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The telecommunications divide among Indian states

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ABSTRACT

Using data for 16 major states in India from 2001 to 2015, this paper examines the patterns, distribution dynamics, and the drivers of telecommunications (telecom) services across different states. We apply both parametric and nonparametric econometric techniques to study the distribution dynamics of telecom services across the states. Further, we employ the generalised method of moment (GMM) to examine the determinants of telecommunications services in India. Our results indicate that the interstate gap in telecommunications services has been declining over time and there is a tendency for convergence in teledensity towards the national average. The regression analysis suggests that per capita income and network externality are significant determinants of teledensity across states in India. Furthermore, literacy rate and relative size of the service sector are independently significant predictors of teledensity. If we consider rural and urban areas separately, there are some important differences. For example, while the interstate gaps in telecom services in rural areas seem to have declined, there is little evidence of such a tendency in urban areas. However, the regression results with respect to the importance of per capita income and network externality for telecom services are robust to the rural-urban divide and to the inclusion of additional explanatory variables. The findings of this study have important policy implications.

1. Introduction

Telecommunications (or telecom) services are essential for accessing and reaping the benefits of modern information and communications technology (ICT). As technologies get integrated and a wide range of services (telephone service, messaging, the Internet, music, movie, radio) are being delivered through a single device, the demand for telecom services increases by leaps and bounds. The economic growth enhancing effect of ICT in general and telecom in particular has been documented in the economics literature. For example, according to Leff (1984), modern telecommunication facilitates faster transmission of information which eventually promotes overall economic development by reducing transaction and information cost. A well-developed telecommunication infrastructure improves efficiency in an economy by reducing information asymmetry among producers and consumers (Abraham, 2007; Eggleston, Jensen, & Zeckhauser, 2002; Sen, 1994). Studies by Lam and Shiu (2010) for European countries, Roller and Waverman (2001) and Datta and Agarwal (2004) for OECD countries, and Ghosh and Prasad (2012) and Ghosh (2016) for India present further evidence to highlight the importance of telecommunications for economic growth and development.

As one of the fastest growing emerging markets, India receives special attention from the researchers. Several authors have attributed the rapid growth of the Indian economy in recent years to acceleration in the service sector growth (Babu, 2005;

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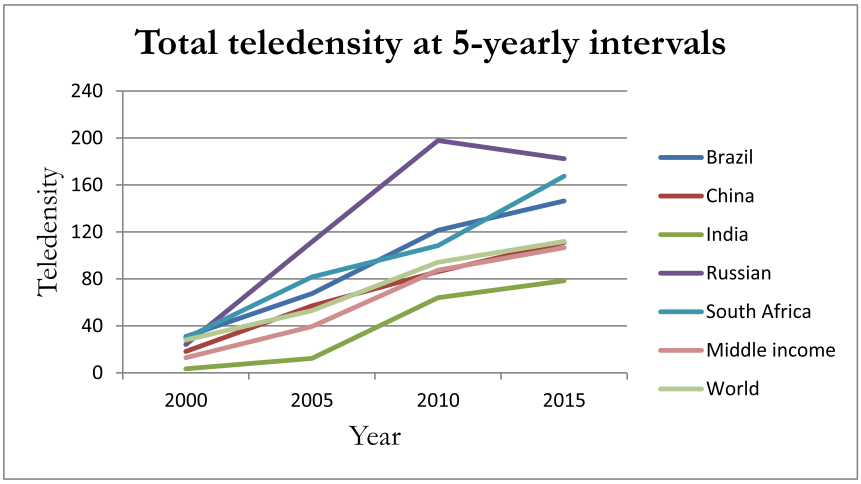

Source: World Development Indicator, World Bank

Fig. 1. Teledensity in India vis-à-vis middle-income countries, BRICS, and the world.
Source: World Development Indicator, World Bank

Balakrishnan & Parameswaran, 2007). Among various service categories, ICT or ICT enabled services are the prime drivers of India's economic growth (Eichengreen & Gupta, 2011; Gordon & Gupta, 2004). However, notwithstanding this growth in these specific services, their overall growth relative to the potential is considerably low as a substantial section of India's population is still do not have access to modern telecommunication facilities such as basic telephone connections. In comparison to the world-wide average access to telecommunications, India has been lagging behind. As Fig. 1 shows, the overall teledensity (both fixed landline and mobile telephone subscriptions per 100 population) in India has been consistently lower than the average for middle income as well as other BRICS (Brazil, Russia, India, China, and South Africa) countries, the two groups to which India belongs. The figure also indicates that teledensity grew at a faster pace between 2005 and 2010 and then it slowed down.

Despite lagging behind the world average, because of its population size, India is the second largest and one of the fastest growing telecom markets in the world. Although there has been substantial increase in the number of telephone connections during the last decade or so, the digital divide (the disparity in the access to various ICTs including telecom) continues to be significant in India (Government of India, 2012).[1] Furthermore, the growth in the access to telecommunication has also not been uniform across states in India. Several studies document the uneven growth in the number of telephone subscribers and highlight the existing digital divide or digital gap across the states (Ghosh & Prasad, 2012; Sridhar, 2010). It is interesting to note that the disparity in access to telecommunication exists in spite of a uniform policy framework across the length and breadth of the country.[2] In this context, it is pertinent to investigate the distribution of telecom services and its dynamics over time across various states. Therefore, in this paper, our purposes are to examine the distribution pattern and dynamics of telecommunications services in India and the factors that are responsible for their uneven diffusion. Specifically, our paper attempts to address two questions: (i) what are the patterns and dynamics of diffusion of telecommunication services across states and over time in India? and (ii) what are the drivers of telecommunication diffusion across states in India?

Using data for 16 major states in India from 2001 to 2015, this paper examines the patterns, distribution, dynamics and the drivers of telecommunications services across different states.[3] We apply both parametric and nonparametric econometric techniques to study the distribution dynamics of telecom services. Further, we employ the generalised method of moment (GMM) to examine the determinants of telecommunication services in India. Our results indicate that the interstate gap in telecommunication services has been declining over time and there is a tendency for convergence in teledensity towards the national average.[4] The regression analysis suggests that per capita income and network externality are significant determinants of teledensity across states in India. Additionally, literacy rate and the relative size of the service sector in a state are independently significant predictors of teledensity. If we consider rural and urban areas separately, there are some important differences. For example, while the interstate gap in telecom services in rural areas seems to have declined, there is little evidence of such a tendency for urban areas. However, the regression results with respect to the importance of per capita income, education, and network externality for telecom services are robust to the rural-urban divide and to the inclusion of additional explanatory variables.

[1] In the ICT literature, the gap between those who have access to technology such as a telephone and those who do not is known as the digital gap or digital divide (Rao, 2005).

[2] The Indian Constitution assigns telecom services to the Central Government List. Accordingly, all policies for promotion, development, regulation (including licensing and pricing) of telecom services are formulated and implemented for the nation as a whole.

[3] India's financial year runs from April 1 in a year to March 31 in the following year. For instance, 2000–2001 comprises data from April 1 of 2000 to March 31 of 2001. In order to keep our description simple, we write 2001 for the financial year of 2000–2001, 2002 for 2001–2002, and so on.

[4] Teledensity is defined as the number of telephone (both fixed landlines and mobile phones) subscribers per 100 population.

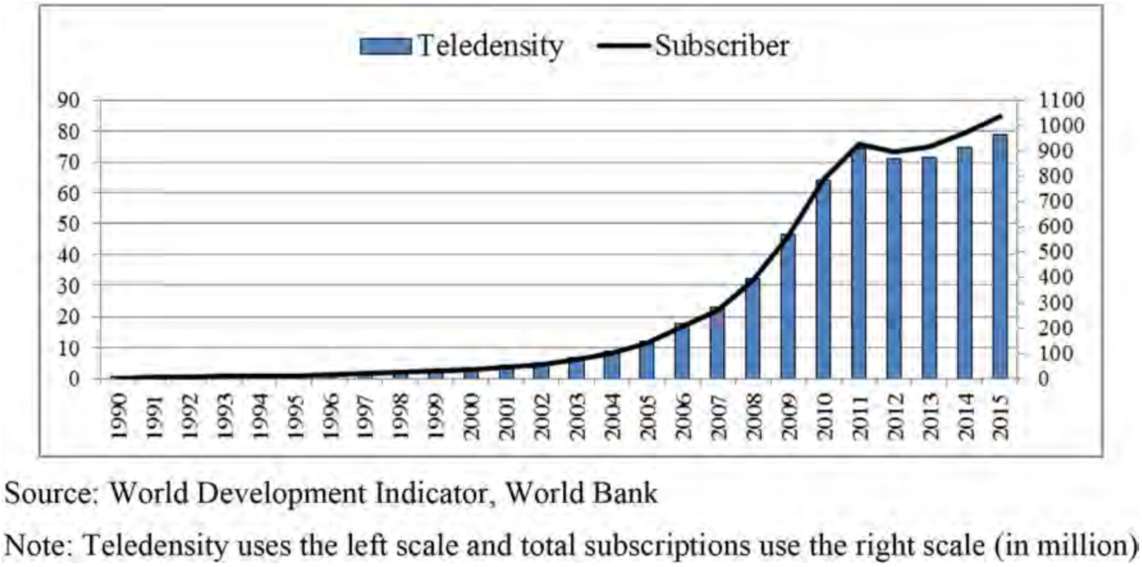

Fig. 2. Trends in teledensity and total telephone subscriptions in India: 1990–2015.
Note: Teledensity uses the left scale and total subscriptions use the right scale (in million).
Source: World Development Indicator, World Bank

Overall, this paper makes three important contributions. First, to the best of our knowledge, this is the first study to examine the distribution dynamics of teledensity across different states in India highlighting both its nature and speed. Second, this paper uses nonparametric kernel density distribution to study the dynamic evolution of state-level teledensity and parametric GMM to explore the state-level drivers of teledensity. Instead of focusing on point estimates, the nonparametric technique considers the entire distribution that reveals richer dynamics. GMM is useful in handling endogeneity that naturally arises in macro-level data. Third, this study also highlights the differences in the key dynamic aspects of teledensity in rural and urban areas across different states.

The rest of the paper is organised as follows. Section 2 presents a brief description of the telecommunication policies and the evolution of the sector in India. A brief discussion of a theoretical framework for the empirical analysis is included in Section 3. Section 4 describes data and the methodologies used for the empirical analysis. The empirical results and their analysis are presented in Section 5. Section 6 includes the results from the sensitivity analysis. The final section includes a summary of the findings, policy implications, and a few concluding remarks.

2. Telecommunications in India

The telecommunications services have made considerable penetration in India over the years, particularly during the last decade. The extent of this proliferation is reflected in the rising number of telephone subscribers and teledensity in the country. As Fig. 2 shows, both the total number of telephone subscribers and teledensity have been rising continuously and the growth accelerated between 2005 and 2011. The organizational changes of the telecom sector in the 1980s and the market-oriented reforms and economic liberalization of the 1990s are mainly credited for the rapid growth of telecom services in India during the subsequent period (Ghosh & Prasad, 2012; Panagariya, 2008). Of course, the unprecedented ICT advances during this period also contributed to this development. The advent of the Internet, email, e-commerce, data transmission through telephone network using digital technology and the innovations that it unleashed in different sectors of the economy created enormous demand for telecommunication services.

Prior to the economic liberalization, most policy making and regulatory functions related to telecommunications were vested on the Department of Telecommunication (DoT) under the Ministry of Telecommunication (Panagariya, 2008). During that phase, DoT was the sole provider of telecom services in India. However, the entry of private investors - which is an outcome of economic liberalization - brought structural changes in the telecommunication sector and created a competitive marketplace rather than a monopoly. After liberalization, Government of India enacted its first telecom policy- National Telecom Policy 1994 (NTP 1994) - with an aim to provide telecommunication services to all. NTP 1994 set physical targets such as on demand telephone service and extension of telecom services to all villages and at least one Public Call Office (PCO) for every 500 persons by 1997 in urban areas in order to meet the goal of telecommunication services to all. However, these targets could not be attained particularly for telecommunications in rural areas (Prasad, 2008). Increasing demand for telephone connections during this period produced a huge resource gap and therefore the Government of India emphasized the need for more private investment to bridge the resource gap.[5]

Considering poor achievements of NTP 1994, the government announced New Telecom Policy 1999 (NTP 1999) with a new

[5] http://www.trai.gov.in/.

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framework that further liberalized the telecom sector. Furthermore, government of India enacted the Telecom Regulatory Authority of India (Amendment) Act, 2000, that separated the policy making and licensing function of DoT from the service provision function. This separation in functions further boosted the corporatization of the telecom sector (Government of India, 1999). NTP 1999 highlighted the importance of telecommunications in achieving social and economic goals of the country and mainly focused on ensuring affordable and effective communications for the citizens. Given the changing dynamics of the telecom sector and an objective to provide secure, affordable and high quality telecommunication services to all citizens, the Government of India launched National Telecom Policy 2012 that envisaged broadening telecom infrastructure in both rural and urban areas (Government of India, 2012).

As Gupta and Jain (2012) note, competition among private players - facilitated primarily by NTP 1999 - resulted in significant drop in call tariff which in turn accelerated the diffusion of mobile telephony in India.[6] Introduction of new technologies such as Global System of Mobile (GSM), Code Division Multiple Access (CDMA), and Calling Party Pays (CPP) regime further sped up this proliferation. They also report that fixed line and mobile telephony are substitutes in India. A more recent study by the same authors (Gupta & Jain, 2016) examines the effect of introducing new technologies such as CDMA on the diffusion of an existing technology, viz GSM and vice versa. The empirical results reported in the study indicate that the CDMA diffusion had a positive impact on the proliferation of GSM. The competition between these two technologies has made mobile telephony more affordable thus contributing to its overall growth in India. Despite faster diffusion of CDMA, GSM continues to be the dominant technology. The authors conclude that along with introduction of new technologies, innovative ideas and customer-friendly pricing strategies would lead to acceleration in the diffusion of mobile technology in India.

Despite substantial growth in telecom service along with the economic progress over the last decade, there is a significant divide in the provision of the service across the country (Government of India, 2012). Singh (2008) notes that notwithstanding momentous growth in telecommunication services, enormous variation in teledensity exists among different states within India. A broad view of disparity in terms of teledensity across states in India is presented in Fig. 3 where states with the highest and the lowest teledensity along with national average are plotted for the period 2001–2015. The figure shows substantial differences between the states with the highest and the lowest teledensity.

Although the disparity in penetration of telephone services among the states had been acknowledged as early as in the midterm appraisal of the Ninth Five Year Plan in 2000, large differentials in terms of teledensity still exist among the states (Planning Commission, 2000).

3. A theoretical framework

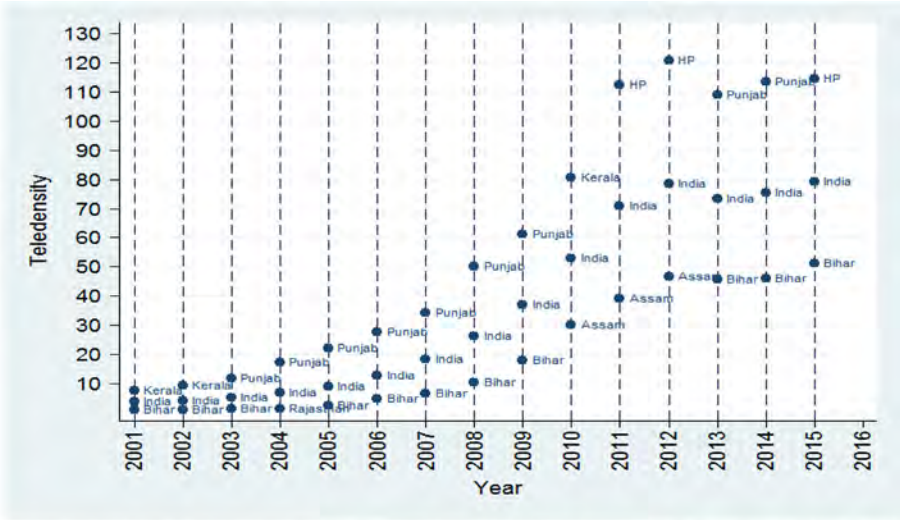
The seminal papers by Artle and Averous (1973), Von Rabenau and Stahl (1974), Squire (1973), Rohlfs (1974) and Littlechild (1975) – all in the Bell Journal of Economics and Management Science – articulate a theoretical model framework for analyzing demand for telecommunications. This framework is the workhorse of vast empirical research into the topic. Two books by Taylor (1980 and 1994) provide an excellent summary and a synthesis of those early theoretical works and a review of the existing empirical research. Taylor (2007) presents an updated overview of the theoretical and empirical literature.

Identifying the peculiarities of telecommunications and adequately capturing them in theoretical models have been the formidable challenges in developing this framework. Taylor (1994 & 2007) discusses some of the important features that any theory of telecom demand needs to consider. First, there is a clear distinction between demand for access and that for use of telecommunications. The latter depends on the fulfilment of the first. Second, both access and use involve externalities that imply interdependent preferences across subscribers. Third, subscribers' willingness to pay for the option of making or receiving calls even though the calls may never take place makes telecommunications demand an option demand. Finally, telecommunications may take place in a variety of forms: call, message, video calls etc. With the advances and integration of information technologies, the variety has expanded.

Using a static resource allocation framework, Artle and Averous (1973) handle the discreteness associated with the access (no access) aspect of telecommunications demand and then develop a dynamic analysis that highlights the importance of the public-good property of telecommunications for the growth of telecom demand. However, their theoretical exposition is incomplete as the social production possibility function subsumes prices and the model largely ignores the use aspect of telecom demand. Von Rabenau and Stahl (1974) further explore the dynamic aspects of the public-good property of telecommunications. Unlike Artle and Averous, Rohlfs (1974) focuses on individual demand. In his model, market demand is the sum of individual demands derived from utility maximization. In this framework, price enters as an explicit factor determining demand. However, Rohlfs (1974) does not distinguish between access and use. Squire (1973) uses a consumer surplus framework to relate the demand for access to that for use. He makes a fundamental contribution by showing that the relationship flows from use to access, rather than the other way around.

The studies above consider consumption externalities with reference to the total number of telephones. De Fontenay and Lee (1983) and Breslaw (1985) distinguish between two forms of network externality that are related to an increase in penetration (of telephone) rate with population remaining constant and an increase in population with penetration rate remaining constant. Taylor (1994 & 2007) weaves these ideas and concepts into a cohesive theoretical structure and further extends it to incorporate the ideas of

[6] There is a large emerging literature on the diffusion of telecommunication technologies in different countries. A representative sample includes studies by Botelho and Pinto (2004) for Portugal, Gamboa and Otero (2009) for Colombia, Gruber and Verboven (2001) for European Union, Jang, Dai, and Sung (2005) for OECD countries and Taiwan, Kim, Lee, and Ahn (2006) for Korea, Massini (2004) for Italy and the UK, and Michalakelis, Varoutas, and Sphicopoulos (2008) for Greece.



Source: Authors' estimation using data obtained from http://www.indiastat.com and Department of Telecommunication, Government of India

Fig. 3. Inter-State differences in teledensity across states: 2001–2015.
Source: Authors' estimation using data obtained from http://www.indiastat.com and Department of Telecommunication, Government of India

option demand and telecom use forms.[7] The theoretical research provides the basis for the empirical studies some of which we cite while specifying our empirical model in the next section.

4. Data and methodology

4.1. Data

The relevant data for this study are obtained from five different sources: (i) Department of Telecommunications, Government of India; (ii) Handbook of Statistics on Indian Economy, Reserve Bank of India; (iii) Ministry of Human Resource Development, Government of India; (iv) Office of the Registrar General and Census Commissioner India, Government of India; and (v) Publications Division, Ministry of Information and Broadcasting, Government of India. We consider the sample period from 2001 to 2015.

We obtain the data on telephone subscription and teledensity from the annual reports of the Department of Telecommunications (DoT) which comes under the purview of the Ministry of Communications, Government of India. However, the annual reports are available online only since 2007. Therefore, teledensity data for the remaining period (2001–2006) are extracted from the IndiaStat Database (http://www.indiastat.com). Note that telephone subscription includes both fixed landline and mobile telephone subscription. Further, teledensity is defined as the number of telephone subscribers (both fixed landline and mobile telephone) per 100 population.[8]

Government of India divides the entire country into twenty three telecom service areas referred to as “telecom circles”. Among these circles, the jurisdictions for nineteen coincide approximately with the respective state borders while the remaining circles represent four metropolitan cities in India.[9] Since the treatment in our empirical analysis takes place at the state level, we intend to include a telecom circle (in our sample) that coincides with a single state. However, the data on teledensity in some of these circles are not uniform over the sample period. These inconsistencies arise due to the fact that three new states were carved out from erstwhile Bihar, Uttar Pradesh (UP), and Madhya Pradesh (MP) in 2000.[10] Data for the new states were published separately from 2002 to 2011. Subsequently, the teledensity data for these states have been merged with data for their respective parent states. Therefore, for consistency, we construct teledensity data for erstwhile Bihar, Madhya Pradesh and Uttar Pradesh for the entire sample period by combining the data for the new states with those for the respective parent states for the intervening period of 2002–11.

Similarly, data for six northeastern states namely Meghalaya, Mizoram, Tripura, Arunachal Pradesh, Manipur and Nagaland were combined and reported as for ‘North East’ for the year 2001 and 2002. However, from 2003 to 2011, data for these states were presented under two groups: ‘North East-I’ that includes Meghalaya, Mizoram and Tripura; and ‘North East-II’ that consists of

[7] See Ch. 2 & 3 of Taylor (1994) and Taylor (2007) for a detailed discussion.

[8] This definition of teledensity is taken from the "World Telecommunication/ICT Indicators" published by International Telecommunication Union.

[9] A detailed description of the service area is given in Appendix Table A.1.

[10] In August 2000, three new states namely Jharkhand, Chhattisgarh and Uttarakhand (initially named as Uttaranchal) were carved out from Bihar, Madhya Pradesh and Uttar Pradesh respectively (For details, see http://parliamentofindia.nic.in/jpi/December2000/CHAP-7.htm).

Arunachal Pradesh, Manipur and Nagaland. In 2012, the agency went back to the earlier practice of presenting combined data for these six states as a single entity as ‘North East’. In order to construct and use a consistent data series, in this case, North East-I and North East-II are clubbed for the period from 2003 to 2011 as well.[11]

Furthermore, the teledensity data for Tamil Nadu and West Bengal are not available in a consistent manner for the entire sample period. For example, the data on teledensity in Tamil Nadu do not include the metropolitan area of Chennai for certain years while they include data for the metropolitan area for other years. Similarly, the data for West Bengal include Andaman and Nicobar Islands for a number of years and include data for Sikkim for some other years. This lack of uniformity makes it difficult to construct consistent teledensity data for these two states. Therefore, we exclude Tamil Nadu and West Bengal from our sample.

The data on Net State Domestic Product (NSDP) and gross value addition in services sector across states are gathered from various issues of the Handbook of Statistics on Indian Economy published annually by the Reserve Bank India (RBI). The Handbook presents NSDP data with different base years. To make them comparable, the data are spliced to construct a consistent series of NSDP data with a common base year.[12]

Relevant data on literacy rate (percentage of people above the age of 7 who can read and write) are downloaded from the NITI Aayog Website (http://niti.gov.in/content/literacy-rate-7years.), originally collected and compiled by the Office of the Registrar General and Census Commissioner, India as part of its decennial census in 2001 and 2011. The annual data for the intervening periods in our sample are constructed using linear interpolation.[13] The summary statistics of the variables discussed above are presented in Table 1.

4.2. Methodology

4.2.1. Methodologies for examining the evolution of teledensity

In order to examine how the distribution of teledensity in India has evolved over time, we first define a relative teledensity measure as follows.

$$R_{i,t} = Teledensity_{i,t} - \overline{Teledensity_t} \tag{1}$$

where, $R_{i,t}$ is the measure of relative teledensity whereas $Teledensity_{i,t}$ and $\overline{Teledensity_t}$ denote absolute teledensity in state i in period t and national average teledensity in time t respectively. A negative value of $R_{i,t}$ implies teledensity below national average. In contrast, a positive value of $R_{i,t}$ indicates a higher teledensity above the national average. In order to examine the dynamics of teledensity across states in India, the present study utilises both parametric and non-parametric methods.

4.2.2. Parametric panel unit root tests

We first use panel unit root test procedure to examine whether relative teledensity across states is mean-reverting, i.e. converging towards a steady state in the long run.[14] In order to assess the stationarity property of relative teledensity, we begin with frequently used panel unit root tests proposed by Levin, Lin, and Chu (2002) (LLC) and Im, Pesaran, and Shin (2003) (IPS).[15] Under the null hypothesis, each teledensity series is a unit root process. Thus, the rejection of the null hypothesis would be interpreted as evidence in support of convergence to the national average teledensity. The LLC procedure, one of the most frequently used panel unit root tests, examines the stationarity of panel data using the following regression model.

$$\Delta y_{i,t} = \rho y_{i,t-1} + \sum_{k=1}^{p_i} \theta_{i,k} y_{i,t-k} + \alpha_{m,i} d_{m,t} + \varepsilon_{i,t} \tag{2}$$

where y_{it} is the variable of interest, d_{mt} is the vector of deterministic elements and ε_{it} is the independently and identically distributed error term. The null hypothesis that each individual time series contains a unit root implies that H_0: ρ = 0. The alternative hypothesis is that each time series is stationary (H_1: ρ ≠ 0). However, the LLC test is restrictive in nature as the alternative hypothesis requires ρ to be homogeneous across cross-sections (Enders, 2014). In contrast, the IPS test procedure allows for heterogeneity in autoregressive coefficients for different cross sections. The null hypothesis in Im et al. (2003) is that each panel contains a unit root against the alternative hypothesis that some of the cross sections have unit roots.

However, these panel unit root tests are criticised for their assumption of cross sectional independence. Baltagi (2014) considers this assumption as restrictive and points out existence of significant cross-sectional correlation in panels. Therefore, the present study also conducts a second generation panel unit root test proposed by Pesaran (2007) which allows for cross sectional dependence. The method, also known as cross-sectionally augmented ADF test (CADF), augments the standard ADF regression with lagged value of cross sectional average and its first difference as shown in equation (3).

[11] These adjustments are made in other variables as well.

[12] In the present study, NSDP data series with different base years are combined to a common series with 2011–12 as the base year. In order to combine the series, a method outlined in Nagar and Das (2004) is utilized.

[13] This is a common practice in empirical work. For example, the 2010 United Nations Human Development Report states: “Linear interpolation was used to fill missing values when both earlier and later values were present.” (p. 217).

[14] Several empirical studies have investigated convergence in relative prices across cities within a country employing panel unit root test (e.g. Cecchetti, Mark, & Sonora, 2002; Culver & Papell, 1999; Nath & Sarkar, 2009). A rejection of the null hypothesis that a unit root exists is interpreted as evidence in support of convergence. As Nath and Sarkar (2009) explain, the use of panel unit root technique in order to test convergence increases power of the tests as such methods combine cross-sections and time series which increases number of observation.

[15] Baltagi (2014) presents a detailed discussion on first and second generation panel unit root tests.

Table 1
Summary statistics of the variables at the state-level for the sample period: 2001–2015.
Source: Authors' estimation

State	Teledensity (per 100 person)				Per Capita NSDP in Indian Rupee				Share of Services to NSDP				Literacy Rate			
	Mean	Std.Dev	Min	Max	Mean	Std.Dev	Min	Max	Mean	Std.Dev	Min	Max	Mean	Std.Dev	Min	Max
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Andhra Pradesh	28.8	27.92	4.1	80.93	52509.25	11096.76	38494.94	68866	57.61	2.52	52.85	60.61	64.42	2.59	60.47	68.38
Assam	14.7	15.95	1.33	46.66	33740.34	4344.09	28344.23	41142	56.35	2.64	53.23	61.04	68.71	3.58	63.25	74.17
Bihar[a]	14.05	17.14	1.15	48.95	18871.96	3906.23	14759.77	26503.38	56.54	5.38	49.59	64.34	57.47	5.83	48.58	66.36
Gujarat	33.12	30.48	5.19	92.23	59024.95	17237.29	36497.75	87481	54.08	2.29	51.62	57.80	74.73	2.67	69.14	80.33
Haryana	31.53	30.66	4.07	89.42	76106.28	18508.62	52558.12	107343	56.37	4.00	48.88	62.16	72.71	3.15	67.91	77.51
Himachal Pradesh	41.94	41.42	5.94	120.76	66175.17	12949.93	49441.44	87721	58.87	1.42	57.17	61.47	80.50	2.63	76.48	84.51
Jammu & Kashmir	21.1	20.83	1.72	54.88	41752.57	5737.54	34687.17	51382	62.86	2.87	59.15	67.03	62.79	4.77	55.52	70.06
Karnataka	34.46	33.08	4.69	97.3	68110.08	14902.88	50936.96	89899	63.52	3.37	55.72	68.55	71.57	3.23	66.64	76.50
Kerala	42.77	35.9	7.67	106.91	69749.19	17512.9	47296.86	97912	74.66	2.31	70.30	78.05	92.54	1.10	90.86	94.22
Maharashtra	27.63	25.4	6.08	77.19	70369.81	18514.6	47921.42	98910	53.73	2.11	50.85	57.80	80.20	2.17	76.88	83.51
Madhya Pradesh[b]	17.44	18.85	2.43	53.86	35371.31	6901.26	26332.16	46863.5	53.73	2.11	50.85	57.80	67.70	2.44	63.98	71.42
North East[c]	20.56	22.85	1.92	65.72	39640.53	7332.99	29735.82	52265.5	65.93	1.97	63.54	68.63	75.33	4.29	68.78	81.87
Orissa	19.14	22.62	1.5	65.88	36628.18	7873.68	25932.74	47019	58.32	3.20	52.55	63.30	68.78	3.74	63.08	74.49
Punjab	45.69	38.99	6.82	119.35	68250.79	10656.36	56879	85577	48.61	2.07	44.45	52.37	73.52	2.53	69.65	77.38
Rajasthan	24.47	26.23	1.32	73.05	41016.47	8649.06	29111.12	57427	56.76	2.28	51.66	59.63	64.07	2.40	60.41	67.73
Uttar Pradesh[d]	18.65	20.93	2.14	61.02	27146.17	4667.28	22118.35	35224.56	56.07	2.88	50.71	59.22	64.26	4.76	57.01	71.52

Note: a. Includes Jharkhand, b. Includes Chhattisgarh, c. Includes Meghalaya, Mizoram, Tripura, Arunachal Pradesh, Manipur and Nagaland, d. includes Uttarakhand.

$$\Delta y_{i,t} = \alpha_i + \rho_i y_{i,t-1} + \varphi_0 \overline{y_{t-1}} + \sum_{j=0}^{p} \theta_{j+1} \Delta \overline{y_{t-j}} + \sum_{k=1}^{p} \lambda_k \Delta y_{i,t-k} + \varepsilon_{i,t} \tag{3}$$

where, $\overline{y_{t-1}}$ and $\Delta\overline{y_{t-j}}$ denote lagged averages of all cross sections at time t and its first difference. The individual CADF statistic is given by the coefficients of ρ_i. The Pesaran (2007) test is a modified version of the IPS unit root test and it averages CADF over cross sections in the panel to obtain the cross-sectionally augmented IPS (CIPS) statistic. Then the null hypothesis that all series have unit roots against the alternative hypothesis that at least one series is stationary is examined using the CIPS statistic.

We are interested not only in the evidence of convergence but also in its speed. Therefore, using the autoregressive coefficient (ρ) obtained from the panel unit root test equation, half-life is estimated. Half-life is the time required for any deviation from the steady state (the national average teledensity in our case) to dissipate by one half. Half-life is estimated using the following simple equation.

$$H(\rho) = \frac{\ln(0.5)}{\ln(\rho)} \tag{4}$$

where, $H(\rho)$ is the half-life and ρ is the AR(1) coefficient.

4.2.3. Nonparametric kernel density distribution dynamics

However, the empirical investigation of convergence using parametric methods like panel unit root is not free from criticism. According to Quah (1996), standard parametric convergence empirics are uninformative because of their inability to explain the entire distribution dynamics. Therefore, in addition to parametric techniques, we also use non-parametric methods to examine the distribution dynamics of relative teledensity of different states over the years.

We first use the following kernel density estimator to obtain the probability densities for relative teledensity across states:

$$\hat{f}(x) = \frac{1}{nh} \sum_{i=1}^{n} K\left(\frac{x - X_i}{h}\right) \tag{5}$$

where, X_i's are a sample of independently and identically distributed observations on a random variable X (relative teledensity measure R in our case), h is the bandwidth of the interval around a given realization x and K is the kernel function. The kernel density estimator assigns a weight between 0 and 1 to each observation in the interval around x, based on the distance between x and the observation. The resulting density estimate obtained from the vertical sum of frequencies at each observation provides the basic information and properties such as skewness and multi-modality of the given set of data (Silverman, 1986) that enable us to visualize the shape of the distribution of relative teledensity and study its evolution over time.

Next, we estimate the Markov transition matrix of relative teledensity across states to examine the evolution of its distribution over time. A transition probability matrix depicts the distributional dynamics across various pre-defined categories.[16] In the present study, we define two categories, one corresponds to the states that have negative relative teledensity (i.e. teledensity below the national average) and the other to those having positive relative density (i.e. teledensity above the national average). This categorization allows us to examine the telecommunication divide (much along the line of digital divide) among the Indian states and its evolution over time. In matrix notation, the transition dynamics can be captured in the form of the following equation.[17]

$$Q_{t+1} = M \times Q_t \tag{6}$$

where Q_t is the distribution of relative teledensity across states at time t and Q_{t+1} represents the distribution at time $t + l$, where $l = 1,2,3 \ldots m$. In the equation, M is a finite discrete Markov transition matrix. It contains a complete description of the distributional dynamics as it maps Q_t into Q_{t+1}. The transition matrix M is given by.

$$M = \begin{bmatrix} p_{ii} & p_{ij} \\ p_{ji} & p_{jj} \end{bmatrix}$$

where p_{ii} denotes the probability that state which is in category i at time period t would remain in the same category at time $t + l$. Similarly, p_{ij} denotes the probability of a state making transition from category i in period t to category j in period $t+1$. Assuming that transition probabilities are time invariant and independent of previous transitions, the evolution in the distributions can be studied by iterating equation (6) k times. Taking k to the limit as $k \to \infty$, the iteration yields the long run or ergodic distribution as presented below.

$$\lim_{k\to\infty} M_{ij}^k = \delta_j > 0, \quad \sum \delta_j = 1$$

In the equation, $i, j = 1, \ldots N$ indicate the initial and final category at time t and $t + l$, respectively. The ergodic distribution eventually allows us to analyse the long-run tendencies of relative teledensity across the states in India.

4.2.4. Methodology for examining the determinants of teledensity across states

We also make an attempt to identify the determinants of teledensity across states using a panel data regression framework. The

[16] Here category refers to a particular group based on certain criteria.

[17] This is similar to Nath, Liu, and Tochkov (2015).

theoretical model framework discussed in Section 3 and the extant empirical literature on the determinants of telecommunications (and other ICTs) provide some general guidelines for our empirical model specifications. In our baseline model, we include per capita Net State Domestic Product (*NSDP*), literacy rate (*Lit*), the NSDP share of the service sector (*Service*), and lagged teledensity (*Tele*) as explanatory variables:

$$Tele_{i,t} = \beta_1 \ln NSDP_{i,t} + \beta_2 Lit_{i,t} + \beta_3 Service_{i,t} + \beta_4 Tele_{i,t-1} + \mu_i + \eta_t + \varepsilon_{i,t} \tag{7}$$

where μ_i and η_t are unobserved state fixed and time fixed effects respectively while $\varepsilon_{i,t}$ is the independently and identically distributed error term in the model. i and t index state and year respectively.

Here, per capita NSDP is a measure of average income. Both theoretical and empirical studies highlight the importance of income for telecommunications demand. For example, according to Jha and Majumdar (1999), higher income implies greater prosperity that generates more demand for telecommunication services. A number of empirical studies (e.g. Chinn & Fairlie, 2007; Gutierrez & Gamboa, 2010; Madden, Neal, & Dalzell, 2004; Ono & Zavodny, 2007; Quibria, Ahmed, & Tschang, 2003) including studies specific to India (e.g. Narayana, 2011; Sridhar, 2010) examine per capita income as one of the determinants of different ICTs including telecommunications. Literacy presumably represents the capability to use ICT such as telephone services. Studies by Fuchs and Horak (2008), Quibria et al. (2003), Madden et al. (2004), Jain and Raghuram (2005), Gutierrez and Gamboa (2010) and Biancini (2011) argue that literacy is an important determinant of telecommunication services.

Furthermore, Indian economy has experienced rapid growth in services during the last one and half decades. This acceleration in the overall services sector is not uniform across its segments and is concentrated mainly in ICT-enabled business services (Gordon & Gupta, 2004). However, the growth of these services crucially hinges on the expansion of telecommunication services. Therefore, it is possible that the rapid growth of the service sector may have generated demand for telecommunication services leading to higher teledensity. In order to capture the effect of services sector in determining teledensity, we consider the service sector share in NSDP (*Service*) as one of our explanatory variables.

In addition to the variables discussed above, we include one period lag of the dependent variable as an independent variable in the regression equation. The lagged teledensity can be interpreted as capturing network externality. A large number of existing telephone subscriptions is likely to generate higher positive externality which in turn induces more subscriptions (Sridhar, 2010). However, the literature (Allen, 1988; Markus, 1987 & 1994; Rogers, 1995; Schoder, 2000; Slyke, Ilie, Lou, & Stafford, 2007) points out that there is a critical mass or a threshold level of telecommunication adoption up to which network externality is important for its diffusion. Once the critical mass is reached, further adoption becomes self-sustaining. Markus (1990), Lou, Luo, and Strong (2000) and Slyke et al. (2007) further note that it is difficult to measure the critical mass. Lou et al. (2000) and Slyke et al. (2007) utilize a perceived measure of critical mass in their respective studies. For example, Lou et al. (2000) include a question in their survey about the degree to which a person believes that most of his/her peers are using telephone and use it as a perceived measure of critical mass. In a study using macro-level data like ours, it is not straightforward to have a measure of the critical mass and therefore we do not attempt it here.

All four explanatory variables discussed above are expected to have positive impacts on teledensity. However, per capita NSDP, literacy rate, and service sector share are likely to be correlated.[18] Therefore, our strategy would be to include all of them together and then to use one of these variables at a time in the regression equation. To be consistent with the demand theory framework, we would like to include a price variable as a determinant of teledensity. However, relevant data are not readily available by states. Further, anecdotal evidence suggests that while prices for telecommunication services vary by providers, they do not seem to vary by states, the units of our treatment in the regression model.

As Baltagi (2014) shows, the lagged dependent variable as a regressor is correlated with unobserved state specific effects and, consequently, the ordinary least square (OLS) estimates of the regression coefficients of our model above would be biased and inconsistent. Furthermore, possible influence of the dependent variable on the explanatory variables may lead to the endogeneity problem.[19] This problem may also arise as some of the variables may be determined within the system. In order to address the potential endogeneity issue in the model, the generalised method of moments (GMM) estimator developed by Arellano and Bond (1991) for panel data is used for the regression. This method transforms the basic regression equation by differencing the model. This differencing eliminates the state specific fixed effects and ensures stationarity of the variables (Lam & Shiu, 2010). In addition, the method uses lagged values of dependent as well as independent variables as instruments in the estimation of the model.

5. Empirical results

5.1. Unit root test and half-life

Table 2 presents the LLC, IPS, and CIPS panel unit root test results and the estimated half-life from the AR(1) coefficient of the unit root test equations. The null hypothesis of unit root is rejected at least at the 10 percent level by all three test procedures. The rejection of the null hypothesis implies that relative teledensity across states for our sample period converges to a steady state. The

[18] For our sample of data, the pairwise correlation coefficients are: Corr (*NSDP, Lit*) = 0.75, Corr (*NSDP, Service*) = 0.31, Corr (*Lit, Service*) = 0.58. Certainly, these values indicate moderate to high positive correlations between these variables.

[19] For example, Kathuria, Uppal, and Mamta (2009) uses state-level data to show that mobile phone penetration has a significant positive effect on the growth per capita income.

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Table 2
Panel unit root test results and half-life estimates for teledensity across Indian states.
Source: Authors' estimation

Test methods	Test statistic	Average ρ	Half-life
	(1)	(2)	(3)
Levin et al. (2002)	−3.53***	−0.25	2.40
Im et al. (2003)	1.82*	−0.14	4.59
Pesaran (2007)	−3.27**	–	–

Note: ***, ** and * indicate significant at the 1%, 5% and 10% level respectively.

estimated half-life ranges from 2.4 to 4.6 years. This implies that it requires about 2.4–4.6 years for any deviation in state teledensity from the national average to dissipate by half.

5.2. Kernel density estimates

In addition to the unit root test, the distribution dynamics of relative teledensity are explored using the kernel density plot. The kernel density distributions of the relative teledensity for the years 2001, 2006, 2011 and 2015 are presented in Fig. 4.

The kernel density plot for 2001 exhibits a large concentration of probability mass around −1.5 that indicates that most states had teledensity below the national average in 2001. However, there appears to be a smaller, not-very-distinct peak around 2.5. It indicates that there are a small number of states with teledensity much above the national average. Five years later, in 2006, the concentration of probability mass shifted farther left to around −2.5 with a wide peak while a small cluster is visible on the positive side around 15. These patterns indicate large interstate inequality in teledensity: while a large number of states are falling behind the national average, a relatively small number of states are far ahead of the rest. The kernel density curve for 2011 has a single peak that lies around −7.5 representing farther deviation of teledensity from the national average of the country. This indicates that the penetration of telecom services grew more unevenly among the states during this period as the variance of relative teledensity has increased considerably. Subsequently, there have been significant changes in the shape of the density curve. The kernel density plot for 2015 exhibits concentration of probability mass around 7.5 with a relatively smaller variance as compared to the distribution for 2011. With more states lying above the national average, this indicates considerable improvement in teledensity across our sample states. The single peak of the density curve is an indication of convergence in teledensity across the states in India.

It may be informative to look at the evolution of fixed line teledensity and mobile teledensity separately. As Gupta and Jain (2012) indicate diffusion of mobile telephony has had a negative impact on fixed telephony. We find support for their conclusion in our data as well. Overall, average fixed line teledensity decreased from 4.53 in 2006 to 2.01 in 2015 while average mobile teledensity increased from 4.24 to 77.57 at the national level during the same period of time. Although we observe similar trends in all states there are wide variations in their speeds across states. Fig. 5 presents kernel density distribution of relative fixed line and mobile teledensity respectively for 2006, 2011, and 2015. Note that telephone subscriptions data are not available separately for fixed and mobile connections before 2006. A comparison of these plots with those in Fig. 4 clearly indicates that the evolution of overall teledensity has closely followed that of mobile teledensity, particularly in later years. This is not surprising given the fact that mobile subscriptions have grown from about half of total telephone subscriptions in 2006 to about 97.5 per cent in 2015. As the kernel density plots of the upper panel in Fig. 5 show, although fixed teledensity in most states has remained below national average, it has been persistently above the national average in a few states. An examination of the underlying data indicates that fixed teledensity in Gujarat, Himachal Pradesh, Karnataka, Kerala, and Punjab has been consistently above the national average.

5.3. Transition probability matrix

In addition to the kernel density plot, the distribution dynamics of relative teledensity over our sample period are examined using transition probability matrix for three transition horizons: 1 year, 3 years, and 5 years. The transition probability matrix presented in Table 3 shows that the probabilities for transition along the diagonal elements of the matrix are higher than those off the diagonal elements.

Higher diagonal elements imply persistence in relative teledensity across the sample states for the corresponding time horizon. This means that the states with teledensity lower or higher than the national average are likely to remain in the same respective categories during the time horizon considered in the present study. For example, there is a 95 per cent probability that a state with negative relative teledensity would remain in the same category in 1 year time horizon. Although the probability decreases to 89 and 83 percent respectively in 3 and 5 year horizon, they still represent very high level of persistence. The corresponding probabilities for the states with positive relative teledensity are: 98, 98, and 97 percent. The upper right corner elements of the transition probability matrix indicate that there is a 5 to 17 percent chance that a state with negative relative teledensity will make transition to the category of positive relative teledensity in the time horizon of 1–5 years. In contrast, there is only a 2 percent probability that a state with above-the-national-average teledensity would make a transition to the below average category. In the 5 year horizon, this probability increases only to 3 percent. Overall, the states with below-the-national-average teledensity are slowly gaining in teledensity while those with above average teledensity are not changing their status. These results seem to be largely consistent with the slow speed of convergence as reflected in large half-life estimates reported in the previous sub-section.

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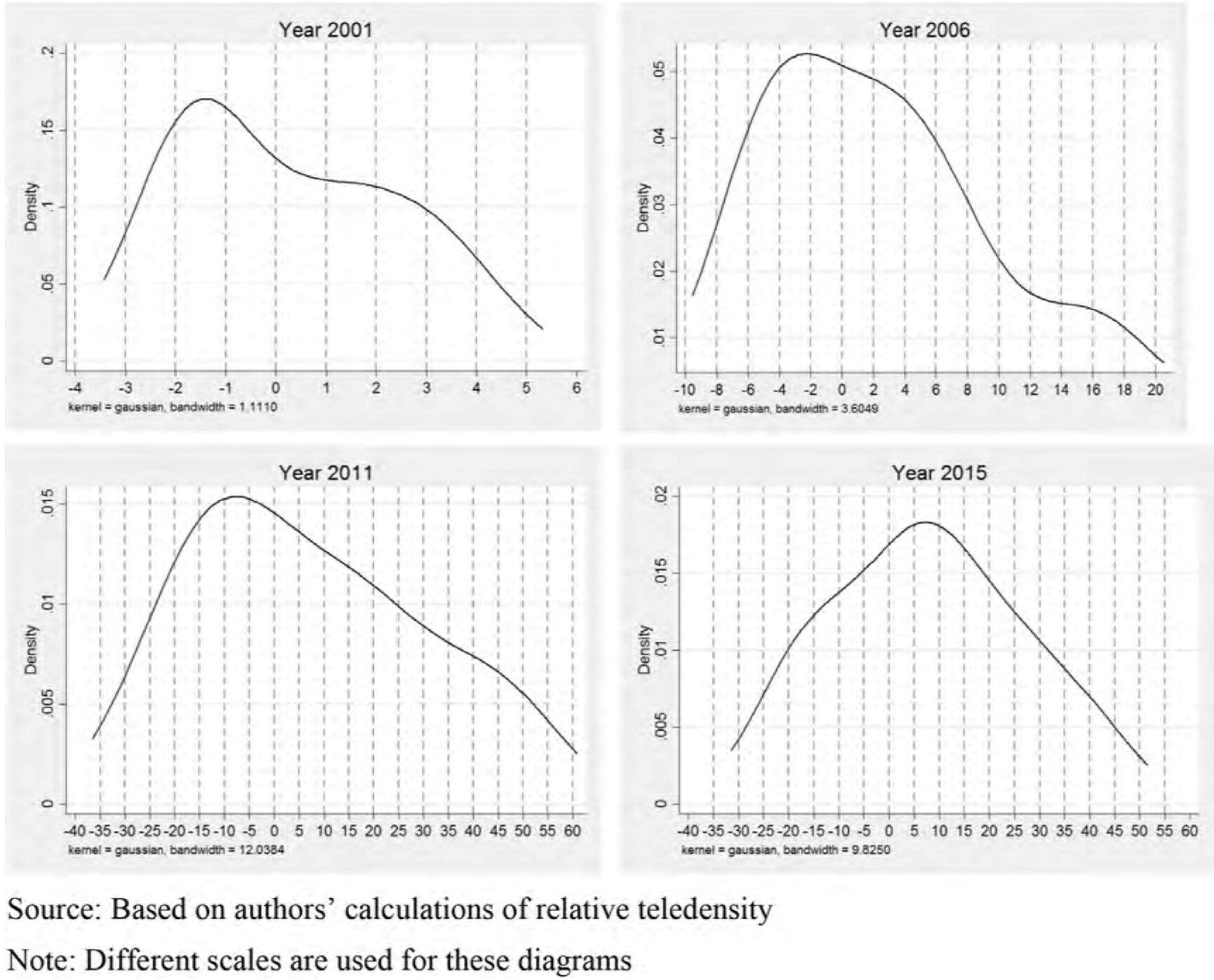
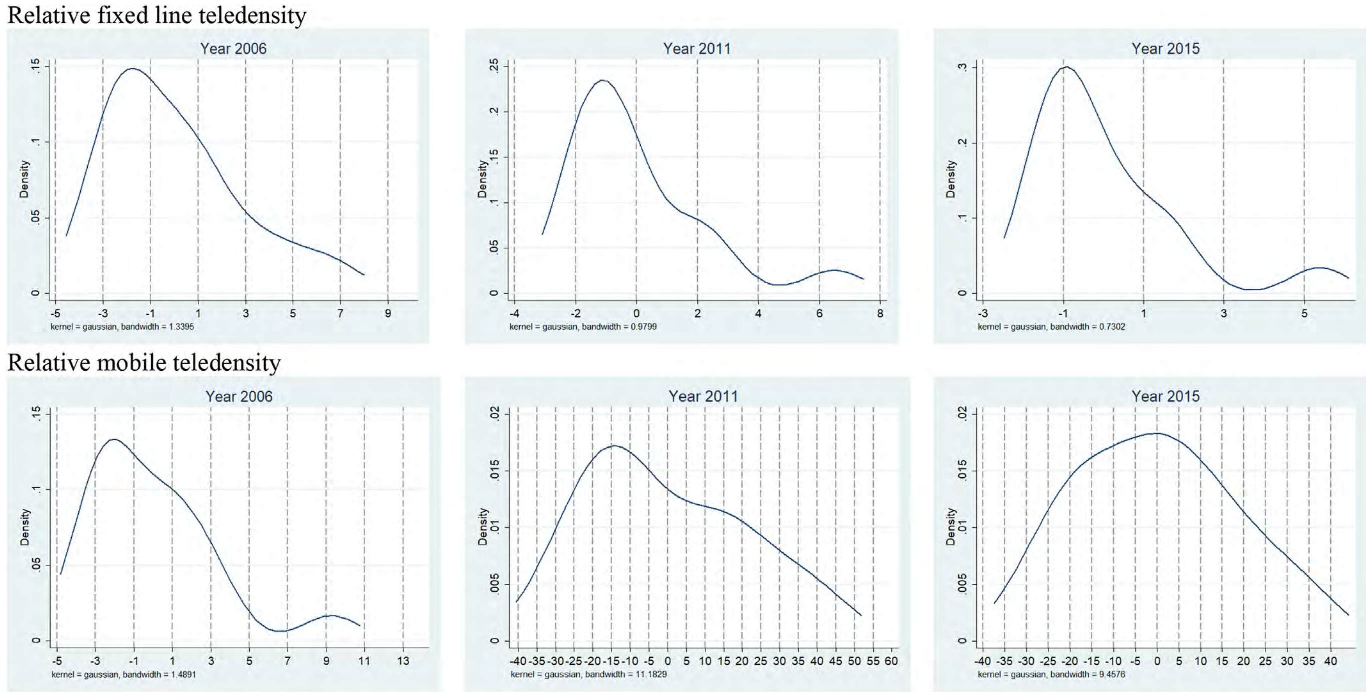


Fig. 4. Kernel density plots of relative teledensity.
Note: Different scales are used for these diagrams.
Source: Based on authors' calculations of relative teledensity



Source: Based on authors' calculations of relative teledensity
Note: Different scales are used for these diagrams

Fig. 5. Kernel density plots of relative fixed and mobile teledensity.
Note: Different scales are used for these diagrams.
Source: Based on authors' calculations of relative teledensity

Table 3
Transition probability matrix for relative teledensity across Indian states.
Source: Authors' estimation

	Below national average	Above national average
	(1)	(2)
1-year horizon		
Below national average	0.95	0.05
Above national average	0.02	0.98
3-year horizon		
Below national average	0.89	0.11
Above National Average	0.02	0.98
5-year horizon		
Below national average	0.83	0.17
Above national average	0.03	0.97

Table 4
GMM estimation results for the baseline model. (Dependent variable: Teledensity).
Source: Authors' estimation

Variables	Estimated coefficients			
	(1)	(2)	(3)	(4)
Log of Per Capita NSDP (ln*NSDP*)	54.28***	45.77***		
	(5.13)	(0.31)		
Literacy Rate (*Lit*)	−0.94		1.37***	
	(0.59)		(0.09)	
NSDP Share of the Services Sector (*Service*)	0.69			3.06***
	(0.60)			(0.13)
1-year Lagged Teledensity ($Tele_{i,t-1}$)	0.86***	0.86***	1.04***	1.04***
	(0.01)	(0.00)	(0.00)	(0.01)
No. of states	16	16	16	16
No. of observations	144	144	144	144
Hansen's J statistic	14.40	15.42	15.80	15.56
Hansen's J p-value	0.27	0.34	0.32	0.34

Note: ***, ** and * indicate significant at the 1%, 5% and 10% level respectively. Standard errors are in parentheses.

5.4. *Determinants of teledensity across states*

Table 4 presents the regression results from the GMM estimation.[20] The estimated coefficient for per capita NSDP is positive and significant at the one percent level with a point estimate of 54.28. This indicates that a one percent increase in per capita NSDP is associated with a 0.54 percentage point increase in teledensity. Thus, an increase in per capita NSDP generates demand for telecom services leading to greater teledensity. This may be a possible explanation for high teledensity in some of the rich states and low teledensity in poorer states.

The estimated coefficient for literacy rate is negative and that for service sector share is positive but both are statistically insignificant. The unexpected sign for literacy rate and lack of significance for both of these intuitively important variables seem to indicate that the correlations between these variables – the problem of multicollinearity – may have played a role. Relatively high standard errors for the estimated coefficients also point in that direction. Therefore, as we have mentioned before, we now estimate the equation including one of these three variables at a time. The results are reported in col. (2)–(4). As the estimated coefficients indicate, each of per capita NSDP, literacy rate, and service sector share is independently a significant determinant of teledensity.

Finally, the estimated coefficient of the lagged dependent variable is also positive and statistically significant at the one percent level for all four specifications. The coefficient for network externality is 0.86 (in col 1 & 2) which implies that a one percentage point increase in teledensity in the previous year leads to a 0.86 percentage point increase, on an average, in the current period teledensity. The estimated coefficients for other two specifications are slightly larger in magnitude. These results accord well with the argument that higher number of existing subscribers is likely to generate higher positive network externality. The results from Hansen's *J*-test procedure indicate that the instruments used in the model are valid. Note that 2–3 lags of the dependent variable and 1–2 lags of the independent variables are used as instruments in our estimation. In summary, the results of the regression analysis suggest that the significant positive impacts of per capita income and network externality on teledensity are robust across different model specifications. Furthermore, literacy rate and service sector share can independently be significant predictors of teledensity across states.

[20] Due to unavailability of data for the recent years, we estimate the model using data from 2001 to 2012.

Table 5
Panel unit root test results and half-life estimates for rural and urban teledensity across Indian states.
Source: Authors' estimation,

Test methods	Rural teledensity			Urban Teledensity		
	Test statistic	Average ρ	Half-life	Test statistic	Average ρ	Half-life
	(1)	(2)	(3)	(4)	(5)	(6)
Levin et al. (2002)	2.08**	−0.07	8.84	−0.84	–	–
Im et al. (2003)	1.66*	−0.29	1.96	−0.27	–	–
Pesaran (2007)	−6.16**	–	–	−0.88	–	–

Note: ***, **, and * indicate significant at the 1%, 5%, and 10% level respectively.

6. Sensitivity analyses

In order to examine the robustness of our analysis for the overall teledensity, we make an attempt to explore the distribution dynamics of teledensity across states separately for rural and urban areas. This exercise provides us with the distribution patterns and dynamics of teledensity for rural and urban areas separately and allows us to compare these patterns and dynamics with the overall distribution dynamics. Furthermore, we examine the determinants of rural and urban teledensity along the same line as with the baseline model.

Moreover, we consider a few additional variables in our regression analysis to see if there are important variables that have been omitted from our regression analysis and to examine if the results from our baseline regression models are robust. The following subsections present the results of the sensitivity analysis.

6.1. Distribution dynamics in rural and urban areas

First, unit root tests are conducted to check the stationarity of relative teledensity for urban and rural area separately. The results of these tests reveal that the null hypothesis is rejected at least at the 5 percent level in all three tests for rural teledensity but not for urban teledensity (Table 5). Thus, while there is evidence of convergence in teledensity in rural areas across Indian states, there is no such evidence for urban areas. The estimated half-life ranges from two to nine years for the rural areas, which is longer than for overall sample.

Second, the kernel density plots for 2001, 2006, 2011 and 2015 illustrate the distribution dynamics of rural and urban teledensity. Fig. 6(a) and (b) present the kernel density plots for rural and urban areas respectively. These plots for rural areas indicate that the multi-peak distribution in 2001 evolved into a single peak density distribution during the following 15 year period indicating convergence of rural teledensity towards a steady state. In case of urban teledensity, the shape of the density curve has changed over the years with no clear pattern of convergence.

In addition to the unit root test and kernel density plots, the distribution dynamics of relative teledensity in rural and urban areas are examined with the help of transition probability matrix for three different time horizons: 1, 3, and 5 year (Table 6).

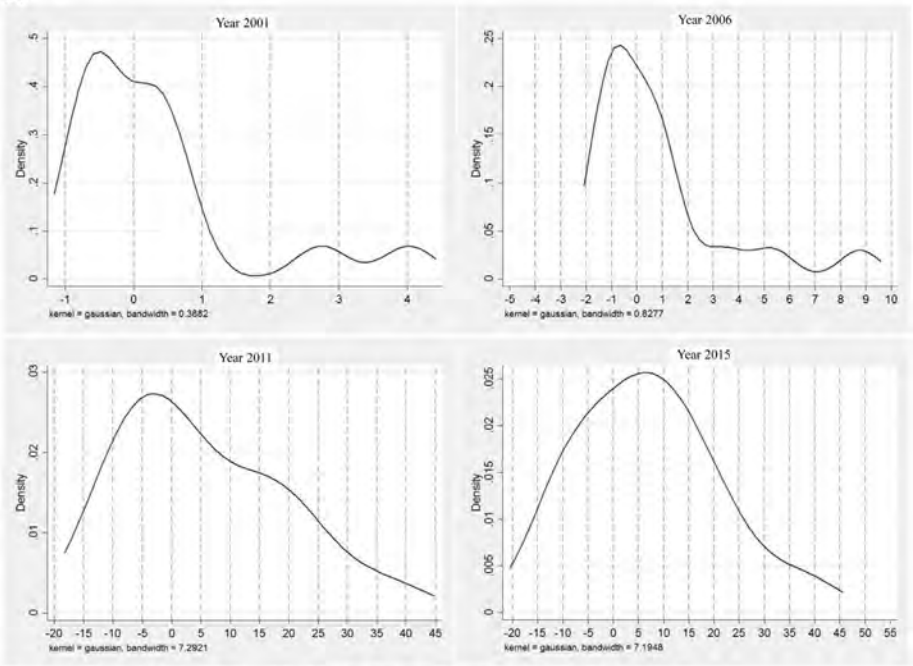
The transition probabilities reported in Table 6 indicate that there is high level of persistence for states with above average rural teledensity. However, there is some movement in case of the states with rural teledensity below the national average. For example, there is a 15 per cent probability that those states will switch to the category of above average rural teledensity in 5 year time horizon. There are relatively higher probabilities of inter-category movements of the states in urban teledensity. For example, there are 12, 28, and 40 percent probability of a state with below-the-national-average urban teledensity moving above in 1, 3, and 5 year time horizon respectively. Similarly, the probabilities of a state with above-the-national-average urban teledensity moving below in 1, 3, and 5 year horizon are estimated to be 10, 23, and 31 percent respectively. These larger movements in both directions are consistent with our earlier result of absence of convergence.

6.2. Determinants of teledensity in rural and urban areas

We further estimate two sets of regression equations to examine the determinants of urban and rural teledensity. In the first set of equations, we take rural teledensity as the dependent variable while, in the second set of equations, we take urban teledensity as the dependent variable. Data on per capita income are not available for rural and urban areas separately. We use data on monthly household consumer expenditure for rural and urban areas from various rounds of household survey (National Sample Survey Organisation, 2002; National Sample Survey Organisation, 2003; National Sample Survey Organisation, 2005a; National Sample Survey Organisation, 2005b; National Sample Survey Organisation, 2006; National Sample Survey Organisation, 2008a; National Sample Survey Organisation, 2008b; National Sample Survey Organisation, 2010; National Sample Survey Organisation, 2011; National Sample Survey Organisation, 2014) conducted by the National Sample Survey Organization (NSSO) for the sample period to calculate the rural-urban consumption ratio and apply those ratios to construct per capita NSDP for rural and urban areas separately for each state.[21] Data on literacy rate are available separately for rural and urban areas in 2001 and 2011 from decennial census. As in case of overall literacy rate, we use linear interpolation (extrapolation) to construct annual data.

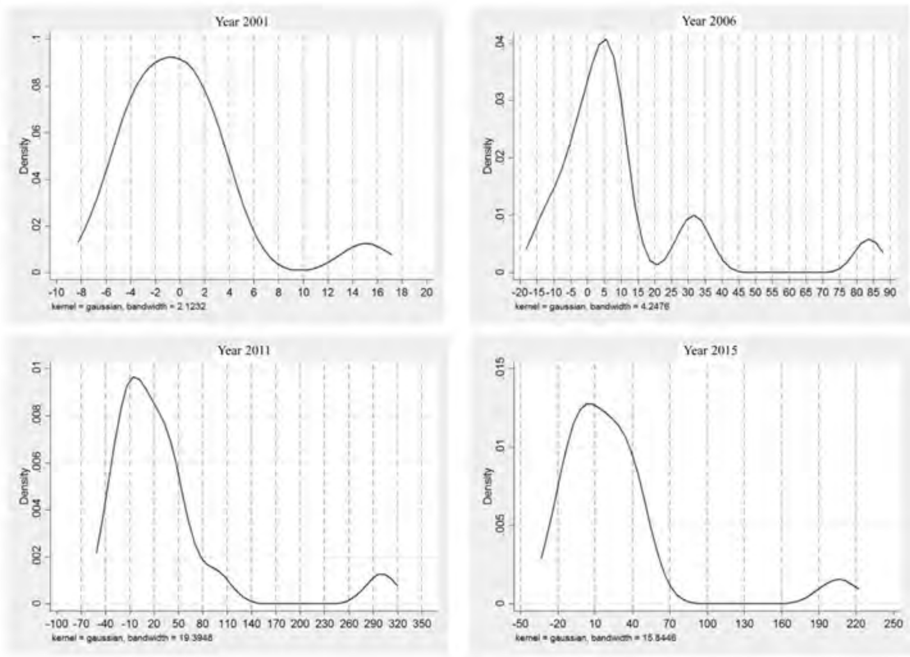
[21] The underlying assumption is that the income ratio between rural and urban areas is same as the consumption ratio. The method used to construct rural and urban NSDP data is discussed in Appendix 2.

(a)



Source: Based on authors' calculations of relative teledensity
Note: Different scales are used for these diagrams

(b)



Source: Based on authors' calculations of relative teledensity
Note: Different scales are used for these diagrams

Fig. 6. (a). Kernel density plots of relative teledensity (rural). (b) Kernel density plots of relative teledensity (urban).
Note: Different scales are used for these diagrams.
Source: Based on authors' calculations of relative teledensity

Table 6
Transition probability matrix for relative teledensity for rural and urban areas across Indian states.
Source: Authors' estimation

	Rural teledensity		Urban teledensity	
	Below national average	Above national average	Below national average	Below national average
	(1)	(2)	(3)	(4)
1-year horizon				
Below national average	0.93	0.07	0.88	0.12
Above national average	0.04	0.96	0.10	0.90
3-year horizon				
Below national average	0.87	0.13	0.72	0.28
Above national average	0.05	0.95	0.23	0.77
5-year horizon				
Below national average	0.85	0.15	0.60	0.40
Above national average	0.03	0.97	0.31	0.69

Table 7
GMM estimation results for the rural and urban teledensity.
Source: Authors' estimation

Variables	Estimated coefficients			
	(1)	(2)	(3)	(4)
Panel A: Dependent variable: Rural teledensity				
Log of Per Capita NSDP (ln*NSDP*)	43.65***	33.04***		
	(2.36)	(0.48)		
Literacy Rate (*Lit*)	−1.34***		0.71***	
	(0.19)		(0.01)	
NSDP Share of the Services Sector (*Service*)	0.69***			2.51***
	(0.07)			(0.04)
1-year Lagged Teledensity ($Tele_{i,t-1}$)	0.87***	0.83***	1.05***	1.04***
	(0.01)	(0.01)	(0.00)	(0.00)
No. of states	16	16	16	16
No. of observations	144	144	144	144
Hansen's J statistic	14.48	15.41	15.67	15.77
Hansen's J p-value	0.27	0.35	0.33	0.32
Panel B: Dependent variable: Urban teledensity				
Log of Per Capita NSDP (ln*NSDP*)	106.08**	99.06***		
	(46.37)	(4.25)		
Literacy Rate (*Lit*)	−1.21		8.22***	
	(8.47)		(0.48)	
NSDP Share of the Services Sector (*Service*)	−3.27*			8.99***
	(1.88)			(0.39)
1-year Lagged Teledensity ($Tele_{i,t-1}$)	0.93***	0.86***	0.97***	0.94***
	(0.05)	(0.01)	(0.00)	(0.02)
No. of states	16	16	16	16
No. of observations	144	144	144	144
Hansen's J statistic	13.63	15.62	15.77	14.20
Hansen's J p-value	0.32	0.33	0.32	0.43

Note: ***, ** and * indicate significant at the 1%, 5% and 10% level respectively. Standard errors are in parentheses.

However, we do not have data for service sector share for rural and urban areas separately and therefore use the same data for this variable in both sets of models. The results are reported in Table 7.

For both urban and rural areas, per capita NSDP and network externality are statistically significant determinants of teledensity. The counterintuitive significant negative effect of literacy rate on rural teledensity and that of service sector share on urban teledensity may have reflected the multicollinearity problem. In a related study on rural telecom penetration, Jain and Raghuram (2007) also report that rural per capita income is a significant determinant of rural teledensity and note that rural literacy rate is correlated with income.[22] They further demonstrate that urban teledensity is a significant driver of rural teledensity. We conduct a similar

[22] An earlier study by the same authors (Jain & Raghuram, 2005) finds that rural literacy is a major determinant of telecom demand in rural India.

exercise and we find support for their conclusion while maintaining robust results for other variables that we include in our models. That is, urban teledensity has a significant positive impact on rural teledensity.[23,24]

In summary, it was found that teledensity in rural areas are tending towards convergence whereas the pattern of urban teledensity does not show any such trend. The regression analysis reveals that similar determinants drive teledensity in rural as well as in urban areas.

6.3. Additional explanatory variables

It is possible that there are additional variables that are important determinants of teledensity along with the variables we consider in our baseline models. We therefore examine the robustness of the results for our baseline specification by including four additional variables, namely population, length of surfaced roads per thousand square kilometer, percentage of urban population, and per capita annual electricity consumption in the regression equation. As De Fontenay and Lee (1983) and Breslaw (1985) argue, an increase in population with no change in the penetration rate captures one form of network externality. Therefore, we would expect it to have a positive impact on telecom demand. Further, well-developed road network facilitates smooth, cheap and timely transportation of equipment and materials required for telecommunication services. Thus, it is expected to have a positive impact on teledensity. Similarly, as Chinn and Fairlie (2007) argue, electricity is an essential infrastructure for ICTs such as personal computers and the Internet service. ICT such as telephone is not an exception as electricity is essential not only to provide the basic services but also to utilize those services. Finally, we include the percentage of population living in urban areas in our empirical model. As noted by Graham and Marvin (1995), urban centers as hub of economic, social and cultural life tend to have strong relation with infrastructure like telecommunication. As a result urban centers exert extensive demand for telecommunication.

Note that we obtain data on road length from *Infrastructure Statistics* 2013 and 2014, published by the Central Statistics Office, Government of India. Similarly, data on per capita electricity consumption and population (total as well as urban) are obtained from the *Annual Report (2013–14) on The Working of State Power Utilities and Electricity Departments* prepared by the Power and Energy Division of Planning Commission, Government of India in 2014, and the Office of the Registrar General and Census Commissioner, Government of India, respectively.[25] However, the electricity consumption data are not available for the entire sample period. Therefore, we estimate three specifications of our expanded model. The first specification includes logarithm of population and road length per thousand square kilometer as additional explanatory variables and is estimated for the entire sample period. We then add urban population share in the second specification. In the third extended model, we include all four new variables but estimate only for the period: 2007–12. The results are presented in Table 8.

In all three specifications, the estimated coefficients for per capita NSDP and network externality remain positive and statistically significant, and those for literacy rate and service sector share are insignificant as in our baseline model. Among the additional variables, the estimated coefficient for population is positive and statistically significant in all three extended models. Road length per square kilometer is a statistically significant determinant in the first two extended specifications. The other two additional variables are not statistically significant in the expanded models.

Overall, the evidence of positive and significant impacts of per capita NSDP and network externality on teledensity is a robust result. In addition to the results reported above, it may be useful to consider a state policy context for the evolution of teledensity across different states. Although the diffusion of telecommunication services on the supply side is largely governed by the national-level telecom policies, state-level IT policies can play a role on the demand side. Indian states have formulated and implemented state policies to encourage the growth of the ICT sector during past two decades or so. However, there are substantial differences in the year of introduction, scope, and implementation of these policies. In the absence of systematic and transparent record keeping, it is difficult to find an exhaustive list of these policies in different states. According to Das and Sagara (2017), Andhra Pradesh, Karnataka, Tamil Nadu, Delhi and Maharashtra are some of the early and successful states (rather the major cities therein) in implementing state-level policies to render the IT sector dynamic in response to growing global market needs. In contrast, less developed states like Odisha, Chhattisgarh, and Uttar Pradesh are the late entrants in this arena. These policy differences may have an impact on teledensity across different states. There is some evidence that the states that enacted and implemented proactive state policies early on are also the states that have high teledensity.

7. Concluding remarks

The Government of India through implementation of various policies (NTP 1994; NTP 1999; NTP 2012) is constantly making effort to improve the telecommunications services across the length and breadth of the country. As a result, during the last decade, telecommunications services in the country expanded considerably in terms of the number of subscriptions and teledensity. However, despite having similar pan-India policy, the expansion of telecommunication services is uneven across states and significant

[23] We do not report the entire set of results to save space. Interested reader may obtain the results from the corresponding author via email.

[24] In an interesting study on adoption of mobile telephony in rural India using micro-level survey data from Chhattisgarh and Uttar Pradesh, Gupta and Jain (2014) report that perceived usefulness is the most significant factor in the intention of adoption followed by personal image and mobility. According to the study, adopting mobile telephony results in the gain in status among the adopter social group. Furthermore, it finds social influence to be one of the key factors in the intent of adoption. The opinion of friends and relatives are an important driver of the adoption of mobile telephone in rural India. The study finds no effect of service quality on the adoption. Evidently, the potential adopter does not consider issues in services quality as permanent and assumes that it would be resolved in due course of time.

[25] In the Indian context, yearly data on urban population for the states are not available as census enumeration takes place decennially. However, in 2006, the Office of the Registrar General and Census Commissioner, India, published a report projecting population of India and its states for the period 2001 to 2026. The present study utilises the projected population figures to obtain percentage of population living in urban areas across the sample states.

Table 8
GMM estimation results for extended models. (Dependent variable: Teledensity).
Source: Authors' estimation

Explanatory variables	Estimated coefficients			
	Baseline Model	Extended model 1	Extended model 2	Extended Model 3
	(1)	(2)	(3)	(4)
Log of Per Capita NSDP (ln*NSDP*)	54.28***	29.33**	35.69**	205.90**
	(5.13)	(14.01)	(16.51)	(88.67)
Literacy Rate (*Lit*)	−0.94	−0.45	−0.84	−3.31
	(0.59)	(1.23)	(1.30)	(3.48)
NSDP Share of the Services Sector (*Service*)	0.69	−0.15	−0.05	0.23
	(0.60)	(0.44)	(0.43)	(0.97)
1-year Lagged Teledensity ($Tele_{i,t-1}$)	0.86***	0.85***	0.85***	0.26**
	(0.01)	(0.02)	(0.02)	(0.13)
Log of population		45.70***	39.28**	204.87***
		(14.52)	(17.18)	(64.78)
Log of Available Road Per 1000 Square Kilometer		14.55***	15.71***	5.10
		(2.60)	(3.12)	(8.26)
Percentage of Urban Population			−0.52	4.52
			(1.38)	(6.90)
Log of Per Capita Electricity Consumption				−16.59
				(19.48)
No. of states	16	16	16	16
No. of observation	144	144	144	48
Hansen's *J* statistic	14.97	15.12	14.48	11.82
Hansen's *J* *p*-value	0.24	0.12	0.10	0.15

Note: *** and * indicates significant at 1% and 10% respectively. Standard errors are in parentheses.

differences in terms of teledensity continue to prevail. Against this backdrop, this paper analyses the dynamics of differential penetration of telecommunication services in terms of teledensity across states in India.

Using data for 16 major states in India from 2001 to 2015, this paper examines the patterns, distribution dynamics, and the drivers of telecommunications (telecom) services across different states. We apply both parametric and nonparametric econometric techniques to study the distribution dynamics of telecom services across the states. Further, we employ the generalised method of moment (GMM) to examine the determinants of telecommunications services in India. Our results indicate that the interstate gap in telecommunications services has been declining over time and there is a tendency for convergence in teledensity towards the national average. The regression analysis suggests that per capita income and network externality are significant determinants of teledensity across states in India. Additionally, literacy rate and the relative size of the service sector are independently significant predictors of teledensity. If we consider rural and urban areas separately, there are some important differences. For example, while the interstate gaps in telecom services in rural areas seem to have declined, there is little evidence of such a tendency in urban areas. However, the regression results with respect to the importance of per capita income and network externality for telecom services are robust to the rural-urban divide and to the inclusion of additional explanatory variables.

The findings of this study have important policy implications. In general, policies that would accelerate growth in the states that are lagging behind are likely to create higher demand for telecommunications services and that would go a long way in closing the gap. ICT or ICT enabled services have been concentrated only in a few states and cities of India and have been primarily catering to the external demand.[26] For example, according to Das and Sagara (2017), the export revenue from ICT and ICT enabled services was about three times greater than the revenue earned from the domestic market. As they note, the ICT exports are highly dependent on the markets in the US (62%) and Europe (28%).[27] Thus, it does not seem to have any catalytic impact of spreading telecom services uniformly to different parts of the country. However, if the domestic demand for these services grow– especially through robust economic growth – that would be helpful in reducing the gaps across different states or regions.

Furthermore, as Hutchinson and Ilavarasan (2008) note rising wages, high staff turnover, and crumbling infrastructure in ICT

[26] According to The Digital Indian Cities Survey, 2016 conducted by the CEOWORLD Magazine, Bengaluru, Delhi National Capital Region (NCR), Mumbai, Hyderabad, Pune, Ahmedabad & Gandhinagar, Chennai, Thiruvananthapuram, Jaipur, Kolkata, Chandigarh, and Mysore are the top 12 digital technology cities (http://ceoworld.biz/2016/12/02/indias-top-12-tech-cities-digital-indian-cities-survey-2016/, accessed on February 10, 2018) in India. It also means that there is a substantial concentration of ICT or ICT enabled services in the states where these cities are located. Furthermore, as Das and Sagara (2017) show, Andhra Pradesh, Karnataka, Maharashtra, and Tamilnadu accounted for 80% of the total exports from registered units with Software Technology Parks of India (STPI) in 2012–13. This is another indication of agglomeration of ICT service industries in a select number of states.

[27] A study by Nath et al. (2015) shows that India gained comparative advantage vis-à-vis the US in several information-intensive services such as computer and information services, management and consulting services, and research, development, and testing services around the turn of the century. In a related recent study Nath and Goswami (2018) show that India has global comparative advantage in computer and information services and other business services that include a number of information-intensive services such as hardware and software related services, data processing services, trade-related services, operational leasing (rentals), and miscellaneous business, professional and technical services like legal, accounting, management consulting, public relations services, advertising, market research and public opinion polling, research and development services, architectural, engineering, and other technical services, agricultural, mining and on-site processing.

cluster cities like Bengaluru, Hyderabad have created opportunities for shifting ICT and ICT enabled services to secondary urban cities and second-tier cities. The local and state governments, particularly in states that have been lagging behind, could proactively formulate and implement policies to attract such investments. Successful implementation of such policies will contribute to the growth of teledensity.

The possibility of providing ICT enabled services like healthcare, banking, education, agricultural extension services, retailing over a mobile platform would contribute to the growth of domestic demand for telecom services thereby increasing the teledensity. Also, the proliferation of e-governance that involves the use telecommunications for delivery of various public administrative services would motivate people to subscribe to telecom services increasing teledensity. The state governments can formulate and implement policies to expedite the introduction of ICT enabled services and e-governance. In recent years, Bhoomi project in Karnataka, Gyandoot in Madhya Pradesh, Lokvani in Uttar Pradesh, Project Friends in Kerala, e-Mitra in Rajasthan, and e-Seva in Andhra Pradesh have been some of the most successful e-government projects.

Although the study finds some interesting results, there are certain limitations of the present study. The primary limitation is that of data. The study considers only 16 states of the country. Furthermore, the regression analysis uses data only until 2012 as data on some of the explanatory variables are not available since then.

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Appendix 1

Table A1
Description of Telecom Circles in India
Source: Department of Telecommunication, Government of India

Sl. No.	Name of Telecom Circle	Areas covered
01.	West Bengal	Andaman & Nicobar Islands + West Bengal + Sikkim excluding Kolkata
02.	Andhra Pradesh	Andhra Pradesh
03.	Assam	Assam.
04.	Bihar	Entire area falling within the re-organised State of Bihar and newly created State of Jharkhand pursuant to the Bihar Reorganisation Act, 2000 (No.30 of 2000) dated 25th August 2000.
05.	Gujarat	Entire area falling within the State of Gujarat and Union Territory of Daman and Diu, Silvassa (Dadra & Nagar Haveli).
06.	Haryana	Haryana except the local areas served by Faridabad and Gurgaon Telephone exchanges.
07.	Himachal Pradesh	Himachal Pradesh
08.	Jammu & Kashmir	Jammu & Kashmir + autonomous council of Ladakh.
09.	Karnataka	Karnataka
10.	Kerala	Kerala + Union Territory of Lakshadeep and Minicoy.
11.	Madhya Pradesh	Madhya Pradesh
12.	Maharashtra	Maharashtra + Union Territory of Goa, excluding Mumbai
13.	North East	Arunachal Pradesh Meghalaya, Mizoram, Nagaland, Manipur and Tripura.
14.	Orissa	Orissa.
15.	Punjab	Punjab + Union territory of Chandigarh.
16.	Rajasthan	Rajasthan.
17.	Tamil Nadu	Tamilnadu + Union Territory of Pondichery excluding Chennai
18.	Uttar Pradesh-West	Entire area covered by Western Uttar Pradesh with the following as its boundary districts towards Eastern Uttar Pradesh: Pilibhit, Bareilly, Badaun, Etah, Mainpuri and Etawah. It will exclude the local telephone area of Ghaziabad and Noida. However, it will also include the newly created State of Uttaranchal pursuant to the Uttar Pradesh Re-And Act, 2000 (No.29 of 2000) dated 25th August 2000.
19.	Uttar Pradesh _ East	Entire area covered by Eastern Uttar Pradesh with the following as its boundary districts towards Western Uttar Pradesh: Shahjahanpur, Farrukhabad, Kanpur and Jalaun.

(*continued on next page*)

Table A1 (*continued*)

Sl. No.	Name of Telecom Circle	Areas covered
20.	Chennai	Local Areas served by Chennai Telephones, Maraimalai Nagar Export Promotion Zone (MPEZ), Minzur and Mahabalipuram Exchanges
21.	Delhi	Local Areas served by Delhi, Ghaziabad, Faridabad, Noida, and Gurgaon Telephone Exchanges
22.	Kolkata	Local Areas served by Calcutta Telephones.
23.	Mumbai	Local Areas served by Mumbai, New Mumbai and Kalyan Telephone Exchanges

Appendix 2

Method for constructing rural and urban NSDP.
Define

C^R = monthly rural household consumer expenditure
C^U = monthly urban household consumer expenditure
Y^R = annual rural per capita NSDP
Y^U = annual urban per capita NSDP

$$r = \frac{C^R}{C^U} \tag{B1}$$

Assume that the ratio of annual rural-urban per capita NSDP is same as the ratio of monthly rural-urban household consumer expenditure. That is

$$\frac{Y^R}{Y^U} = \frac{C^R}{C^U} = r$$
$$\Rightarrow Y^R = rY^U \tag{B2}$$

We can write a formula for per capita NSDP for a state as follows:

$$\frac{Y^R \times P^R + Y^U \times P^U}{P^R + P^U} = Y \tag{B3}$$

where P^R and P^U are total rural and urban population respectively, and Y is the per capita NSDP of the state. Substituting for Y^R from (B2) in (B3) and solving for Y^U, we obtain

$$Y^U = \frac{(P^P + P^U) \times Y}{(r \times P^R + P^U)} \tag{B4}$$

Now, substituting for Y^U in (B2), we can obtain Y^R.

Note that we obtain data on C^R and C^U from the household consumer expenditure surveys conducted by NSSO, population data from the Office of the Registrar General and Census Commissioner, India, and per capita NSDP data from RBI.

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