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# Exploring the Main Factors Affecting Mobile Phone Growth Rates in Indian States

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**Abstract**
This paper investigates the growth of mobile telecommunications across the 23 circles (or states) in India for the period 2005–2021. From this study, we note that diffusion of mobile phones in Indian circles (or states) was influenced by the telecommunication policy of the Indian government. We noted that the growth rates of mobile telephony in all the 23 states followed a logistic model. From this, we inferred that some of the Indian states, with low GDP per capita income started rolling out mobile telephony operations later than states with high GDP per capita income, but could catch with the later. It also follows that states with more rural regions had more adoption of mobile telephony. From this study, we can inform policy makers and telecom providers that electrical power consumption, Human Development Index (HDI), Herfindahl Index (HHI) and proportion of rural to urban ratio do not form an important parameter for mobile growth.

**Keywords** Diffusion of mobile phones · Logistic model · Macroeconomic factors · Price effect · Indian telecommunication policy

## Introduction

Telecommunications especially mobile helped connect billions of people globally to carry out work and life from home during the Covid-19 pandemic (IFC report, 2022). Mobile telephone subscribers are rapidly expanding (in both developed and developing nations) across the globe. According to the International Telecommunication Union (ITU), there were over 4 billion internet users at the end of 2019, out of which 3 billion users where from the developing countries (IFC report, 2022). While in 2014, mobile phone diffusion per 100 was 107 for Guatemala, 108 for the Congo,

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138 for Bulgaria, 120 for Germany, 98 for USA and 74 for India (World Bank, 2014). Scholars have argued that mobile phones can reduce the digital divide and increase economic growth in developing nations are bypassing the mainline phone infrastructures and thus accelerating the speed of mobile phone diffusion (Yang et. al. 2014; Srivastava, 2010). Mobile phone diffusion study in India is important as it may provide guidance of information and communication technology (ICT) diffusion in other developing nations. For example, provincial (or state) level ICT diffusion within a nation is rare in the literature. It is important as the overall mobile diffusion per 100 may hide the truth of diffusion when state-level diffusion in a nation is considered. The roles of several factors such as Herfindahl index (representing competition) on mobile diffusion rate are not sufficiently studied as is the role of price in mobile diffusion at the state level. This paper addressed these gaps.

Figure 1a shows the estimated number of mobile-cellular subscriptions to be 8 billion in 2021. Figure 1b shows that about 4 billion mobile subscribers are from the Asia-Pacific region. Developing countries alone account for 78% of the world's mobile-cellular subscriptions. In 2021, the estimated penetration rate of mobile-cellular in developing versus developed countries was 90% and 121%, respectively. Figure 1b also shows that the mobile phone penetration in Africa, Asia and the Pacific reached 69% and 89%, respectively of the total mobile segment. The Commonwealth of Independent States (CIS), Arab States, the Americas and Europe and developed countries have reached penetration levels above 100%.

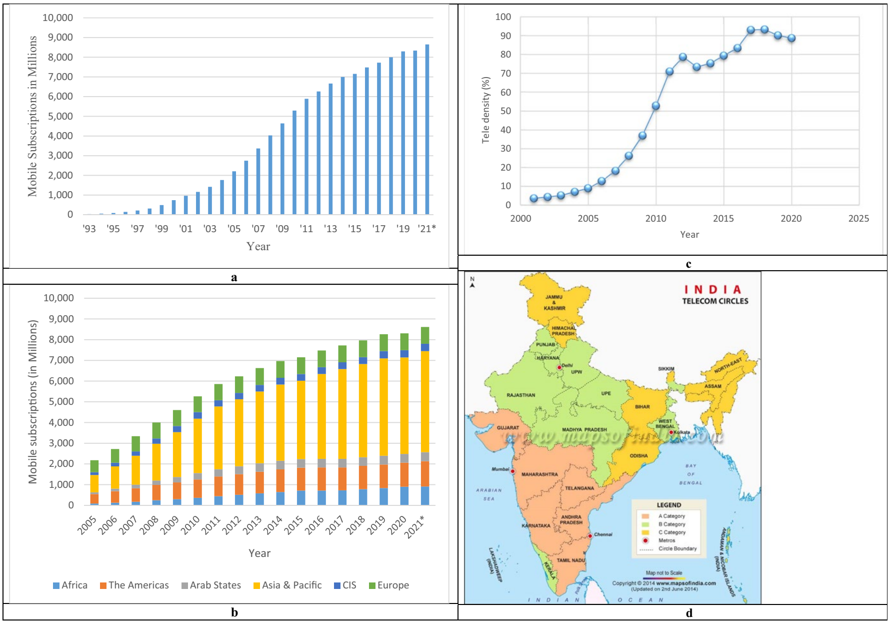


**Fig. 1** **a** Mobile phone penetration rates [Source: ITU], **b** Mobile phone penetration rates [Source: ITU], **c** Tele density of cellular phones in India, **d** Telecom Circles in India

India has shown a phenomenal growth in mobile phone adoption since 2005 (Bisht and Mishra, 2016). In 2021, according to the Telecom Regulatory Authority of India (TRAI) reports, there are 84 million mobile phones in India via-a-vis 2 million fixed line phones. The overall tele density is 86 per 100 citizens (TRAI, 2021). This clearly shows a huge growth of mobile phones in India in contrast to the quarter that ended March 2012 when the tele density of India was 78.66. The average tele density was then around 80 (urban and rural tele density was about 170 and 39, respectively) and the number of wireless phone users in urban India was double the number of users in rural India. In 2012, the number of wired users in India was about 31 million, of which urban and rural users account for around 24 million and 7 million, respectively (TRAI, 2021). Based on the survey data, the average monthly revenue per user has declined from 132 Indian Rupees ($2.64) to 97 Rupees ($1.94), although the number of users, as well as gross revenue, has increased (i.e., more low-income people are using mobile phones as the nation experiences increase in gross revenue).

It follows that the mobile phone diffusion has been extensive in India and has replaced the fixed line telephony across the country. Figure 1c shows the tele density of mobile subscribers in India. The tele density (i.e., fixed and mobile connections), has increased significantly, although the urban and rural digital divide is slowly disappearing (TRAI, 2021). This has facilitated the hypothesis: “Connectivity is productivity” (Quadir, 2003). The diffusion of mobile telephones in India has happened in the last 10 years and has positively impacted the Indian economy and changed the lives of millions of Indians, especially the poor (Bisht & Mishra, 2016). This has led to critical economic activity.

Figure 1d represents the 23 Telecom circles in India. The Telecom circles are mostly co-terminus with the states in India. The Indian province has been divided into three metro circles, five A circles, eight B circles and six C circles, based on propensity of expenditure of the citizens. Mostly, the western and southern states of the country are denoted as A circle baring Kerala. Similarly, north and western states of India are demarked as A. While the eastern and north eastern states, along with Jammu and Kashmir and Himachal Pradesh is denoted as C circle. Only baring West Bengal in the eastern India is a B circle. While Delhi, Mumbai and Kolkata are marked as metro circles (Jha et al., 2019).

Given the explosive growth in mobile phone adoption in India, it is important to empirically explore the factors that contribute to it. A few studies (Gupta & Jain, 2014; Sridhar, 2007) investigate these factors using one or very few circles/states in India. A few earlier studies (e.g. Gupta & Jain, 2014) focus only on rural parts of India. The findings of such studies cannot be generalized, and so there is a need for a study that covers several circles and includes both urban and rural communities in India. In this study, we trace the growth of mobile telecommunications across the 23 circles in India. The growth rates of all states are determined using a logistic model and the fits are investigated. Inter-circle and intra-circle growth rates differences are also studied. Next, the effect of other macroeconomic factors, such as state-level domestic product, power consumption, Human Development

Index (HDI), Herfindahl Index (HHI) and proportion of rural to urban ratio on mobile growth rates are observed. We also try to investigate whether late adopting states have been able to catch up with early adopters. Finally, we determine whether price decrease had any effects and whether these effects vary between states.

The paper is divided into 8 sections. The "Literature Summary" section contains a review of literature related to mobile phone diffusion in India, and the "Theory and Hypothesis Development" section is devoted to theory and hypotheses development. The "Data" section is on data, and the "Methodology" section is on methodology. The "Results" section contains results and the "Discussion" section is for discussion and future research. The "Conclusion" section finishes with conclusions.

Table 1 shows the overall growth of fixed line and cellular telephone services in India from 2000 to 2021. In 2007, TRAI removed cap on the maximum number of cellular mobile service providers (CMSP) that could obtain licenses in a circle. As a result, more private CMSPs joined in every Telecom circle across the country. Currently, Bharti-Airtel, Reliance Jio and Vodafone Idea are the private CMSPs

**Table 1** Telephone subscribers India (in billions)

| Year | Fixed line subscriber | Cellular subscriber | Fixed Line Tele density | Cellular Tele density |
|---|---|---|---|---|
| 2000 | 32.44 | 3.58 | 0.0035 | 0.3386 |
| 2001 | 38.54 | 6.54 | 0.0047 | 0.6084 |
| 2002 | 41.42 | 13.00 | 0.0075 | 1.1890 |
| 2003 | 42.00 | 33.69 | 0.0126 | 3.0310 |
| 2004 | 46.20 | 52.22 | 0.0208 | 4.6228 |
| 2005 | 50.18 | 90.14 | 0.1175 | 7.8546 |
| 2006 | 40.77 | 166.05 | 0.1973 | 14.2473 |
| 2007 | 39.25 | 233.62 | 0.2645 | 19.7446 |
| 2008 | 37.90 | 346.89 | 0.4398 | 28.8914 |
| 2009 | 37.06 | 525.09 | 0.6361 | 43.1205 |
| 2010 | 35.09 | 752.19 | 0.8904 | 60.9415 |
| 2011 | 32.84 | 893.84 | 1.0678 | 71.4925 |
| 2012 | 30.94 | 864.72 | 1.1836 | 68.3152 |
| 2013 | 29.03 | 886.30 | 1.1655 | 69.1970 |
| 2014 | 27.00 | 970.97 | 1.2157 | 72.8626 |
| 2015 | 25.52 | 1010.89 | 1.2932 | 76.4076 |
| 2016 | 24.40 | 1127.37 | 1.4083 | 85.1487 |
| 2017 | 23.23 | 1167.44 | 1.3339 | 87.3177 |
| 2018 | 21.87 | 1176.00 | 1.3433 | 86.9426 |
| 2019 | 21.00 | 1151.44 | 1.4020 | 84.2700 |
| 2020 | 20.05 | 1153.77 | 1.6630 | 83.6019 |
| 2021 | 23.79 | 1154.62 | 1.7300 | 84.1734 |

who provide mobile telephony in India along with Bharat Sanchar Nigam Limited (BSNL), the incumbent provider.

The above discussion shows that various telecom circles adopted mobile phones at different periods of time as dictated by the Indian telecom policy. The richer states in Circle A started mobile phone diffusion earlier (time units 1–4). Poorer states in Circle B (time units 1–9) and Circle C (time units 1–77) started late. Thus, the GDP per capita of states may have contributed to the mobile diffusion (Park et al., 2008). In the next section, we discuss the various factors that could have played a role in the mobile diffusion.

## Literature Summary

We have classified the literature related to Indian telecom into six broad classes, such as (i) role of Telecom Regulatory (Prasad et.al., 2009, Srivastava & Sinha, 2001, Sridhar & Prasad, 2011, Dokeniya, 1999, Jain, 2006), (ii) Impact of Telecom policy on growth of mobile telephony (Athreya (1996)), (iii) Diffusion of mobile phones vis-à-vis fixed lines (Gupta, and Jain, 2012, K. Singh, 2008, Sridhar, (2010), Biancini, 2011), (iv) Factors impacting the adoption of mobile telephony in rural areas (Gupta and Jain, 2014, Gupta & Jain, 2014), (v) Modeling the demand of mobile and fixed lines (Narayana, 2009, 2010, 2011) and Pricing of services for mobile telephony (Das & Srinivasan, 1999), (vi) recent studies like re-segmentation of the mobile circles, forecasting the growth of 3G, 4G and mobile broadband in India (A Jha et al. (2019), A Jha et al. (2020), A Jha et al. (2021)). Table 2 lists the papers from 1999 to 2021, along with the focus area and the research issues studied.

## Theory and Hypothesis Development

Innovation diffusion follows a normal distribution as shown in Figure 2. Generally, few innovators formulate new ideas and have a risk taking capability. Next are the early adopters who have first mover advantage and their top lines grow. Early majority devote time to developing industry standards and best practices such that the adoption of the technology happens fast. Late majority are conservative and pragmatic, and they follow the existing norms. Laggards are risk averse, and they prefer not to indulge in new products ( Danaher et al. 2001; Gurbaxani et.al., 1990; Kauffman et.al., 2005; Rogers, 2003; Fritsch & Franke, 2004).

The rate of diffusion is given in Equation (1) and depends on the coefficient of diffusion, the total number of potential adopters less the number of adopters (Mahajan & Peterson, 1985).

$$\mathrm{dN\ (t)/dt} = \mathrm{g(t)[N - N(t)]} \tag{1}$$

where $N(t) = \int_{to}^{t} n(t)dt$, N(t = t0) = N0, N = total number of potential adopters, dN (t)/dt = rate of diffusion, N0 = cumulative number of adopters at time to, n(t) = number of adopters at time $t_o$.

**Table 2** List of articles related to Indian Telecom

| *Author* | Focus area | Research issues |
|---|---|---|
| L. Srivastava & S. Sinha (2001) | Role of regulator in India | Role of TRAI in revenue-sharing between fixed and mobile operators to ensure interconnection |
| V. Sridhar & R. Prasad (2011) | | Identify the casual variables for effective management and allocation of spectrum effectively in emerging and advanced markets |
| A. Dokeniya (1999) | | 1. Private investors look for a reasonable ROI<br>2. Governance mechanism to insulate private players against arbitrary discretion. |
| R. Jain (2006) | | 1. Models for interconnection charges 2. Implications of fast technological changes in India |
| M B Athreya (1996) | Policy | Implementation challenges of the New Telecom Policy,1990 |
| R. Gupta & K. Jain, 2014 | Adoption in rural India | Factors that affect it are : perceived health hazard, service quality, ease of service accessibility, cost of handset ,and transparency of service offerings |
| R. Gupta & K. Jain (2014) | | The probable factors moderated by gender, age, and techno affinity.<br>Sample: Uttar Pradesh and Chhattisgarh |
| R. Gupta & K. Jain (2012) | Diffusion of mobile phones vis-à-vis fixed lines | Investigate the relationship between diffusion speed and the social, technological, economic and political (STEP) factors |
| K. Singh (2008) | | Identify the diffusion pattern and predict the future growth of the subscribers. |
| V Sridhar (2010) | | Mobile phone growth in India is dependent on Techno-economic, Demographic, Competition and network effects. |
| S. Biancini (2011) | | Reforms and exploiting the information contained in the new market organization (the Circles classification). |
| M.R. Narayana (2009). | Telecom demand of mobile and fixed lines | Fixed line telecom demand is dependent on education, income and castes.<br>Sample: State of Karnataka. |
| M.R.Narayana (2010). | | 1. Telecom demand depends on usage price.<br>2. Price elasticity affects Telecom demand.<br>3. Notes fixed and mobile technologies show a substitution effect. |
| P. Das & P. Srinivasan (1999). | Pricing of telecom services in India | Estimate the price elasticity between local and long distance call |
| A Jha et al. (2019) | Redefine the telecom circles in India | Using Human Development Index, Gross Domestic Product, and Tele density indicator data and using clustering algorithm the telecom circles have been redefined. |
| A Jha et al. (2020) | Forecast growth rates of 3G and 4G services in India | Using non-linear regression techniques the growth rate of 3G and 4G mobile subscribers have been forecasted. |
| A Jha et al. (2021) | Growth of mobile broadband in India | Analysis of reasons that deter the Growth of mobile broadband in India |

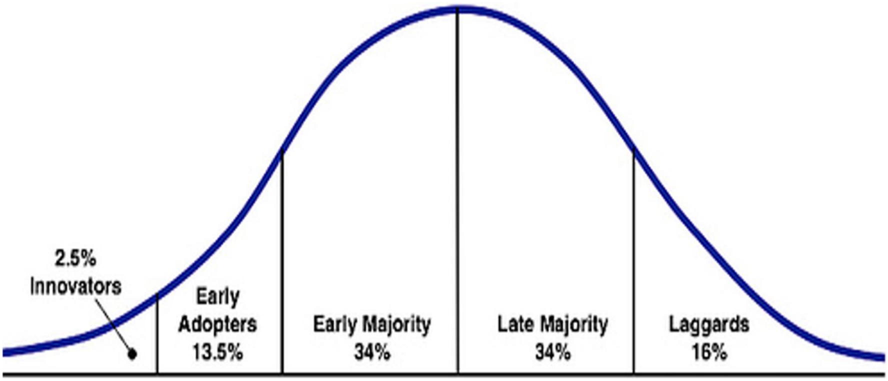


**Fig. 2** Stages of Telecom adoption

Diffusion rate can be assumed to represent the expected increase in the number of users over time since g(t) is equated to the probability of growth. In Figure 3, we propose a research model to study the macro-economic factors affecting the growth rate of mobile telephony.

## Mobile Phone Adoption

Diffusion curves such as the logistic, Gompertz or the mixed model can be used to model mobile growth rates (Mahajan & Peterson, 1985). Singh (2008) noted that the overall growth rate of mobile telecom in India from years 1995 to 2006 (early years) could be modeled by a Gompertz and Logistic curve. An empirical study on mobile diffusion in Taiwan shows that the Gompertz model outperforms other models for the period prior to diffusion take-off, whereas the Logistic model is superior after diffusion inflection (Wu & Chu, 2010). Their study further shows that the mobile diffusion could be a stage-dependent, and logistic model is superior on an aggregate level. Additionally, since we are considering a longer period of time (1997 to 2014), the growth rates may tend to be more symmetric in various states, and

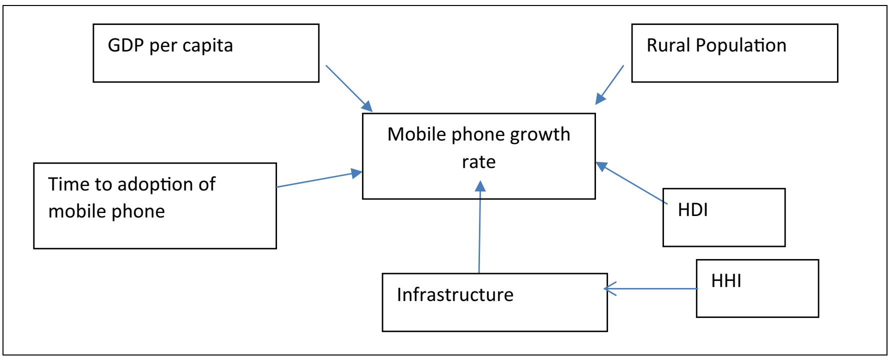


**Fig. 3** Casual diagram to measure mobile phone growth in India

thus, a logistic diffusion model could be appropriate. The logistic model has been applied in modeling of many telecommunications diffusion (Gruber & Verboven, 2001a; Franke, 2004; Lee and Cho, 2007; Wu and Chu, 2010). Bagchi et al. (2005) also noted that the diffusion of mobile and telephone follows a logistic model. These studies lead the following hypothesis:

**H1: A Logistic model can estimate the growth of mobile telephony over circles and over time.**

### Macroeconomic Factors Impacting Mobile Phone Growth Rates across States

We have modeled mobile phone adoption growth rate as a function of GDP per capita, time of adoption, rural population, HDI, HHI, and infrastructure. These factors and the related hypotheses are discussed below.

### GDP Per Capita

GDP per capita seems to influence mobile growth level and/or rates in different nations (Dekimpe et al., 1998; Ahn and Lee 1999; Lee et al., 2007; Burki and Aslam, 2000; Gruber, 2000; Gruber et al., 2001a; Madden et al., 2004; Frank et al., 2004; Chu et al., 2009). High poverty rates lead to low growth, and low growth leads to more poverty (Perry et al., 2006). However, James (2012) has noted that in general, leapfrogging (use of mobile phone, bypassing the fixed-line telephones) is negatively associated with GDP per capita. One can conclude from this that the overall impact of GDP per capita will be most significant and negative on mobile growth rate. In other words, there will be a convergence in mobile phone growth rates in low GDP states (which started later) and will exhibit higher mobile growth rates. These arguments lead us to the next hypothesis.

**H2a. Mobile phone growth rates are inversely proportional to GDP per capita of a state.**

### Time to Adoption and Mobile Growth Rate

Dekimpe et al. (2000), and Kumar and Krishnan (2002) have observed that diffusion of a product in lead markets (earlier diffusion markets) can influence the diffusion of the product in a lag-market (later-diffusion markets). Therefore, we hypothesize that:

**H2b. Mobile phone growth rates depend inversely on time to adoption.**

### Rural Population

The rural population has been shown to affect mobile phone growth level or rate (Gruber 2001; Burkhi et al., 2000; Loboda, 1974; Proenza, 2001). By 2000, more than 50% of the World's population was living in urban area. Therefore, urbanization is an important factor in ICT growth. With respect to ICTs, Loboda (1974) found that the diffusion of televisions in Poland predominately started in the urban parts of the country. Proenza (2001) notes that the use of ICTs has grown rapidly in only the most urban regions in Africa. This could be true for mobile growth rates in India. We can accordingly hypothesize that:

**H2c. Mobile phone growth rates and rural population are inversely related.**

### Human Development Index (HDI)

HDI (UNDP, 1990) is a function of the three indicators: (i) Longevity, as measured by life expectancy at birth, (ii) Education Attainment, as measured by the combination of adult literacy and combined primary, secondary and tertiary enrollment ratios; and (iii) Standard of Living, as measured by real GDP per capita adjusted with Purchasing Power Parity (PPP). Economic growth theorists have shown that the accumulation of human capital can sustain long-term economic growth (Ciccone, 1994; Lucas, 1990). This could be true for mobile phones. Hence the hypothesis:

**H2d. Mobile growth rates increase as HDI index of a state decreases.**

### Infrastructure

Shakeel et al. (2001) found that lack of communications and power infrastructure could contribute to less ICT development. Mwesige (2003) has emphasized that poor basic infrastructures (such as electricity, trained technical workers, and communication networks) are a barrier to ICT adoption. This could be true also for mobile phone growth.

**H2e. Electricity consumption of a state and mobile growth rates are positively related.**

### Herfindahl Index (HHI)

HHI is a measure of the size of firms in relation to the industry and an indicator of the amount of competition among them. It is defined as the sum of the squares of the market shares of the firms within the industry where the market shares are expressed as fractions. HHI can range from 0 to 1.0, moving from a huge number of very small firms to a single monopolistic producer. Increases in the Herfindahl index (HHI) generally indicate a decrease in competition and an increase of market power, whereas decreases indicate the opposite. Competition impacts mobile phone growth (Sridhar, 2007; Sridhar, 2010; Chu et al., 2009; Hwang et al., 2009).

**H2f. Low HHI leads to increased mobile growth rates.**

### The Lag Effect

There generally exists a lag-effect in any diffusion process. In other words, the later the start of the diffusion process of a product, the faster the diffusion rate is, everything else being equal (Barro, 1991). The design of the telecom circles in India was based on economic conditions. As shown in Figure 4, the richer states in Circle A started mobile phone diffusion (time units 1–4). While poorer states in Circle B (time units 1–9) and Circle C (time units 1–77) started late. As a result, the mobile phone growth rates of states are different between circles and are similar to circles.

**H3a. The intra-circle mobile phone growth rates will be similar,**
**Hb3b. The inter-circle mobile phone growth rates will be different.**

Based on the above, we next consider Model 1 and Model 2 to determine the macro economic factors that impacted the growth of mobile telephones in India.

| Model 1 | Model 2 |
|---|---|
| Mobile phone growth rate =Time lag +<br>Per capita power consumption +<br>HDI +<br>Rural percentage +<br>LN(GDP)+HHI | LN (GDP) =Mobile phone growth rate |

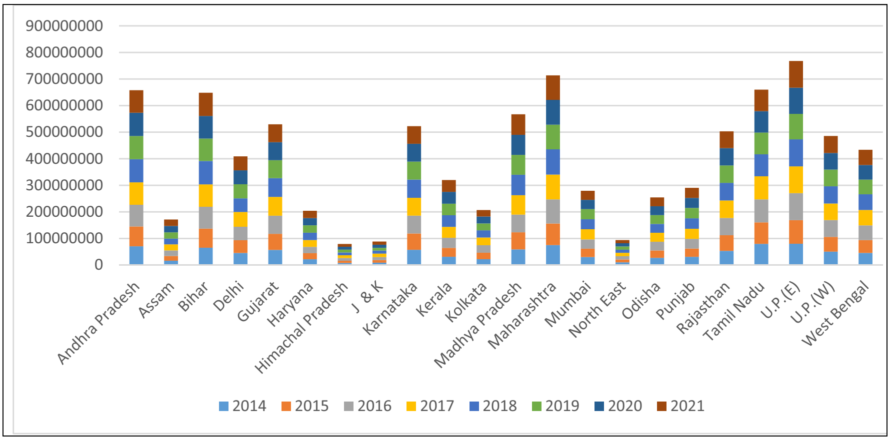


**Fig. 4** Mobile phone growth from 2002 to 2021 in different circles/states in India

## Data

In Table 3, we summarize the data sources and the central tendencies (mean and standard deviation (sd)) of the casual variables. Table 4 shows the summary of circle-wise subscriber data. (The Appendix Table 11 shows the names of states/circles and their abbreviations as used in this study). Table 5 and Figure 5 give the chronology of introduction of mobile telephony in various circles across India.

## Methodology

For testing H1, we used logistic model for calculating the growth rates of mobile phone adoption, over time, in each circle. The logistic model is given in Equation (2)

**Table 3** Source and central tendencies of the independent variables

| Variables | Source | N | Mean | Std dev |
|---|---|---|---|---|
| GDP per capita | Indiastat.com | 18 | 11.09 | 0.80 |
| Time to adoption | TRAI,COAI | 18 | 9.17 | 17.17 |
| Rural Population | Indiastat.com | 18 | 73.97 | 9.73 |
| HDI | UNDP | 18 | 0.55 | 0.08 |
| Infrastructure(power) | Indiastat.com | 18 | 376.91 | 219.71 |
| HHI | Calculated | 18 | 0.281 | 0.07 |

**Table 4** Summary of Circle Wise Subscriber data (in millions)

| Circle A(5) | N | Mean | Sd | Circle B (8) | n | Mean | Sd | Circle C(6) | N | Mean | Sd |
|---|---|---|---|---|---|---|---|---|---|---|---|
| AP | 254 | 33.33 | 37.20 | Haryana | 254 | 9.08 | 12.51 | HP | 254 | 3.54 | 4.77 |
| Karnataka | 253 | 27.70 | 30.00 | Kerala | 254 | 14.42 | 19.29 | Bihar | 239 | 30.69 | 39.61 |
| Gujarat | 251 | 27.05 | 29.19 | MP | 252 | 25.28 | 34.13 | Orissa | 246 | 11.70 | 15.40 |
| Maharashtra | 251 | 35.44 | 40.98 | Rajasthan | 252 | 22.80 | 29.78 | Assam | 244 | 8.01 | 10.53 |
| Tamil Nadu | 251 | 33.56 | 36.97 | UP.W&E | 253 | 28.10 | 39.43 | NE | 235 | 4.52 | 5.71 |
| | | | | Punjab | 251 | 13.13 | 17.34 | J&K | 177 | 5.60 | 5.66 |
| | | | | WB | 318 | 15.43 | 24.55 | | | | |

**Table 5** Introduction of Mobile Phone in circles across India

| Time<br>Circle | Mar'97 | Apr'97 | May'97 | Jun'97 | Nov'97 | Jan'98 | Oct'98 | Aug'03 |
|---|---|---|---|---|---|---|---|---|
| A | AP | Karnataka | - | Maharashtra | - | - | - | - |
| A | Gujarat | - | - | TN | - | - | - | - |
| B | Haryana | UP (W) | Rajasthan | Punjab | WB | Kerala | - | - |
| B | - | - | UP (E) | - | - | - | - | - |
| B | - | - | MP | - | - | - | - | - |
| C | - | - | - | - | Orissa | Assam | NE | J&K |
| C | - | - | - | - | Bihar | - | HP | - |

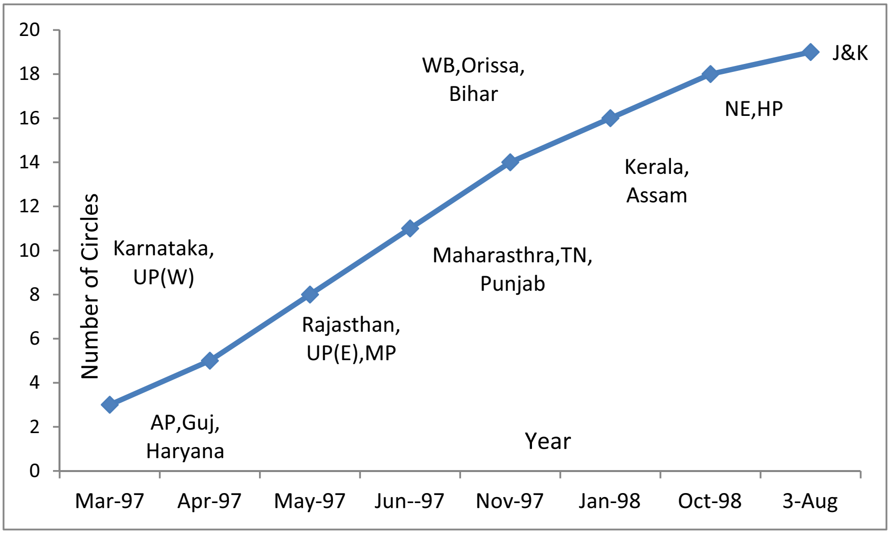


**Fig. 5** Introduction of Mobile Phone in Circles across India

$$Y = \frac{1}{\left(\frac{1}{u} + \left(b_0 * {b_1}^t\right)\right)}$$

$$\mathrm{Ln}\left(\frac{1}{Y} - \frac{1}{u}\right) = \ln\left(b_0\right) + \ln\left(b_1\right) * t \tag{2}$$

where Y is the predicted value, u is the upper boundary value, and t denotes time, $b_0$ and $b_1$ are constants. The rate is given by –ln($b_1$). This methodology was used by Dwyer et al., (2003). For testing H2, we used correlation due to lack of data points. For testing H3a-b, independent *t*-tests were employed.

## Results

### Mobile Adoption

The logistic model provided a good fit for mobile subscription data for all the Telecom circles. As shown in Table 6, the $R^2$ values ranged from 0.906 to 0.997 thus providing support to the fact that a Logistic model can estimate the growth of mobile telephony in Indian Telecom circles over time.

The logistic fits for various circles are shown in Figure 6.

**Table 6** Coefficients of the logistic regression and fitness

| Circle A(5) | $b_0$ | $b_1$ | $R^2$ | Circle B (8) | $b_0$ | $b_1$ | $R^2$ | Circle C(6) | $b_0$ | $b_1$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| AP | −11.223 | 0.051 | 0.995 | Haryana | −9.113 | 0.065 | 0.996 | HP | −10.271 | 0.0701 | 0.996 |
| Karnataka | −8.841 | 0.065 | 0.994 | Kerala | −9.026 | 0.066 | 0.991 | Bihar | −10.146 | 0.076 | 0.997 |
| Gujarat | −9.069 | 0.066 | 0.990 | MP | −9.993 | 0.070 | 0.994 | Orissa | −10.254 | 0.073 | 0.997 |
| Maharashtra | −8.866 | 0.064 | 0.992 | Rajasthan | −3.006 | 0.067 | 0.993 | Assam | −10.268 | 0.074 | 0.990 |
| Tamil Nadu | −9.876 | 0.071 | 0.995 | UP.W&E | −9.675 | 0.066 | 0.993 | NE | −11.640 | 0.089 | 0.994 |
| | | | | Punjab | −9.258 | 0.071 | 0.982 | J & K | −7.528 | 0.115 | 0.906 |
| | | | | WB | −10.153 | 0.051 | 0.966 | | | | |

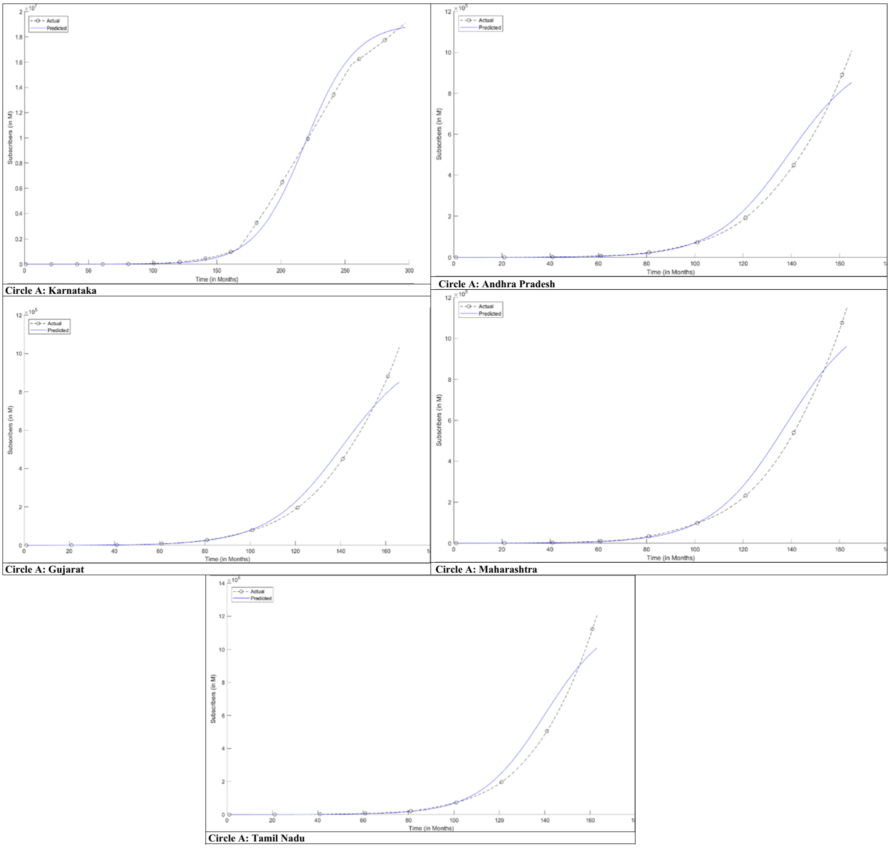


**Fig. 6** Logistic Fits of mobile phone subscribers for Telecom Circles of India

## Macroeconomic Factors Impacting Mobile Phone Growth Rate Across States

For testing H2a- H2e, we used regression analysis. From correlation analysis, it follows that time lag and LN_GDP are significant and the signs are in the predicted direction. Refer to Figure 7. Other independent variables are not significant.

We next conducted a multiple regression with all the independent variables. Table 7 illustrates the coefficients of independent variables for Model 1 and Model 2. Model 1 contains all variables of interest. Model 2 uses LN_GDP as the only independent variable. Only LN_GDP came out as a strong significant indicator. Rural percentage and HDI index were weakly significant (significance at 1-t level). However, LN_GDP alone could explain 57% of the variability of growth rate (Model 2). Thus, H2a, H2c-H2d, are supported and H2b, H2e are not supported. The regression equation of Model 2 was LN_GDP = 14.84–64.87*growth

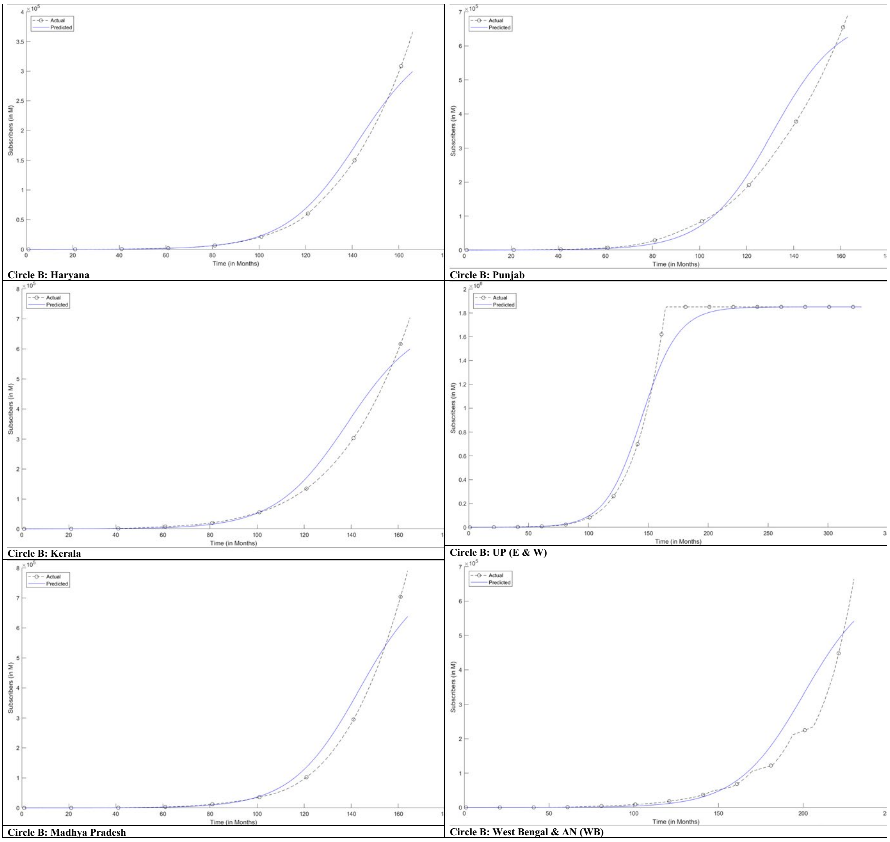


**Fig. 6** (continued)

rate. This showed that as mobile phone growth rate increases, the LN_GDP of states decreases. In other words, poor states are catching up with rich states with a higher growth rate, i.e., convergence of mobile growth across states holds (Refer to Figure 7).

## Modeling Growth Rates of Circles Taking into Account Lag in Diffusion

Table 8 shows the growth rates of mobile telephones in each of the Telecom Circles taking into account the time lag effect in months (Refer to the Appendix Table 11 for names of circles/states).

H3a and H3b were tested employing independent *t*-test. Refer to Table 9 for results. Inter-circle *t*-tests were different between circle B and circle C as well as between circle A and C ($p <= .01$). However, there is no statistical difference between the means of circles A and B. Intra-circle means for Telecom Circle A, B,

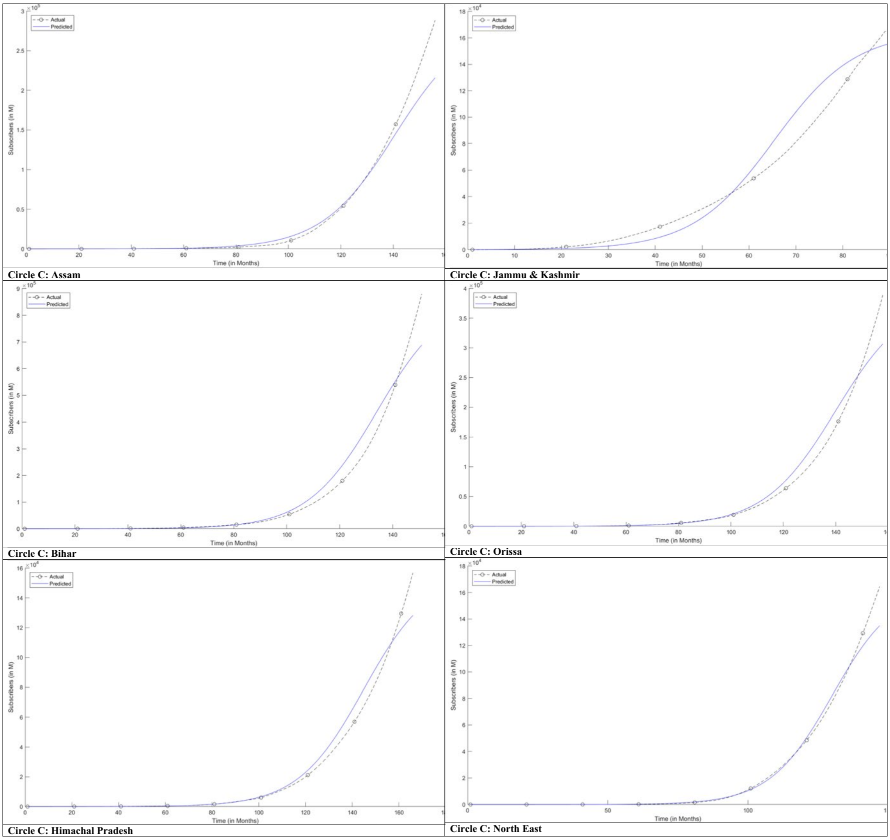


**Fig. 6** (continued)

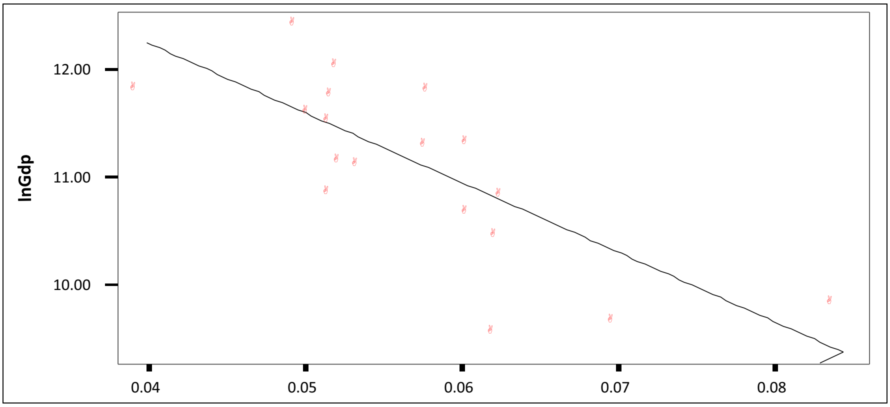


**Fig. 7** The Convergence of Mobile Growth in India. X-axis: Mobile growth Rate Y axis: LN_GDP per capita. LN_GDP =14.84-64.87*mobile growth rate

**Table 7** Regression results with growth rates of Circles as the Dependent variable

| Variable | Model 1 | | | | Model 2 | | | |
|---|---|---|---|---|---|---|---|---|
| | Coefficient | Std. Error | *T* | *p* | Coefficient | Std. Error | *T* | *p* |
| Constant | 0.271 | 0.082 | 3.321 | 0.007* | 0.154 | 0.021 | 7.335 | 0.000*** |
| Time_lag (X1) | −0.000 | 0.000 | −0.495 | 0.630 | | | | |
| Per_capita_power_cons (X2) | −0.000 | 0.000 | −1.249 | 0.238 | | | | |
| HDI_96 (X3) | −0.042 | 0.027 | −1.518 | 0.157+ | | | | |
| Rural_percentage (X4) | −0.001 | 0.000 | −1.574 | 0.144+ | | | | |
| LN_GDP (X5) | −0.013 | 0.004 | −2.952 | 0.013* | -0.009 | 0.002 | −4.606 | 0.000*** |
| HHI (X6) | 0.003 | 0.027 | 0.108 | 0.916 | | | | |
| R-squared | 0.677 | | | | 0.570 | | | |
| Adjusted R-squared | 0.501 | | | | 0.543 | | | |

***, ** and * significance at 1%, 5% and 10% levels, respectively. + denotes weak significance

and C are 0.053, 0.055 and 0.067, respectively. The standard deviations for the circles were quite low: 0.004, 0.007 and 0.009, respectively. Intra-circle growth rates did not differ much (refer to Table 9). This provided support for H3a and H3b.

## Discussion

Table 10 summarizes the hypotheses testing results. H1 which states that a logistic model estimates fairly well the growth of mobile telephony over circles and over time found support in this study. Previous studies (Gruber & Verboven, 2001b; Wu & Chu, 2010; Bagchi et al., 2005) found that logistic model is a good fit to ICT diffusion rate in various nations. H2a was supported. The finding that mobile phone growth rate is inversely proportional to GDP per capita of a state and is in line with the previous literature (Dekimpe et al., 1998; Ahn & Lee 1999; Lee et al., 2007; Burki and Aslam, 2000; Gruber et al., 2000; Gruber et al., 2001a; Madden et al., 2004; Frank et al., 2004; Chu et al., 2009). Refer to Figure 7. Prior studies have found that GDP per capita is positively related to mobile phone growth level and inversely related to the mobile phone growth rate (Chu et al.,2009; James; 2012). The study found that the mobile growth rates in telecom circles in India do not depend on time to adoption (H2b). Refer to Table 6, which lists regression coefficients of variables of interest. H2c, which states that mobile phone growth rate and rural population are inversely related, weakly significant. This result is in agreement with earlier studies (Loboda, 1974; Proenza,

**Table 8** Growth rates of Circle vis-à-vis Time lag

| Circle A(5) | Time lag | Growth rate (Logistic) | Circle B (8) | Time lag | Growth rate (Logistic) | Circle C(6) | Time lag | Growth rate (Logistic) |
|---|---|---|---|---|---|---|---|---|
| AP | 1 | 0.052 | Haryana | 1 | 0.052 | HP | 1 | 0.063 |
| Karnataka | 2 | 0.052 | Kerala | 2 | 0.052 | Bihar | 9 | 0.063 |
| Gujarat | 4 | 0.051 | MP | 3 | 0.058 | Orissa | 9 | 0.061 |
| Maharashtra | 4 | 0.050 | Rajasthan | 3 | 0.061 | Assam | 11 | 0.063 |
| Tamil Nadu | 4 | 0.059 | UP (W) UP (E) | 3 | 0.052 | NE | 21 | 0.084 |
| | | | | | | J & K | 77 | 0.070 |
| | | | Punjab | 4 | 0.054 | | | |
| | | | WB | 9 | 0.040 | | | |
| Mean Growth rate | | 0.053 | Mean Growth rate | | 0.055 | Mean Growth rate | | 0.067 |

**Table 9** *T*-test results for Diffusion growth rate difference between Circles

| | Circles A, B | Circles B,C | Circles A, C |
|---|---|---|---|
| *t*-stat value (2-tail) | −0.077 | −3.247 | −3.705 |
| *p*-value | 0.940 | 0.0100 | 0.0100 |
| Significant difference? | No | Yes | Yes |

**Table 10** Summary of results

| Hypothesis | Supported | Not supported |
|---|---|---|
| H1 | Y | - |
| H2a | Y | - |
| H2b | - | Y |
| H2c | Y | - |
| H2d | Y | |
| H2e | - | Y |
| H2f | - | Y |
| H3a | Y | - |
| H3b | Y | - |

2001). HDI was also weakly significant, and the results are in line with earlier studies done in different areas (Ciccone, 1994, Lucas, 1990). However, neither infrastructure nor HHI (measuring competition) had any relation to mobile growth rate (H2e, H2f) although these variables had impact on previous studies related to ICT diffusion (Mwesige, 2003; Shakeel et al., 2001; Sridhar & Prasad, 2011). This is an area that needs further investigation with additional data.

H3a, which states that the intra-circle mobile phone growth rates will be similar, and H3b states the inter-circle mobile phone growth rates will be different found support in the present research.

This study has managerial implications and important signal to policy makers: African and Asian and other developing countries may like to follow the Indian mobile growth model. They can make use of this result. These new insights will help in policy making on future telecommunications products.

## Policy Implications

Mobile penetration in many developing nations, including India, is reducing the digital divide (Sridhar, 2012). Mobile penetration in various states in a developing country such as India can yield some insights. In economic terms, not all

Indian states are equally advanced. This means that digital technology penetration such as the availability /use of Internet may not be equal among all states. India as a nation, for example, has only on average 18 Internet users per 100 in the year 2014 (World Bank, 2014). On the other hand, mobile penetration in terms of mobile users per 100 citizens in India has increased significantly, and the growth is impressive. Mobile users can access the Internet through mobile phones thus decreasing the digital divide among states. To reduce digital divide, many other government and corporates can provide more mobile phone–based services to the citizens of India.

## Conclusion

This is an exploratory study based on secondary data. In this study, we noted that the growth rates of mobile telephony in all the 23 states followed a logistic model. From this, we inferred that some of the Indian states, with low GDP per capita income started rolling out mobile telephony operations later than states with high GDP per capita income, but could catch with the later. It also follows that states with more rural regions had more adoption of mobile telephony. We also noted that lower tariff helped in quicker diffusion of mobile telephony in poor vis-à-vis rich states. From this study, we can inform policy makers and telecom providers that power consumption, Human Development Index (HDI), Herfindahl Index (HHI) and proportion of rural to urban ratio do not form an important parameter for mobile growth. The paper contributes to the stream of research in the area of mobile phone diffusion: First, the growth of mobile telecommunications across the 23 circles in India was investigated. Second, the growth rates of all states are determined using a logistic model, and the fits are investigated. Inter-circle and intra-circle growth rate differences are also studied and it is found that Inter-circle growth rate differences exist but intra-circle growth rate differences do not. Third, the effect of several macroeconomic factors such as state-level GDP per capita, power consumption, Human Development Index (HDI) index, Herfindahl Index (HHI) and proportion of rural to urban ratio on mobile growth rate are investigated. Only GDP per capita emerges as strongly significant in regression analysis. Rural percentage population and HDI became weakly significant in regression. Fourth, we also try to investigate whether some poorer states, which have started late, have been able to catch up with early adopters such as some rich states in India. Future research may study several other diffusion models like a mixed model. Researchers may explore telecommunications products other than a mobile phone. Additionally, the role of corruption on mobile phone diffusion is worth investigating. Cell phone health hazards are also a factor which can be investigated in the future.

## Appendix A

**Table 11** The names of states and their abbreviations as used in the study

| Indian States/Circles | Abbreviations Used (if any) |
|---|---|
| Andhra Pradesh | AP |
| Assam | |
| Bihar | |
| Gujarat | Guj |
| Haryana | |
| Himachal Pradesh | HP |
| Jammu and Kashmir | J & K |
| Karnataka | |
| Kerala | |
| Madhya Pradesh | MP |
| Maharashtra | |
| North East | NE |
| Orissa/Odisha | |
| Punjab | |
| Rajasthan | |
| Tamil Nadu | TN |
| Uttar Pradesh West | UP (W) |
| Uttar Pradesh East | UP (E) |
| West Bengal | WB |

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