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Does mobile telephony spur growth? Evidence from Indian states

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ABSTRACT

Using data on Indian states during 2001–2012, the paper analyses the impact of mobile telephony on economic growth. Using advanced panel data techniques, the evidence suggests that mobile telephony exerts a positive and statistically significant impact on growth. The magnitude of the response differs across states with high and low mobile penetration. Additionally, mobile telephony is observed to exert a significant impact on financial inclusion and especially on the loan behavior.

1. Introduction

Few technological advances have come to dominate the debate on public policy in recent times as information and communications technology (ICT). Within the realm of ICT, the advancements in mobile telephony and internet have been rapid and furious. According to *Statista*, a leading statistics company, globally, the number of internet users has increased from 413 million in 2000 to 2.5 billion in 2012. Likewise, the total subscriber base has reached 3.2 billion in 2012 and aided by multiple devices or use of multiple subscriber identification modules (SIMs) to access the best tariffs, the number of mobile phone users has increased 7 billion in 2012, with a major chunk of this increase taking place in emerging economies (GSM Association, 2013). Coupled with technological advancements, this revolution has not only re-shaped the way people think and analyse, but in a much broader sense, transformed the way they work and communicate.

In tandem with these global advancements, the experience of India has been nothing short of phenomenal. To illustrate, the number of mobile users in India has increased from 5.5 million in 2000 to nearly 500 million in 2012 (Internet Stat Live.com). Likewise, the mobile internet subscriber base has grown from around 3 million subscribers in 2000 to reach 150 million by early 2007, registering an average growth of 700% over a 7-year period (International Telecommunications Union, 2012). It has since increased to over 850 million by 2012. Coupled with the fact that a fifth of the global population without bank accounts resides in India (Demirguc Kunt, Klapper, Singer and Van Oudheusdhen, 2015), this brings to the forefront the relevance of mobile telephony as a tool for enhancing financial inclusion.

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The low levels of financial inclusion in relation to the large number of mobile phone subscribers makes it imperative to investigate whether an expansion of mobile phone deployment in general can contribute to greater financial inclusion.

Research has documented that the some of the major barriers to financial inclusion include costs, distance and documentation (World Bank, 2014). Illustratively, high costs and fees charged tend to raise the costs of making small transactions, impeding access. Besides, distance is an equally important consideration: low branch penetration raises overall transactions costs and hinders access. In addition, onerous documentation requirements might compel workers with no formal proof residence or credit history to be excluded from the formal financial system. The challenges of such financial exclusion can be manifold, ranging from credit constraints to greater vulnerability to adverse shocks (Claessens, 2006), lower investment (Chakrabarty, & Pal, 2013) as well as the perpetuation of income inequality and poverty (Beck, Demirguc Kunt, & Levine, 2005; Demirguc Kunt, Beck, & Honohan, 2008; Demirguc Kunt & Levine, 2008).

In this context, innovative use of mobile telephony can be a game changer. To exemplify, mobile telephony makes it possible to seamlessly manage a large volume of small-ticket transactions, making it easier to provide these services in a cost-effective manner (Faye, & Triki, 2013). Besides, greater mobile penetration can provide a fillip to rural development since it allows dispersed families to stay in touch, which reduces vulnerability and isolation. Better information flows through mobiles mitigates information asymmetries for the farmer, improving bargaining power and thereby making the development of economic activities that are non-agricultural possible (Andrianaivo, & Kpodar, 2012). As a greater number of people come within the fold of formal finance, the size of the financial sector increases, which in turn contributes to economic growth (Levine, 2005; Mehrotra & Yetman, 2015).

The paper has a two-fold purpose. First, we investigate the effects of mobile penetration on economic growth in major Indian states during 2001–2012. Secondly, we expand the analysis further by analysing whether financial inclusion is one of the channels through which mobile phone penetration affects economic growth.

We make three contributions to the literature. First, the paper augments the thin literature on the impact of mobile telephony on economic growth at the sub-national level for a leading emerging economy. Most studies of this genre are in the nature of cross-country studies (Andrianaivo, & Kpodar, 2012; Waverman, Meschi, & Fuss, 2005). There are few studies in this area for India. In an early exercise, Kathuria, Uppal and Mamta (2009) employed data on Indian states during 2000–2008 and found that mobile penetration exerts a statistically significant impact on economic growth. More recently, using both qualitative and quantitative methods, Gupta and Jain (2012) provide evidence that handset price, perceived usefulness and mobility being among the key factors driving the demand for rural telephony. They conclude that once mobile is penetrated deeply in rural India, the levels of financial inclusion can increase. These studies are either at the aggregate level or even if they combine both aggregate and disaggregated data, employ an information base that is of dated vintage.

Second, the paper belongs to the literature that explores the sub-national effects of greater banking outreach and the role played by mobile telephony in this regard. Although several studies for India have focused on the finance-growth interface (Burgess, & Pande, 2005; Topalova, 2008), few studies identify the relevance of mobile telephony in impacting economic growth, especially at the sub-national level.

Finally, the study belongs to a broader literature which examines the role of ICT policies in influencing economic growth. The literature, both for India (Aghion, Burgess, Redding, & Zilibotti, 2008; Besley & Burgess, 2004; Imbert & Papp, 2015; Muralidharan, Niehans & Sukthankar, 2014; Sarma & Pais, 2011) and elsewhere (Jack & Suri, 2011; Lee, Lavendis & Gutirrez, 2009) have identified important effects of varied legislations on growth performance. Whether and to what extent some of these legislations interact with mobile penetration to influence economic growth has not been examined earlier and this is one of the important aspects being addressed in the paper.

India provides a compelling case among emerging markets to study this aspect in some detail. First, akin to the US and other large economies such as Brazil, Germany and Malaysia, India is a federal polity comprising of states with their own democratically-elected government. With widely divergent size (the largest state is nearly 12-times the size of the smallest, in terms of area) and the uneven distribution of population (the largest state by population was fourth largest by area in 2005), it remains a moot question as to how the impact of mobile telephony would differ across states (Ghosh, 2015). Second, notwithstanding the high mobile penetration, there remains substantial divergence across states. According to the Telecom Regulatory Authority of India (2008, 2012), in 2012, the total wireless phones in Madhya Pradesh was 52 million as compared to over 70 million in Maharashtra. Third, the levels of financial inclusion also differ markedly across states. According to CRISIL (2012), Kerala ranked high on financial inclusion with a score of 80.4 (out of a maximum of 100) in 2012; in contrast, Bihar was lowly placed with a score of 25.5 during the same period. There is a broad consensus among policymakers that the growth needs to be more inclusive and broad-based, if its benefits are to permeate all segments of the population (Planning Commission, 2008; RBI, 2015). With the growth in brick-and-mortar branches plateauing given the significant upfront costs, mobile financial services can function as a substitute for bank branches, creating opportunities for people living in far-flung areas to reap the benefits of formal finance.

The reminder of the analysis unfolds as follows. Section 2 reviews the relevant literature, followed by a discussion of the database. Subsequently, we highlight the empirical framework, followed by a discussion of the results, including robustness checks (Section 5). The final section concludes.

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2. Prior research

In order to have a sufficiently broad perspective on mobile telephony and the role played by financial inclusion, we provide an overview of prior studies on mobile penetration and income, and the role played by financial inclusion in this regard. Accordingly, we first discuss the extant research on the interlinkage between ICT and economic growth, followed by research on financial inclusion.

2.1. Mobile telephony and economic growth

Although the literature regarding the impact of mobile telephony on economic growth begun since the 1980s, it is only in recent years that availability of consistent time series data has prompted researchers to take a fresh look at this issue. In an early cross-country study, Hardy (1980) analysed the correlation between GDP and number of telephones per capita, using data for the period 1960–73. The study provided evidence in support of bi-directional causality: telephone penetration was both a cause and consequence of GDP growth. Thereafter, Norton (1992) showed that telecommunications investments causes growth in the financial sector and thereby enhances GDP growth.

Using data for the period 1975–90 coinciding with the early years of digital adoption, Roller, and Waverman (2001) estimate a simultaneous equation model of telecom investment and a macro production function for OECD countries during 1970–90. Their results provide evidence of a strong causal relationship between telecommunications infrastructure and productivity, and additionally this occurs only when telecommunications services reach a certain threshold, suggestive of network effects. Extending the framework to incorporate mobile phones covering a 20-year period in a cross-country framework, Torero, Chowdhury, and Bedi (2002) uncover a positive link from telecom to GDP. According to their findings, the impact of telecom on GDP is non-linear and appears to be particularly manifest for countries with telecom penetration in the range of 5–15%. Thereafter, using a cross-country sample of low and middle-income countries, Sridhar, and Sridhar (2007) show that there is a statistically significant effect of cellular services on national income, after controlling for the effects of capital and labor.

More recently, based on a sample of over 90 countries covering the period 1980–2003, Waverman et al. (2005) show that mobile phones and fixed lines are substitutes in developing countries, but complements in advanced economies. Contextually, it may be mentioned that several studies have examined this interlinkage and the findings are mixed (See Vogelsang (2010) for a review). In an early cross-country study, Ahn, and Lee (1999) uncovered a complementary relationship between fixed and mobile telephony. These findings were echoed in subsequent research for African (Hamilton, 2003) and Central European OECD (Gruber, 2001) provide evidence in support of substitutability between fixed and mobile telephony for both advanced (Garcia-Marinoso and Suarez, 2013; Rodini, Ward, & Woroch, 2003; Srinuan, Srinuan, & Bohlin, 2012) as well as in diverse emerging markets, such as Korea (Sung, & Lee, 2002), Egypt (Gelvanovska, Rogy, & Rossotto, 2014) and India (Gupta, & Jain, 2012, 2014). Recognizing the possible endogeneity between mobile phone penetration and economic growth, recent studies have addressed this deficiency by using system GMM estimator, as in Lee, Lavendis, and Gutirrez (2009). Using data on sub-Saharan African economies, their results show that regions with few fixed lines are associated with a higher marginal benefit of mobile phones, reiterating possible substitutable effects.

Prior work on the interlinkage between ICT and economic growth did not take into account the price effect of telecommunications nor the channels through which mobile phones can influence growth. Andrianaivo, and Kpodar (2012) developed an empirical framework, taking on board these possible drawbacks. Using a sample of African countries during 1988–2007, their analysis suggested that mobile telephone development contributed to economic growth: a 10% point increase in the mobile penetration rate led to an increase in GDP growth by 0.6% points, on average.

Several papers come close to the spirit of the present analysis. In the case of India, Kathuria et al. (2009) investigate the impact of mobile phone penetration on economic growth across Indian states for the period 2000–2008. The findings indicate that states with higher mobile phone penetration rates can expect higher growth rates: a 10% increase in mobile penetration improves state incomes by over 1% point. In contrast, Sridhar (2010) does not find any discernible impact of per capita income on the adoption of mobile services in Indian states during 1997–2007. Of late, utilising data for 1980–2004, Erumban, and Das (2016) show that ICT has been a key factor in driving macroeconomic growth in India, primarily by improving the productivity of the services sector. Within an endogenous growth framework focused on African economies, Andrianaivo, and Kpodar (2012) find that a 10% increase in mobile penetration leads to a 0.6% point increase in GDP growth per capita.

Although our research is similar in spirit to these studies, there are also significant differences. First, as compared to cross-national studies, data comparability issues are less of a concern within a country (Honohan, 2008; Rodrik, 2012). Second, as compared to prior research for India, we focus on a more recent time span at the intra-national level. Third, given the explicit emphasis by policymakers on financial inclusion (Government of India, 2015, 2016; RBI, 2015) we link the access to mobile communication to new channels for the unbanked population. Finally and from a technical standpoint, prior research for India does not account for the possible endogeneity between mobile penetration and economic growth. By utilising advanced panel data techniques that takes on board this endogeneity, our results are able to provide much more conclusive evidence.

2.2. Mobile telephony and financial inclusion

Empirical studies on financial inclusion have exploded in recent years, driven by the availability of data, both at the cross-country level (Amidzic, Massara, & Mialou, 2014; Demirguc Kunt, & Klapper, 2013; Beck, Demirguc Kunt and Martinez Peria, 2008; Demirguc Kunt, Klapper, & Singer, 2013; Demirguc Kunt et al., 2015; European Commission, 2008) and also at the country level (Allen, Carletti, Cull, Qia, Senbet and Valenzuela, 2013; Brune, Gine, Goldberg, & Yang, 2011; Burgess et al., 2005).

The pervasive use of mobile telephony is providing evidence that this innovation is impacting the socio-economic structure of modern societies and economic growth. Perhaps the best-known example is Kenya, where the mobile-based SIM platform for communicating with agents has enabled a tremendous growth in the number of mobile money providers and led to a leapfrogging in the levels of financial inclusion in the country. As reported by the World Bank (2011, 2014), the percentage of adults having account has nearly doubled in Kenya: from 42% in 2011–75% in 2014; the percentage of mobile accounts stood at 58% in 2014. According to the Central Bank of Kenya (2015), as at end September 2015, there were nearly 40,000 agents licensed by 17 commercial banks facilitating transactions worth USD 10 billion, up from transactions worth USD 2 billion facilitated by 11,000 agents in March 2011.

Studies on the interlinkage between mobile banking and financial inclusion are limited, and often of indirect nature. McKay, and Pickens (2010) for instance, find that branchless banking (including mobile money) to be nearly 20% cheaper, on average. Mas, and Radcliffe (2010) note that some of the attractive features of M-PESA including strong latent demand for domestic remittances driven by a rapidly rising urbanisation ratio, enabling regulatory environment, a dominant mobile operator with low airtime commissions and simple and transparent pricing have augmented the scalability of the process. By enabling people to receive and send money as and when they need it, mobile banking has led to ‘anytime’ financial inclusion (Stuart, & Cohen, 2011). Field experiments by Aker, and Mbiti (2010) found that mobile money enabled recipients to enjoy better diets and deplete fewer assets during times of natural calamities.

In India, several innovative financial inclusion initiatives have emerged in recent times. For instance, EKO, a mobile-based fintech firm, witnessed a rapid rise in its transactions volume after it launched a low-cost remittance product by partnering with a leading state-owned bank (Federation of Indian Chamber of Commerce & Industry, 2011). Financial Information Network and Operations Limited (FINO), a financial services provider supported by angel investors has developed a technology platform based on biometric smart cards, that offers customers an entire range of banking services, including value-added services such as utility bill payments, mobile recharges and train ticket booking.

We build on prior research by considering larger time frames and additional variables that are deemed relevant in impacting mobile telephony. Accordingly, we collate data on major Indian states for 2001–2012 and examine the impact of mobile telephony on economic growth, holding constant other factors that are important in impacting growth. We next turn to a description of the dataset, followed by the empirical specification.

3. Database and variables

We use a sample comprising of an unbalanced longitudinal data for the period 2001–2012 for 14 major Indian states.[1] The choice of these states is in line with the accepted practice of comparing the economic performance of states that treats smaller or North Eastern states differently (Ahluwalia, 2002; Kalra, & Sodsriwiboon, 2010; Nachane, Ghosh, & Ray, 2002). As a result, we do not include ‘special category’ states and certain newly constituted states carved out of existing ones. In 2012, the final year of the sample, these states accounted for roughly three-quarter of India's land area, over 80% of her population and around four-fifths of the domestic product.

The analysis combines several sets of data at the state-level: macroeconomic data, mobile-related data, financial inclusion data, and finally, other state-specific data.

Macroeconomic data: State-level domestic product (State GDP) is proxied by Net State Domestic Product per capita, which is the measure of state income employed in state-level research on India (Ghosh, 2013; Krishna, 2004; Purfield, 2006; Sachs, Bajpai, & Ramaiah, 2002). The data is derived from the Handbook of Statistics on Indian Economy (RBI, 2013a,b). Using this data, we construct an annual series on real per capita output and the shares of registered and unregistered manufacturing, separately by appropriately splicing the sets of base-year series. Using the EPW Research Foundation database, we obtain the state-wise population number. The information on state-wise government expenditure is obtained from the Handbook of State Finances (RBI, 2010) coupled with the annual state finance document (RBI, 2013a,b).

Mobile-related data: The technology related data include: number of cellular and internet subscribers are sourced from IndiaStat.com, a private data service aggregator which provides socio-economic statistical data about India and its states and number of cellular service providers. Information on the number of subscribers the number of cellular service providers was obtained from the website of the Telecom Regulatory Authority of India (TRAI) and the Cellular Operators Association of

[1] These states, in order are regional location are, Andhra Pradesh (AP), Karnataka (KARN), Kerala (KER) and Tamil Nadu (TN) in the Southern region, Haryana (HARY), Punjab (PUNJ) and Rajasthan (RAJ) in the Northern region, Bihar (BIH), Odisha (ODIS) and West Bengal (WB) in the Eastern region, Gujarat (GUJ) and Maharashtra (MAH) in the Western region and finally, Madhya Pradesh (MP) and Uttar Pradesh (UP) in the Central region.

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India (COAI), supplemented by IndiaStat database.[2]Financial inclusion data: Following previous literature (Ardic, Heimann, & Nataliya, 2011; Beck et al., 2008; Demirguc Kunt et al., 2015; Kendall, Mylenko, & Ponce, 2010), we utilize the following indicators of financial inclusion outreach at the state-level:

(a) geographic access: number of bank branches per 1000 sq. kms.
(b) demographic access: number of bank branches per 100,000 people
(c) loan accounts per capita: number of loan accounts per 1000 people
(d) deposit accounts per capita: number of deposit (aggregate of savings, term and current) accounts per 1000 people
(e) loan-income ratio: average size of loans to per capita income
(f) deposit-income ratio: average size of deposits to per capita income.

Our focus is primarily on banking outreach for three reasons. First, in India, the banking sector intermediates most of the funds in the economy: bank asset to GDP ratio is around 100%. Second, the Indian central bank has pursued a bank-led financial inclusion strategy (RBI, 2012), which makes the focus on bank-related indicators all the more imperative. Contextually, it may be mentioned that the Indian approach to financial inclusion contrasts with the experience of Kenya which pursued a non-bank led model or for that matter, that of Philippines, wherein a combination of the brand and execution of the service by a mobile network operator in partnership with a commercial bank substantially improved access to finance. And finally, the statistical information for this sector is easily available as compared to other non-bank service providers. The data are culled out from the Basic Statistical Returns, a yearly central bank publication which provides detailed state-level information on deposits and credit of commercial banks (RBI, 2002, 2006, 2008, 2012).

The six indicators listed above take on board the three major dimensions of an inclusive financial system: penetration, availability and usage. In particular, indicators (a) and (b) measure the outreach of the financial sector. More specifically, while geographic access focuses on banking penetration, the latter considers the availability of banking services. These measures however, have limitations as indicators of access to physical banking outlets. More importantly, these measures implicitly assume a uniform distribution of bank outlets within a country's area and across its population. In reality, bank branches and ATMs could be concentrated across population groups, limiting its utility in certain cases. To overcome this drawback, indicators (c) through (f) measure the use of banking services. As observed by Beck, Demirguc Kunt, and Martinez Peria (2007), higher values of indicators based on the number of loans and deposits signal greater use of services. On the contrary, higher values for the average size of loans or deposits to per capita income indicate that banking services are more limited in use, since they are likely only to be used only by the affordable sections of the society.

Other state-specific data: Other state-specific variables we utilize are roads per 1000 square kilometres and number of post offices per lac of population. Information on these variables is obtained from the annual publication of the Government, the Statistical Abstract (Government of India, 2002, 2005, 2008, 2014). Finally, we obtain information on literacy rates from the Statistical Abstract (Government of India, 2002, 2005, 2008, 2014).

4. Empirical strategy

4.1. Mobile telephony and growth

In order to analyse the impact of mobile telephony and economic growth, we follow previous research (Andrianiavo and Kpodar, 2012; Lee et al., 2009) and apply an endogenous growth framework. First, let $y_{s,t}$ be the logarithm of real per capita income (PCI) for state s at time t and $y_{s,t-1}$ denote its lagged value, then the growth rate can be computed as $\hat{y}_{s,t} = y_{s,t} - y_{s,t-1}$. Therefore, the reduced form specification for state s at time t can be specified as in Eq. (1):

$$\hat{y}_{s,t} = \alpha\, y_{s,t-1} + \beta\, Mobile_{s,t} + \gamma\, \mathbf{X}_{s,t} + \mu_s + \varepsilon_{s,t} \quad (1)$$

where $\mathbf{X}$ denotes a set of state-specific growth determinants such as financial deepening, education, inflation, government size and institutional factors. Further, μ represents state fixed effects and ϵ is the error term.

The coefficient of interest is β, which captures the impact of mobile telephony on economic growth. Provided mobile telephony improves economic growth as the extant literature would suggest, $\beta > 0$.

We estimate the dynamic model with the system GMM estimator. The advantage of this methodology is its ability to control for endogeneity that arises when some of the variables are determined within the system. It combines a differenced equation with a level equation. We adopt the system GMM estimation procedure since first difference GMM may suffer from weak instruments problems (Blundell, & Bond, 1998).

The reliability of the system GMM estimation depends on the validity of the instruments. We consider the validity of the instruments by presenting the Sargan test on over-identifying restrictions, which tests the validity of the null hypothesis of the (over-identifying) instruments. In addition, we also test the reliability of the instruments of the level equation by

[2] Inclusion of a proxy for the price of mobile, proxied by the average revenue per user of mobile (Kathuria et al., 2009) proved unsuccessful, since data for this variable was available beginning only for a limited time span.

presenting the Difference Sargan test. This is calculated by subtracting the value of the Sargan test of a first differenced GMM estimate from the value of the Sargan test of system GMM estimate. The Difference Sargan test is also asymptotically distributed as χ^2.

The consistency of the estimates also depends on the absence of serial correlation in the error terms. To do this, we present the first-order (AR1) and second-order (AR2) serial correlation tests to justify the lack of serial correlation in the error terms.[3] The null hypothesis relates to insignificance; this entails a low p-value for AR1 and a high p-Value for AR2.

Although we have suitably scaled the variables, it is possible that some of them might contain a unit root. Taking this consideration on board, we test for a unit root in the mobile and growth variables. Since the data has a short time series and a large cross-section dimension, we use the Levin-Lin-Chu (LLC) panel unit root test, which assumes that each cross section unit shares the same AR(1) (Levin, Lin, & Chu, 2002). The LLC test rejects the hypothesis of a common unit root for these variables.

The results are as follows:

Variable	Adjusted t	Probability
CELLULAR	−14.4808	0.0000***
TEL	−6.3140	0.0000***
GROWTH	−9.4634	0.0000***

The null hypothesis of the LLC test is that there is a common unit-root process for all states.
*** Indicates statistical significance at the 1% level.

4.2. Financial inclusion and mobile telephony

To further understand whether mobile telephony is a key factor driving financial inclusion, akin to Andrianaivo and Kpodar (2012) and Kendall et al. (2010), we also estimate the following model, as in Eq. (2):

$$FI_{s,t} = \alpha_o + \alpha_1 y_{s,t} + \alpha_2 \, Mobile_{s,t} + \gamma \, \mathbf{X}_{s,t} + \mu_s + \varepsilon_{s,t} \quad (2)$$

where FI is the indicator of financial inclusion, represented alternately by the number of deposit and loan accounts and number of bank branches, **X** is a vector of state-level controls such as per capita income, education and number of mobile network operators. Lee (2001) recognizes the role of human capital as a key ingredient in the development of ICT.

We estimate the model by fixed effects regression, based on the Hausman test which supports the former. Following recent research (Cameron, Gelbach, & Miller, 2011), we double cluster the standard errors at the state and year levels.

5. Results and discussion

5.1. Summary statistics and correlations

Table 1 provides a description of the empirical variables of interest, including their data source and the summary statistics. Per capita income growth over the period averaged 2.4%; the values at the 75th and 25th percentile were 3.6% and 1.4%, respectively. This suggests that growth across states has displayed significantly variability.

The logarithm of cellular subscribers per 100,000 persons translates into a number of 6150 cellular subscribers per 100,000 persons. Across regions, cellular penetration is much higher in the Western (9600 subscribers/100,000 persons) and Southern (9010 subscribers/100,000 persons) as compared to Northern (7220 subscribers/100,000 persons) region. The Eastern and Central regions exhibit lowest penetration with the number of subscribers per 100,000 persons being 3480 and 3950, respectively.

Besides including state-specific controls, such as number of post-offices and road density, we also include a proxy for competition, such as the number of mobile network operators (MNO) in a state. Without loss of generality, greater number of MNOs would mean higher competition and consequently, greater likelihood of mobile penetration. The average number of MNOs in a state during the period was 1.6. Finally, following Andrainaivo and Kpodar (2012), we control for state population density.

Table 2 presents the correlation matrix of the empirical variables of interest. Growth appears to be positively correlated with mobile penetration, with a coefficient of 15%, although it is not statistically and significant correlated with any of the other variables. These raw correlations do not take on board state-specific factors or for that matter, the business cycle.

We compute the average values of mobile penetration and per capita income growth for each state over the sample period. We plot this relationship in Fig. 1, which shows that higher mobile penetration is associated with higher per capita income. While this is consistent with our contention that higher mobile penetration entails higher economic growth, a rigorous econometric framework is necessary to establish a causal relationship between these empirical variables of interest.

[3] The test statistics are asymptotically distributed as standard normal variables.

Table 1
Variable definition and summary statistics.

Variable	Empirical definition	Data source	Mean (SD)	p.75 (p.25)
GROWTH	Log difference of per capita income at constant prices	RBI (2013a)	0.024 (0.029)	0.036 (0.014)
CELLULAR	Log (number of cellular subscribers/100,000 persons)	IndiaStat.com	3.79 (0.81)	4.52 (3.22)
TEL	Log (number of telephones/100,000 persons)	IndiaStat.com	1.18 (0.53)	1.66 (0.78)
POSTOFF	Log (post office/100,000 persons)	Statistical Abstract	1.15 (0.12)	1.24 (1.04)
ROADS	Log (roads/1000 sq. kms.)	Statistical Abstract	3.04 (0.25)	3.14 (2.86)
GOV	Government expenditure/State GDP	RBI (2010, 2013b)	0.23 (0.08)	0.27 (0.18)
LITERACY	Literacy rate	Statistical Abstract	0.73 (0.10)	0.78 (0.67)
Sh_MFG	Share of manufacturing/ state GDP	EPW States database	0.15 (0.13)	0.17 (0.09)
Sh_UNREG	Share of unregistered manufacturing/State GDP	EPW States database	0.05 (0.02)	0.06 (0.04)
NUMBER	Number of mobile network operators in the state	TRAI/COAI/Indiastat.com	1.56 (0.39)	1.79 (1.39)
DENS	Log (population/1000 sq. kms.)	Numerator is from EPW States database. Denominator is from Wikipedia	1.47 (0.55)	2.02 (1.02)
MERGER	Dummy = 1 for the bifurcated state in the year of merger	Wikipedia	0.21 (0.41)	–

*TRAI: Telecom Regulatory Authority of India.

Table 2
Correlation matrix.

	GROWTH	CELLULAR	POSTOFF	ROADS	GOV	LIT.	Sh_MFG	Sh_UNREG	NUMBER	DENS
GROWTH										
CELLULAR	0.149**									
POSTOFF	0.001	−0.097								
ROADS	0.044	0.332***	0.025							
GOV	−0.059	0.441***	−0.202***	0.109***						
LITERACY	0.115	0.443***	0.039	0.542***	−0.271***					
Sh_MFG	0.027	−0.146**	0.139*	−0.351***	−0.243***	−0.158*				
Sh_UNREG	−0.069	−0.023	−0.149**	−0.153**	−0.332***	0.096	0.324***			
NUMBER	0.068	0.702***	−0.209***	0.300***	0.462***	0.285***	−0.145*	−0.126*		
DENS	−0.013	0.096	−0.473***	0.650***	0.118	0.197**	−0.327***	0.141*	0.186***	

*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.10$.

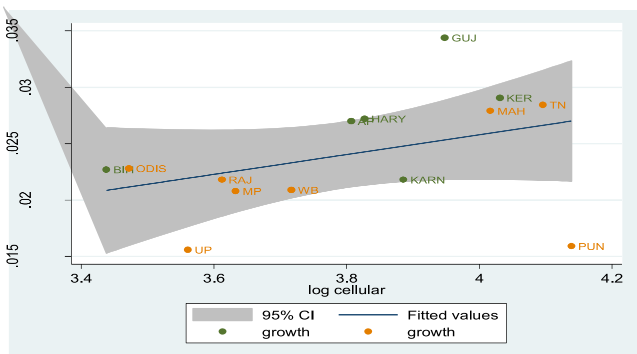

Fig. 1. Mobile penetration and economic growth per capita for Indian states.

5.2. Baseline results

5.2.1. Mobile telephony and economic growth

The regression results are presented in Table 3. In column 1, the coefficient on cellular is positive and significant with a point estimate of 0.09. In other words, a 10% increase in cellular penetration leads to an increase in the growth rate of per capita income by 0.9% points. These numbers are consistent with Qiang, Rossotto, and Kimura (2009) who report that in developing markets, an increase in mobile penetration by 10% increases GDP per capita by 0.8% points.

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Table 3
Mobile Telephony and Economic Growth – Baseline results.

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lagged real per capita NSDP	−0.278*** (0.087)	−0.288*** (0.087)	−0.279*** (0.083)	−0.263*** (0.081)	−0.445*** (0.132)	−0.254*** (0.077)	−0.435*** (0.123)
CELLULAR	**0.091* (0.049)**	**0.097** (0.049)**	**0.073* (0.039)**	**0.074** (0.036)**	**−0.729** (0.373)**		**0.055* (0.029)**
Sq.(CELLULAR)					**0.134** (0.062)**		
POSTOFF		−0.094 (0.076)	−0.084 (0.065)	−0.093 (0.062)	−0.227** (0.099)	−0.073 (0.066)	−0.261** (0.123)
ROADS		−0.028 (0.029)	−0.031 (0.026)	−0.009 (0.046)	−0.055 (0.065)	0.022 (0.039)	−0.043 (0.058)
NUMBER			0.050 (0.032)	0.044 (0.031)	0.027 (0.039)	0.049 (0.032)	0.033 (0.042)
DENS				−0.019 (0.017)	−0.014 (0.022)	−0.022 (0.015)	−0.022 (0.019)
TEL						0.089** (0.045)	−0.715 (0.495)
CELLULAR*TEL							0.096** (0.048)
GOV	−0.307 (0.265)	−0.329 (0.254)	−0.350 (0.221)	−0.411* (0.219)	−0.114 (0.306)	−0.498** (0.229)	−0.108 (0.416)
Sh_MFG	0.048 (0.039)	0.054 (0.037)	0.045 (0.036)	0.046 (0.035)	0.022 (0.054)	0.033 (0.032)	0.038 (0.050)
Sh_UNREG	−0.581 (0.476)	−0.845* (0.496)	−0.702* (0.412)	−0.551 (0.424)	−1.145** (0.596)	−0.348 (0.362)	−1.377* (0.785)
LITERACY	−0.011 (0.068)	−0.011 (0.071)	0.005 (0.068)	−0.012 (0.066)	0.069 (0.091)	−0.009 (0.068)	0.065 (0.090)
MERGER	Y	Y	Y	Y	Y	Y	Y
N. Observations	125	125	125	125	125	125	125
N. States	14	14	14	14	14	14	14
AR1, AR2	0.03; 0.38	0.02; 0.58	0.02; 0.86	0.01; 0.72	0.03; 0.99	0.03; 0.95	0.05; 0.99
Sargan test (*p*-Value)	15.38 (0.80)	16.42 (0.74)	15.94 (0.77)	16.52 (0.74)	5.87 (0.99)	16.21 (0.75)	6.27 (0.99)
Diff. Sargan (*p*-Value)	6.74 (0.97)	6.37 (0.95)	5.59 (0.96)	6.11 (0.91)	3.45 (0.98)	6.24 (0.90)	3.92 (0.95)

Standard errors in brackets.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.10$.

We sequentially augment the basic model by including additional state-level controls and continue to find evidence of a positive and statistically significant impact of mobile telephony on economic growth. In column 2, we include additional controls, such as the number of post office and road infrastructure. Economically, state with more extensive transport and communications network should be better able to facilitate economic activity. The sign on these variables should therefore, be positive. In column 2, both these variables enter with the wrong sign, but are statistically insignificant. The coefficient on CELLULAR remains statistically significant with a point estimate of 0.097.

Column 3 includes the number of mobile network operators (MNO) in the state. Higher number of MNOs would entail greater likelihood of mobile penetration and consequently, engender higher growth. As observed in column 3, the coefficient on the number of MNOs is positive, but not statistically significant; the coefficient on CELLULAR continues to remain statistically significant.

Column 4 includes population density as an additional state-level control. Higher population density engenders higher demand and thereby, higher growth. Although the coefficient on this variable is not statistically significant, the coefficient on CELLULAR maintains its sign and significance.

Column 5 examines possible non-linearities in cellular penetration, what is popularly known as network effects (Daganoglu & Grzybowski, 2007; Karacuka, CAtiK & Haucap, 2013; Kathuria et al., 2009; Roller & Waverman, 2001). To test this aspect, we include squared term of CELLULAR among the independent variables. The estimates suggest that an increase in mobile penetration results in a significant lowering in per capita income for mobile penetration up to a threshold. Beyond this level however, further increase in mobile penetration is accompanied by an increase in per capita growth. Taken together, the findings are consistent with the presence of a U-shaped relationship between mobile penetration and per capita income growth.

To investigate this further, we employ the Lind, and Mehlum (2011) test. Based on the estimates in column 5 of Table 3, the Sasabuchi *t*-test to detect the presence of non-linear relationship rejects the null hypothesis and thus indicates that the results are in conformity with the U-shaped relationship between mobile penetration and per capita output growth, as observed earlier. The last row of Table 4 reports a 95% Fieller interval and shows that the relationship between cellular penetration and income growth is not statistically significant when mobile penetration lies in the given range.

Column 6 examine the relevance of an alternate mode of communication: the telephone density. The estimates show that the coefficient on TEL is positive and significant with a point estimate of 0.089: a 10% increase in telephone density improves per capita income growth by roughly 0.9%, marginally smaller than what is observed with respect to mobile penetration.

Finally, we examine possible complementarities between mobile and fixed (landline) penetration. These complementarities can arise if, for example, people with mobile telephony also augment their communication capacity by installing fixed (landlines) phones, which in turn, raises their capacity to communicate more seamlessly (e.g., through Wifi).

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Table 4
Tests for U-shaped relationship.

	(1)
Slope at lower bound of CELLULAR	−0.24
Slope at upper bound of CELLULAR	0.59
LM test for inverse U-shape	1.59
p-Value	0.05
Fieller 95% confidence interval	[−0.34, 3.05]

Conversely, the higher the fixed (landline) penetration, the greater the likelihood of mobile penetration, because mobile networks are often dependent on fixed networks and not able to efficiently meet the demand of users without the contributions made by fixed network.

The estimates in column 7 suggest that this is indeed the case: mobile and fixed telephony are complements. Based on the point estimates, the impact of mobile telephony on per capita income growth works out to 0.14 (0.05+0.09=0.14), comprising of a direct impact of 0.05% points and an indirect impact, working through fixed landline of 0.09% points. The findings are consistent with evidence proffered by OECD (2012) who observe that fixed and mobile telephony are complementary, with each reinforcing the other. However, they run contrary to cross-country findings by Gupta and Jain (2014) and Waverman et al. (2005) who find these two forms of communications technology to be substitutes.

Summing up, the evidence suggests that mobile penetration exerts a positive and statistically significant impact on economic growth and the magnitude is, by all means, quite substantial.

5.2.2. Robustness

We next examine the robustness of the baseline results. Akin to Kathuria et al. (2009), we categorise states into high- and low-penetration states, based on their median mobile penetration over the period. Provided the coefficient on mobile penetration for high income states exceeds that for the low income states, this would support the critical mass hypothesis. We include the state-level control variables across all specifications, although these are not reported for purposes of brevity.[4]

There are three major findings of interest in Table 5. First, comparing columns (1) and (4), we find that the coefficient on CELLULAR for the high-penetration states is 0.22, which is three-and-a-half times that of the number for the low income states. The point estimates therefore imply that a 10% increase in mobile penetration would improve per capita income growth in the high-penetration states by roughly 2.2% points as compared to 0.6% points in the low-penetration states.

Second, although there is evidence of non-linearity for the high-penetration states, no such non-linearity is in evidence for the low-penetration states.

And finally, the complementarity between mobile telephony and fixed landlines is manifest only for high-penetration states; there is limited evidence of such complementarity for low-penetration states.

We next turn to a discussion of the impact of mobile telephony on financial inclusion.

5.2.3. Financial inclusion and mobile telephony

Next, we examine the impact of mobile penetration on financial inclusion. As our earlier discussion suggests, by lowering costs and improving the speed of transfer even from far-flung areas, mobile telephony has exerted a perceptible impact on financial inclusion. Table 6 presents the regression results.

The coefficient on CELLULAR is positive and statistically significant in column 1. The impact of mobile penetration on financial inclusion is quite substantial. Based on the point estimates, it can be inferred that a one standard deviation increase in mobile penetration would improve the outreach of bank offices by 31%. With average demographic penetration in the sample being 7.6, this is an extremely substantial number. As compared to this, mobile penetration does not appear to exert any perceptible impact on geographic branch penetration.

Perhaps the biggest impact of mobile penetration is on use and more specifically, on the use of deposit and loan accounts (Columns 3 and 4). In column 3, the coefficient on deposit accounts is 0.94. To obtain a sense of the magnitudes, consider an increase in mobile penetration by 40% from 3.22 to 4.15, equal to a move from the 25th to the 75th percentile of the distribution. Based on the point estimates, this will lead to an increase in the use of deposit accounts by roughly 37%. As compared to this, a similar increase in mobile penetration would improve the use of loan accounts by nearly 60%. Economically, one would expect mobile telephony to exert a more pronounced impact on deposits as it improves the flexibility of remittances, akin to the M-PESA experience in Kenya. The evidence in the Indian case appears to suggest that mobile telephony improves the information set of customers regarding the use of loan products much more than that related to deposit products. More often than not, borrowers and typically small borrowers lack collateral and credit histories, which makes it difficult for them to access formal (bank) finance. By linking these borrowers with suppliers (e.g., business

[4] The regression including only one lag of mobile telephony failed to fulfil the Sargan test of over-identifying restrictions and the Arellano-Bond test for autocorrelation of the error term. The introduction of additional lags allowed fulfilling the post-estimation test requirements.

Table 5
Mobile Telephony and Economic Growth – Robustness.

	High mobile penetration			Low mobile penetration		
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Lagged real per capita NSDP	−0.554*** (0.073)	−0.513*** (0.072)	−0.545*** (0.073)	−0.238 (0.062)	−0.264*** (0.066)	−0.258 (0.162)
CELLULAR	**0.215*** (0.071)**	**−0.687* (0.392)**	**0.113** (0.052)**	**0.063*** (0.019)**	**−0.052 (0.162)**	**0.045 (0.107)**
CELLULAR, lag	**−0.086 (0.060)**		**−0.064 (0.069)**		**0.040 (0.028)**	
Sq.(CELLULAR)		**0.101* (0.059)**			**0.016 (0.024)**	
Controls	Y	Y	Y	Y	Y	Y
TEL			−0.238 (0.385)			−0.314 (0.268)
CELLULAR*TEL			0.060* (0.036)			0.084 (0.076)
MERGER	Y	Y	Y	Y	Y	Y
N. Observations	43	43	43	55	55	55
N. States	14	14	14	14	14	14
AR1, AR2	0.01; 0.94	0.08; 0.70	0.02; 0.81	0.00; 0.21	0.01; 0.16	0.00; 0.19
Sargan test (*p*-Value)	21.86 (0.14)	22.75 (0.12)	22.03 (0.11)	18.38 (0.14)	16.61 (0.12)	14.35 (0.13)
Diff. Sargan (*p*-Value)	3.89 (0.79)	4.45 (0.72)	3.81 (0.57)	5.42 (0.24)	2.37 (0.30)	2.39 (0.38)

Standard errors in brackets.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.10$.

Table 6
Regression Results – Financial Inclusion and Mobile Telephony.

Variable	Log (Bank office/ 100000)	Log (Bank office/1000 sq. kms)	Log (Deposit Ac/ 1000)	Log (Credit Ac/ 1000)	Log (Deposit/ Income)	Log (Credit/ Income)
Real per capita NSDP, lagged	−0.576 (0.439)	−1.312 (1.533)	−0.659 (0.771)	−0.679 (0.693)	−0.711 (0.857)	−0.301 (0.628)
CELLULAR	**0.386** (0.169)**	**0.114 (0.399)**	**0.935*** (0.257)**	**1.467*** (0.254)**	**−0.147 (0.258)**	**0.053 (0.349)**
CREDIT	−0.169* (0.092)	−0.089 (0.244)	−0.056 (0.133)	0.054 (0.117)	0.116 (0.150)	0.095 (0.177)
Sh_MFG	−0.034 (0.153)	−1.434* (0.858)	0.007 (0.191)	0.194 (0.228)	0.039 (0.116)	0.009 (0.249)
Sh_UNREG	−0.189 (0.412)	1.016 (0.707)	0.461 (0.370)	−1.572 (3.749)	−0.667 (1.469)	0.897*** (0.301)
GOV	−0.012 (1.034)	−0.305 (1.828)	−3.586* (2.092)	−0.590*** (0.189)	0.742 (2.062)	−0.348 (0.976)
LITERACY	0.579 (0.451)	1.859 (1.697)	0.805 (0.537)	0.107 (0.748)	−0.334 (0.637)	−0.909 (0.876)
MERGER	Y	Y	Y	Y	Y	Y
N. Observations	125	125	125	125	125	125
N. States	14	14	14	14	14	14
R-squared	0.581	0.325	0.826	0.913	0.392	0.403

Standard errors (clustered by state and year) in brackets.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.10$.

correspondents) who can directly monitor their credit and repayment history *via* the unique identification as embedded in their mobile SIM, it raises the activity in loan accounts.

6. Concluding remarks

Using data on Indian states during 2001–2012, the paper analyses the impact of mobile penetration on economic growth. Employing an advanced panel data framework that takes into account the possible endogeneity issues, the findings suggest that mobile telephony exerts a significant and non-negligible impact on economic growth. More specifically, a 10% increase in mobile telephony is associated with a 0.9% point improvement in economic growth, after taking into account other factors that are deemed relevant in influencing growth. The findings also provide evidence in support of non-linear effects, wherein increases in mobile penetration lowers income growth up to a threshold, beyond which increases in mobile penetration exerts a positive impact on economic growth (Karacuka, CAtiK, & Haucap, 2013; Maicas, Polo, & Sese, 2009). In addition, the results suggest that mobile telephony and fixed landlines are complements, with each reinforcing the other. The findings also testify to the fact that mobile telephony exerts a positive impact on financial inclusion, especially the use of loan and deposit accounts.

The findings have important implications for policy. First, in a recent policy document, the Government has articulated the growth of mobile telephony as an important leg of the triad for furthering the cause of financial inclusion (Government of India, 2015).[5] In this context, innovative delivery channels such as mobile payments can prove to be a useful mechanism for easily collecting data about access to and patterns of usage of financial services that can inform the further refinements of financial products and services for the poor, in turn, acting as a powerful intervention for growth. Second, the analysis supports the fact that there has been a wide and divergent effect of mobile telephony on income growth for high and low-penetration states. The innate advantages of high-penetration states in achieving higher levels of private investment are compounded by the fact that an efficient financial system will redirect financial savings towards the better-performing states. In view of the above, it is imperative that public investment be utilised appropriately to build economic infrastructure and push mobile telephony in the low-penetration states. This, in turn, could help remove constraints on growth in these states and help leverage a larger flow of private investment and thereby, augment growth. Finally, while research on the usefulness of mobile technology for augmenting growth is still evolving, most studies veer around the view that mobile phones can act as an important conduit in communicating information and in the process, have positive growth externalities.

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[5] The acronym for the triad is JAM (JanDhan, Aadhaar and Mobile), where JanDhan, a government-driven financial inclusion scheme initiated in August 2014 seeks to provide a bank account to every household within a stipulated time frame and Aadhaar is a unique individual biometric identity that the government is gradually employing in all economic and financial transactions.

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