Determinants of Digital Divide using Demand-Supply Framework: Evidence from India

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Abstract

In last two decades, India has seen high economic growth. Concomitantly, there has been increase in availability and use of information and communication technologies (ICTs). However, ICT penetration in India is much less when compared to global averages. There exists a substantive level of inequality in ICT access and use. Empirical studies on extent and nature of digital divide in India are few, especially those with explicit theoretical demand-supply framework, using consistent and reliable pan India data. This paper is an attempt to address these research gaps. It examines the digital divide in India across socio-economic classes and different political-geographic regions. The reduced form demand equations for two ICT instruments – Internet and mobile phone - are estimated separately for households aggregated at subnational level. A multi-variate econometric model identifies both demand and supply side factors shaping differential access by households. Findings indicate digital divide is a reflection of existing socio-economic divide. On the demand side, socio-economic inequality as manifest in the economic conditions of households, social category, occupational profile, age and education status are key determinants of district level digital divide. Further, supply side factors like availability of electricity, mobile network and extent of urbanization also play an important role.

Keywords: Digital Divide, Key Determinants, Econometrics, India, Census

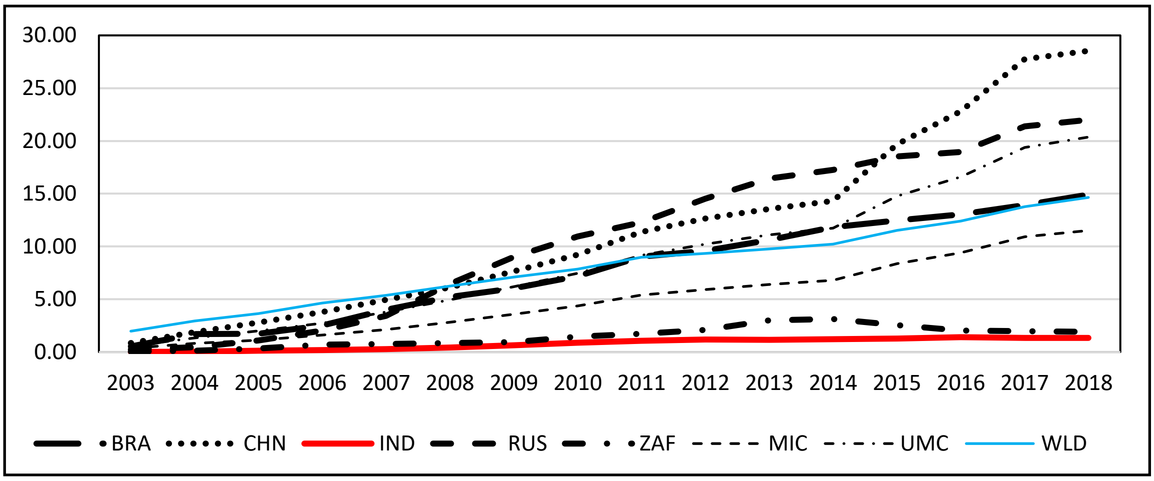
1 Introduction

Proactive policies and decreasing cost of data and mobile phones has led to rapid diffusion of information and communication technologies (ICTs) in India (Dutta, 2018). According to the latest data available in the International Telecommunication Union's ICT indicator database[1] the mobile-cellular subscription that was 19.8 per 100 inhabitants in 2007 became 71.67 in 2011 and 85.17 in 2016. During the same time period, the fixed broadband subscription per 100 inhabitants increased from 0.27 to 1.41. The mobile broadband subscription per 100 inhabitants was 0.94 in the year 2011 and has shown a steep rise to 16.41 by the year 2016.

However, despite huge improvement in availability and access, the overall penetration of ICTs in India is much less when compared to global averages. For the period between 2003 and 2018, the values for India's subscription of fixed broadband per hundred people, fixed telephone per hundred people and mobile subscription per 100 people is substantially and

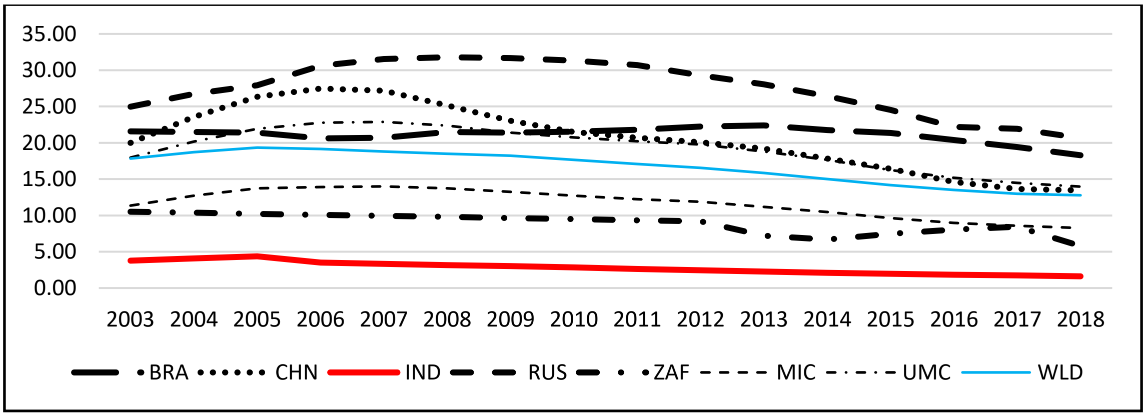
[1] http://www.itu.int/net4/ITU-D/idi/2017/index.html

consistently lower than individual BRICS countries, and from averages of the middle-income country group, upper middle-income country group and world as a whole (See Figures 1a, 1b, and 1c). The comparatively low penetration of ICT instruments in India was also observed by Barman, Dutta and Nath (2018). This huge gap in key ICT development indicators between India and world average is surprising. It is because, in last two decades (year 2001 to 2019), the annual average real GDP growth rate (in 2010 constant US dollar value) of India was 6.65 per cent, whereas the global average was 2.85 percent (Source: World Development Indicator). This indicates that India was one among the high growth economies of the world during the period. And across countries, the most prominent characteristics of the economic growth during this period was the growth of ICT and its diffusion. This had created an expectation that high growth economies will also experience high level of ICT diffusion. Thus, the low level of ICT penetration in comparison to other countries, despite having very high GDP growth in last two decades, calls for examining in depth the nature and extent of ICT diffusion in India. It is worthwhile to investigate if the overall low penetration of ICTs in India is because of uneven spread of required ICT infrastructure or difference in socio-economic characteristics of households. Specifically, in this paper we seek: (a) to examine the extent of digital divide in India at the national, state and district level and (b) to determine the demand and supply side factors causing digital divide at district level.



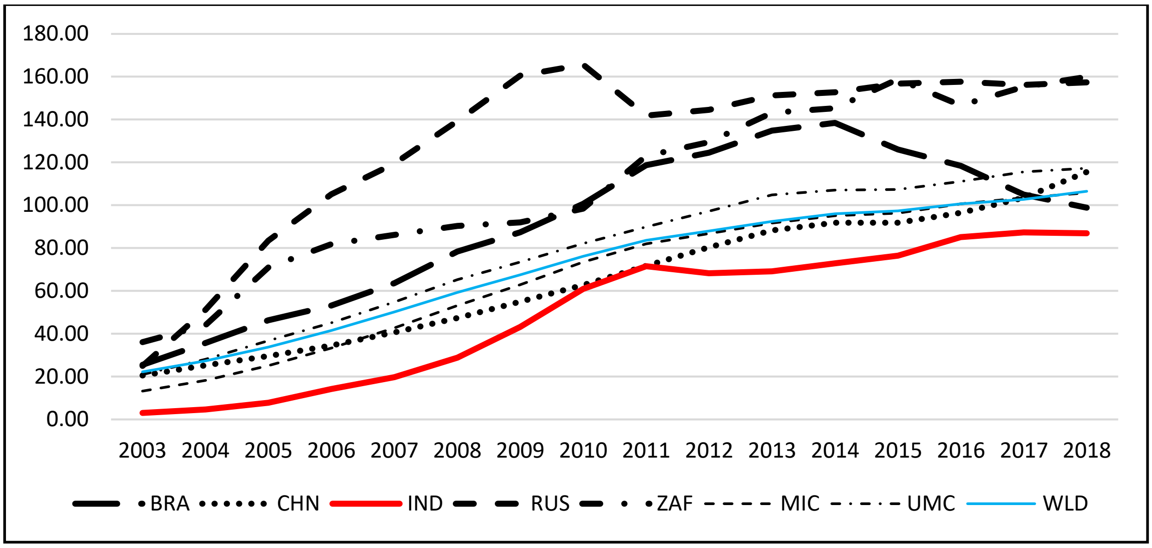
Data Source: WDI Indicators, World Bank

Figure 1a: Fixed broadband subscriptions (per 100 people)



Data Source: WDI Indicators, World Bank

Figure 1b: Fixed telephone subscriptions (per 100 people)



Data Source: WDI Indicators, World Bank

Figure 1c: Mobile cellular subscriptions (per 100 people)

The study contributes towards addressing key theoretical and empirical gaps in the extant research on digital divide in India. Theoretically, none of the existing studies on digital divide use an explicit demand-supply framework to determine the causes of digital divide in India. This paper uses the concept of realised demand to arrive at the single equation econometric model based on the demand-supply framework to find out the factors causing digital divide. In the process of arriving at single equation the problems of endogeneity and identification has been also taken into consideration. Empirically, the demand and supply side factors are considered at the district level using large and consistent public datasets. In future, as data collection becomes more systematic and available, the theoretical model and findings of this study will serve as a reference to further studies on diffusion and adoption of ICTs in India.

Following the introduction, the paper proceeds as follows. The second section reviews the existing literature on digital divide, identifying the theoretical and empirical gaps and highlighting the contribution of this research. The third section on methods and data includes description of the theoretical framework, data sources, variables and the econometric model. The next three sections give the results and discussion followed by policy implications and concluding remarks.

2 Review of Literature

ICTs are classified as general-purpose technologies, with applications that can increase the efficiency and productivity of individuals, households and firms (Doong & Ho, 2012; James, 2007). In general, ICTs make production of goods and services more efficient by reducing operational costs and increasing productivity (Dewan & Riggins, 2005; Vu, 2011). The use of ICTs by government reduces transaction, transportation and communication costs. For households, use of ICTs reduce communication cost and increase access to various services. In any economy, households provide labour and savings. Use of ICTs by households can make labour more productive and their savings can be channelized to the financial sector more efficiently. Thus, in an increasingly connected world, it is necessary for any country to have a robust, and standardised ICT infrastructure along with widespread diffusion and adoption of ICT instruments that can potentially increase productivity, efficiency and effectiveness of all sectors (*Ibid*). However, it is seen that diffusion, adoption and use of ICTs by individuals, groups, households, firms and countries is generally uneven leading to differential outcomes. This has implications for a country's economic growth and human development (James, 2007).

Digital divide refers to this "gap between individuals, households, businesses, and geographic areas at different socioeconomic levels with regard both to their opportunities to access ICTs and to their use of the Internet for a wide variety of activities" (OECD, 2001). Conceptualizations and definitions of digital divide have evolved over the years. The early definitions simply looked at the phenomenon as difference between "haves" and "have-nots", the gap between entities based only on availability and access to certain kinds of latest ICTs (Rice & Katz, 2003). Current understanding about digital divide is more nuanced, taking into consideration factors that give rise to such inequality in access and use (Chinn & Fairlie, 2007; Dewan & Riggins, 2005; Scheerder, Deursen, & Dijk, 2017)). The digital divide between any two entities is categorised as either first order or the second order digital divide. While first order digital divide refers to the difference in access to and utilization of technologies, second order digital devices refer to the difference in skills or capabilities of those who have access to ICTs and can benefit from their use (Dewan & Riggins, 2005).

2.1 Existing Studies on Digital Divide

Existing studies on digital divide can be broadly grouped into two. The first set of studies examine the presence and extent of digital divide (Coria et al., 2013; Cuervo & Menéndez, 2006) and investigate the underlying socio-cultural, economic, infrastructural and institutional factors that give rise to digital divide among various entities both across (Andonova, 2006; Doong & Ho, 2012; Kiiski & Pohjola, 2002; Pick, Sarkar, & Johnson, 2015) and within countries (Coria et al., 2013; Nishida, Pick, & Sarkar, 2014; Nishijima, Ivanauskas, & Sarti, 2017; Sujarwoto & Tampubolon, 2016). The objective of these studies is generally to put forth policy level recommendations for broader diffusion and adoption of technologies. Thus, digital divide has been explored in terms of technology infrastructure at the country level (Ahn & Lee, 1999; Chinn & Fairlie, 2007; Cuervo & Menéndez, 2006; Kiiski & Pohjola, 2002; Zhang, 2017), adoption of information systems by firms (Lera-lopez & Marco, 2016) diffusion and utilization of ICT instruments and related services by individuals, groups (Dobransky & Hargittai, 2006), and households (Billon, Marco, & Lera-lopez, 2009; Zhao, Collier, & Deng, 2014). In general, studies have observed that the gap in access and use of ICTs among different entities are reflection of the prevailing socio-economic, infrastructural and institutional divides (Andonova, 2006; Baliamoune-lutz, 2003; Kiiski & Pohjola, 2002;) However, there are differences in the findings regarding the factors, and the quantum of their influence. For example, most studies looking at global level digital divide indicate that education plays a significant role in diffusion of technology in developing countries, but not so significantly in developed countries because of low variability (Baliamoune-Lutz, 2003; Kiiski & Pohjola, 2002).

The second set of studies evaluate the impact of ICTs on growth and human development, and some also investigate if digital divide between and within countries have converged or led to divergence over the years (Gulati & Yates, 2012; Park, Choi, & Hong, 2015). These studies indicate that as compared to computers and Internet, diffusion of mobile and mobile broadband services has been faster and more inclusive. This might be because fixed costs and asset-specificity of mobile networks and skills for using mobile phones is generally less (Andonova, 2006).

The particular quantitative technique or method adopted by the studies depends not only the level and aspect of digital divide being examined, but also on the availability of relevant datasets. Spatial analysis is a common method adopted to study the presence and extent of digital divide (Coria et al., 2013; Pick & Nishida, 2015). Determinants of digital divide has been examined using various forms of regression techniques (Nishijima et al., 2017). Factor analysis and/or principal component analysis is done to identify the factors before running a regression and/or to create a composite index to characterise the digital-divide (Park et al., 2015; Vicente & Lopez, 2011). Various forms of tests have been used to check whether the gap between "haves" and "have-nots" have converged or diverged over the years (Park et al., 2015; Rath, 2016).

2.2 Empirical Studies on Digital Divide in India

The number of empirical studies examining the extent and nature of digital divide in India is comparatively less (Barman et al., 2018; Saibal Ghosh, 2016; Sajal Ghosh & Prasad, 2014; Gupta & Jain, 2012; Haenssgen, 2018; Pick & Sarkar, 2015; Singh, 2008). Specific studies on digital divide in India (See Appendix A1) have sought to understand the extent of digital divide (Pick & Sarkar, 2015), diffusion of various forms of mobile technologies (Gupta & Jain, 2012), factors for ICT utilization and impact of ICTs on economic growth (Ghosh, 2016; Narayana, 2011), access to healthcare (Haenssgen, 2018) and financial inclusion (Saibal Ghosh, 2016). Key findings are that spread and impact of technologies has been differential.

As in case of other countries, diffusion and use of different ICTs in India have been shaped by technology characteristics and perceived utility (Barman et al., 2018; Gupta & Jain, 2012; Pick & Sarkar, 2015). The rate of diffusion of mobile telephony has been faster than others. The study done by Singh (2008) has analysed the pattern and rate of adoption of mobile phones in India by using diffusion model and estimated future trends. Similarly, using an epidemic diffusion model, Gupta and Jain (2012) analysed the diffusion process of two mobile technologies – Code Division Multiple Access (CDMA) and Global System for Mobile (GSM). They found that while the diffusion of CDMA was faster than GSM, the latter remained the dominant mobile technology in India.

Few studies have examined the relationship between telecommunication services and development outcomes. Ghosh (2016) investigate the effects of mobile penetration on economic growth in major Indian states during 2001–2012. The study found that financial inclusion was one of the channels through which mobile phones exerted a positive and statistically significant impact on economic growth. However, the quantum differs across states with high and low mobile penetration. Using a small household sample, Narayana (2011) determined that prices have a negative impact whereas income variable has a positive impact on household demand for fixed and mobile phone. Haenssgen (2018) in his study of diffusion of mobile phone has observed that while mobile phones increase opportunities to improve rural health care delivery system, poor people not owning one are at disadvantage.

2.3 Gaps in extant research and the contributions of this study

This paper seeks to address three specific gaps in the literature on digital divide in India – (a) lack of explicit theoretical framework to examine the nature and extent of digital divide in India, taking into consideration demand and supply side factors, (b) lack of studies that takes into heterogeneity at the sub-national (district) level, (c) using large, and consistent public dataset.

In terms of theoretical framework, none of the existing studies have incorporated both demand side and supply side factors for examining digital divide in India. Narayana (2011) has estimated the demand for ICT instruments using data from a small sample survey of subscribers of a public sector telecom company in Karnataka. However, in his estimation the endogeneity problem between price and quantity demanded was ignored. Pick & Sarkar (2015) have taken into consideration both demand and supply side factors to examine digital divide across states, but without adopting the demand-supply framework. In their econometric analysis, ICT utilisation, defined as number of subscribers, is taken as the dependent variable while education, economic factors, social capital, level of openness in the society and electricity are the explanatory variables. However, it has not theoretically developed the estimated equation. Further, due to lack of relevant data, this study has not considered some of economic variable, like-exports, which were not available at the state level prior to implementation of Goods and Service Tax (GST). The authors have themselves recognised that the data used for analysis did not belong to the same year. Barman, Dutta and Nath (2018) have examined the determinants of state level variations in teledensities without using any specific theory to support the estimated equation. The authors have not conducted the panel unit root test for the explanatory variables, though they have conducted it for the dependent variable. Further, for some variables like populations, literacy rate, and ratio of urban populations, data has been extrapolated from two consecutive census. Hence, it is obvious that these variables have a trend. For per capita consumption, the study has used NSSO's state-level small sample dataset. Since the number of surveyed observations is small, the estimation of per capita rural and urban consumption might not be accurate.

Most studies on digital divide in India focus only on the national level data. Specific studies investigating the determinants of digital divide at the sub-national level is not yet available. It would be pertinent to examine the differential access and use of ICTs at district level because digital divide in India manifests as regional, and rural-urban digital divide (Parayil, 2005) because of various reasons. Since early seventies, a series of policies and incentives by both central and state governments helped in establishing the Indian software development and IT-enabled services (IT/ITeS) industry. However, the predominantly export-oriented IT/ITeS industry led to an "enclave" form of development (Parayil, 2005) generating economic opportunities for English speaking and technically trained people (Dutta, 2018) with little spill-over effects on other domestic manufacturing or services industries.

Further, while the National IT Policy of 1998 gave a common framework for the country, it was adapted and implemented by different states as per their capabilities and priorities (Pick & Sarkar, 2015). Thus, some states like Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu and Kerala with better institutional, infrastructural and human capital could take lead in developing robust and competitive IT/ITeS industry through appropriate environment and incentives (Dutta, 2018; Mukerji, 2013). However, even in these states, the spill-over effects of the IT/ITeS sector in terms of economic opportunities was limited to specific districts or geographical areas (Parayil, 2005). Intra-state digital divide also manifested in the form of rural-urban divide, with urban areas having higher penetration of computers and Internet (Pick & Sarkar, 2015). Internet penetration in urban India is around 59 per cent but it is as low as 18 per cent in rural India (Gupta, 2018). The empirical contribution of this study is to examine the demand and supply side factors characterising the digital divide at the district level in India. In India, a district is the highest administrative unit in a state. Considering districts as level of analysis also enables us to obtain comparable data for most variables.

Further, it aligns with the general practice in decentralised development planning, where the district is the unit of plan, action and accountability.

The third contribution of the paper is that it makes an attempt to partially address the unavailability of recent and appropriate data, often cited as a reason for lack of studies on digital divide in India. Unlike many other countries, large-scale data collection or survey on access and use of ICTs at individual and household level is not institutionalised in India. Data that can be used for undertaking such analysis are scattered across multiple databases, dated differently and often behind a paywall. Much effort is required to combine them and prepare a consistent dataset. This study uses household, population and district level data available in Census 2011 and supplemented by data published by TRAI on supply side factors. Hence, the analysis is based on internally consistent data, expected to be free from biases that often arise in small sample surveys.

To summarise, this paper seeks to contribute to literature by examining the nature, extent and determinants of digital divide in India using an explicit demand-supply theoretical framework, using large and consistent database aggregated at district level.

3 Methods and Data

This research has two objectives. The first objective is to examine the extent of digital divide in India at the national, state and district level and the second is to determine the factors that causing digital divide at district level. For the first objective, data has been taken from the NSSO surveys and analysed using descriptive statistics. For accomplishing the second objective of finding the determinants of digital divide at the district level, we have developed a demand supply framework, and applied it to derive the reduced form of demand equation for the two ICT instruments – computers with Internet and mobile phone. The determinants of digital divide at the district level are then estimated using a multivariate econometric model.

3.1 Theoretical Framework

In order to understand the reasons for digital divide at district level, it is imperative to understand the demand for ICT instruments. This article defines ICT instrument as any computing/communication devices like computer, Internet and mobile phone. At the equilibrium, the demand for particular ICT instrument (Q_d) will be equal to the supply of the ICT instrument (Q_s).

$$Q_d = a - b_1 P + \sum_{i=1}^{n} b_{2i} X_i + u \quad (1)$$

$$Q_s = c + d_1 P + \sum_{j=1}^{m} d_{2j} Z_j + v \quad (2)$$

At equilibrium, $Q_d = Q_s = Q$

Equation 1 is a demand function. It is assumed to be linear. We take 'Q_d' as the district-level aggregate household demand for a particular ICT instrument. 'P' is the price of the ICT instrument, 'X_i' are exogenous variables representing the various household and population characteristics, aggregated at the district level. These include socio -economic status of households, educational level of the population, and occupational characteristics, among others. 'n' is number of exogenous variables. 'a', 'b_1' and 'b_{2i}' are the coefficients. Equation 2 is a supply function, assumed to be linear. 'Qs' is the supply of ICT instruments. 'P' is the price of ICT instrument. 'Z_j' are the 'm' exogenous variables characterising the various supply side factors like urbanization, availability of electricity, availability and quality of service of broadband and mobile phone networks at the district level. 'c' and 'd_1', 'd_{2j}' are the coefficients.

Estimating a set of simultaneous equation consisting of demand and supply equations may give rise to the problem of endogeneity. To avoid this, we use the reduced form of these equations, derived from the equilibrium condition. This reduced form of equation is suitable for Ordinary Least Square (OLS) estimation. However, to estimate the coefficients of the demand and supply equations, mentioned above, the identification problem will arise, as both 'm' and 'n' are greater than the number of endogenous variables. Here we are not interested in estimating the coefficient of demand and supply equation, but seek to understand the relationship between district-level demand of ICT instruments and the various exogenous variables. Hence, estimation of reduced form equation with 'Q' as dependent variable, which is suitable for OLS estimation, will serve our purpose. Thus, the reduced form equation we are estimating is:

$$Q = A + \sum_{i=1}^{n} B_i X_i + \sum_{j=1}^{m} D_j Z_j + w$$

where, $A=(ad_1 + b_1c)/(b_1 + d_1)$,

$B=d_1b_2/(b_1 + d_1)$

$D=b_1d_2/(b_1 + d_1)$

$w=(d_1u + b_1v)/(b_1 + d_1)$

Existing literature guide the selection of exogenous variables that shape the demand for particular ICT instruments. Broadly, exogenous variables would include factors related to economic status of households, their social categories, and occupational, age and gender profiles (Andonova, 2006; Dewan & Riggins, 2005; Nishida et al., 2014; Pick & Azari, 2008; Vicente & Lopez, 2011). Household income determines the budget constraint of consumer (Chinn & Fairlie, 2007) and is one major factor that should influences the demand for ICT instruments. Preference for owning an ICT instrument is also likely to vary depending on individuals' exposure to and perceived usefulness of owning them (Gupta & Jain, 2012). This, in turn might be related to a person's occupation (Cuervo & Menéndez, 2006) and education (Chinn & Fairlie, 2007). It is expected that the use of ICT instruments will be more among those who are in service sector than those in agriculture and industries (Barman et al., 2018; Park et al., 2015). This is because as compared to agriculture and manufacturing sectors, the very nature of service sector requires greater degree of communications between different stakeholders. Further, if a person belongs to some backward community, the exposure to new technologies is expected to be less. Similarly, it is expected that young people will adopt new technologies more readily, and hence demand of ICT instruments will be more among younger population (Kiiski & Pohjola, 2002). Status of women within family and society might be an important factor in enabling them to adopt new technologies.

The supply side exogenous variables are size of the market and urbanization. (Andonova, 2006; Vicente & Lopez, 2011). Both of them can influence the cost of supplying ICT instruments. Size of the market provides economies of scale which can reduce average cost of supply. Urban areas are more likely to have better transportation facility and higher concentration of population that facilitates greater diffusion of ICT infrastructure. Since one cannot use a particular ICT instrument without electricity or communication network, the other supply side exogenous variables are availability of electricity (Chinn & Fairlie, 2007; Kiiski & Pohjola, 2002), Internet and mobile networks (Barman et al., 2018) along with quality of their services. Further, we have also included competitiveness among various network service providers as a supply side variable. Greater competition should lead to lower price of connectivity, hence creating greater demand for ICT instruments, especially for the mobile phones. So, we have included all these exogenous variables to estimate the reduced form of demand equation for ICT instruments. The independent variables of the study are: (1) economic status of households, which also proxy the market size (2) educational profile, also proxy for the status of women, (3) occupational characteristics, (4) age distribution, and (5) social category. (6) extent of urbanization, (7) availability of electricity, (8) availability of broadband network, (9) broadband service quality, (10) availability of mobile network, (11) mobile network service quality, and (12) degree of competitiveness. The next section describes the data sources and indicators for these variables.

3.2 Data, Data Sources and Variables

The nature and extent of digital divide is examined primarily by using two public databases – the Census 2011 database and 68th and 75th rounds of sample survey by National Sample Survey Organisation (NSSO). The 68th round survey of NSSO provides data on household consumption expenditure for the year 2011-12. The 75th round survey of NSSO provides data for the year 2017-18 through its report on household expenditure on education. However, this report does not provide data on possession of mobile phone, which is too important to ignore in any discussion on digital divide presently. Hence, we use the data on household possession of mobile phones provided in both the Census and 68th round NSSO survey for the year 2011.

But there are some important differences between the two datasets. Census 2011 has data on the household possession of ICT instruments like landline, mobile phones, computers and computers with Internet, disaggregated up to village level. However, it does not provide data on household expenses on ICTs, which is available in the NSSO database. On the other hand, since NSSO is primarily a sample survey, in terms of geographical disaggregation, the NSSO estimates, even though this particular round of survey is of large sample size, are not much reliable beyond the level of large sized states due to further lowering of the sample size. Thus, we have used the NSSO data from 68th round survey to describe the nature and extent of digital divide at the national level by using descriptive statistics. Since there are 29 States (with even lower number of large states) in India, we have not used the NSSO data in the econometric models due to lack of adequate degrees of freedom. To avoid the problems arising out of low degrees of freedom, the econometric models are estimated using the district level data. In the econometric models, we have used Census of India 2011 and reports on Indian Telecom Services Performance Indicators, January - March 2011, published by Telecom Regulatory Authority of India (TRAI).

In Census 2011[2] database, district level data is organized state-wise and is located in multiple tables including District Census Handbook[3] (DCH), Population Census Abstract[4] (PCA), Household Assets and Amenities[5] (HAA) and Education Level by Age and Sex for Population

[2] http://www.censusindia.gov.in
[3] http://www.censusindia.gov.in/2011census/dchb/DCHB.html
[4] http://www.censusindia.gov.in/pca/DDW_PCA0000_2011_Indiastatedist.xlsx
[5] http://www.censusindia.gov.in/2011census/hlo/Houselisting-housing-PCA.html

Age 7 and above[6] (EDU). A particular challenge was to identify appropriate variables corresponding to the factors specified in the theoretical framework. Proxy variables had to be defined for data not available in direct form. All the data corresponding to dependent variables and demand side explanatory variables of the econometric models has been taken from the Census of India, 2011 database. Two supply side explanatory variables, to capture urbanisation and electricity connectivity, has also taken from the Census, 2011 database. Data corresponding to other supply side explanatory variables of the econometric models were extracted from reports published by TRAI (See Appendix A2).

3.2.1 Dependent Variable

The Census of India 2011 in its tables on Household Asset and Amenities (HAA) provides information on percentage of households in a district having (a) landline (b) computer, (c) computer with Internet, and (d) mobile phones. The variations in the characteristics of these four ICT instruments fulfil different kinds of household needs and hence there could be different reasons for possessing them (Gupta & Jain, 2012). Varying degree of substitutability and complementarity among these four ICT instruments (Gupta & Jain, 2012; Narayana, 2011) makes it is difficult to create one combined dependent variable for household access to ICT instruments. While all the four variables are reasonable indicators of access to ICT instruments, we use only the last two in our analysis. As computers without Internet do not create any medium of communication, and the percentage of households with landline telephone is very low, we do not consider the corresponding variables. The variable – computer with Internet is the only one that gives some idea about Internet penetration at household level. Further, existing studies indicate that mobile phones have a higher rate of diffusion as compared to landline, computers and/or Internet (Gupta & Jain, 2012; Singh, 2008). Hence, we estimate the reduced form of demand equation separately for these two ICT instruments – computers with Internet and mobile phones. It is to be noted that in Census 2011 the variable mobile phone only indicates the ownership of a mobile phone. It does not indicate whether a household has more than one mobile phone or the type of mobile phone or use of mobile Internet. We expect that together these two variables would reasonably represent ICT access and use by households at the district level. Thus, for our analysis we define the following two dependent variables as proxy to household demand for particular ICT instruments at the district level.

1) *Share_of_households_having_computers_with_Internet*: is defined as the ratio of the number of households in a district possessing computer with Internet to total number of households in a district
2) *Share_of_households_having_mobile_phones*: is defined as the ratio of the number of households in a district possessing mobile phones to total number of households in a district

3.2.2 Independent Variables

1) *Economic well-being of households*: In India around 92 per cent of the workforce are in informal sector. Close to 50 per cent of this workforce is in the agriculture sector dominated by marginal and small farmers practicing subsistence farming. Even large farmers are largely unincorporated. Given this employment profile in the Indian economy, it is very difficult to acquire reasonably good quality data on household

[6] http://www.censusindia.gov.in/2011census/C-series/C08.html

income. In fact, for measuring poverty and inequality, Government of India uses consumption expenditure data. Since Census 2011 also does not have data on household income, we use the data of the variable type of roof as a proxy to determine the economic status of households. Based on this variable households are divided into three distinct economic classes. The households with concrete roof-top are assumed to be economically well-off. Households classified as economically poor have houses with roofs made of grass, polythene, or hand tiles. Those belonging to economically middle category are ones with roof made of burnt brick, stone, asbestos and machine tiles. For our analysis, we have defined the ratio of poor and economically middle households to economically well-off in a district (*Ratio_of_poor_and_middle_to_welloff_households*) as an indicator for economic status of households aggregated at the district level. It is also used as proxy for market size. We can expect, higher the ratio of economically poor and middle income to well-off households lower will be the market size.

2) *Education and Gender*: The district level educational profile is captured by the variable called *Share_of_person_educated_at_middle_school_and_above*. It is defined as share of total number of persons attaining middle level school education and above in total population. Similarly, a variable called *Share_of_women_educated_secondary_and_above* indicates the status of women at the district level. It is defined as share of total number of females attaining secondary level school education and above in total female population. It was found that both the variables are highly correlated with correlation co-efficient of 0.95 and can be used interchangeable. Hence, we use only one of them for estimating the reduced form of demand function of the two dependent ICT variables. For estimating the demand for computers with Internet, we use the variable *Share_of_women_educated_secondary_and_above* as independent variable. Various information criteria, like, Akaike Information Criterion (AIC), Bayesian Information Criteria (BIC) also shows, among these two education variables, *Share_of_women_educated_secondary_and_above* is best fit. Since mobile phones require relatively lower level of education and skills, we take the *Share_of_person_educated_at_middle_school_and_above* as independent variable for estimating the demand for mobile phones. The AIC and BIC criterion also shows that it is the best fit. The variable, *Share_of_women_educated_secondary_and_above* not only captures the level of education but also captures the state of women and openness within the household. Since, both the education variables are highly correlated, the variable S*hare_of_person_educated_at_middle_school_and_above* should also proxy for the other one.

3) *Occupational characteristics*: To capture the occupational characteristics, we use the ratio of the workforce involved in service sector to total workforce in the district (*Share_of_workers_in_service_sector*) as the indicator.

4) *Age distribution*: To capture the effect of age, we take the ratio of population in the age cohort of 15 years to 35 years to the total population of the district (*Share_of_pop_age_between_15to35*).

5) *Social Category*: In India, for socio-historical reasons certain groups referred to as Scheduled Caste and Scheduled Tribe (SC/ST) are considered to be disadvantaged than

others. Thus, to capture social backwardness of a district, we use the share of SC/ST population to the total population of the district (*Share_of_SCST_pop*).

6) *Extent of urbanization*: The extent of urbanization in a district is captured by considering the share of population residing in urban area to total population (*Share_of_urban_population*).

7) *Availability of electricity*: We have taken the share of households with electricity to total households in a district (*Share_of_households_with_electricity*) as independent variable.

8) *Availability of broadband network*: The availability of broadband network and its service quality reasonably captures the presence of district level infrastructure for Internet access. We have taken the share of village panchayats with broadband connections in total number of village panchayats (*Share_of_villages_with broadband_coverage*) as a proxy variable[7]. For our analysis, we have mapped the circle level figure given in the report for broadband coverage to corresponding districts. For those districts, which are completely urban (this holds only for big cities), it is expected that they are completely covered by the broadband network. Hence, these districts have been assigned the value '1'.

9) *Service quality of broadband network*: The data for service quality of broadband network connectivity is taken from a Telecom Regulatory Authority of India (TRAI) report on performance indicators for Indian telecom services for the period January 2011 to March 2011[8]. The report lists fifteen parameters[9] for measuring broadband service quality of a service provider. TRAI has fixed a minimum threshold for each of these parameters. If a service provider exceeds this minimum threshold value, the quality of service on that particular parameter is considered to be satisfactory. For our analysis, we have created an index, named *Index_average_service_quality_broadband_network* for each district that comes under particular circles in different states. A score of 1 is assigned if the particular parameter crosses the minimum threshold value, otherwise 0. Since in the year 2011 more than 80 per cent of broadband connections in India was with the public sector unit, BSNL-MTNL[10], we calculate the simple (not taking the market share of service provider as the weight) average for each parameter. We then

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[7] Data is taken from the report to Delivery Monitoring Unit set up under Prime Minister's Office, [DMU(PMO)] for the March 2011, having an Annexure on Broadband Coverage of Village Panchayats under Bharat Nirman-II (A Govt. of India sponsored scheme to create rural infrastructure).

[8] https://main.trai.gov.in/release-publication/reports/performance-indicators-reports

[9] These parameters are – (1) percent of connections provided within 15days of registration of demand, (2) percent of faults repaired by next working day (>90%), (3) percent of faults repaired within 3 working days, (4) percent of bills disputed, (5) percent of billing complaints resolved within 4 weeks, (6) percent of cases to whom refund of deposits is made within 60 days of closures, (7) percent of calls answered by operator (voice to voice) within 60 sec to customer, (8) percent of calls answered by operator (Voice to voice) within 90 sec to customer, (9) percent international bandwidth utilization during peak hours (TCBH) (Enclose MRTG) <90%, (10) Broadband Connection Speed available (download) from ISP node to user, (11) Service availability /uptime (for all users) in percent, (12) Packet loss (for wired broadband access) in percent, (13) User reference point at POP/ISP Gateway node to IGSP/NIXI, (14) User reference point at ISP Gateway node to International nearest NAP port abroad (terrestrial), (15) User reference point at ISP Gateway node to International nearest NAP port abroad (satellite)

[10] Source: "Telecom Sector in India: A Decadal Profile", 2012, prepared by NCAER at the behest of TRAI

take the average of these values for all the 15 parameters to get a value of index. This index can be considered as average broadband service quality for a particular circle. The circle level index values are then mapped to corresponding districts.

10) *Availability of mobile network*: The District Census Handbooks have data indicating the presence or absence of mobile network towers, but only for rural areas. Thus, for each district, we define the *Share_of_villages_with_mobile_network* as an indicator of physical availability of mobile network coverage. For the year 2011, the demand for computers with Internet connection is less likely to be dependent upon availability of mobile network.

11) *Service quality of mobile network*: based on statistical data from the same TRAI report[11] that has been used for creating the index for average service quality of broadband networks, we create an index, named, *Index_average_service_quality_mobile_network* for measuring the service quality of mobile network. For assessing the service quality of mobile networks, the publication lists 17 parameters. If a service provider exceeds a minimum threshold value, the quality of service on that particular parameter is considered to be satisfactory. To combine these 17 parameters[12], we assign a score 1 if the minimum threshold value of a particular parameter is crossed, otherwise score is 0. Then for each parameter the weighted average is calculated across service providers. The assigned weights correspond to the share of different service providers in a particular circle. A mean of the 17 weighted average is calculated to get the value of *Index_average_service_quality_mobile_network* for a particular circle. The index values for each circle are then mapped onto the corresponding districts.

12) *Competitiveness*: The *Degree_of_Competition* is defined as the coefficient of variation of market share of each mobile network service provider within a particular circle. Higher the value of the co-efficient of variation, lower the degree of competition, as we can expect, in a more competitive world market share should become more even. Further, this value of coefficient of variation is being assigned against the districts that comes under this particular circle. The data for market share has been taken from the same TRAI report[13]. We have not calculated it for broadband service, as in 2011, more than 80 percent of broadband services were provided by BSNL-MTNL.

Appendix A2 summarises the variables, their indicators and data source. It also indicates the variables that have been used for estimating the specific reduced form of the demand equations.

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[11] https://main.trai.gov.in/release-publication/reports/performance-indicators-reports

[12] These parameters are – (1) BTSs Accumulated downtime (%), (2) Worst Affected BTSs due to downtime (%), (3) Call Set up Success Rate (within licensees own network), (4) SDCCH/paging chl. Congestion (%), (5) TCH Congestion (%), (6) Call Drop Rate (%), (7) Worst Affected Calls having more than 3% TCH drop (Call drop) rate (%), (8) Connection with Good Voice Quality, (9) POI Congestion averaged over quarter, (10) Metering and billing credibility (post paid), (11) Metering and billing Credibility (pre paid), (12) Resolution of billing complaint, (13) Period of applying credit/adjustment,(14) Accessibility to Call Centre, (15) percent of Call Answered, (16) percent request for termination, (17) Time taken for refund deposit

[13] https://main.trai.gov.in/release-publication/reports/performance-indicators-reports

3.3 Econometric Model

We estimate the reduced form of demand equation for the two ICT instruments separately using the following equations:

1) *Share_of_households_having_computers_with_Internet* = a + b_1 X *Ratio_of_poor_and_middle_to_welloff_households* + b_2 X *Share_of_women_educated_secondary_and_above* + b_3 X *Share_of_workers_in_service_sector* + b_4 X *Share_of_pop_age_between_15to35* + b_5 X *Share_of_SCST_population* + b_6 X *Share_of_urban_population* + b_7 X *Share_of_households_with_electricity* + b_8 X *Share_of_villages_with_broadband_coverage* + b_9 X *Index_average_service_quality_broadband_network* + €

2) *Share_of_households_having_mobile_phones* = a + b_1 X *Ratio_of_poor_and_middle_to_welloff_households* + b_2 X *Share_of_person_educated_middle_school_and_above* + b_3 X *Share_of_workers_in_service_sector* + b_4 X *Share_of_pop_age_between_15to35* + b_5 X *Share_of_SCST_population* + b_6 X *Share_of_urban_population* + b_7 X *Share_of_households_with_electricity* + b_8 X *Share_of_villages_with_mobile_network* + b_9 X *Index_average_service_quality_of_mobile_network* + b_{10} X *Degree_of_Competition* + €

4 Results and Discussion

4.1 Nature and Extent of Digital Divide:

According to Census 2011, 56.70 per cent of household in India have mobile phones. In contrast, only 9.06 per cent of households have landline telephone. Further, while 8.25 per cent of households own a computer, only 2.36 per cent of the total households have computers with Internet (see Table 1). These figures indicate that in the year 2011, a very large number of households did not have access to ICT instruments. While comparable data for recent years is not yet available, as next census is due only in the year 2021, the ITU Handbook for the year 2017[14] indicates that the level of access to ICT instruments has substantially improved, maybe as result of both policy interventions and market mechanisms. In particular, mobile broadband subscription per 100 inhabitants increased from 0.94 in the year 2011 to 16.41 by the year 2016. The NSSO 75th round (2017-18) survey report on household expenditure in education tells us that 10.7 per cent and 23.8 per cent of households in India, have computers and internet connections respectively. So, while access to internet through mobile has definitely witnessed a rapid improvement, even then it is accessed by only one-fourth of the Indian households.

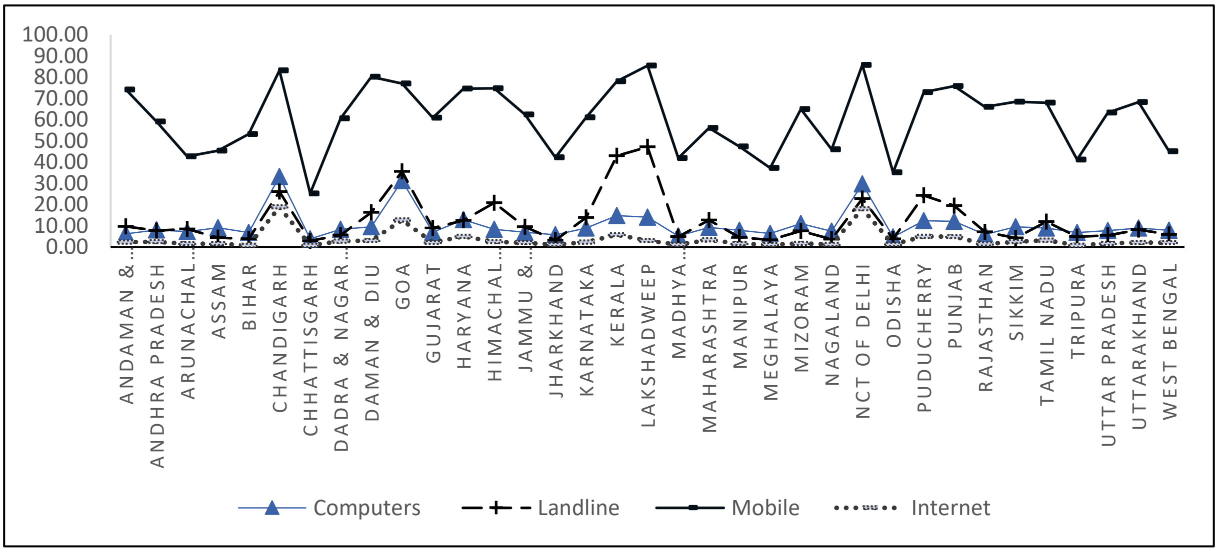
[14] Telecommunication/ICT Indicators 2007-2016, Yearbook of Statistics 2017, Page 120

Item	Landline	Computer	Internet	Mobile
Mean	9.06	8.25	2.36	56.70
Top 3 states	Lakshadweep (47.10) Kerala (42.99) Goa (36.65)	Chandigarh (33.20) Goa (31.15) Delhi (29.66)	Chandigarh (18.80) Delhi (17.89) Goa (12.70)	Delhi (85.78) Lakshadweep (85.50) Chandigarh (83.20)
Bottom 3 states	Bihar (3.72) Nagaland (3.68) Meghalaya (3.39)	Rajasthan (5.95) Jharkhand (5.79) Madhya Pradesh (5.21)	Jharkhand (1.03) Meghalaya (1.03) Chhattisgarh (0.86)	Madhya Pradesh (41.93) Tripura (41.10) Meghalaya (37.24)

Data Source: Census 2011

Table 1. Households' Possession of ICT instruments in India

The diffusion of ICT instruments is not even across the country (Figure 2). There is much difference in the spread of various ICT instruments in different states. It is also observed that states which had lower penetration of computers and landline, also have relatively less penetration of Internet and mobile phones.



Data Source: Census 2011

Figure 2. Share of Households having ICT instruments in Total Households in different states (in %)

Share of Households with:	Min	Max	Coefficient of Variations (in %)
Landline	0.80	55.00	96.47
Computer	1.70	39.30	69.09
Internet	0.20	24.20	147.88
Mobile Phones	9.00	88.20	30.12

Data Source: Census 2011

Table 2. District-wise Dispersion in Households' Possession of ICT instruments

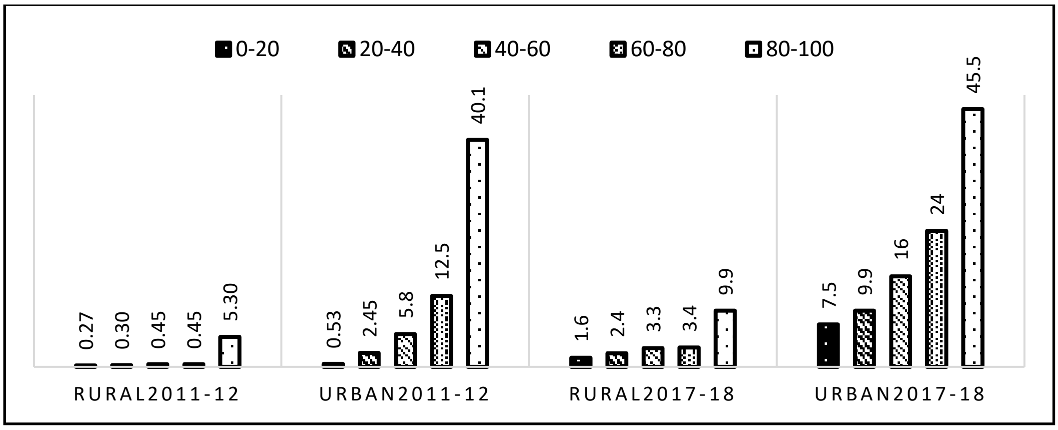
Table 2 gives the district-wise dispersion in possession of various ICT instruments. District-wise dispersion is lowest for mobile phone and highest for the computer with internet. The 68th Round survey on household consumption expenditure for the year 2011 by National Sample Survey organisation (NSSO) tells us that 1.5 and 14.9 per cent of the rural and urban households respectively have computers. The same survey also tells us 77.6 and 92.2 per cent of the rural and urban households respectively have mobile phone. This indicates that the rural-urban divide is more than eight times in case of computers than for mobile phones. In 2011 only 1 and 7.2 per cent of the rural and urban household respectively had internet connectivity (Table 3).

ICT Instrument	2011-12			2017-18		
	Rural	Urban	Rural-Urban Ratio	Rural	Urban	Rural-Urban Ratio
Computer	1.5	14.9	0.10	4.4	23.4	0.19
Mobile	77.6	92.2	0.84	NA	NA	-
Internet	1.0	7.2	0.14	14.9	42.0	0.35

Source: NSSO Survey Report no. 558 (68th Round) and Report no. 585 (75th Round)

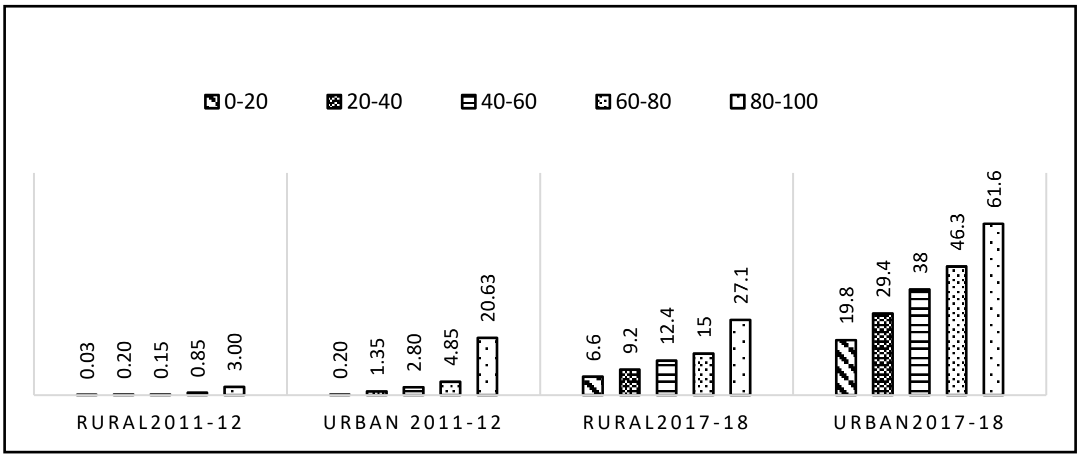
Table 3: Share of Households having ICT instruments in India in the year 2011-12 and 2017-18

After 68th round, the NSSO has not published the report of survey (large sample based) on household consumption expenditure citing some technicalities. However, they have published the report of large sample-based survey on household expenditure in education (75th round). This 75th round report provides us data on household having computers and Internet connection for the year 2017-18. According to this report, 4.4 and 23.4 per cent of the rural and urban household, respectively have computers. Further, 14.9 and 42.0 per cent of the rural and urban household, respectively have internet connectivity (Table 3). So, there is a very large number of households in India who still do not have access to internet. The rural-urban ratio tells us there is a continuation of huge rural-urban gap in possession of computer and internet; though the extent of rural-urban gap has reduced in 2017-18 in comparison to 2011-12. This is because both the possession of computers and internet connection has increased. However, the spread of internet is much faster than that of computers. This indicates access to internet through mobile phone has contributed substantially in this spread of internet. The NSSO survey further indicates that richer households have greater access to ICT instruments (computers and internet connection) as compared to poorer households (Figure 3a and 3b). This trend has not been changed between the years 2011-12 to 2017-18. However, the gap in possession of these two ICT instruments between different economic classes has come down during this period. We have clubbed cumulative distribution of household consumption expenditure through quintile classes grouped as – (a) up to lowest 20 percent, (b) 20-40 percent, (c) 40-60 percent, (d) 60-80 percent and (e) 80-100 percent. The gap in possession of computers among the different economic classes is higher than that of internet connection. The gap between the rural and urban classes is higher in possession of computers than that of internet.



Source: NSSO Survey Report no. 558 (68th Round) and Report no. 585 (75th Round)

Figure 3a: Percentage of Households having computer for each Quintile Class



Source: NSSO Survey Report no. 558 (68th Round) and Report no. 585 (75th Round)

Figure 3b: Percentage of households having internet facility for each quintile class

With regards to possession of mobile phones, the rural-urban divide exists and the richer economic classes in both rural and urban areas possess more. However, the gap between share of households having mobile phone in rural and urban is much less in compare to that of other ICT instruments like computers and internet connection. Further, the gap in possession of mobile among different economic classes is also less in compare to possessions other ICT instruments (Figure 4).

Data Source: NSSO 68th Round

Note: we have 12 fractile economic classes based upon cumulative monthly per capita consumption expenditure. The fractile classes are i) less than 5%, ii) 5 to 10%, iii) 10 to 20%, iv) 20 to 30%, v) 30 to 40%, vi) 40 to 50%, vii) 50 to 60%, viii) 60 to 70%, ix) 70 to 80%, x) 80 to 90%, xi) 90 to 95 %, xii) 95 to 100%.

Figure 4. Number per 1000 household possessing Mobile Handset in fractile classes of MPCE

Figures 3a, 3b and 4 together show that more than 95 per cent of rich households in urban areas have mobile phone. However even among the richest 20 per cent of urban households, roughly 55 per cent does not have computer and roughly 39 per cent did not have Internet connectivity. So even among richest urban household, there is substantial gap in possession of ICT instruments. Households in rural India and those belonging to urban poor have substantially low possession of ICT instruments. All this evidence conclusively highlights that there is substantial level of inequality in digital access in India. This inequality exists between states, between districts, among rural-urban areas and different economic classes. In the next two sub-sections, we examine in detail the factors creating this inequality in household possession of two ICT instruments – computers with Internet and mobile phones using econometric models arising out of demand –supply framework.

4.2 Factors behind Digital Divide

4.2.1 Estimation of Reduced Form Demand Equation of Households for Computers with Internet

In the previous section, we saw that the rural-urban digital divide is very wide for household possession of computers with Internet. Hence, we estimate the reduced form of demand function for computers with Internet by taking extent of urbanisation as an explanatory variable. We have estimated the equation twice; first for all districts together and then separately for pre-dominantly rural districts only. For this purpose, we define a rural district as one in which the urban population is less than or equal to 40 percent. The total number of districts is 634, after removing outliers, 512 were identified as rural districts. Since, by definition, the value of the independent variable *Share_of_household_having_computers_with_Internet* will lie between 0 and 1 (confirmed by the Appendix A3.3), we take its logistic transformation before running the OLS [See Appendix A4, Equation1, 2]. The Breusch-Pagan test suggest that there is no heteroscedasticity. Both the information criteria - Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC) suggested that *Share_of_women_educated_secondary_and_above* is providing a better fit in comparison to *Share_of_person_educated_middle_school_and_above*. Thus, the former is included as a variable for both education and gender. The Ramsey test of specification on this estimation suggests no specification error due to omitted variables. The regression result (Table 4) shows that five independent variables – *Share_of_urban_population*, *Share_of_pop_age_between_15to35*, *Share_of_workers_in_service_sector*, *Share_of_women_educated_secondary_and_above*, *Index_average_service_quality_broadband* - have positive statistically significant relationship with the dependent variable. The variable *Share_of_SCST_population* has negative statistically significant relationship with the dependent variable. However, the variables *Share_of_villages_with_broadband_coverage*, *Ratio_of_poor_and_middle_to_welloff_households* and *Share_of_households_with_electricity* do not have any statistically significant impact.

The above regression results indicate that districts with a smaller number of SC-ST population, higher percentage of young population, higher level of education and maybe with better social status of women, more service sector-oriented economy, with higher degree of urbanisation and better broadband network service quality have greater diffusion of computer with Internet. Among all these, higher education, especially of women and share of young population are the two most important factors. Prominence of service sector economy follows next. The three other significant factors are degree of urbanisation, broadband network service quality[15], and share of SC/ST population. The economic status of households appears to be less important as compared to other factors since the value of its coefficient is less and it is not statistically significant even at 10 per cent level. One possible reason can be that even the economically well-off in India are not using computers and Internet, unless required for occupational need. Further, higher levels of education appear to be enabling people to use computer with Internet.

[15] Though the co-efficient of broadband network coverage is not statistically significant, broadband network service quality is. It most probably indicates that users are more sensitive to the quality of network services that they are getting, rather than merely availability of network on paper. It is true for mobile network coverage and network service quality too.

Independent Variables	Dependent Variable:					
	Logistic transformation of Share_of_households_having_Computers_with_Internet				Logistic transformation of Share_of_households_having_mobile_phones	
	All Districts		Rural Districts		All Districts	
	Value of Co-Efficient	Level of Significance	Value of Co-Efficient	Level of Significance	Value of Co-Efficient	Level of Significance
Ratio_of_poor_and_middle_to_welloff_households	-0.02976	Not significant	-0.0473291	Sig. at 10 % level	-0.058002	Sig. at 5% level
Share_of_women_educated_secondary_and_above	4.598076	Sig. at 1 % level	4.378131	Sig. at 1 % level	-	-
Share_of_persons_educated_middle_school_and_above	-	-	-	-	0.679934	Sig. at 5% level
Share_of_workers_in_service_sector	1.385045	Sig. at 1 % level	1.845224	Sig. at 1 % level	-0.160926	Not Significance
Share_of_pop_age_between_15to35	3.209441	Sig. at 1 % level	2.50101	Sig. at 1 % level	5.097142	Sig. at 1% level
Share_of_SCST_pop	-0.328500	Sig. at 1 % level	-0.3122073	Sig. at 1 % level	-1.289316	Sig. at 1% level
Share_of_urban_population	1.181709	Sig. at 1 % level	-	-	0.023099	Not Significance
Share_of_households_with_electricity	0.000885	Not significant	0.1127426	Not Significant	0.279126	Sig. at 1% level
Share_of_villages_with_broadband_coverage	-0.474380	Not significant	2.764722	Not Significant	-	-
Index_average_service_quality_broadband	0.456850	Sig. at 1 % level	0.7294781	Sig. at 1 % level	-	-
Share_of_villages_with_mobile_network	-	-	-	-	0.167741	Not Significance
Index_average_service_quality_mobile_network	-	-	-	-	1.158066	Sig. at 1% level
Degree of Competition	-	-	-	-	-0.153752	Not Significance

Source: Detailed Result in Appendix A4, Equation 1 & 3
Source: Detailed Result reported in Appendix A5, Equation1

Table 4. Regression Result of Reduced form Demand Equation Estimation

The supply side factors like broadband network quality and degree of urbanisation also appears to play a deciding factor here, though at a lesser extent than the other three factors, which essentially generate demand. Further, this result also indicates that household possession of computers with Internet is less among SC-ST communities. To summarise, the results commensurate with the expectation that educated youth (relatively less from SC-ST community), men and women from more urbanised districts, somewhat dependent on service sector economy access and use computers with Internet more than others.

We then estimate the reduced form demand equation for computers with Internet for the rural districts (see Appendix A4, Equation 3), the Breusch-Pagan test suggest that there is no heteroscedasticity. Both the information criteria - Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC) suggested that *Share_of_women_educated_secondary_and_above* is providing a better fit in comparison to *Share_of_person_educated_at_middle_school_and_above*. Thus, *Share_of_women_educated_secondary_and_above* is included as the education variable. The Ramsey test of specification on this estimation suggests no specification error due to omitted variables. The estimated results (Table 4) for rural districts show three important departures from the previous estimated results of all districts. First, among the rural districts relatively economically well-off districts are having greater number of households possessing computers with internet. Second, the values of all coefficients of demand side factors are lower for rural districts than the corresponding co-efficient values obtained when all districts are considered. Third, the values of all coefficients of supply side factors are higher for rural districts than the corresponding co-efficient values obtained when all districts are considered. However, the absolute value of statistically significant coefficient of most of the demand side factors remain higher than that of supply side factors. Thus, demand side factors remain prominent to explain the possession of computers with Internet for rural districts. And there is an increasing importance of supply side factors to explain digital divide in rural districts. However, broadly speaking, the causes for digital divide in rural districts are similar to that of the general story of all districts of India, but with the exception that the economic status of households also becomes a statistically significant factor.

4.2.2 Estimation of Reduced Form Demand Equation of Households with Mobile Phones:

The dependent variable is *Share_of_households_having_mobile_phones*. Since, by definition, its value will vary between 0 and 1 (confirmed by the Appendix A3.3), we take its logistic transformation before running the OLS. The rural-urban divide in household possession of mobile phone is comparatively less. During analysis, we found that extent of urbanization is not a statistically significant independent variable for explaining households' possession of mobile phone. Hence, here we do not estimate the regression equation separately for rural districts. Further, instead of the variables *Share_of_villages_with_broadband_coverage* and *Index_average_service_quality_broadband*, we use the independent variables corresponding to mobile network coverage and quality of its services. Also, as compared to computer, skills required to use a mobile phone is comparatively less. Hence, instead of considering educational level as secondary school and above, we take *Share_of_persons_educated_middle_school_and_above*. A supply side explanatory variable, *Degree_of_competition*, is introduced to indicate level of competition among mobile network service provider. The Breusch-Pagan test suggest presence of heteroskedasticity, which was addressed through robust estimator provided in Stata. However, on plotting the residual with the fitted value, we found some outliers. After removing these outliers, we have again estimated the equation. The Ramsey test of specification on this estimation suggests no specification error due to omitted variables (Appendix A5, Equation1).

Results (Table 4) indicate that the independent variables: *Share_of_pop_age_ between_15to35*, *Share_of_persons_educated_middle_school_and_above*, *Share_of_households_with_electricity* and *Index_average_service_quality_mobile_network* have positive statistically significant relationship with the dependent variable *Share_of_households_with_mobile_phones*. The independent variables: *Share_of_SCST_population* and *Ratio_of_poor_and_middle_to_welloff_households* have negative statistically significant relationship with the dependent variable. The variables: *Share_of_workers_in_service_sector*, *Degree_of_competition*, *Share_of_villages_with_mobile_network_coverage* and *Share_of_urban_population* do not have statistically significant impact. The largest value of co-efficient is that of *Share_of_pop_age_between_15to35*, followed by the *Share_of_SCST_population* and *Index_average_service_quality_mobile_network*. The other significant factors that are influencing the possession of mobile are level of education, electricity connection and economic condition of the household.

The analysis indicates that with regards to household possession of mobile phones, the rural-urban divide is not statistically significant. However, availability of the electricity and quality of mobile network services are important. Young people with basic level of education are embracing the mobile. In fact, we estimated the same equation by replacing the variable *Share_of_person_educated_middle_school_and_above* with *Share_of_persons_educated_below_middle_school* and *Share_of_pop_age_between_15to35* with *Share_of population_with_age_not_between_15to35* (Appendix A5, Equation 2). Both the new variables show statistically significant inverse relationship with the dependent variable *Share_of_households_with_mobile_phones*. However, household possession of mobile phones caused negatively by the poorer economic conditions and being SC-ST. However, household possession of mobile phones does not appear to significantly different between those working in service sectors and others.

5 Policy Implications

The paper was an attempt to empirically investigate the determinants of digital divide in India using available public data. The Census of India 2011, collected for the first time, household possession of four ICT instruments – landline, computer, computer with Internet and mobile phone. Applying the demand-supply equation as our theoretical framework, we use this data to separately estimate the reduced form demand equation for computers with Internet and mobile phones. Our findings indicate that three factors – (1) spread of education, (2) being young, and (3) being member of SC-ST community significantly influence the possession of both the ICT instruments. While the first two factors positively influence possession of ICT instruments, the last factor has a negative effect.

Household possession of computers with Internet is higher in districts having more educated, young and urban population. Presence of educated young people also has very large positive impacts on possession of mobile phone. However, as compared to household possession of computer with Internet, mobile phones did not require higher level of education. Similarly, working in service sector and residence in urban area does seem to encourage household possession of computer with Internet but these two factors do not have any significant influence on household possession of mobile phones. However, availability of electricity and mobile network service quality are important factors for household demand of mobile phones in both rural and urban areas.

On the whole, findings indicate that in 2011, the digital divide in India was largely a reflection of existing socio-economic divides. Thus, a key policy implication is that efforts and interventions to close the digital divide should not only look at supply side interventions but also focus on policies that reduce existing socio-economic divides and thereby contribute to greater diffusion of ICTs.

The results also show that while possession of the two ICT instruments were not sensitive to availability of network, they were sensitive to quality of service of broadband and mobile networks. This might be because customers in the year 2011 did not distinguish between non-availability of network and poor quality of network services. Hence, digital divide is likely to lessen if the price of ICT instruments and data access is reduced, along with improvement in the quality of network services. Firms focussing on better network services at lower rates will not only capture greater market share but also expand the market size for the industry.

On the whole, diffusion of mobile phones is more broad-based than computers with Internet. We did not find statistically significant rural-urban divide or essentiality of higher education or specific service oriented occupational requirement for mobile phones. Unlike computers with Internet, there is not much variability in household possession of mobile phone among various occupational categories. This bodes well for current policy emphasis on delivery of mobile-based services. However, being a SC-ST household or a relatively poor household does seem to negatively impact household possession of both the ICT instruments. Results indicate that districts with greater share of SC-ST population have substantially lower access to mobile phone. Hence a targeted policy for increasing accessibility and usage of mobile phones for SC-STs will further reduce the digital divide faster. Further, to increase the spread of computer with internet, spread of education, especially of women, at secondary and above level is very important. So, policy intervention and schemes that aim to incentivise schooling of girl child by linking it with a conditional cash transfer scheme will lead to reduction in gender-based digital divide.

6 Concluding Remarks

This paper is a modest attempt to examine the nature and extent of digital divide at the district level in India and the factors determining the relatively low and unequal household access to ICTs. The context is set against a high economic growth led by IT/ITeS sectors but relatively low and unequal diffusion of ICTs across districts. A demand-supply framework was developed and applied on a large, and consistent public dataset to arrive at the results. The analysis provides evidence that the district level digital divide in India is a reflection of existing socio-economic divide. The overall low penetration of ICTs in India is because of both uneven spread of required ICT infrastructure and difference in socio-economic characteristics of households. Thus, policy makers need to simultaneously address constraints on both demand side factors, coming out of socio-economic divide as well as on ICT infrastructure. Policy measures that aim to reduce the existing socio-economic divides including enhancement of employment opportunities and education for women and SC-STs, income of the poor, along with reduction of infrastructural gap between urban and rural, will contribute towards greater diffusion of ICTs.

The report of 75th round of NSSO survey on household expenditure on education tells us that there is a reduction in digital divide in comparison to that of 2011. However, this report does not provide information on households' possession of mobile phone which appears to be playing a key role in increasing diffusion of Internet and related services. As more data becomes available, future research can examine if any changes in socio-economic divides bridging the digital divide or it is primarily due to the better ICT infrastructure and lowering price has reduced the digital divide. The findings of this study will serve as a baseline for such studies examining digital divide in India.

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Appendix A1: Select studies on digital divide in India

Author / Year	Focus of the Study	Period / Dataset	Key Findings
Haenssgen (2018)	Examines if uneven distribution of Mobile Phones benefit all equally in the context of rural healthcare services	2005-2012 Panel data of 12,003 rural households in IHDS database	Rapid mobile phone diffusion creates opportunity to improve people's access to healthcare in rural India, but it also creates new forms of marginalisation among poor rural households.
Barman, Dutta and Nath (2018)	Examines patterns of distribution dynamics, and the drivers of telecommunications (telecom) services across 16 different states of India	2001-2015 16 states of India – TRAI database	The interstate gap in telecommunications services has been declining and it is converging. Per capita income and network externality are significant determinants of teledensity across states in India. Literacy rate and relative size of the service sector are independently significant predictors of teledensity.
Ghosh (2016)	Analyse the impact of mobile telephony on economic growth.	Panel data for the years 2001-12 of 14 major Indian states	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.
Gupta and Jain (2012)	To identify factors affecting the adoption of mobile telephony in rural India and examine their impact on its adoption	ITU databases from 1998 to 2009; TRAI	The study reveals that competition and government intervention played a significant role in accelerating the diffusion speed of mobile telephony by making the technology affordable. It is found that mobile telephony is a substitute for fixed line telephony in India.
Narayana (2011)	Estimates the growth contribution of telecom services by public and private sectors. Socio-economic determinants of demand for telecom services are estimated for fixed and mobile phones	Sample survey of Households	Significant negative impact of both access and usage price on household demand for fixed and mobile phones and a positive impact of income variables; Substitutability of mobile phones for fixed phones Distinguishes the importance of social caste, education level, nature or occupation, age of the head of the household, and family size.

Appendix A2: Variables used and their Data-Source

Sl. No.	Factor	Variable Name	Source of Data	Used in Regression Equation of:	
				Computer with Internet	Mobile Phone
DV1	ICT Instrument	Share_of_households_having_Computer_with_Internet	Table HAA, Census 2011	DV	-
DV2	ICT Instrument	Share_of_households_having_Mobile_phones	Table HAA, Census 2011	-	DV
1	Economic Status	Ratio_of_poor_and_middle_to_welloff_households	Tables HAA, Census 2011	IV	IV
2	Education and Gender	Share_of_persons_educated_middle_school_and_above	Tables EDU, Census 2011	-	IV
3	Education and Gender	Share_of_women_educated_secondary_and_above	Tables EDU, Census 2011	IV	-
4	Occupational Profile	Share_of_workers_in_service_sector	Tables PCA, Census 2011	IV	IV
5	Age Profile	Share_of_pop_age_between_15to35	Tables PCA, Census 2011	IV	IV
6	Social Status/ Backwardness of a District	Share_of_SCST_pop	Tables PCA, Census 2011	IV	IV
7	Extent of Urbanization	Share_of_urban_population	Tables PCA, Census 2011	IV	IV
8	Infrastructure/ Electricity	Share_of_households_with_electricity	Tables HAA, Census 2011	IV	IV
9	Infrastructure/ Broadband network coverage	Share_of_villages_with broadband_coverage	Annex-II, Report to DMU PMO for the Month of March,2011, Broadband Coverage of Village Panchayats Under Bharat Nirman-II	IV	-
10	Infrastructure/ Broadband Service Quality	Index_average_service_quality_broadband	Annexture 4.3, The Indian Telecom Service Performance Indicators, Jan-Mar, 2011, TRAI	IV	-
11	Infrastructure/ Mobile network coverage	Share_of_villages_with_mobile_network	Tables DCA, Census 2011	-	IV
12	Infrastructure/ Mobile Network Service Quality	Index_of_mobile_network_service_quality	Annexture 4.1, The Indian Telecom Service Performance Indicators, Jan-Mar, 2011, TRAI	-	IV
13	Competitiveness	Degree_of_competition	Annexture 1.2, The Indian Telecom Service Performance Indicators, Jan-Mar, 2011, TRAI	-	IV

IV: Independent Variable
DV: Dependent Variable

Appendix A3

Sl. No.	Variable Name	Var1	Var2	Var3	Var4	Var5	Var6	Var7	Var8	Var9
Var1	Share_of_SCST_ pop	1								
Var2	Share_of_workers_in_service_sector	-0.30*	1							
Var3	Ratio_of_poor_and_middle_to_welloff_households	0.25*	-0.07	1						
Var4	Share_of_women_educated_secondary_and_above	-0.30*	0.75*	-0.18*	1					
Var5	Share_of_persons_educated_middle_school_and_above	-0.29*	0.73*	-0.15*	0.95*	1				
Var6	Share_of_pop_age_between_15to35	0.09*	0.41*	0.067	0.34*	0.39*	1			
Var7	Share_of_households_with_ electricity	-0.09*	0.53*	-0.20*	0.66*	0.64*	0.48*	1		
Var8	Index_average_service_quality_broadband	-0.19*	-0.01	-0.22*	0.26*	0.18*	0.11*	0.38*	1	
Var9	Share_of_villages_with broadband_coverage	-0.27*	0.40*	-0.21*	0.53*	0.42*	0.05	0.32*	0.27*	1
Var10	Share_of_urban_population	-0.24*	0.74*	-0.19*	0.71*	0.64*	0.44*	0.56*	0.33*	0.39*

Note: '*' indicates statistically significant at 5% level

Table A3.1: Correlation co-efficient of the independent variables used in reduced demand equation estimation for computers_with_Internet

Sl.No.	Variable Name	Var1	Var2	Var3	*Var4*	*Var5*	Var6	Var7	Var8	Var9
Var1	Share_of_SCST_population	1								
Var2	Share_of_workers_in_ service_sector	-0.30*	1							
Var3	Ratio_of_poor_and_middle_to_welloff_households	0.25*	-0.07	1						
Var4	Share_of_persons_educated_middle_school_and_above	-0.28*	0.73*	-0.15*	1					
Var5	Share_of_pop_age_between_15to35	0.09*	0.41*	0.06	0.39*	1				
Var6	Degree_of_competition	0.23*	-0.20*	0.06	-0.29*	-0.05	1			
Var7	Share_of_households_with_electricity	-0.09*	0.54*	-0.20*	0.64*	0.48*	-0.00	1		
Var8	Share_of_Villages_with_Mobile_network	-0.30*	0.30*	-0.25*	0.39*	0.17*	-0.00	0.54*	1	
Var9	Index_Mobile_Network_Service_Quality	-0.42*	0.22*	-0.19*	0.16*	-0.04	0.19*	0.14*	0.26*	1
Var10	Extent_of_urbanisation	-0.24*	0.74*	-0.19*	0.64*	0.45*	-0.16*	0.56*	0.32*	0.14*

Note: '*' indicates statistically significant at 5% level

Table A3.2: Correlation co-efficient of the independent variables used in reduced demand equation estimation for Mobile_Phone

Sl. No.	Variable Name	Mean	Std. Dev.	Min	Max
DV 1	Share_of_households_having_Computer_with_Internet	0.0236	0.0349	0.0020	0.2420
DV 2	Share_of_households_having_Mobile_phones	0.5119	0.1447	0.0800	0.7960
1	Ratio_of_poor_and_middle_to_welloff_households	0.2014	0.6187	0.0020	9.9700
2	Share_of_persons_educated_middle_school_and_above	0.3187	0.1038	0.0732	0.5972
3	Share_of_women_educated_secondary_and_above	0.1634	0.0895	0.0204	0.4448
4	Share_of_workers_in_service_sector	0.4370	0.2102	0.1015	0.9910
5	Share_of_pop_age_between_15to35	0.3723	0.0258	0.2850	0.5680
6	Share_of_SCST_pop	0.3259	0.2259	0.0034	0.9858
7	Share_of_urban_population	0.2642	0.2112	0.0000	1.0000
8	Share_of_households_with_electricity	0.6588	0.2833	0.0190	0.9970
9	Share_of_villages_with broadband_coverage	0.0046	0.0023	0.0002	0.0100
10	Index_of_broadband_service_quality	0.5863	0.1148	0.3333	0.8094
11	Share_of_villages_with_mobile_network	0.8446	0.0450	0.7663	0.9285
12	Index_of_mobile_network_service_quality	0.7659	0.2167	0.0033	1.0000
13	Degree_of_competition	0.9404	0.0956	0.5888	1.1127

Table A3.3: Descriptive Statistics of the Variables of Reduced form Demand Estimation

Appendix A4: Demand Estimation of Computer with Internet

Dependent Variable: Logistic transformation of share_household_computers_with_internet	**All Districts [a]**		**Rural Districts[b]**
Independent Variables	Equation1	Equation 2	Equation 3
Share_of_SC-ST_population	-.3285015 (.0717976)***	-.2982297 (0.0777549)***	-.3122073 (.0769693)***
Share_workers_in_service_sector	1.385045 (0.1413372)***	1.677573 (0.1490896)***	1.845224 (0.147666)***
Ratio_of_poor_and_middle_to_well-off_households	-.0297621 (.0246302)	-.0261717 (0.0265226)	-.0473291 (0.0243419)*
Share_of_women_educated_secondary_and_above	4.598076 (.3008528)***		4.378131 (.3395891)***
Share_of_person_educated_at_middle_school_and_above	…………..	2.593129 (0.2410297)***	………..
Share_of_population_age_ between_15 to 35	3.209441 (.7240674)***	2.068897 (0.7799134)***	2.50101 (.8418013)***
Share_of_households_with_electricity	0.0008851 (.0768176)	.1250661 (0.0819864)	.1127426 (.0829464)
Index of average service quality of broadband	0.4568503 (.1642788)***	.6953176 (0.176321)***	.7294781 (.1679193)***
Share_of_villages_with_broadband_coverage	-0.4743803 (7.362669)	20.29096 (7.670942)***	2.764722 (8.492882)
Share_of_urban_population	1.181709 (0.1243345)***	1.372428 (.1325794)***	…………
Adjusted R^2	0.8753	0.8554	0.7395
F Test	F(9, 624) = 494.62***	F(9, 624) = 417.13***	F(8, 503) = 182.33***
Information Criteria	AIC = 480.14 BIC = 524.6	AIC=561.34 BIC= 605.85	AIC=368.21 BIC=406.36
Heteroskedasticity[C]	X^2 = 0.22	X^2 = 0.79	X^2 = 0.89
Normality[d]	X^2 = 2.43	X^2 =39.49***	X^2 =0.43
Functional Form[e]	F(3, 621) = 1.66	F(3, 621) = 3.51**	F(3, 500) = 0.31

Note: Standard Errors are in bracket

(a) Demand Estimation of computers_with_Internet (Equation 1 &2) for All Districts
(b) Demand estimation of computers_with_Internet (Equation 3) for rural districts (defined as having urban population less than 40 percent of the total population).
(c) Breusch–Pagan/ Cook-Weisberg heteroskedasticity test. In case of the existence of heteroscedasticity, adjustment was made to make it robust.
(d) Test of skewness and kurtosis of residuals. Since the degree of freedom is more than 500, the assumption of normality can be made (due to law of large number) without testing it.
(e) Ramsey RESET test using powers of the fitted values.

*Statistically significant at 10%.
**Statistically significant at 5%
*** Statistically significant at 1%

Appendix A5: Demand Estimation of Mobile

Dependent Variable: logistic transformation of share_of_households_having_mobile_phones	**All Districts [a]**	
Independent Variables	Equation1	Equation 2
Share_of_SC-ST_population	-1.289316 (.0977918)***	-1.289316 (.0977918)***
Share_workers_in_service_sector	-.1609256 (.1524257)	-.1609257 (.1524257)
Ratio_of_poor_and_middle_to_well-off_households	-.0580019 (.0232608)**	-.0580019 (.0232608)**
Share_of_person_educated_at_middle_school_and_above	.679934 (.2688573)**	…….
Share of person educated at below middle school	……..	-.6799339 (.2688573)**
Share_of_population_age_ between_15 to 35 years	5.097142 (.8690987)***	……….
Share of Population age not within 15 to 35 years	………	-5.097142 (.8690986)***
Degree of Competition	-.1537522 (.1835348)	-.1537523 (.1835348)
Share_of_households_with_electricity	.2791257 (.0976886)***	.2791257 (.0976886)***
Share_of_villages_with_mobile_network	.1677409 (.11098)	.1677408 (.11098)
Index of average service quality of mobile network	1.158066 (.4109839)***	1.158067 (.4109839)***
Share_of_urban_population	.0230995 (.1228256)	.0230996 (.1228256)
Adjusted R^2	0.5185	0.5185
F Test	F(10, 592) = 88.40	F(10, 592) = 88.40
Information Criteria	AIC = 630.43 BIC = 678.86	AIC = 630.43 BIC = 678.86
Heteroskedasticity[b]	robust	robust
Normality[C]	X^2 = 1.449	X^2 = 1.449
Functional Form[d]	F(3, 589) = 2.09	F(3, 589) = 2.09

Note: Standard Errors are in bracket

(a) Demand Estimation of Demand Estimation of Mobile (Equation 1 &2) for All Districts
(b) Breusch–Pagan/ Cook-Weisberg heteroskedasticity test. In case of the existence of heteroscedasticity, adjustment was made to make it robust.
(c) Test of skewness and kurtosis of residuals. Since the degree of freedom is more than 500, the assumption of normality can be made (due to law of large number) without testing it.
(d) Ramsey RESET test using powers of the fitted values.

*Statistically significant at 10%.
**Statistically significant at 5%
*** Statistically significant at 1%