 GPTs are defined by three characteristics- pervasiveness, improvement over time, and the ability to spawn innovation

Since the global financial crisis of 2008, many countries have invested millions of dollars in telecom infrastructure with the objective of reaping direct and indirect benefits of the Keynesian multipliers associated with that investment. The most immediate direct effect is that of increased demand for products that are used in the manufacture of cables, switches and other components of telecoms networks. The indirect effects are the efficiency enhancements to other sectors, and arguably are much greater than the returns to the sector itself.[2] These are captured by the economy due to improved access to information which in turn enhances coordination ability and productivity[3]. Jonscher[4] argues that the observable firm level impacts of ICT can be exploited to build a strong case for the macroeconomic linkages between technology adoption and increases in productivity. As communication systems improve, the costs of doing business fall, and output increases for individual firms across different sectors of the economy. In 1980, Andrew Hardy[5] declared, *"If the telephone does have an impact on a nation's economy, it will be through the improvement of the capabilities of managers to communicate with each other rapidly over increased distances."* The efficiency of household operations also increases as telecommunications allow better access to goods and services[6].

The empirical literature on digital technologies provides adequate evidence of the role telecommunications, in particular the Internet, has had on economic growth. More recently, another genre of studies has emerged that estimates the opportunity cost of depriving access to the Internet. A study by Brookings in 2016 found that Internet shutdowns cost countries $2.4 billion dollars during the period July 2015 and June 2016[7]. A parallel study titled "The Anatomy of an Internet Blackout: Measuring the Economic Impact of Internet Shutdowns in India[8]" found that a 16,315 hours of Internet shutdown in India cost the economy approximately $3.04 billion during the period 2012 to 2017.

This study captures the changing nature and magnitudes of telecom spillovers for India and also for South and South East Asia. The focus is primarily economic, although some social impacts are illustrated through case studies. The report is structured as follows – Section 2 provides a comprehensive literature review of the impacts generated by telecoms and other forms of physical infrastructure. Section 3 focuses on the celebrated digital dividends narrative for India, its achievements and potential. It details several econometric formulations adopted for the estimation of growth multipliers for telecoms in India. It also uses case studies to illustrate the micro mechanisms through which such impacts are generated. Section 4 concludes.

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2 Roller.L and Waverman. L,(2001). "Telecommunications Infrastructure and Economic Development: A Simultaneous Approach", *The American Economic Review,* Vol. 91, No. 4 pp. 909-923

3 M Vu. K, (2011). "ICT as a source of economic growth in the information age: empirical evidence from the 1996 – 2005 period", *Telecommunications Policy* 35, 357-372

4 C Jonscher, (1980). "Economic Causes of the Rising of Information Intensive Societies" (Unpublished)

5 Hardy. A, (1980). "The role of the telephone in economic development", *Telecommunications Policy,* Volume 4, Issue 4, pp 278-286

6 Wellenius, (1976). "Telecommunications in Developing Countries" *Telecommunications Policy*, Volume 1, No. 4 pp 269 - 297

7 West. D, (2016). "Internet Shutdowns Cost Countries $2.4 Billion Last Year", *Brookings, Centre for Technology Innovation.* Available at https://www.brookings.edu/wp-content/uploads/2016/10/intenet-shutdowns-v-3.pdf

8 Kathuria.R, Kedia. M, Varma. G, Bagchi. K and Sekhani. R(2017). The Anatomy of an Internet Blackout: Measuring the Economic Impact of Internet Shutdowns in India, https://icrier.org/pdf/Anatomy_of_an_Internet_Blackout.pdf

1.1 Changing nature and magnitude of the economic impact of communications infrastructure

Theoretically there are clear linkages between communications and economic growth. By reducing information asymmetries and transactions costs, telecoms drive efficiencies in the economic system. Empirically, while estimates vary by geography and time, the available evidence unequivocally suggests that substantial benefits accrue to investment in telecoms. A series of studies measuring the impact of IT on aggregate productivity and output growth for individual countries, especially in the United States, found little contribution of ICT to productivity[9]. Solow summarised these findings into his famous aphorism *"you can see the computer age everywhere but in the productivity statistics"*[10] Several attempts were made to resolve this productivity paradox in the research that followed using the Solow growth equation that postulates long-run economic growth to be a function of capital, labor and other inputs. Increases in productivity, commonly referred to as technological progress or total factor productivity is captured as the residual. Various researchers beginning with Hardy[11] in 1980, Norton[12] in 1992 and others[13] found an "externality" associated with enhanced fixed telecoms penetration – that is, GDP is higher, and growth faster in countries with more advanced telecoms networks.

Röller and Waverman [RW] (1996) were the first to quantify the impact of telecoms on growth after controlling for the effect of rising GDP on demand for telecoms. They addressed this 'endogeneity' problem explicitly by estimating a four-equation structural economic model with an aggregate production function, telecommunications demand and supply functions and a telecommunications production function using data from 35 countries for the years 1970 through 1990, controlling also for country-specific characteristics that might be correlated with a given country's telecom infrastructure. The paper found that in their sample of both developed and developing countries a 10 percent increase in the penetration rate produced 2.8 percent increase in GDP and, what's more, a minimum threshold of telecom density of around 24 percent growth. In a later paper (2001)

9 Roach (1987, 1989, 1991); Baily (1986b); Zachary (1991); Berndt and Morrison (1995), Jorgenson and Stiroh (1995)

10 Triplett . J, (1999)."The Solow Productivity Paradox: What do Computers do to Productivity?, *The CanadianJournal of Economics / Revue canadienne d' Economique* Vol. 32, No. 2, Special Issue on Service Sector Productivity and the Productivity Paradox (Apr., 1999), pp. 309-334 (26 pages)

11 Hardy. A, (1980). "The role of the telephone in economic development", *Telecommunications Policy,* Volume 4, Issue 4, pp 278-286

12 Norton.S.W, (1992). "Transaction Costs, Telecommunications, and the Microeconomics of Macroeconomic Growth." *Economic Development and Cultural Change,* 1992, 41(1), pp. 175-96.

13 Among these others are Leff, Nathaniel H. "Externalities, Information Costs, and Social Benefit-Cost Analysis for Economic Development: An Example from Telecommunications." Economic Development and Cultural Change, 1984, 32(2), pp. 255-76. And Greenstein, Shane and Spiller, Pablo T. "Estimating the Welfare Effects of Digital Infrastructure." National Bureau of Economic Research (Cambridge, MA) Working Paper No. 5770, 1996.

they found that about one third of the economic growth for a cross-section of 21 OECD countries over the same period could be attributed to growth in telecommunications infrastructure[14]. In the OECD from 1970 to 1990, incremental increases in penetration rates below universal service levels generated only small growth dividends. Only at near universal service (30 mainline phones per 100 inhabitants which is near 70 or so mainline phones per 100 households) were there strong growth externalities from telephone rollout. In this study, the threshold teledensity or critical mass was about 30 percent. This non linearity in impacts is due to the network effects inherent in ICTs which magnify the economic impact when the levels of penetration exceed a critical mass.

Torero, Choudhary and Bedi (2002)[15] extended the RW model to include mobile phones. They used data from 113 countries over a 20-year period and also found a positive causal link from telecommunications to GDP. They show that the critical mass for telecom penetration was in the range 5–15 percent, indicating a lower threshold for the network effects to kick in. Waverman, Meschi and Fuss (2005) used data on 92 high- and low-income countries from 1980 to 2003, and found that mobile telephony had a positive and significant impact on economic growth, and that this impact could be twice as large in developing as compared to developed countries[16].

In the aftermath of the global financial crisis of 2008, governments made significant investments in expanding their telecom infrastructure. For example the United States, Britain, Canada, Germany, Portugal and Finland all included measures to expand broadband access and to augment speeds in their planned economic stimulus packages. Australia, France, Ireland, Japan, Singapore and the Republic of Korea also created separate broadband plans to stimulate their economies, including jobs growth.[17] Countries, especially developing ones, witnessed a massive change in the quality and nature of telecom investments. Attention shifted to Internet and broadband and various factors including availability, quality and affordability of broadband services were introduced as deciding factors for investors to invest in a specific region. The literature that evolved showcased that growth dividends from Internet and broadband were higher than that from fixed and mobile telephony.

Several studies support the growth hypothesis for broadband. In 2009, a World Bank study (Qiang et al 2009) using a sample of 120 predominantly developing countries found the relative magnitudes of growth dividends of different communication technologies establish a sort of hierarchy of impacts, with fixed being the lowest and broadband being the highest[18]. Interestingly,

14 Röller, L. H., & Waverman, L. (2001). Telecommunications Infrastructure and Economic Development: A Simultaneous Approach. American Economic Review, 91(4), pp. 909-923.

15 Torero, Maximo; Chowdhury, Shyamal and Bedi, Arjun S.(2002). "Telecommunications Infrastructure and Economic Growth: A Cross-Country Analysis." Mimeo, 2002.

16 Waverman, L., Meschi, M., and Fuss, M. (2005). The impact of telecoms on economic growth in developing countries (pp. 10-23). In Africa: The impact of mobile phones. The Vodafone Policy Paper Series, Number 2.

17 Ibid

18 Christine Zhen Wei Qiang, Carlo Rossotto and Kaoru Kimura (2009), "Economic impact of Broadband" Information and Communications for Development, World Bank

for each variable, the impact is higher for developing countries than that for high income countries, confirming the premise that communication technologies compensate for other forms of inadequate infrastructure in developing countries thus generating bigger impacts (Refer Table 2.1).

Table 2.1: Economic effects of fixed, Mobile, Internet and Broadband

	High Income	Low Income
Fixed	0.43	0.73
Mobile	0.60	0.81
Internet	0.77	1.12
Broadband	1.21	1.38

Source: Qiang 2009

Another panel study with 25 Organization for Economic Co-operation and Development (OECD) countries over the period 1996–2007 concluded that a 10 percent increase in broadband penetration could generate GDP growth between 0.9 - 1.5 percent (Czernich et al 2009)[19]. At a country level, Katz et al (2010) use data from 424 German Landkreise (administrative unit beneath a "Länder") to show that 10 percent increase in broadband penetration results in 0.26 percent increase in GDP. Similar studies conducted in China, United States, Panama, Philippines, Senegal etc. have showcased positive impacts of broadband infrastructure.

Several studies have also found evidence of job creation. Using the input-output method, Crandall et al. (2003)[20] estimated that an investment of USD 63 billion (needed to reach ubiquitous broadband service in the United States) could result in the creation of 1.2 million jobs. Similar studies were conducted by Atkinson et al. (2009)[21], Liebenau et al. (2009)[22] and Katz et al., 2008[23]. Appendix 1 provides a snapshot of various studies that estimate the economic impact (both direct and indirect) of telecom infrastructure. Beyond economic growth and job creation, telecom infrastructure also has positive effects in generating consumer surplus that is not captured in the GDP statistics[24]. These include efficient access to information, savings in transportation and benefits in health and entertainment, and can be measured in terms of the difference between consumers' willingness to pay for the broadband service and its actual price. Given the rapid evolution of telecom technology and the pervasive uses that have developed around telecom infrastructure, it could be justifiably claimed that the benefits from telecom overshadow those from others GPTs before it.

1.2 Comparing Digital Communications with other form of Infrastructure

That availability of quality infrastructure is crucial for economic growth, rapid human development and poverty reduction needs no validation. Empirically, clear linkages have been established between infrastructure and development. Infrastructure typically exhibits substantial economies of

19 Czernich, Nina, Oliver Falck, Tobias Kretschmer, and Ludger Woessmann. 2009. Broadband Infrastructure and Economic Growth. http://papers.ssrn.com/abstract=1516232.

20 Crandall, R., Jackson, C., & Singer, H. (2003). "The Effect of Ubiquitous Broadband Adoption on Investment, Jobs, and the U.S. Economy". Washington DC: Criterion Economics

21 Atkinson, R., Castro, D. & Ezell, S.J. (2009). "The digital road to recovery: a stimulus plan to create jobs, boost productivity and revitalize America". *The Information Technology and Innovation Foundation,* Washington, DC

22 Liebenau, J., Atkinson, R. D., Kärrberg, P., Castro, D. & Ezell, S. J. (2009, April 29). "The UK's Digital Road to Recovery". Retrieved from: http://ssrn.com/abstract=1396687

23 Katz, R. L., Zenhäusern, P. & Suter, S. (2008b). An evaluation of socio-economic impact of a fiber network in Switzerland. Polynomics and Telecom Advisory Services, LLC.

24 Greenstein, S. & McDevitt, R. (2009). The Broadband Bonus: Accounting for Broadband Internet's Impact on U.S. GDP (NBER Working Paper 14758). Retrieved from www.nber.org/papers/w14758.

scale, implying that cost declines as more people use the infrastructure. Accordingly, infrastructure displays certain characteristics of a public good i.e. it is often non-rivalrous and confers substantial economic and social benefits that are not internalized. Critical infrastructure includes roads, railways, airways, ports, utilities such as gas and electricity, as well as telecommunications and information technology (IT). These are often used as services and intermediate goods essential for productive processes in manufacturing, agriculture, and services (Agrawal 2015). A recently published book by the Asian Development Bank Institute presents some of the latest research on the impact of infrastructure on various economic outcomes[25]. Some notable studies summarised in Table 2.2 cite benefits that various infrastructures have had on countries across the globe.

Table 2.2: Impact of Critical Infrastructure on Growth

Author, Title	Research problem	Result
Yoshino, N. and Abidhadjaev, U. (2018), "An Impact Evaluation of Infrastructure Investment: The Case of the Tashguzar– Boysun–Kumkurgon Railway in Uzbekistan" Asian Development Bank Institute	Authors examine the nature and magnitude of the effects of infrastructure provision on regional economic performance in Uzbekistan using the difference-in-difference method	The empirical results suggest that the Tashguzar–Boysun–Kumkurgon railway line in Uzbekistan increased the regional GDP growth rate in affected regions by around 2%, in the frame of connectivity effects
Yoshino, N. and Abidhadjaev, U. (2018), "Impact of Infrastructure Investment on Tax: Estimating the Spillover Effects of the Kyushu High-Speed Rail Line in Japan on Regional Tax Revenues" Asian Development Bank Institute	Authors analyze the impact of the Kyushu high-speed rail line in Japan on the tax revenues of prefectures using the difference-in-difference method	Results suggest that the Kyushu high-speed rail line in Japan had a statistically significant and economically growing impact on tax revenue after it was completed and connected to large cities such as Hiroshima and Osaka
Adu, G., Dramani, J.B., Oteng-Abayie, E.F., (2018), "Powering the powerless: Economic impact of rural electrification in Ghana", IGC Policy Brief 33415	Authors examine the socio-economic effects of rural electrification on households.	Authors find that electricity access improves real gross income by 64% for households with access to electricity compared to those without. Real household expenditure per capita is 63.7% higher for households in rural communities connected to the national grid compared to rural communities without a grid connection.
Banerjee, A., Duflo, E., Qian, N. (2010), "Transport Infrastructure and Economic Growth in China", IGC Policy Brief 1006	Authors examines the effect of transportation networks in China on long term growth, from 1986-2005	Regions closer to historical transportation network have higher GDP per capita, higher income inequality, and higher number of firms. The effects of transportation networks on growth are subdued by other mobility factors such as capital and skills, but investments in such networks remain important to growth.

25 Yoshino, N., Helbe, M., Abidhadjaev, U. (2018), Financing Infrastructure in the Asia Pacific, Asian Development Bank Institute

Esfahani, H.S., Ramirez, M.T., (2003) "Institutions, Infrastructure, and economic growth", Journal of Development Economics, 70.	Authors examine the institutional-economic factors that mediate infrastructure-GDP interactions by developing cross-country structural model	Authors find that if the growth rate of telephone per capita rises from 5% per year in Africa, and 10% per year in East Asia, annual growth rate of GDP per capita would rise by 0.4 percentage points. In the power sector, an increase of per-capita production growth rate from 2% in Africa and 6% in East Asia can raise annual GDP growth rate by 0.5 percentage points.
Datt, G., and Ravallion, M., (1997), "Why have some Indian States Done Better than Others at Reducing Rural Poverty?", Economica, Vol.65, No. 257.	Authors track the evolution of various poverty measures of Indian States using pooled state-level data for the period 1957-1991.	Authors find that among other factors, states starting with better infrastructure and human resources saw higher long-term rates of poverty reduction
Michaels, G., (2008) "The Effect of Trade on the Demand for Skill- Evidence from the Interstate Highway System", The Review of Economics and Statistics, Vol. 90, Issue. 4.	Author exploits the advent of United States Interstate Highway System as a unique policy experiment to identify the impact of connectedness on trade, and demand for skilled labor	Author finds that counties that were connected through the highway system experienced increase in trade-related activities by 7-10 percentage points per capita. Highways raised the relative demand for skilled workers in manufacturing.

Source: Compiled by Author

Several studies using firm-level data have examined the impacts of India's Golden Quadrilateral (GQ), a network of highways connecting India's top metropolitan cities[26], on economic growth. Datta (2011) documented the increase in input sourcing and inventory efficiency for formal manufacturing enterprises located on the GQ network. Ghani, Goswami and Kerr (2016) attributed the improved infrastructure and road quality to greater allocative efficiency of manufacturing activity in local areas Khanna (2014) analysed the dispersion of economic development around the GQ upgrades, using nightlight luminosity as a proxy.[27]

While the importance of infrastructures including roads is acknowledged in the literature, the impact of telecommunications infrastructure on GDP growth and its social return to most countries are far more impressive. The average payoff from telecommunications infrastructure is higher, when payoffs from infrastructure are unbundled into its components[28]. In the next section we provide a quantitative assessment of impacts. We also use a clutch of case studies that provide evidence of the channels through which such impacts manifest themselves at the micro level.

26 The project was launched in 2001 as a part of the National Highways Development Project in India.

27 Chaurey and Le (2016)

28 Estache. A and Gregoire. G,(2012)." The impact of infrastructure on growth in developing countries", IFC; https://www.ifc.org/wps/wcm/connect/054be8804db753a6843aa4ab7d7326c0/INR+Note+1+-+The+Impact+of+Infrastructure+on+Growth.pdf?MOD=AJPERES

2. Digital Communications in India

The development of communication networks in India has been impressive. Overall tele density has increased from about 1 percent in 1994, when murmurs of reform of the telecommunications sector were first heard in India, to about 90 percent as on June 2018. Increasing competition and the rapid advancement of wireless technologies enabled the telecom sector to surge ahead of other infrastructures to register unprecedented rates of growth. With a subscriber base of 1.17 billion[29], India's telecom market is the world's second-largest and contributes significantly towards GDP growth and job creation. It is without question a mobile first economy, and has 1.15 billion mobile subscribers as on June 2018 and 491 million mobile internet subscribers, compared to about 21 million fixed Internet users.[30] India's mobile appetite is reinforced by the relentless rise in smart phone users, especially in rural areas.

These salutary outcomes are a result of years of regulatory and market reform that allowed private sector to participate and more importantly compete on several dimensions, including price, innovation, investments and deployment of new affordable technologies[31]. These have been discussed at length elsewhere and therefore need not detain us. It is predicted that imminent growth will be fueled by further and rapid diffusion of smartphones, deployment of Internet of Things (IoT) and the use of machine-to-machine (M2M) connections. The Internet in India is expected to deliver US$ 250 billion by 2020, contributing up to 7.5 percent to GDP[32].

29 TRAI Performance Indicators Report, June 2018

30 TRAI Performance Indicators Report, June 2018

31 Jain. R and Raghuram. G (2015). "Lessons of Reforms of the Telecom Sector". Indian Institute of Ahmedabad, W.P No. 2015-03-22

32 BCG-TiE Report, 2017; https://media-publications.bcg.com/BCG-TiE-Digital-Volcano-Apr2017.pdf

Since 2009 ICRIER has estimated the growth dividends due to telecom[33]. These include the impact of mobile, Internet, Broadband, and more recently for data traffic and telecom investments. The growth multipliers vary in magnitude but not in direction, which are positive everywhere and every time. In what follows we provide a short review of international and India specific studies of this genre. We also update the India telecom growth multipliers for various model specifications based on data from recent time periods. Most revisions use data from the year 2000 -2001 to 2017-18. We have had to adapt some data series because of change of applicable base. The sub-sections detail the methodology and present a comparison of estimates across the different methods and technologies.

2.1 Impact of Mobile

In 2009, ICRIER estimated the impact of mobile penetration exploiting the geographical diversity between Indian States. The model used Roller Waverman's (2001) framework to estimate the growth dividends from mobile penetration in India[34]. Using data for 19 states over the period 1999-2000 to 2007-08, the report found that a 10 percent increase in mobile penetration resulted in a 1.2 percent increase in rate of SGDP growth. Mobile penetration did explain some of the difference in growth rates between states. The estimated growth coefficient for developed states was significantly higher than developing states. The study also estimated a critical teledensity of 25 percent, the level of mobile penetration above which network effects become apparent.[35] Since 2009, all states in India have surpassed this threshold. The median tele-density across states in the quarter ending March 2018 was 96.61. A strong positive correlation continues to exist between mobile penetration and the level of state per capita GDP. Figure 3.1.1 and 3.1.2 plot the correlation between mobile penetration and income across Indian states at a point in time and for the average income and mobile penetration over a period of time respectively. These states are mostly based on the telecom circle classification, with metros like Mumbai and Kolkata accounted under their respective states. Also, certain circles like UP West and UP East have been combined as UP (since other economic data are available only at the aggregate state level).

Figure 3.1.1: Correlation between State GDP Per capita and Mobile Penetration (Average for 2010-11 to 2017-18)

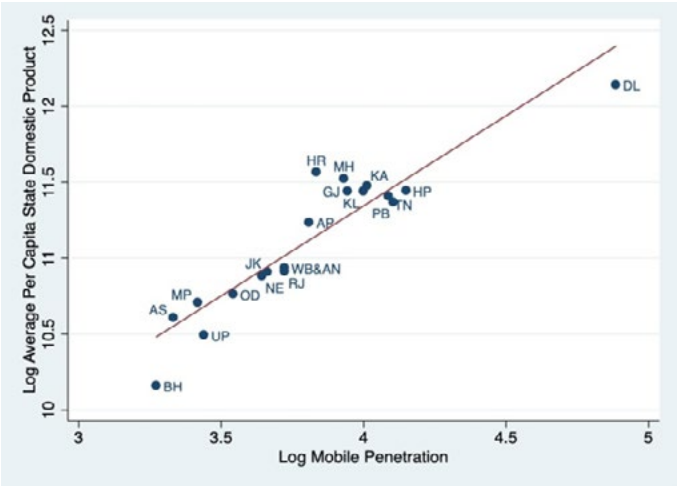
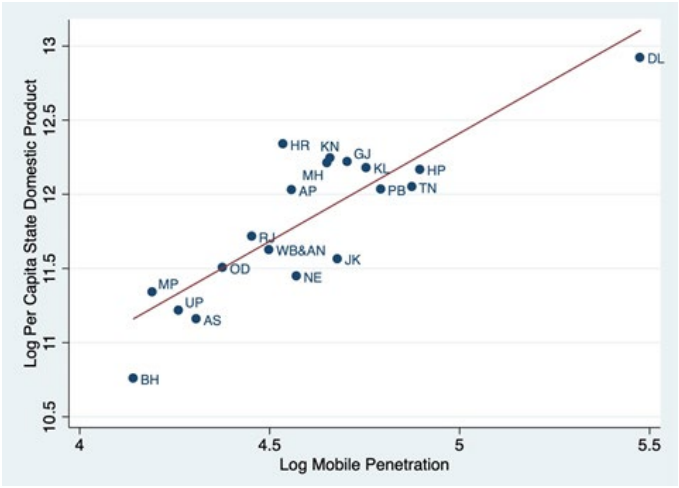


Figure 3.1.2: Correlation between State GDP Per capita and Mobile Penetration (2017-18)



Source: Compiled by Author

33 Kathuria et al 2009, Kathuria et al 2010, Kathuria and Kedia (2012), Kathuria et al (2016), Kathuria et al (2017)

34 Kathuria. R and Kedia. M (2009)."India: Impact of Mobile Phones", Moving the Debate Forward, Policy Paper Series, Number 9, Vodafone Group

35 For a description of the model and results see "Mobile India Revisited: Analysis of Impact of Communication on the Indian Economy", NCAER Centre for Macro Consumer Research, 2011

We revisit the model first estimated in 2009 with minor modifications using data from 2001 to 2018. The model consists of three equations - an output equation, a demand equation and a supply equation all estimated together to take account of the two-way causation between telecommunications and growth. The model specifications are provided in Box 3.1.1 below and details of definitions and data sources are provided in Appendix 2.

Box 3.1.1: Econometric Specification for Estimating the Impact of Mobile Penetration

The impact of mobile telecommunication on growth has been estimated using a structural model that is a slight modification of the framework developed by Roller and Waverman (2001). It consists of three equations; an output equation, a demand equation and a supply equation, estimated simultaneously to account for two-way causation.

The output equation models the level of output **($SGDP_{it}$)** in state i at time t as a function of the total investment net of telecom investment **(K_{it})**, a measure of human capital (labour engaged in industries) and the mobile penetration **($MPEN_{it}$)**. We use a dummy variable for each state **(D_i)**, to control for fixed effects, unobservable characteristics that are specific to each state.

$$SGDPit = \alpha_0 + \alpha_1 K_{it} + \alpha_2 L_{it} + \alpha_3 MPEN_{it} + \alpha_4 D_i + \varepsilon \quad (1)$$

The demand equation for mobile models the level of mobile penetration **($MPEN_{it}$)** in state i at time t as a function of per capita SGDP **($SGDP\_PC_{it}$)**,price for mobile which is proxied by average revenue per user(ARPU) **($PriceM_i$)**, and fixed line subscribers **($SubscriberF_{it}$)**.

$$MPEN_{it} = \beta_0 + \beta_1 SGDP\_PC_{it} + \beta_2 PriceM_{it} + \beta_2 SubscriberF_{it} + \varepsilon' \quad (2)$$

The supply equation models the growth rate of mobile penetration **($MPEN_{it} - MPEN_{it-1})/ MPEN_{it}$** in state i at time t as a function of the price of mobile **($PriceM_{it}$)**, the geographical area **(GA)** and a time dummy **T**.

$$(MPEN_{it} - MPEN_{it-1})/ MPEN_{it} = \theta_0 + \theta_1 GA + \theta_2 PriceM_{it} + \theta_3 T_t + \varepsilon'' \quad (3)$$

Where i goes across 19 states in India and t goes from 2001-to 2018

The key results of the estimation are:

- The coefficient for mobile penetration is both positive and significant and *implies that a 10 percent increase in mobile penetration delivers, on average 1.9 percent increase in output*

- The estimated demand equation shows that *mobile demand is highly sensitive to price.* Own-price-elasticity of mobile phones is minus 1.54 which implies that a 10 percent price increase would reduce demand by roughly 15.4 percent. Also, demand for mobile is positively related to income. The *income elasticity* is 1.33, implying that expenditure on mobile rises more than proportionately to rise in income. These elasticities are lower than the ones estimated in the study conducted in 2009 implying the ubiquity of mobile use in everyday life and individuals becoming less sensitive to the change in prices or the change in income with respect to consumption of mobile services.

- With the rapidly declining fixed line usage in India, the relationship between mobile and fixed line services has become debatable The cross price elasticity measured using fixed line subscribers in this model is significant at the 90% level and finds mobile and fixed line services to have become complements.

Results of the regression are summarised in Table 3.1 below.

Table 3.1: Results of the Model estimating impacts of mobile penetration in India

Variables	Output Equation	Demand Equation	Supply Equation
K_{it}	.189 (5.44)		
L_{it}	.305 (3.94)		
$MPEN_{it}$	.188 (13.17)		
$SGDP\_PC_{it}$		1.33 (14..73)	
$PriceM_{it}$		-1.54 (-14.57)	.77 (1.15)
$SubscriberF_{it}$		.103 (1.90)	
GA			.094 (2.30)
Constant	(dropped)	-3.65 (-2.51)	-7.4 (- 1.47)
R-Square	.932	.865	.478

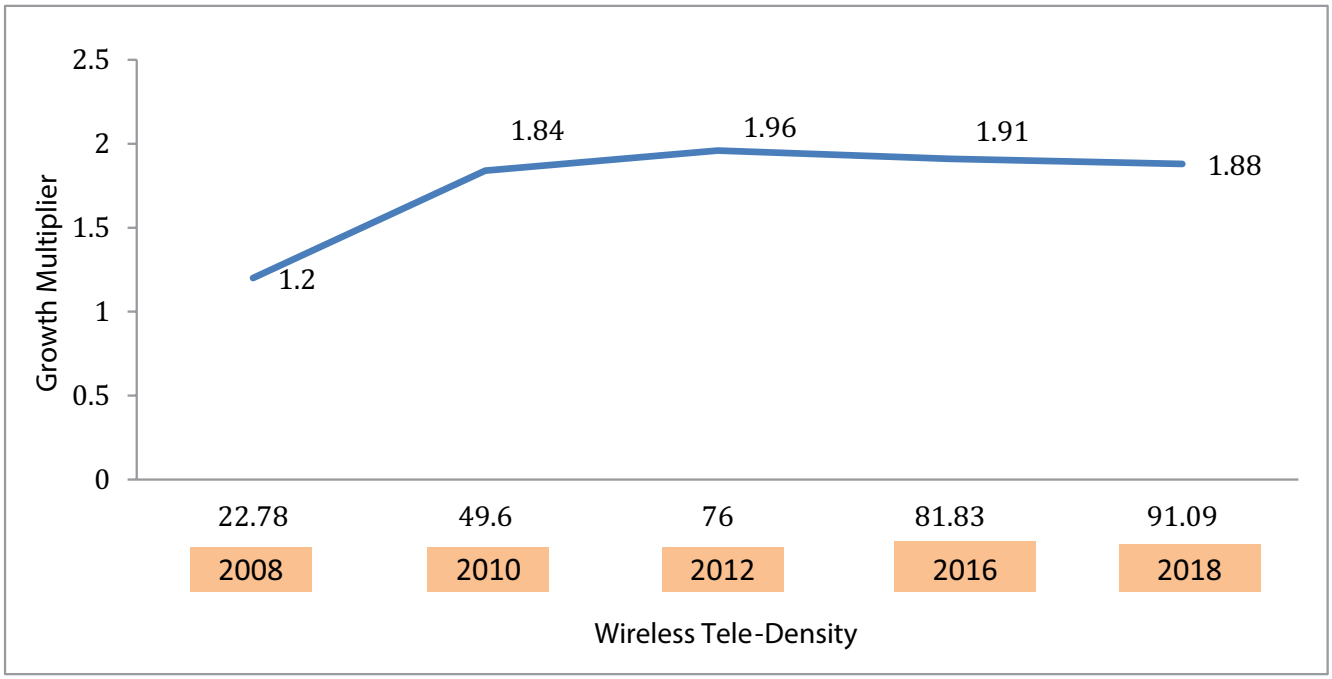
Note: (i) All t values at 95percent level of significances in parentheses, (ii) Variables are in their natural logarithm (iii) The model has been bootstrapped to check for heteroskedasticity

We also segregate the sample between developed and developing states and by penetration rates. Appendix 3 provides the list of developing and developed states on the basis of a median per capita state domestic product and high and low penetration states using the level of mobile penetration in March 2018. There continues to be a discernible difference in impact experienced by developed and developing states. The estimation finds that 10 of the 19 states in our sample are likely to experience a 2.6% growth in GDP with an additional increase of 10 percent in mobile penetration. The corresponding growth dividend for developing states is 1.6 percent for every 10 percent increase in mobile penetration. Similarly a low penetration state (at less than 96.61 tele-density) is expected deliver additional GDP growth of 1.5 percent with a 10 percent increase in mobile penetration. While the growth dividend for a high penetration state in 2.5 percent.

In a temporal analysis of growth dividends for mobile penetration we find a gradual moderation in impacts with rising levels of penetration. We use the model to estimate the growth coefficients for the period 2000 to 2010, 2000 to 2012, 2000 to 2016 and 2000 to 2018. Interestingly we find a decline in growth dividends after 2012 when teledensity had crossed 75% at the all India level. In Figure 3.1.3 we show the rise and the gradual decline in the magnitudes of the mobile dividends since 2008, also keeping in mind that overall teledensity in India is about 50% overestimated because of multiple sims and dual sim handsets[36]. The inflection point indicated by our analysis is likely to lie between a teledensity of 76 and 82, or 38 and 41 for unique subscribers.

36 Queries by JS. Cabinet Secretariat on 17.09.2018 and DoT's responses, Telecom Live

Figure 3.1.3: Moderation of Growth Multipliers



Source: Based on Author's Econometric Estimations

2.2 Impact of Internet

After a slow beginning, Internet and broadband diffusion have begun to pick up pace in India. Predictably their impacts have also risen and are now higher in magnitude than the mobile impacts.

Using an adaption of Barro's endogenous growth model (1991), ICRIER presented the first estimates of the impact of Internet on economic growth across Indian states. The data consisted of a panel of socio-economic variables across 19 states in India for the period 2001 to 2010. The study found that *a 10 percent increase in internet subscribers delivers, on average 1.08% increase in output.* This estimate was expected to be a conservative lower bound since internet penetration was far below the critical mass at the time[37]. The model was revised in 2016 using data from 2001 to 2014 using an instrumental variable regression with fixed effects. The study found that a 10 percent increase in Internet subscribers results in an increase of 2.4 percent in the growth of state per capita GDP. This was a significant jump from the coefficient estimated in 2012 due in part to the increase in Internet penetration from 1.51 in 2010 to 20.2 in 2014. With current Internet penetration levels at 38.02, we revisit the estimation to measure the impact of Internet today, and to gauge its changing magnitude. The positive correlation between state incomes and state–level subscribers

37 Data is taken from 2001-2010

Figure 3.2.1: Correlation between State GDP Per capita and Fixed Internet Subscribers (Average for 2010-11 to 2017-18)

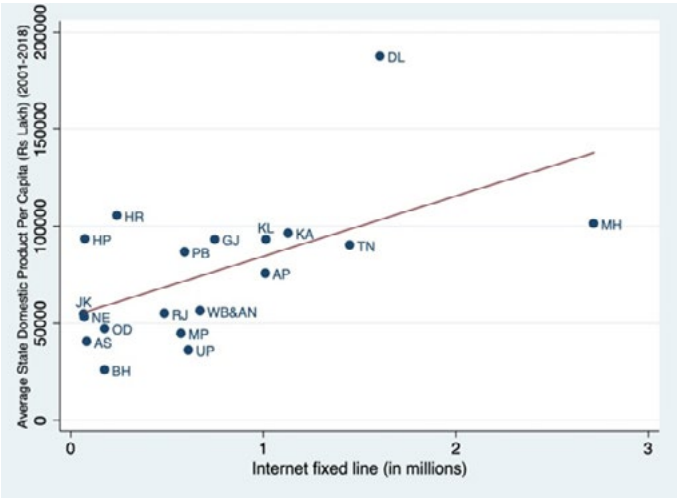
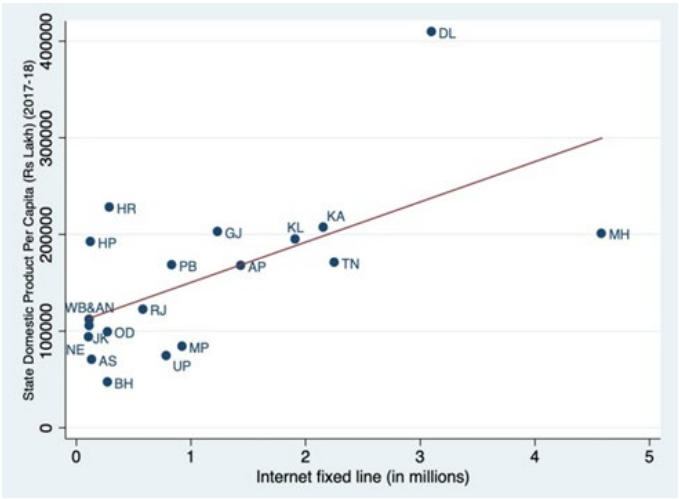


Figure 3.2.2: Correlation between State GDP Per capita and Fixed Internet Subscribers (2017-18)



continue to be robust (Refer Figure 3.2.1 and 3.2.2).

We use data from 2001 to 2018 to estimate the impact of Internet in India using the instrumental variable technique with fixed effects. It is important to note that the estimations are based on data for fixed line Internet subscribers. While they form a miniscule proportion of total Internet subscribers, a bulk of the Internet traffic flows through fixed infrastructure. We elaborate upon this discussion in Section 3.2.1. The Telecom Regulatory Authority of India revised definitions for

Box 3.2.1 Model Specification for Estimating the Impact of Internet Subscribers in India

$LogSGDP\_PC_{it} = a0 + a1Log\ K_{it} + a2Log\ L_{it} + a3\ LogISubit + Di + e_{it}$

i = each of the 19 States t = year from 2001 to 2018

Log $SGDP\_PC_{it}$ is the natural log of per capita income for ith state in year t (This data is from CSO)

Log K_{it} is the natural log of gross capital formation in industries excluding investment in telecom services for the ith state in year t (This data is from CSO and TRAI)

Log L_{it} is the natural log of total number of persons engaged in telecom in the ith state in year t (This data is from ASI)

Log $ISub_{it}$ is the natural log of Internet subscribers in the ith state in year t (Internet subscribers include only the fixed line users of Internet across states. This data has been extracted from Lok Sabha starred questions and TRAI). Data on Internet Subscribers has been instrumented using BTS. The data for BTS was made available by Industry Associations and DoT.

Di represents state dummies

Since we use a log-log form all coefficients are to be interpreted as elasticies.

wireless Internet users in 2012. This break in the series does not allow for the use of a longer panel. The specifications of model are provided in Box 3.2.1

We find that the growth dividends from Internet have increased over time. According to our new

estimates a 10% increase in Internet subscribers results in a 3.2 percent increase in rate of growth of state per capita GDP. The results are provided in Table 3.2.1. The reported standard errors are bootstrapped. Results of the model are provided in Appendix 4.

2.2.1 Impact of Internet Subscribers versus Impact of Internet Traffic

The launch of Reliance Jio coincided with explosion of data usage in India due to a steep fall in tariffs of Internet data plans and increasingly affordable smartphones. These trends are being reinforced with the lowering cost of technology, rising competition in the services market, rise of vernacular content and higher digital literacy. Mobile data usage in India jumped 144 per cent (y-o-y) to 2,360 petabytes, with average consumption per user in 4G broadband reaching 11 gigabyte per month in December 2017[38]. During the period 2012 to 2018, the compounded annual growth rate for Internet usage was 26.4%, while that for subscribers for 24.5%. Using data traffic to estimate impact is an improvement on using subscriber numbers as a proxy because usage could vary across subscribers. With Internet adoption approaching saturation in some countries[39], an assumption of monotonic increase in value (i.e. usage) based on number of users might erroneously overestimate the impact. Internet penetration elasticity is not the same as Internet usage elasticity. The empirical literature on Internet penetration or Internet user elasticity, finds that a 10% increase in broadband penetration can increase GDP growth by 0.9% to 1.5% on average.[40] The corresponding numbers for Internet usage elasticity are significantly lower

An ICRIER study titled *Estimating the Value of New Generation Internet Based Applications in India (2017)* first attempted to measure growth elasticities based on Internet usage (measured by total Internet traffic and mobile Internet traffic) in India. With over 90 percent subscribers accessing the Internet on mobile, India is rightly classified as a mobile first economy. Although Internet use on mobile has increased dramatically in the last few years, according to Cisco data, it continues to contribute less than 10% to global Internet traffic[41]. The proportion of mobile Internet traffic to total Internet traffic in India is much higher than the global average, estimated at 22.9% in 2016[42]. However, traffic cannot be proportionately attributed to time spent. For example, video traffic, which contributed to more than 50% of total Internet traffic, is primarily consumed using fixed line Internet, even if viewed on a mobile device.

The study estimated that 10 percent increase in India's total Internet traffic, delivers on average

38 Nokia MbIT Index 2018 , https://networks.nokia.com/in/mbit-index

39 Internet penetration in United States South Korea, United Kingdom, Japan, Germany, France, Italy, etc. are all over 85%

40 Qiang et al (2009); Koutrompis (2009); McKinsey (2012)

41 CISCO VNI data 2016 https://www.cisco.com/c/dam/m/en_us/solutions/service-provider/vni-forecast highlights/pdf/India_2021_Forecast_Highlights.pdf

42 *Ibid*

43 Kathuria. R, Kedia . M , Varma.G and Bagchi. K (2017). "Estimating the Value of Internet New Generation Based Applications in India", Broadband India Foundation. http://icrier.org/pdf/Estimating_eValue_of_Internetpercent20Basedpercent20Applications.pdf

a 3.1 percent increase in GDP per capita, and a 10 percent increase in India's mobile Internet traffic, delivers on average a 1.3 percent increase in India's GDP[43]. This estimation was based on an instrumental variable regression using panel data for a set of 19 Indian states over the period 2013-2016. When translated into absolute impacts, this implies that a 17 percent[44] increase in total Internet traffic during the period 2015-2016, resulted in an absolute increase of USD 103.9 billion in GDP[45]. This includes direct expenditure on the Internet as well as spillovers into the other sectors of the economy and accounted for about 5 percent of nominal GDP in 2016.

This study was updated in the following year to estimate the economic impact of Internet shutdowns in India[46]. The elasticities for mobile and Internet use were computed using the instrumental variable method adopted earlier. With an additional year of data, the results found that a 10% increase in India's mobile traffic will deliver on average a 1.6% increase in India's GDP per capita and a 10% increase in India's total Internet traffic will deliver on average a 3.1% increase in India's GDP per capita. The returns to mobile data have increased, while that for total Internet use is unchanged. The model specifications and results are provided in Appendix 5.

2.3 Impact of Communications Investment on GDP Growth in India

Disruptive innovations in communications have led to technological convergence. Convergence implies that eventually all voice and data services will belong to a single data stream. Converged networks usually employ the Internet protocol (IP). The National Digital Communications Policy, 2018 (NDCP) also mentions infrastructure convergence for IT, telecom and broadcasting. Revolutionary technologies including 5G and IoT will be supported through converged technical environments. While calibration of impacts for technology type is important, in a converged world it is also meaningful to capture impacts for the overall communications industry (excluding broadcasting). This is possible by developing an index that appropriately captures impacts in a technology neutral manner such as using investment data for the sector. Using investment data we are also able to capture the spillover benefits from say the US$ 100 billion investment envisioned in the new NDCP. What multiplier effects those investments would produce will be of interest to government and business alike because of the far- reaching implications for policy and strategy respectively. Early this year ICRIER engaged in an exercise to measure the impact of investments in communications on GDP growth. Predictably we find a strong degree of correlation between investment in communications and income across Indian states at a point in time as well as for the average income and investments over a period of time (Refer Figure 3.3.1 and 3.3.2). The average is calculated for the period 2000-01 to 2017-18. The positive correlation between income and telecom investment[47] indicates the manifestation of network externalities that drive the growth of other sectors in the economy along with growth in the sector itself.

44 17percent increase in Internet traffic in India is based on linear extrapolation for values between 2011 and 2015 made available by CISCO VNI data

45 This value is given by 0.17 (growth in Internet traffic)*0.33 (growth elasticity) *USD 1,873 billion (Nominal GDP in 2015)

46 Kathuria. R, Kedia . M , Varma.G and Bagchi. K (2017). "Estimating the Value of Internet New Generation Based Applications in India", Broadband India Foundation.

47 In the absence of state-wise data on telecommunication investment, data at the country-level has been distributed across states using state-proportions for BTS installed.

Figure 3.3.1: Correlation between State GDP Per capita and Investment in Communications (Average for 2000-2001 to 2017-18)

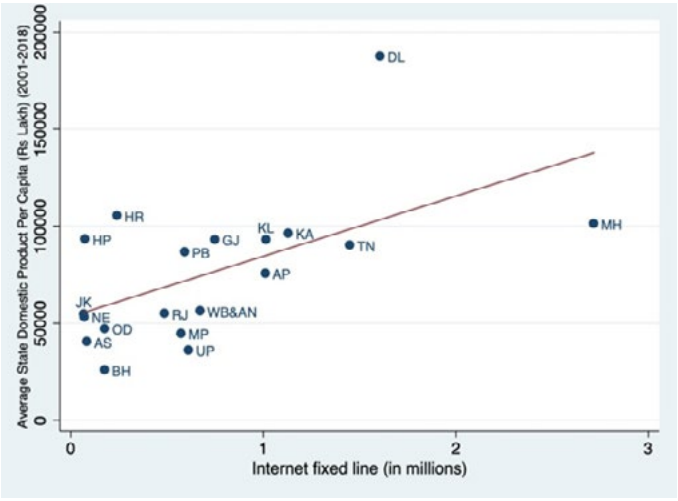
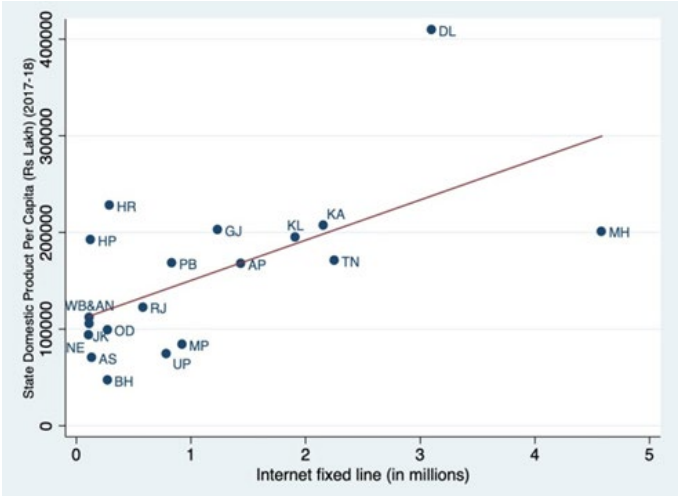


Figure 3.3.2: Correlation between State GDP Per capita and Investment in Communications (2017-18)



Source: Compiled by Author

The econometric analysis estimates the elasticity using data for 19 telecom circles[48] for the period 2010-11 to 2017-18. The start of the sample period marks a departure from the preceding years in that it represents a decisive shift towards data and the corresponding development of data enabled business models. The 3G and BWA auctions in 2010 and subsequent rounds of spectrum auctions and liberalization marked the commercial launch of 3G and 4G technologies. This period was accompanied by a sharp rise in Internet penetration[49] and smartphone users[50]. Such outcomes were a result of several factors including massive investment in communication technologies. Investments in telecom increased at a compounded annual growth rate (CAGR) of 16.3% during 2010-11 to 2017-18. The cumulative investment during this period was Rs. 7,47,652.8 crore amounting to 2.5% of the total gross fixed capital formation for India through those years. The details of the model including assumptions and data sources are provided in Box 3.3.1

The growth dividend estimated by a standard econometric model captures both the direct and indirect benefits of this massive digital investment. The customary instrumental variable technique is used to estimate the investment multipliers. The results show that a 10 percent increase in India's investment in communications has the potential to deliver on average a 3.3 percent increase in India's GDP. The USD 100 billion investment envisioned in the National Digital Communications Policy, 2018 could cumulatively add USD 1.21 trillion[51] (Rs.78, 90,711 crore[52]) to GDP over the duration of the proposed investment. The detailed results are provided in Table 3.3.1 below.

48 State data has been added where necessary. For example, the circles of Mumbai and Maharashtra, Kolkata and West Bengal, UP East and UP West have been aggregated

49 *Internet subscribers grew at a CAGR of 29.2% during the period 2012-13 to 2017-18*

50 *Smartphone shipments increased from 8 million in 2010 to 92.5 million in 2017 (IBEF)*

51 An additional investment of USD 100 billion in telecom would mean a percentage increase of 1.42 percent in total investments. The absolute value is arrived at by multiplying this percentage increase with the GDP in 2017-18 and the estimated multiplier. While estimated at a point in time, these dividends will emerge only over time.

52 Using 1 USD = 65.07 INR

Box 3.3.1 Model Specification, Assumptions and Data Sources for the Impact of Communications Investments on GDP growth

$LogSDPit=\alpha 1+ \alpha 2Log(K/L)it+ + \alpha 3Log(Inv\_{Telecom})it+Di+\varepsilon$

Where 'i' goes across 19 telecom circles[1] of India and 't' runs from 2010-11 to 2017-18

$Log\ SDP_{it}$ is the logarithmic value of nominal state domestic product per capita in rupees lakhs (using the 2011-12 base) for the *ith* circle in year t. Data for this variable has been extracted from the State Series data of the National Accounts (CSO)[2].

$Log\ (K/L)_{it}$ is the logarithmic value of capital intensity as measured by Net Investments (Net of investments in telecommunication) in rupees lakhs for the *ith* circle in year t divided by Total Persons Engaged in the *ith* state in year t. Data on Net Investments has been estimated by subtracting investments in telecom from total gross fixed capital formation in the country and distributed across states using the proportion of capital formation as distributed across states in the Annual Survey of Industries. Data on Net Investments is extracted from the National Accounts Statistics (CSO) and on total persons engaged from the Annual Survey of Industries3.

$Log\ (InvTelecom)_{it}$ is the logarithmic value of investments in telecom. In the absence of circle level data, total Investments in Telecom for India has been distributed using the proportion of BTS installed in each state. Data on total investments in telecom has been extracted from TRAI for the years 2013-14 to 2016-17 and from CSO for the remaining years. Since CSO reports data for BTS data was made available by TRAI.

Di are 19 circle dummies, $\alpha 1$ and ε are the Constant and Error terms respectively

Data for 2016-17 and 2017-18 have been extrapolated where necessary. The logarithmic value of mobile penetration is used as an instrument. Data on mobile penetration has been taken from TRAI's Performance Indicators Report. The instruments shows high correlation with the endogenous variable Log (Inv_Telecom)it Post estimation tests find the instrument and residual term are statistically uncorrelated, establishing the validity for the choice of instrument.

Since we use a log- log model the estimated coefficients will be elasticities.

Note 1: Telecom data for Mumbai and Kolkata have been added to Maharashtra and West Bengal respectively. UP East and UP West have been combined to represent a single circle

Note 2: State data has been aggregated to represent circles

Note 3: State data has been aggregated to represent circles

Table 3.3.1: Results of the Model Measuring Impact of Communications Investment on GDP Growth

Variable	Co-efficient	T- Statistic (P-value)
K/L	.05	1.72 (0.085)
$(Inv_{Telecom})$	.33	16.6 (0.000)
Number of Observations = 151		
R2 - 0.98		
VIF = 6.71		
Bootstrapped Standard Errors to account for heteroskedasticity		

As we set out to do, our results capture the changing nature and magnitudes of telecom spillovers for India. A key insight is the hierarchy in estimated impacts of various telecom technologies, with data dominating voice as we expected. Thus the growth dividends from Internet are significantly higher than mobile (voice). Moreover, while impacts of mobile may have begun to moderate, the impact of Internet is still on the rise. This is because of increasing use of the internet in improving existing business models and notably creating newer ones thus enabling markets to become more efficient. Another insight is that states and regions in India that lag ought to be fast tracked in use of Internet to capture the spillover benefits. In the next section we illustrate micro level impacts of telecommunications in India.

3. Case Studies: Micro-level impacts of Digital Communications

From fixed line telephones to mobile phones to the inexorable demand for smart phones, the Indian journey has been remarkable in that it has revolutionized the entire communications ecosystem. The manner in which communication technologies have transformed the way individuals, businesses and governments function and interact is best illustrated by case studies that range from simple, for resolution of day to day hassles, to bigger and more complex economic and social problems. How distant the seminal study by Jensen (2007) on Kerala's fisherfolk seems can only be understood by the fact that almost everyone now assumes the availability of simple price information via a mobile to be hackneyed. And yet it was a novelty then. The study immutably showed that between 1996-2001, immediately before and after the introduction of mobile phones in Kerala, the prices of fish dropped significantly and yet increased both consumer and producer welfare. The benefits of faster dissemination of information and disintermediation through the mobile device are well and truly embedded in our collective consciousness thanks to the pioneering effort of Jensen. Several studies after that mimicked the idea in different contexts but the results were always the same. Mobile technology had provided a mechanism for addressing a long-standing problem of market failure due to asymmetric information. Smart phones using internet technology do the same and more effectively but need more and better-quality infrastructure, a fact recognized by NDCP 2018.

The use-cases for upcoming technologies such as 5G and M2M oblige fibre infrastructure to develop alongside. While Bharat Net will extend fibre-connectivity to India's 250,000 Gram Panchayats in due course, initiatives such as Bluetown are providing last mile connectivity to close gaps in service provision in India's remotest areas. Bluetown is a managed hotspot service provider

for BSNL which recently set up WiFi hotspots in conflict intensive areas of Jharkhand. Start-ups such as Bluetown are creating a business case for the unconnected which are directly benefitting from door-step connectivity.

Technology has also enabled tackling other reasons for market failure and churned out outcomes that have improved access to basic needs and resulted in better livelihood opportunities. The march of technology is visible in services that have embraced this change. A case in point is IRCTC. As technology evolved, the ticketing system moved from physical counters to a web-based portal and most recently to a mobile app. About 70percent of passenger bookings are now made on the Internet and it takes 11 seconds on average to complete a transaction online[53]. Compare this with the hours spent in pointless queues to book tickets in the antiquated manual system that generated middlemen and inefficient rent seeking. Digitisation has helped bridge several systemic inefficiencies, inspired confidence in society towards the state-in this case passengers are a far happier lot especially those who had dealt with the manual booking system. Technology can enable chipping away at the trust deficit between the passengers and Indian Railways, between the civil society and the state.

The meteoric rise of telecoms in India also manifests in impacts at the grassroot-level that is often not captured in data because it is hard to translate into a numerical figure. Technology has successfully tackled challenges at the bottom of the socio-economic pyramid. Financial services, health care, education, retail and e-governance services have especially benefitted from technology interventions.

53 Based on inputs from stakeholder interview at CRIS

Financial Services: From physical banking to automated teller machines and more recently to mobile banking and online transactions, the sector has evolved over time. Mobile applications like Paytm have now become commonplace, enabling consumers to execute a host of financial transactions - recharging mobile phones and metro cards, paying electricity bills, transferring money, etc. through their mobile phone. Digital money and mobile wallets have eliminated the cumbersome task of handling cash to a large extent. In the post demonetisation period over 6-7 million merchants were added to the digital payments ecosystem.[54] India's mobile wallet market is forecasted to reach $4.4 billion by 2022, with a CAGR of more than 148percent[55].

Public sector interventions in fintech have been transformational. The government's Bharat Interface for Money (BHIM) program has been downloaded by close to 32.42 million users[56]. With 92 banks registered on the network in June 2018 the volume of transactions through BHIM amounted to Rs 6261.25 crore. Jan Dhan bank accounts linked to Aadhar identities and available on the mobile phone (JAM trinity) has facilitated the mass creation of bank accounts that disintermediated subsidy transfers. The government's Direct Benefit Transfer (DBT) scheme facilitated through JAM has significantly expanded and plugged leakages up to Rs. 82,985 crores, since its launch.[57] Technology has also created an opportunity for design of innovative financial instruments. New technologies such as blockchain, are being leveraged to achieve financial inclusion targets. They also have the potential to streamline land records, asset registries, auto records, voting records, national identities, financial transaction records, etc., the traceability of which can rid the informal sector from the perils of corruption.[58]

Healthcare: Healthcare services have undergone a significant facelift with the adoption of communication technologies. It is now possible for patients to seek prior appointments online and even avail of online consultation. With the development of applications like Practo, the accountability of doctors has increased as they can be reviewed on the internet by patients and their credentials are listed for public viewing. It has become much easier to find specialised doctors in and around one's area of residence. Additionally, other facilities like online ordering of medicines, details of

54 Kathuria, R. et al., 2017. Estimating the Value of New Generation Internet Based Applications in India.

55 Singh. B (2018). "Blockchain: India is headed for a fintech revolution this year", Economic Times https://economictimes.indiatimes.com/news/economy/policy/blockchain-india-is-headed-for-a-fintech-revolution-this-year/articleshow/62478932.cms

56 Press Trust of India (2018). "BHIM Download crosses 17 million downloads, https://www.npci.org.in/bhim-analytics

57 Sharma. A (2018). "Savings from direct benefit transfer pegged at Rs 83,000 crore , Economic Times https://economictimes.indiatimes.com/industry/banking/finance/banking/savings-from-direct-benefit-transfer-pegged-at-rs-83000-crore/articleshow/63423528.cms

57 Singh. B (2018). "Blockchain: India is headed for a fintech revolution this year", Economic Times https://economictimes.indiatimes.com/news/economy/policy/blockchain-india-is-headed-for-a-fintech-revolution-this-year/articleshow/62478932.cms

medicines online such as its composition, side effects etc. help in bridging the information gap between caregivers and receivers. Practo has nearly 200000 registered doctors on its database, and nearly 25percent of its traffic from tier 2 and tier-3 is directed towards easier access to medical facilities in bigger cities with better medical facilities.[59] The app has provided doctors and medical practitioner's greater visibility and access to a wider client base.[60] Additionally, by allowing people outside India to book appointments in the country with ease, Practo has helped promote medical tourism in an unprecedented way.[61]

Another major innovation in this sector is Telemedicine. India's telemedicine market has been growing at a CAGR of over 20percent and is slated to cross $32 million by 2020, according to a study by ASSOCHAM.[62] This can particularly help those living in rural areas by facilitating access to qualified healthcare providers, timely diagnosis and effective course of treatment that can help bridge the disparity in healthcare services between urban and rural areas.[63] At a more grassroots level, telemedicine is helping spread awareness and remove stigma against mental health and facilities such as e-psychiatry is helping many discover a new lease of life. One such example is that of Schizophrenia Research Foundation (SCARF) Telepsychiatry which is an initiative to increase public awareness of mental disorders in rural areas with the use of video-conferencing facilities between the doctor and the patient. In 2010, the program was expanded, with the help of Tata Education Trust to cover the district of Pudukottai in Tamil Nadu.[64] Their mobile unit covering two taluks or counties encompasses 156 villages with a population of about 300,000.[65] At present the focus of the service is only on those with serious mental disorders and about 1500 people have availed of the services offered under the program in Pudukottai.[66] Such interventions are leveraging communication technologies to take basic healthcare services to the remotest areas of the country and thus improving access and aiding in the upliftment of the underprivileged.

59 Op Cit, 4

60 Ibid

61 Ibid

62 Reddy. V(2018). "The boom in digital healthcare is India's opportunity to build global telemedicine companies",Yourstory,https://yourstory.com/2018/01/boom-digital-healthcare-indias-opportunity-build-global-telemedicine-companies/

63 Ibid

64 http://www.scarfindia.org/tele-medicine/

65 Ibid

66 Ibid

Education: The fundamental enabling feature of any communication technology is to provide information. Advancements in communications technology has enabled information to be taken to its complex and structured form: education. It is quite rare for those users of the Internet to not be touched by the utility of a website such as 'Coursera', 'Khan Academy' or 'Byju's', some of the more prominent Massive Open Online Course (MOOC) websites. Large depositories of knowledge, which are open for all and made easy to access is a stepping stone towards a prosperous knowledge society. Pushing towards such a knowledge society, the government rolled out 'Swayam', an online education platform that offers courses from class 9 onwards up to courses at the postgraduate level. Relatedly, the National Digital Library of India, offering 12 million e-books and other items in over 100 languages to its current 1.2 million registered users, allowing users to access immensely useful resources for a fruitful education. There are several other initiatives at the grassroots level. One such example is GIS@School which is a crowdsourced, android-based mobile application and has been implemented across 12500 government schools across the state of Madhya Pradesh. It aims to create comprehensive planning for governance of schools to comply with RTE Act 2009. Over 1300000 geotagged photographs of existing, missing, dysfunctional infrastructure in schools, such as drinking water, separate toilets for boys and girls, clean kitchens etc. have been uploaded on the app and this database is then used to prepare status reports on compliance with the Right to Education (RTE) in schools. In addressing problems of physical infrastructure in educational institutions, communication technology interventions are thus helping educational facilities become more widespread and accessible.

Retail: In no other sector do communication technologies get the limelight more than the retail sector. The phrase '...at your fingertips' is emblematic of the retail revolution enabled by advancements in communication technologies. Visiting brick and mortar stores to evaluate product options, quality and eventually price differences are all done over a mobile phone using the Internet, and with greater speed and efficiency: consumers are met with their diverse demands

at lower than store prices, and at their doorstep. India's e-commerce wave is massive, with 500 million new consumers to join, contributing Rs. 3.44 lakh crores to the sector[67]. The virtues of well known e-commerce platforms such as Amazon or Flipkart are felt across so widely as to not warrant an exposition here. However, certain retail initiatives aided by communication technologies exert considerable influence on sectors such as Agriculture, considered to be the backbone of our economy: private sector initiatives such as Big Basket aim to connect farmers to customers and provide fresh farm products, whereas government initiatives such as e-RAKAM that arose in the context of unsold stock of pulses aims to connect farmers from remote parts of the country to large, global markets and is expected to not just increase farmer incomes, but cut down wastage of stock. The WTO estimates that with e-commerce measures and green logistics corridor, India can boost its agriculture exports from the current USD 38 billion to USD 60 billion by 2022[68], a sign of the wide-ranging potential of communication technology to positively affect the economy.

E-Governance: India has been vastly improving its E-Governance capabilities: According to the latest UN government survey rankings, India transitioned from middle EGDI level group (E-Governance Development Index) to high EGDI level group. From 2013-2018, Government to citizen (G2C) transactions grew by 2912percent. Among the top transactions over government services include UIDAI (8 billion approx.), Kisaan SMS portal (900 million approx.), and e-Courts (450 million approx.)[69]. By its very nature, communication technology is central to a functioning democracy, not just through bridging distance between people, ideas, and markets, but also by making the government's services to its people more accessible and accountable. The centrality of communication technologies to our society can be understood by the fact that such technologies enable good governance and the enforcement of citizen rights: Importantly, the Right to Information act was conceivable only due to presence of capable communication technologies, whereas online portals such as myGov.in, launched in 2014, aim to crowdsource ideas for good governance from citizens. Aside from bridging gaps between the government and the citizen, communication technologies help tackle bureaucratic inefficiencies. Whereas heavily bureaucratized processes such as obtaining a passport has been transformed into a seamless process through online *Passport Seva* facilities, platforms such as UMANG aim to transform the

67 Sheth. A, Anandan. R , Kudva. R et al. (2018)." Unlocking Digital for Bharat $50 Billion opportunity",Bain and Company, Google and Omidyar Network, https://www.omidyar.com/sites/default/files/ Unlocking%20Digital%20For%20Bharat_Final.pdf

68 Press Trust of India (2018), "Green Logistics Corridor, E-commerce to Boost Exports by 2022, Says Agriculture Minister",News18 https://www.news18.com/news/business/green-logistics-corridor-e-commerce-to-boost-exports-by-2022-says-agriculture-minister-1827123.html

69 Kamal. S.(2018). "How The States Stack Up On E-Governance Reforms", Swarajya https://swarajyamag.com/economy/how-the-states-stack-up-on-e-governance-reforms

very nature of bureaucracy by making available all of the Government's services under a single online portal accessible from desktops, tablets, and smartphones.

Innovation in communication technology is a continuous process and newer technologies like 5G, M2M, artificial intelligence etc. are gradually overtaking the communications ecosystem and older technologies find themselves fading into obsolescence. India is witnessing the transformational potential of communication technologies across a wide range of sectors, changing the way its citizens are conducting their daily lives, and for good. By maintaining the necessary ecosystem that such dynamic, and evolving communication technologies demand, India will witness the full utilization of its creative potential, and consequently enable its people to lead the lives they aspire for.

We developed a framework for case study selection and case study analysis that illustrates the impact of communication technologies on different sectors of the economy. The communications technology has been categorized into three types – wireless voice or mobile, Internet (wireless or fixed line and Machine to Machine (M2M)/ IoT. The sectors included in the analysis are health, education, agriculture, e-governance, financial services, women empowerment, transport/logistics and security services. Some cases lie at the intersection of sectors, such as Kilkari, which covers both Health and Women Empowerment sectors. The case studies collectively represent a host of technology applications that are benefitting individuals and businesses. We have adopted a useable categorisation to think of impacts across four broad categories. These are (i) improved access to services and information, (ii) improved efficiency and accountability, (iii) improved income and standard of living and (iv) enable employment generation.

Each case study selected generates one or more of the above-mentioned impacts. We rank the impacts on a scale of 1 to 4, with 1 highlighting the most direct impact generated by the intervention and 4 for the least direct. Some considerations taken into account while assigning a rank to each

case study under this four category-framework include comparing the sheer scale of employment generation capability of the given cases vis-à-vis each other, on the basis of the direct employment they have created and their positive effect on income generation across the value chain relevant for their operations. For instance, Ola's ability to generate employment for a large swathe of drivers across urban India place it at an advantage against a case like the Chennai Flood Map, which largely utilizes crowd-sourcing techniques which require minimal captive, paid, manpower. Moreover, the quality of the web or app interface for each case was analysed and compared amongst each other, in terms of the ease of accessing information/ service. By and large, through a process of elimination, several cases were disregarded and the eventual selection of case studies all rank well on this front. Furthermore, secondary accounts and media reports relating to the efficiency and accountability, as well as the capacity of each case to impact income and the standard of living / quality of life were accessed and utilized while assigning ranks. An example of a highly ranked case on this parameter is the IRCTC next-generation E-ticketing system which has been widely acknowledged to offer very high quality user interfaces and has had an overwhelmingly positive impact on the quality of life of millions of Indians. Each of the 14 case studies is presented in the framework (Table 4.1) and tabulated later (Appendix 6) to detail the type of communication technology used, objective of the intervention and impact on the sector.

Table 4.1: Framework for Selection of Case Studies

Case Study	Communication Technology	Sector	Impact			
			Access to Services and Information	Efficiency and Accountability	Income and Standard of Living	Employment Generation
GIS@School			1	1	2	3
Big Basket			1	1	2	2
HawkEye			1	1	2	4
Kilkari			2	4	1	1
Shipsy			1	1	4	4
IRCTC Next-generation E-ticketing system			1	1	4	4
Ola			1	2	1	1
Byju's			1	1	2	3
GoBolt			2	1	2	2
Zomato			1	2	1	1
MakeMyTrip			1	2	1	3
Chennai Flood Map			1	1	3	4
Practo			1	2	1	3
Paytm			1	2	1	3

Communications Technology: Wireless Voice; Internet; IoT/M2M

Sector Health Education Agriculture E-Governance Women Empowerment Financial Services; E-Commerce Transport/ Logistics/Urban Services Security

4. Conclusions

Digital communications has emerged as critical to a country's growth and well-being and this study has shown why. As a corollary, India could use communication technologies especially in laggard regions to overcome the significant infrastructure and service deficits that continue to persist. India also stands to benefit from new digital technologies and platforms that unlock productivity and tap the opportunities in newer markets. India's digital footprint is rapidly expanding. India's mobile data consumption is already amongst the highest in the world. A recently concluded survey by RailTel and Google[70] found that at least 75 lakh users consumed more than 7,100 of terabytes (TB) of data in April 2018 at 370 railway stations compared to 1600 TB data consumed by 60 lakh people at 110 railway stations in March 2017. Over 200 million Indians regularly use social media and in the last year alone, over 200 million Indians took to mobile banking and digital payments. At the current pace of digitalisation, it is estimated that India's digital economy has the potential to reach one trillion USD by 2025.[71]

In order to avail opportunities presented by the fourth revolution, India must invest in good quality communications infrastructure along with an enabling regulatory framework. There is a strong case for improving physical infrastructure that supports productivity, both as part of the development process and for the 270 million Indians who live in poverty. According to the most recent estimate, the BharatNet program has laid 2, 92,686 km of optical fiber that connects over 1.2 lakhs Gram Panchayats. However, much of this infrastructure remains unutilized. Given the scope and ambition of the BharatNet programme, successful deployment must necessarily be collaborative between the Centre and the States and between the public and private sectors.

The headline result of our study demonstrates that while growth multipliers for different measures of digital communications vary in magnitude, they are positive everywhere and every time. While the impacts of mobile may have begun to moderate, the impact of Internet is still on the rise. This is because of increasing use of the internet in improving existing business models and notably creating newer ones, thus enabling markets to become more efficient. The National Digital Communications Policy, 2018 focuses on the deployment of emerging technologies such as 5G and IoT to build an inclusive digital society for India. It highlights the large financial investments necessary to achieve the goals stated in the policy. The multiplier effects of investment in communications implies that the USD 100 billion investment envisioned in the new policy could cumulatively add USD 1.21 trillion (Rs.78, 90,711 crore) to GDP over the duration of the proposed investment. These are significant impacts and yet could be underestimates given that penetration of internet is still below international levels. The substantial network effects due to internet will become pronounced with rising Internet penetration. India needs internet to be deployed in unserved and underserved area and its quality (read speed) improved in the served regions. That will allow digital India to become a reality.

70 Google completes RailTel WiFi project; to focus on city WiFi projects, https://telecom.economictimes.indiatimes.com/news/google-completes-railtel-wifi-project-to-focus-on-city-wifi-projects/64492147

71 National Digital Communication Policy, 2018 http://www.dot.gov.in/sites/default/files/Final%20NDCP-2018_0.pdf

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Appendix 1: Selected Studies on Estimation of Growth Dividends from Telecommunications

Author	Year	Dependent Variable	Impact Estimate	Statistical Note	Countries
ITU	2009	Broadband Penetration	A 10percent increase in broadband penetration raises per-capita GDP growth by 0.3-09 percentage points	A simultaneous approach by the jointly estimated supply and demand with a production equation	15 European Union (60 observations)
World Bank	2009	Broadband Penetration	(i) In high income economies a 10percent increase in broadband penetration yielded an additional 1.21 percentage points of GDP growth. (ii) A 10 percent increase in broadband penetration yielded an additional 1.38 in GDP growth in low and middle income countries.	Four-equation simultaneous model (namely, the output equation or economy wide production function; demand function for telecommunications; equation determining investment in telecommunications infrastructure; and equation relating investment to increased rollout) used by Röller and Waverman (2001).	(1980-2002 for 66 high income countries) and 120 countries (low and middle income)
OECD	2009	Broadband Penetration	A 10percent increase in broadband penetration raises per-capita GDP growth by 0.9-1.5 percentage points	Macroeconomic production function with constant returns to scale and the three inputs physical capital, human capital, and labor.	(25 OECD (300 observations)
ICRIER	2009	Mobile Penetration	a 10percent increase in mobile penetration delivers, on average 1.2percent increase in GDP	Simultaneous Model	Telecom circles/ states in India

Contd...

ITIF	2009	broadband Investment	broadband deployment aimed at increasing household adoption from 60percent to 95percent, requiring an investment of USD 63.6 billion results in Total jobs: 1.2 million (including 546,000 for construction and 665,000 indirect)	Input-Output Model	
Katz et al. (Germany)	2010	broadband penetration growth	for each 10percent increase in broadband penetration growth, GDP growth increases by 0.255	Input-Output Model	data from 424 German Landkreise
Ericsson (NASDAQ:ERIC)	2010	Broadband Penetration	a 10 percentage point increase in broadband penetration GDP increases by 1 percent.	Input-Output Model	33 OECD countries
Ericsson (NASDAQ:ERIC)	2011	Broadband Speed	Doubling the broadband speed for an economy increases GDP by 0.3percent.	Input-Output Model	33 OECD countries during the period 2008-2010 from OECD database Ookla for broadband speed data
Feng and Ma (China)	2013	Broadband Penetration	Every 10 percentage point increase in broadband penetration there was a 2.14percent increase in GDP.	simultaneous equation model	Administrative data covering 31 provinces, municipalities and autonomous regions in China from 2004 to 2009.
European Investment Bank (EIB),Bohlin, Rohman (2014)	2014	Braodband Speed	An increase in broadband speed leading to an increase in GDP; however, these exact numbers of the coefficients should be interpreted with caution The causality of high speed broadband and economic outputs in all the models shows that the results are robust and that broadband speed does matter	Simple OLS estimation (with country dummy) & instrumental variable approach (using fiber ratio as an instrument for broadband speed) are added for checking robustness of the results	Lower and higher income OECD countries 2008-2012, World Bank, OECD, Ookla, the Heritage Foundation

Source: Compiled by Author

Appendix 2: Data definitions and Data Sources for the Model Estimating the Impact of Mobile Penetration in India

1. **Per Capita State Domestic Product (SDP):** This is an approximate estimation of the value of goods and services produced per person in the state and is equal to the State GDP divided by the population of the state. The Directorate of Economics and Statistics prepares the estimates of Gross/Net State Domestic Product and Per Capita State Domestic Product at current and constant prices any years as per guidelines of Central Statistical Commission (CSO) covering all sectors of the economy. Besides estimates for the current year, previous year estimates are also revised on the basis of latest availability of data. For our analysis, we use the new series of per capita Gross State Domestic Product at current prices from CSO and divide by the state population, data for which has also been collected from CSO (accessed in 2016)
2. **Capital:** This includes value of investments in telecom. In the absence of circle level data, total Investments in Telecom for India has been distributed using the proportion of BTS installed in each state. Data on total investments in telecom has been extracted from TRAI for the years 2013-14 to 2016-17 and from CSO for the remaining years (2000-2013). Since CSO reports data for BTS data was made available by TRAI.
3. **Human Capital:** This involves data relating to the number of person engaged in industries taken from Annual survey of India (ASI).
4. **Mobile Phone Penetration (per 100 persons):** This data includes both GSM and CDMA subscribers. This is collected from various published sources and TRAI.
5. **Price of Mobile:** This is proxied by Average revenue per user of Mobile. This is collected from TRAI and COAI.
6. **Subscriber fixed Line:** This is collected from TRAI
7. **Geographical Area (per sq. Km):** This is collected from Census of India, 2011.

Note: Data for state per capita income has been aggregated for a few states: North East includes Arunachal Pradesh, Tripura, Mizoram, Meghalaya, Nagaland and Manipur; Uttar Pradesh includes Uttar Pradesh and Uttarakhand; Madhya Pradesh includes Chhattisgarh and Madhya Pradesh; Maharashtra includes Goa and Maharashtra; Bihar includes Jharkhand and Bihar; Tamil Nadu includes Tamil Nadu and Puducherry, West Bengal and A&N Islands include West Bengal, Sikkim and A&N Islands; and Punjab includes Punjab and Chandigarh using weighted averages , weights being the state population. Data for 2017-18 has been extrapolated wherever data was missing.

Appendix 3: State Categorization on the basis of Per Capital State Domestic Product and Mobile penetration in 2017-18

State Domestic Product	
Developed	**Developing**
Maharashtra	Jammu and Kashmir
Punjab	Assam
Tamil Nadu	Bihar
Karnataka	Uttar Pradesh
Andhra Pradesh	West Bengal
Delhi	Madhya Pradesh
Gujarat	Rajasthan
Haryana	North-East States
Himachal Pradesh	Orissa
Kerala	

Mobile Penetration	
Over penetrated	**Under penetrated**
Jammu and Kashmi	Assam
Punjab	Bihar
Tamil Nadu	Uttar Pradesh
Karnataka	West Bengal
Kerala	Madhya Pradesh
Delhi	Rajasthan
Gujarat	North-East States
Himachal Pradesh	Orissa
Maharashtra	Andhra Pradesh
	Haryana

Appendix 4: Results for the Econometric Model on Internet Subscribers

logsdppc	Coef.	Std. Err	z	P>|z|	[95% Conf. Interval]
Log(Internet)	.3173946	.0349845	9.07	0.000	.2488262 .3859631
Log(Labour)	.4576299	.0521794	8.77	0.000	.3553601 .5598997
Log(Investment excluding Telecom)	.1053229	.0214275	4.92	0.000	.0633257 .1473201
Constant	8.436859	.3013263	28.00	0.000	7.84627 9.027448
Instrumented: loginternet					
R-sq: within = 0.8892					
Between=1.0000					
Overall=0.9277					
corr(u_i, X) = 0 (assumed)					
Number of Observation =270					
Number of groups =19					
Observation per group: min=12					
Average =14.2					
Max=15					
Wald chi2(21) = 3243.61					
Prob > chi2 = 0.0000					

Appendix 5: Results for the Econometric Model of Mobile Internet Traffic and Total Internet Traffic

Log GDP_PCit $= \alpha + \beta$Log (K/L)it + νLog (MobileInternetTraffic)it + Di + ε (i)

Log GDP_PCit $= \alpha + \beta$Log (K/L)it + νLog (TotalInternetTraffic)it + Di + ε (ii)

where i goes across 19 telecom circles of India and t runs from 2012-13 to 2016-17

In equation (i),

Log GDP_PC_{it} is the logarithmic value of nominal state domestic product per capita in rupees lakh (using the 2011-12 base) for the *ith* circle in year t. Data for this variable has been extracted from the State Series data of the National Accounts (CSO).[2]

Log $(K/L)_{it}$ is the logarithmic value of capital intensity as measured by net investments (Net of investments in telecommunication) in rupees lakh for the *ith* circle in year t divided by total persons engaged in the *ith* state in year t. Data on net investments has been estimated by subtracting investments in telecom from total gross capital formation in the country and distributed across states using the proportion of factories as distributed across states. Data on net investments is extracted from the National Accounts Statistics (CSO) and on number of factories from the Annual Survey of Industries. Labour is measured using data on state-wise higher education enrollment[3].

Log $(MobileInternetTraffic)_{it}$ is the logarithmic value of mobile Internet traffic in petabytes per month for the ith circle in year t. In the absence of circle level data, mobile Internet traffic for India has been distributed using the proportion of adjusted gross revenue accruing to each circle. CISCO VNI made data on total Internet traffic in India available and data on adjusted gross revenue was extracted from TRAI's Financial Reports.

Di are 19 state dummies, α and ε are the constant and error terms respectively

Results of the Instrumental Variable Regression

State GDP_PC		
Log(Capital/ Labour)	.2 (3.04) .	.15 (3.24)
Log(Mobile Internet Traffic)	0.16 (30.95)	
Log(Total Internet Traffic)		0.31 (26.47)
Constant	10.8 (54.17)	10.1 (66.88)
The double log specification implies that the coefficients are elasticities (Numbers in parentheses are t-statistics, denoting significance of over 95% for each variable)		
Fixed effects	Yes	Yes
R-squared (within)	0.94	0.95
R-squared (between)	0.23	0.1
R-squared (overall)	0.28	.16
Number of observations	95	95

Appendix 6: Summary of Case Studies

Name	Objective	Impact
GIS@School	• Crowd-sourced, android-based mobile application. • Aims to create comprehensive planning and governance of schools to comply with RTE Act 2009.	• Implemented across 12500 government schools, in the state of Madhya Pradesh. • Over 1300000 geo-tagged photographs of existing, missing, dysfunctional infrastructure in schools, such as drinking water, separate toilets for boys and girls, clean kitchens etc. • Database used to prepare status reports on RTE compliance in the school
Big Basket	• Online grocery megastore catering to 4 million customers • Provides branded items, fresh fruits, vegetables, dairy and other food products to customer's doorstep. • Direct sourcing from farmers • Digitization of farm management for traceability of organic produce and packaging standards	• Strengthened back-end farmer supply chain • Reduced wastage due to stronger supply-chain infrastructure • Reduced prices due to digitized farm and supply chain management • Increased farmer incomes by 10-15percent
Hawk Eye	• A mobile app that aims to turn citizens into citizen police to check crimes, curb unlawful activities and curb traffic violations • Other services include: pinpoint hovering for SOS, traffic alerts, monitoring police performance, integration of stolen car and mobile data	• Over 3.5 lakh users in coverage area (Telangana) • Increased citizen confidence; Winner under 'innovative use of mobile technology in E-governance' at the National E-Governance Conference, 2017
MIS for State Finance Commission	• Web-based application that standardizes and stores data on revenue, expenditure, assets, disbursal of funds to local bodies from the State finance commission • Covers all local bodies in Assam with access to Internet	• Public access to data on State finance commission and local bodies financial performance • Transparency in functioning of local bodies • Ease of monitoring and enhanced service delivery • Information on fund transfer and Utilization certificate generated on web portal
Kilkari	• Free weekly, time-appropriate audio messages about pregnancy, child birth, and child care directly to family's mobile phones from second trimester of pregnancy until the child is one year old. • Objective is to improve family health, planning, maternal and child health, nutrition, sanitation-by generating demand for healthy practices • In Bihar, it is billed at Rs.1 per week	• Requests to subscribe to Kilkari touched 1,68,846 in 3 years, • 31,75,261 calls made to families subscribed to Kilkari • As a National-Scale up project, Kilkari eventually was rolled out across India
Shipsy	• Software and analytics solutions stack catering to the logistics industry • Solutions transform firm operations such as email, phone and pen-paper tasks and into digital operations. • Digitized operations then used to generate data and business insights	• Accessible logistics and customer-based solutions • Enhanced efficiency due to solutions based on machine learning algorithms • Precision due to data driven decision making
IRCTC Next-generation E- ticketing system	• Next generation E-ticketing system with enhanced performance and seamless access at peak hours • Aims to be user-friendly and flexible to business-rule changes • enhanced Internet capacity of system to handle 7200 tickets per minute with 1,20,000 concurrent connections at any point in time	• Increased annual ticket sale from 68 lakhs in 2006-07 to 19.92 crores in 2015- 16 • 59percent of reserved tickets are booked online • achieves maximum concurrent connections of 5,43,255 • Average of 10 lakh passengers receiving bookings per day

Ola	• Taxi aggregator that integrates city transportation for customers and drivers onto a mobile technology platform • Aims to offer a convenient, transparent, and quick service fulfilment.	• The company averages a total of about 150,000 bookings per day and has the highest market share in India of 60percent • It has expanded to a widely distributed network which comprised of 200,000 cars across 85 cities. • These 85 cities include all the metropolitan cities and various important cities in it.
Byju's	• Addresses the need to improve the understanding of fundamental concepts among young students in their formative years • Focusses especially on smaller cities that do not provide quality education infrastructure • Aims to eradicate rote learning	• Most of BYJU's students come from out-side the top ten cities. The app enables students to track their learning curve. • Developing world class content in education by collaborating with child psychologists and graphic designers • The impact of BYJU's is mostly in terms of their innovative learning techniques. their video lectures are designed in a way that breaks down complex concepts into simpler issues and explained. The videos also have children of similar age groups explain certain concepts, which help students identify with what is being taught and increases the acceptability of the content.
GoBolt	• Cloud based platform founded as a logistics startup focused on short and long haul operations • Platform provides all the transportation solutions such as right vehicle selection, route/ delivery planning, real-time tracking, reliable documentation and control, reduced transit time • Harnesses data analytics and IoT to offer these services, ensuring high asset utilization, efficiency and scale	• The organisation's tech platform 'Launch Pad' has more than 5000 empanelled trucks • Each truck engages a minimum of 3-4 workers, offering them competitive salary structure and training modules related to safety and security
Zomato	• Aggregator for restaurants services • Restaurant discovery and online food delivery company • Also used by consumers to discover, rate, and review restaurants, as well as create their own personal networks of fellow food enthusiasts for trusted recommendations	• 22-23percent month-on-month growth in 2017 • Used by 50 million users everyday in over 10000 cities across 24 countries • Increased restaurant supply available from 12000 restaurants in 2016 to 18000 in 2017
MakeMyTrip	• Roughly 40percent of travellers in India do not book in advance due to distrust in third parties. Among the bookings made online, 50percent-55percent are corporate bookings. • This trust deficit that slows the market for online travel in India. Personalisation, curation and quality assurance are some services that MMT sought to deliver in order to overcome the trust deficit. • Services available include booking air tickets, hotels, buses, IRCTC-authorized railway tickets, cabs as well as holiday packages. Air tickets, hotels and holiday package bookings serve both domestic and international travel	• Online bookings accounted for $3-$4 billion in a $33 billion market in 2010. In 2016, the comparable numbers were $13 billion in a $47 billion market. MMT is a leader of the growing online travel market in India. • • For MMT there have been 39percent more bookings by In- dian travelers in April-July 2017 as compared to the same period in 2016. Mobile transactions at MMT grew 1.3 times in the period July – Dec 2016 versus same time in 2015 and constituted 57percent of the total transactions versus 38percent same time last year. • Mobiles have given customers the flexibility to make bookings on-the-go as well as make spontaneous travel plans. the mobile app accounts for 75percent of the total International and Domestic Hotel transactions.

Chennai Flood Map	• While each citizen was aware of the situation in his/her own locality, the crowd-sourcing feature of the map helped in gathering information about inundated areas across the city. • Using the map, several NGOs were able to identify high-risk areas, coordinate relief supplies and deliver them to those in need. It gave volunteering groups and NGOs real insights into the affected areas. • Chennai Flood Map exemplifies the use of open source mapping as a facilitator of civic participation on a massive scale and community action during natural disasters.	• Chennai Flood Map got over 1 million views in a two-week period. • The map showed around 1515 inundated roads within 24 hours of its operations. • After the map went viral on social media, at peak load, they received 1500 requests per second. • A crowd sourced website called chennairains.org became the epicenter for all information and relief activities, including adding requests for rescue, offers for shelter, food etc. other Indian internet firms Practo, Zomato, Paytm and Ola pooled together relief measures.
Practo	• Aims to address the information asymmetry in the health care industry, especially related to quality of doctors in different localities. • Practo started with the addressing the market need on the supply side, and made inroads into the medical practitioners, clinics, and hospitals with their practice management software called Practo ray, that aided in digitization of medical records and data bases. • On the demand side, it began the Practo platform for finding doctors in a particular area, with feedback from their patients and the ability to fix appointments on through the platform. Practo has also added a number of services such as home delivery of medicines, providing healthcare related content	• Nearly 200,000 registered doctors on its database. • Nearly 25percent of its traffic is from tier-2 and tier-3 cities illustrating improved access to medical facilities in smaller towns. • The feedback and rating system has created more transparency in identification of doctors and the follow on consultations • The online consultation feature enables doctors to see more patients in a day, and also enabled patients to consult doctors with ease for minor ailments. Increasing the efficiency of health care services in a country that suffers from limited health care facilities
Paytm	• To address the lack of digitization in payment processing and the hassle of making payments using the credit/debit card in case of non- cash transactions. • Paytm provided that platform where payments and transactions were being routed through the most widely adopted device – smartphones, thus enabling on-the-go transactions and transfer of money without the hassles of carrying money in the form of either cash or cards.	• Paytm has scaled to over 220 Million registered users. • Mom-and-Pop stores that cannot afford to accept card payments due to high costs of purchasing machines and associated items can easily accept online payments via Paytm. This was especially true for protecting sales of kirana stores in the post-demonetisation period. • Reduces cost of carrying cash and increases convenience of transacting and even transferring money.

Source: Compiled by ICRIER from stakeholder interactions, company websites and media reports


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