Mobile phone penetration, income inequality and economic growth:

A panel data study of Indian states

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Abstract

This paper analyzes the determinants of wireless mobile penetration across 18 major states of India based on data from telecom regulatory authority of India (TRAI) and other secondary data for various states of India for the period 2002-12. Given the diversity among Indian states in terms of economic and social development, the paper analyzes the role played by socio-economic factors like growth in income per capita, consumption inequality, education and age profile of states in mobile technology diffusion. In empirical studies, the relation between inequality and mobile penetration has been found to be mixed. In a developing country context, it is expected to be positively related to inequality in the early stages of diffusion because of its dual role of a production and consumption good. Given the boundedness of dependent variable between 0 and 1, a fractional generalized linear regression model for panel data is estimated that estimates the likelihood of mobile phone adoption as a function of several variables. The study finds that income and inequality have a positive and significant impact whereas population density has a negative impact on mobile penetration.

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I. Introduction

Technology diffusion, particularly penetration of mobile telecommunication plays an important role in the improvement in standard of living and growth of an economy. Two approaches have been broadly used to understand telecommunication technology diffusion—studies that focus on diffusion-speed of mobile technology using epidemic model and those that analyze the factors influencing the penetration rate of mobile phones within countries. The latter approach helps to understand the how socio economic and demographic factors affect the subscription rates, which can in turn help in understanding the dynamics behind the diffusion speed. The present paper adopts the latter method and analyzes the factors influencing mobile penetration in India and inter-state variation from 2002-2012.

India has the highest number of mobile phone users, but its impact on growth is not clear given the diversity in socio-economic and demographic features across states. In India mobile telecommunication industry has witnessed a tremendous growth over the last few years, with one billion mobiles in the country. India has become second largest mobile phone market after China (economictimes.indiatimes.com). However, there is a wide variation in mobile diffusion as well as GDP growth across various states in India, bringing in questions of socio-economic disparities and how technology diffusion may help in convergence of growth process among various states.

Empirical studies have found several factors such as per capita income, income inequality, population density, age profile of population, competition and regulatory structure to have a positive impact on mobile penetration (Yamakawa et al 2013, Chakravarty 2007). The relation between inequality and mobile penetration has been found to be mixed. In some studies, mobile penetration, was found to be negatively related to income inequality; whereas, it is positively related to inequality in the early stages of diffusion (Roeller and Waverman 2001, Hytennin and Toivanen 2011). In the developing country context mobile phones serve dual purposes: one, as consumption good for the rich and two, as a production good for the poor. Case studies from the Africa and Asia have shown the usefulness of mobiles as a production good (Jensen et al 2007, Aker et al 2008, Muto et al 2008). For this reason, income inequality may influence the spread of mobile penetration in the early stages.

Although the impact of economic and demographic factors on mobile penetration has been established, there is not much clarity on the relationship between mobile phone penetration, economic growth and the extent to which this leads to convergence of growth process. This paper analyzes the determinants of wireless mobile penetration across 18 major states of India based on data from telecom regulatory authority of India (TRAI) and secondary data sources on economic indicators for various states of India. Given the diversity among Indian states in terms of economic and social development, the paper analyzes the role played by socio-economic factors like growth in income per capita, consumption inequality, education and age profile of states in mobile technology diffusion. Given the boundedness of dependent variable between 0 and 1, a fractional response model is estimated that estimates the likelihood of mobile phone adoption as a function of several variables.

The paper is organized as follows. Section II provides a review of literature and explores the trends in wireless subscriber growth across various states in India. Section III describes the data and methodology in estimating the determinants of mobile technology diffusion. Section IV discusses the results of the model and presents broad conclusions.

II. Literature Review

Studies on mobile phone penetration are of two types: those which try to estimate the speed of technology diffusion (Gruber and Vernon, 2001, A.Bohlin et al 2010) and those that try to estimate the magnitude and direction of determinants of mobile penetration (Hyytinen and Toivanen 2011) .

Growth in telecommunication industry is intricately linked with the economic growth of a country because of its dual role in production as well as consumption. Research has also shown that because of this duality, income inequality has a positive impact on mobile penetration in the initial stages of diffusion. Hyytinen and Toivanen (2011) in their study of 48 developing countries regress mobile penetration on income inequality and other control variables and find that keeping mean income constant, if we increase proportion of poor then it leads to higher mobile penetration rate (production good) at the early stage of diffusion. Income share of the highest earning deciles are used as measures of inequality and endogeneity problem is addressed using an instrument for measure of inequality, which is agricultural endowments that reflect suitability of land for growing wheat vs sugar.

There is ample anecdotal evidence from developing countries in Asia and Africa, that mobile phones play an important role in improving livelihoods by reducing transaction costs of doing business and connecting producers to markets. Specifically, it has been found that the standard deviation of prices have decreased in the fish market because of mobile usage (Jensen 2007). Mobile penetration also supports the production of perishable crops in Uganda and financial inclusion in Kenya through M-Pesa (Muto 2008).

At a macro level, growth of mobile telephony has been found to have a positive impact on gross domestic product and productivity. Roeller and Waverman (2001) test the reverse causality between mobile penetration and GDP growth using a simultaneous equation system, where four equations namely growth equation, demand for mobile equation, supply of mobile and change in mobile infrastructure are estimated using 3SLS and generalized method of moments (GMM). They find that mobile telecommunications diffusion significantly affects both GDP growth and productivity growth.

Growth in wireless mobile telephony in India

A recent study by Sunil Mani and V.Sridhar shows that telecommunications sector is purely driven by growth in mobile telephones with the ratio of mobile phones to fixed phones as on 30 April 2015 standing at 37. Studies (Bino Paul and Murti, 2015) in the Indian context have shown that based on NSS data for 2012, several socio-economic factors such as caste, religion and factors like, literacy, age, rural-urban and internet use influence mobile ownership at the household level.

Indeed, the growth in mobile penetration has been very high especially from mid- 2000. Table I shows the figures for mobile penetration and its growth, inequality in consumption, literacy rates and net state domestic production per capita for 18 major states in India for the period 2012. Column 2 shows the compound annual growth rate of mobile subscription during 2002-2012 for different states.

Penetration rate is calculated by dividing number of subscribers as on month end (December) divided by the population of the state. For compound annual growth rate (CAGR), a log-linear model is used to calculate the exponential growth in subscribers.

Table 1: Statewise Mobile Penetration, Income and Inequality

	Penetration_2012	CAGR_2002-2012 (%)	Rural Gini	Urban Gini	SDP/capita	density
Delhi	2.09	41.18	0.27	0.38	106677	12823
Tamil Nadu	1.08	57.87	0.28	0.33	57093	522
Punjab	1.04	44.66	0.28	0.31	46325	555
Himachal	0.99	70.50	0.28	0.29	49203	123
Kerala	0.93	48.51	0.36	0.41	52808	895
Karnataka	0.88	64.48	0.26	0.40	41492	313
Maharashtra	0.86	90.93	0.25	0.35	61276	371
Gujarat	0.84	53.77	0.25	0.28	56634	305
Haryana	0.76	60.04	0.26	0.29	61716	585
Andhra Pradesh	0.75	61.42	0.25	0.30	38556	311
Westbengal (A&N)	0.72	68.19	0.24	0.37	32164	1023
MadhyaPradesh	0.69	34.98	0.27	0.36	23272	238
Rajasthan	0.68	79.29	0.25	0.32	29612	201
Northeast	0.63	108.85	0.20	0.23	35166	76
Bihar	0.62	87.04	0.20	0.29	13149	1051
Orissa	0.59	80.82	0.23	0.36	24542	264
UP	0.59	75.22	0.25	0.31	18014	848
Jammu	0.57	81.96	0.24	0.30	28790	53
Assam	0.46	89.83	0.22	0.33	21741	395

Source: TRAI, NSSO, EPWRF.

As can be seen from the table Delhi tops all the states in mobile penetration as well as income per capita. In terms of inequality, Urban inequality is the highest for West Bengal, Karnataka, Kerala and Delhi and Rural inequality is highest for Punjab. North eastern states are the lowest in terms of inequality as measured by Gini coefficient of monthly per capita consumption expenditure. However there is a lot of inequality in mobile ownership within major states because of the presence of large metros with high population density and growth. Figure 2 shows the mobile penetration for three major states with/without including the metros. The mobile penetration of Maharashtra equals that of West Bengal if one removes the subscriber population of Mumbai, which shows the inequality in mobile ownership in major states of India. Richer states also have higher population density.

Figure1: Penetration ratio and SDP per capita in 2012

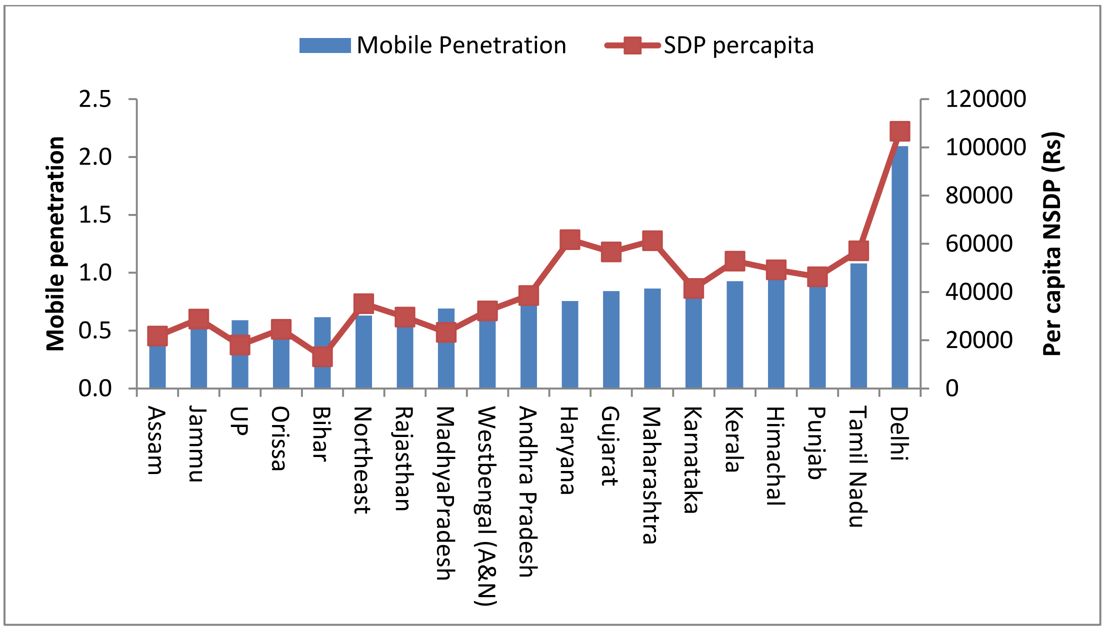
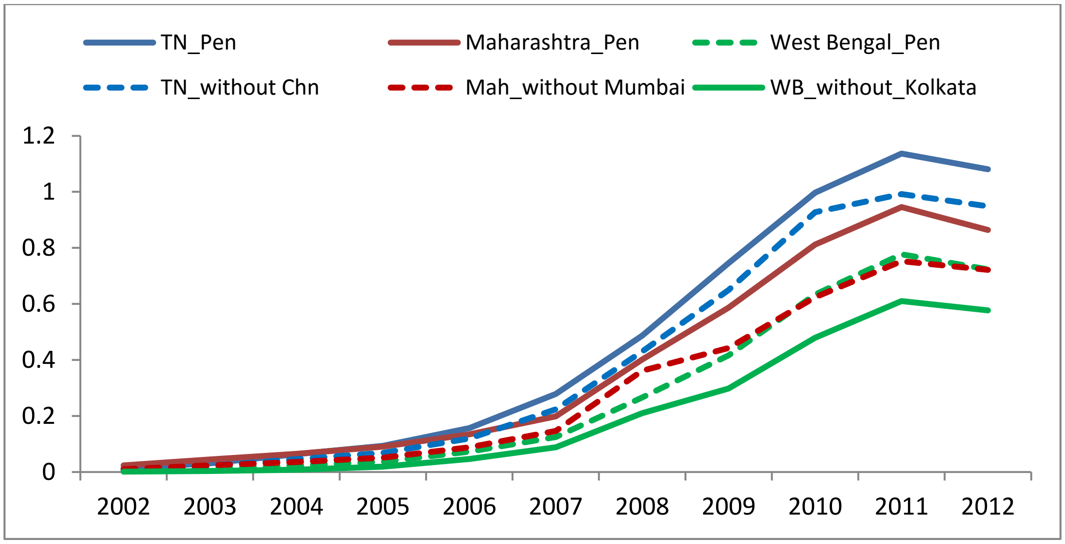
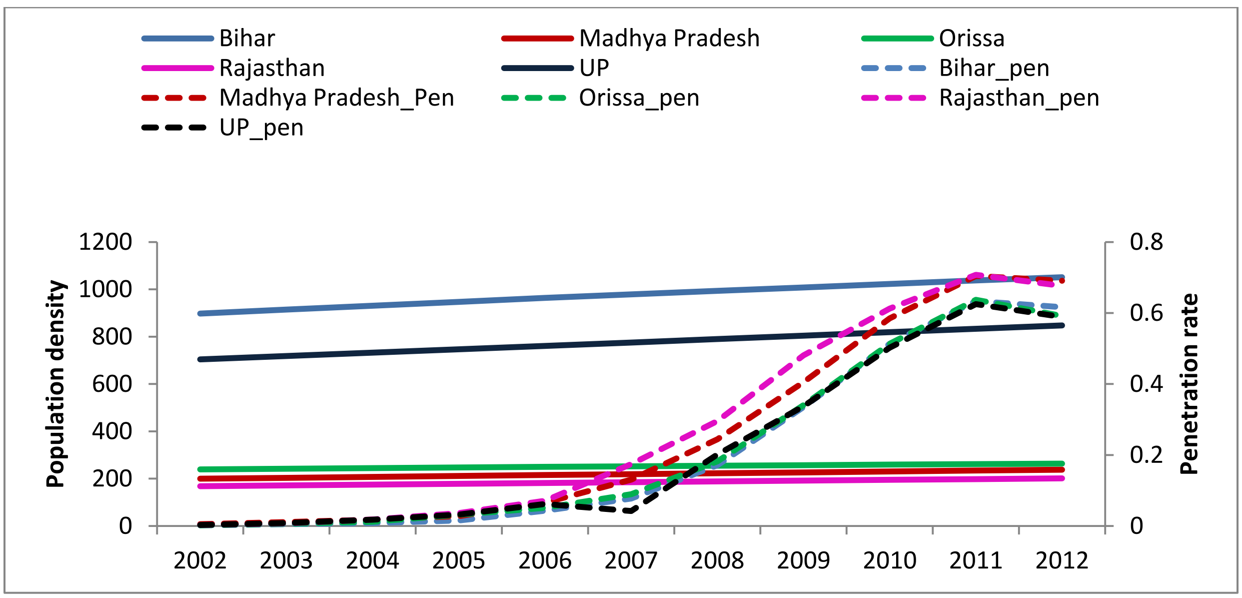


Figure 2: Mobile Penetration in major states with/without Metro cities



Source: TRAI and author's own calculations

Figure 3: Population density and Mobile penetration rate



Source: census, TRAI, authors own calculations

Figure 3 shows the growth in mobile penetration from 2002-2012 in the backward states of India which have low population density as well as low mobile penetration. Among the BIMARU states, Bihar has the highest population density followed by Uttar Pradesh whereas Madhya Pradesh and Rajasthan have the lowest population density, but higher mobile penetration among the group, indicating that growth in mobile penetration could be negatively related to population density.

III. Methodology and Data Sources

The study estimates the determinants of mobile penetration across 18 states in India for the period 2002-2012. A panel data model of the form is estimated to understand how various socio-demographic and economic factors influence mobile penetration in India:

$$(Penetration_{it}) = \alpha + \beta^{x}(Ineq_{it}) + \gamma X_{it} + \varepsilon_{it}.$$

Where, penetration is defined as number of mobile subscribers divided by population of each state. Inequality if measured using Gini coefficient for each state. Xit is the set of control variables that include net state domestic product, age profile of state in terms of proportion of population between 15-59 years, industry concentration measured by Herfindahl index, population density of state and literacy rate. ε_{it} is the error term that captures time invariant unit specific affects and unobserved effects. A fixed effects model is initially estimated. However, as the dependent variable is a fraction and bounded between 0 and 1, estimation using ordinary least squares may produce biased results and predicted values may be outside this interval. It may also not capture the non-linearity involved in the regression involving a fractional response variable. The traditional solution of using the log-odds transformation also fails when there are corner responses, zero and one. Just as importantly, even in cases where the variable is strictly inside the unit interval, we cannot recover the expected value of the fractional response from a linear model for the log-odds ratio. Hence a fractional response model for panel data that allows for time-constant unobserved effects that can be correlated with explanatory is estimated on the lines of Papke and Woolridge (1996, 2008). A generalized linear regression model of the following form is used:

$E(Yit/Xit, Ct) = G(Xti\beta+Ct) = G(\alpha_0 + \beta^{x}(Ineq_{it}) + \Sigma\gamma X_{it})$, where , the function G(.) is a standard normal cumulative distribution function and the conditional expectation is assumed to be of the index form, where the unobserved effect, Ci, appears additively inside the standard normal cdf, In the empirical estimation the a logistic functional form is used to bound the response rate between 0 and 1. Marginal effects are calculated using partial differentiation:

$$\frac{\partial E(Yt/Xt,C)}{\partial Xit} = \beta G(\text{Xi}\beta + \text{C}),\ \text{t}= 1\ldots\ldots \text{T}$$

Empirically, the equation to be estimated is given by:

Penrate= α +β0 Rural Gini + β1 Urban Gini + β2NSDP + β3 Age profile+ β4 Literacy + β5 Herfindahl index + β6 population density + e.

Penrate is the mobile subscription divided by population of respective states for the years 2002-2012. It is obtained from the TRAI website and press releases. Mobile subscription by service provider is aggregated across states to obtain the total wireless subscription for each state. Population figures for 2001 and 2011 are used to project population during 2002-2012 and penetration rate is arrived by dividing the two. It was observed that in major states West Bengal, Tamil Nadu and Maharashtra, subscription of metro cities was skewing the penetration data. Hence two datasets are used, one for the entire state and one excluding the subscription data of metro cities (Kolkata, Mumbai, Chennai) from the respective states.

Urban and rural gini coefficients are obtained from several rounds of NSS consumer expenditure surveys. These were available for 1999-00, 2001-02, 2004-05, 2009-10, 2011-12. The figures for the rest of the years were imputed based on the data available. Data on literacy rate, proportion of population aged between 15-59 years and population density was obtained from census data. Using TRAI service provider data, statewise concentration index was calculated using the Hirschman-Herfindalh index.

IV. Results and discussion

Table 2: Panel data estimation

Dependent Variable= Penetration rate	Fixed Effect estimation Coefficient	Fractional GLM Coefficient (marginal effects dy/dx)	Fractional GLM excluding circle A metro cities Coefficient (marginal effects dy/dx)
NSDP	0.20** (0.00)	0.49 *** (0.10)	0.47 *** (0.05)
Rural Gini	-1.08* (0.65)	0.05 (0.98)	0.47 (0.8)
Urban Gini	0.63 (0.79)	1.71*** (0.65)	1.21 ** (0.60)
Proportion Young	2.8 ** (1.43)	-0.14 (1.01)	-0.08 (1.04)
Literacy rate	-1.07 (0.73)	-0.25 (0.33)	-0.34 (0.31)
HHI	0.035 (0.10)	0.012 (0.16)	0.034 (0.15)
Pop_Density	5.53*** (0.68)	-0.04 *** (0.02)	-0.032 (0.02)
Constant	-35.63*** (2.68)		
R sq	0.12	0.2	0.19
N	209	209	209

***, **, * indicate significance at 1%, 5% and 10% level. Figures in parenthesis indicate standard errors.

Table 2 shows results from the econometric estimation of the relationship between mobile penetration and socio demographic and economic characteristics of major states of India. Column 1 shows results from fixed effects regression, whereas columns 2 and 3 show result from fractional generalized regression model. Column 2 includes all states with the metro cities included, whereas column 3 shows results excluding the metro cities of Kolkata, Chennai and Mumbai. As can be seen, per capita state domestic product is significant and positive. In the fractional GLM model, a 1% increase in NSDP results in 5% increase in mobile ownership. Urban inequality has significant positive impact on mobile penetration, supporting the argument that inequality has a positive impact on mobile diffusion in the early stages of technology diffusion. A one percent increase in urban inequality results in (1.71*0.65) 1.1% increase in the likelihood of mobile phone adoption. In the fixed effects regression, the results are not similar and rural inequality is negative and significant at 10% level.

Population density has a negative impact on the likelihood of mobile adoption in the fractional model, but has a positive but marginal impact in the fixed effects regression. Proportion of productive/young and literacy do not have any significant impact on mobile adoption in the fractional response model, but young age group has a positive and significant in the fixed effects model. The contradictory results can be due to the presence of endogeneity in the model, which needs to be corrected for. Column 3 shows that once metro cities are excluded from the state population, we get similar results for income and inequality but population density is no longer significant at 11%. The results indicate that increase in population density is negatively impacting increase in mobile penetration. A one percent increase in population density may result in -0.08% decrease in mobile penetration.

The paper tries to find the direction and magnitude of the impact of income and inequality on mobile penetration along with other socio-demographic variables. It finds that income, inequality, population density have a significant impact on the penetration of mobile phones across Indian states. It finds that although states with higher population density have higher penetration, growth in mobile penetration may be negatively related to population density. This result is contradictory to other studies which show that population density has a positive impact on mobile penetration. The study also does not find literacy to be significant, which again comes as a surprise because education enables greater use of technology. On the contrary, some studies have pointed out that literacy rate may indicate the overall development of education system in the country but not the skill level. Yet another reason could be that mobile use dies not require great skill or education[1].

The study suffers from some limitations as it does not test for endogeneity, which could bias the results. Also, reverse causality between growth and mobile penetration can also be tested which can throw more insights into the factors determining growth and more specifically the role of technology diffusion.

[1] See Rodney L. Stump, Wen Gong and Zhan Li (2008)

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