

# Universal Telecommunication Service: an Empirical Analysis of the Indian Market \*

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## Abstract

We perform an empirical analysis of the Indian telecommunications market. We estimate different demand specifications and we show that, contrarily to the findings for developed countries, access price elasticity is significant and rather large. Moreover, income and other sociodemographic characteristics play a crucial role in explaining demand. We consider the impact of cellular penetration, identifying a network effect in low penetration areas and some evidence of substitution in the most developed ones. All results are robust to different econometric specifications, including the logistic diffusion model. We finally estimate a supply function, assessing the impact of market competition on investment.

Keywords: Telecommunications, Universal Service, Competition.

JEL codes: L96, L51.

## 1 Introduction

Universal access and universal service policies are aimed to promote the diffusion of a particular service at an affordable and non discriminatory price, independently of local cost conditions. These policies are justified on the basis of different arguments<sup>1</sup>. The most important is the existence of network externalities: the larger the network, the bigger the value of the service for each subscriber. It is not clear, though, that this kind of externality could not be internalized by the operators without any direct public intervention (for instance, Crandall and Waverman, 2000

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<sup>1</sup>For a review of the theory of Universal Service provision, see Cremer, Gasmi, Grimaud, and Laffont, 1998.

clearly dispute this view). Another argument is based on the identification of telecom services as merit goods. Access to telecommunications can reduce exclusion and increase the possibilities of peoples (reducing the so called 'digital divide'). For this reason, access to telecommunication infrastructure should be granted to the all citizens. A third argument sees telecommunications as an instrument for regional development, especially for rural and remote areas. This last point is potentially very important in developing countries and it completes the standard externality argument. Telecommunications may have an impact on firm productivity, education and thus economic growth. Roller and Waverman (2001) estimate the impact on GDP of telecommunications investment, adopting a simultaneous equation model. This allows them to address the double causality issue which relates economic growth and telecom infrastructure. For their panel of OECD countries, they find a positive effect of telecommunications on growth. They also find that a critical mass effect exists and the positive impact on growth is larger when the diffusion of telecommunication is close to universal service (as in more developed countries). Following Roller and Waverman (2001), Sridhar and Sridhar (2004) estimate a similar model on data from non-OECD countries: they find that the positive effect on growth is also present. Moreover, Waverman et al. (2005) show that, when considering mobile telephones, the impact of their diffusion on economic growth is bigger in developing countries than in the developed world.

Even if some of the traditional arguments have recently encountered some critics, most of the countries, and particularly developing ones, have policies aimed to promote universal service in telecommunications.

In the past, telecommunications have been mostly provided by monopolies under regulated price structures. Cross subsidies were implemented in order to provide the service at a subsidized rate to high cost consumers. After the waves of liberalization, motivated by technological change and by the poor performance of many public operators, the scope for cross subsidization has been reduced. Cross subsidies have undesirable efficiency property, distorting consumption and investment behaviors. Moreover, the introduction of competition reduces the feasibility of cross subsidization schemes. Competitors enter in the most profitable segment of the market ('cream skimming'), reducing the margins which could finance the cross subsidies programs. For their inefficiency properties many economists advocate the reduction of cross subsidies in favor of the use of targeted subsidies, allocated through auctions and financed by general taxation (see for instance Hausman, Tardiff, and Belinfante, 1993 and Hausman, 1997).

However, Gasmi, Laffont, and Sharkey (1999, 2000) show that cross subsidies may still be a powerful tool to financing universal service under competition in developing countries. In spite of this theoretical result, other scholars point out that in practice the performance of cross-subsidization policies has been very bad in developing countries. For instance, Clarke and Wallsten (2002) argue that cross subsidization policies have been rather unsuccessful in the experience of developing countries, while liberalization policies had positive effect, also toward the poor. In view of the potential distortions introduced by universal service instruments, it

is crucial to gather empirical evidence on the determinants of telecommunications demand for access and the scope for autonomous market driven development. The costs and benefits of the different policies are an open empirical question. Most of the existing evidence considers developed countries. In these countries, the penetration of telecommunication infrastructure is close to saturation. There are reasons to think that the relevant elasticities could be different in less developed countries. Similarly, the importance of network externalities could be larger at the first stages of diffusion. As opposed to developed countries, for developing ones the empirical evidence is very limited: the present chapter aims to fill this gap. India is an appealing candidate for this kind of analysis. It is a low income country which experienced an impressive development of telecommunications in recent years and it is considered the most promising market for ITC in the developing world. More importantly for our aims, India is a federation of States with fairly different socioeconomic conditions. This would make possible to perform panel data analysis based on homogeneously collected data.

We estimate separately several demand specifications and a logistic diffusion model. This provides both a measure of the relevant demand elasticities and an assessment on the issue of the complementarity/substitutability between fixed and mobile phones. Moreover, we estimate a supply equation trying to capture the effect of competition on investment. This last exercise gives us some preliminary results on the supply side of the market and the potential for market driven development of the sector.

## **1.1 Empirical evidence on telecommunications demand and USO instruments**

Existing studies estimating telecommunication access demand and the potential distortion associated with universal service instruments have been mainly conducted for the United States (for a discussion see Riordan, 2001). Due to the federal structure of the country and the huge availability of data, accurate panel data estimation of telecommunication demand has been performed by several authors. In particular, the results by Hausman, Tardiff, and Belinfante (1993) and Hausman (1997) opened a debate on the effectiveness of universal service policies and the distortions introduced by industry taxes in the US telecommunication sector. They find that demand for access is not very sensitive to prices and subsidies aimed to increase penetration have almost no impact, especially because they tend to tax more elastic segment of the market (long distance, mobile telecommunications) in order to cross subsidize access. Later, Garbacz and Thomson (2002, 2003) made a demand estimation using decennial Census data, with similar results. Ackerman, Riordan, Rosston, and Wimmer (2005) concentrate on low income demand for telecommunication services and account for the possibility of endogenous determination of the policies. They find a higher elasticity of access demand than previous studies. They argue that the impact of universal service policies may have

been underestimated.

Most of the studies show that universal services program has a positive but rather small impact. Recently Garbacz and Thomson (2005) have extended the approach developed in their previous studies to a panel of developed and developing countries. In both case, they find a non significant price elasticity of access for fixed lines, questioning the effectiveness of USO policies focused on subsidized access. They also show the importance of some demographic variables (mainly education) to explain the demand for telecommunication services and suggest a current complementarity of mobile and fixed services (although decreasing with time). This is consistent with the findings of Garbacz and Thomson (2003) for the United States, Ahn and Lee (1999) for a panel of 64 Countries. The issue of substitutability between fixed and mobile phones have also been treated using the logistic diffusion approach. Gruber and Verboven (2001) study the development of mobile services in the European Union. The estimated impact of the fixed network on the diffusion of mobiles is negative. On the contrary, in the estimation made by Gruber (2001) to a panel of Central and Eastern European countries a positive effect is founded. More recently, Madden and Coble-Neal (2004) and Rouvinen (2006) estimate two Gompertz diffusion models on panels of heterogeneous countries. Madden and Coble-Neal (2004) separate the network effect from the pure substitution in usage. They show that the development of fixed lines has a positive effect on the diffusion of cellular phones (positive network effect), but the cross-price elasticity is positive (the two modes of communications are substitutes in usage). Rouvinen (2006) find evidence of network effects and complementarity.

These results make us think that the relation of complementarity or substitutability between fixed and mobiles phones could be different in different countries. In some developing countries, the supply side constraints associated with the inefficiency of the incumbent fixed lines operator may induce households to choose a mobile connection. For instance, anecdotal evidence described in a recent the report commissioned by Vodafone shows that in many African countries mobile phones are a substitute for fixed lines, even in poor and rural villages. This is also supported by econometric evidence presented in the same report for a panel of African and non African middle-income countries (see Waverman, Meschi, and Fuss, 2005).

We investigate below this issue for the case of India: our database is rich enough to decompose the effect of mobile phones in different groups of States at different stages of telecommunication penetration.

## **1.2 Universal Service policies in India**

Telecommunications reforms in India started in 1991, when the Government announced the beginning of private participation to the industry. The actual entry of private operator began some years later, around 1995. In order to issue the licences, the Indian market was divided into 23 separated areas, which roughly correspond to States, groups of small States or big metropolitan areas (Delhi, Mumbai, Kolkata

and Chennai). The metropolitan areas are classified as Metros and the other areas as Circles. The latter are divided in three categories on the basis of the perceived revenue potential (Circles of type A, B or C respectively). Initially, market structure was organized following a duopoly policy, in which the incumbent was largely dominant. In this period the telecommunications sector began to grow, after a long stagnation. The first years of private participation were quite turbulent, with litigations arising from the difficulties encountered by the private entrants in honoring the payment of licences. In 1999 the New Telecommunication Policy was announced: it shifted the licence regime into a revenue share agreement and gave new authority to the regulator TRAI, which was also put in charge of price regulation. In the following year the public incumbent BNSL was corporatized. The duopoly policies was abandoned in favor of more competition. In addition, a rationalization of the interconnection policy boosted the development of cellular telephony. The scope for Universal Service was enlarged and the increase in rural teledensity began a priority. This is the period in which Indian telecommunications started experimenting extraordinary rates of growth. Between 2002 and 2005 the total number of telephones increases from 30 to 104 millions. Interestingly, most of the growth was due to an increase in mobile connections, which passed from 6.4 to 57.4 millions (Noll and Wallsten, 2005). It is difficult to quantify to what extent this growth of mobile connection reaches uncovered households (Malik and De Silva, 2005). It is then crucial to understand if cellulars are acting as a complement or a substitute for fixed lines. As for total teledensity, in recent years the gap between urban and rural teledensity is steadily increasing: the benefits from telecommunications growth seem to be mainly captured by wealthier and urban customers (see Figure 1).

For this reason, the Indian government and regulator are increasingly concerned with the difficulties of promoting universal service goals in the liberalized market. The USO policies have their roots in the 1994 National Telecom Policy, which started the renovation of the sector. The policy has been made more precise under the New Telecom Policy in 1999, which states as a priority the provision of telecom services in rural area. The instruments of this policy are the USO levy and the Access Deficit Charge (ADC). The first is paid as a percentage of the revenue earned by the various operators. The raised funds are transferred to a USO fund after passing through the government budget. The funds are aimed to be assigned through least cost auctions, but most of the funds have not yet been disbursed (see Table 1), leaving a prominent role to the ADC. This fee is mainly paid by private operators to the incumbent for providing access in rural areas at a subsidized rate. It has been criticized for its inefficiency properties by many observers (see for instance Noll and Wallsten, 2005). Recently, the Indian regulator TRAI suggested to replace the current ADC scheme with a general tax and progressively merge it with the USO regime.

The universal service levies are inscribed in the relatively high taxation regime of the telecom industry. Recently, the association of telecom providers AUSPI and

Figure 1: Total Teledensity (source: TRAI)

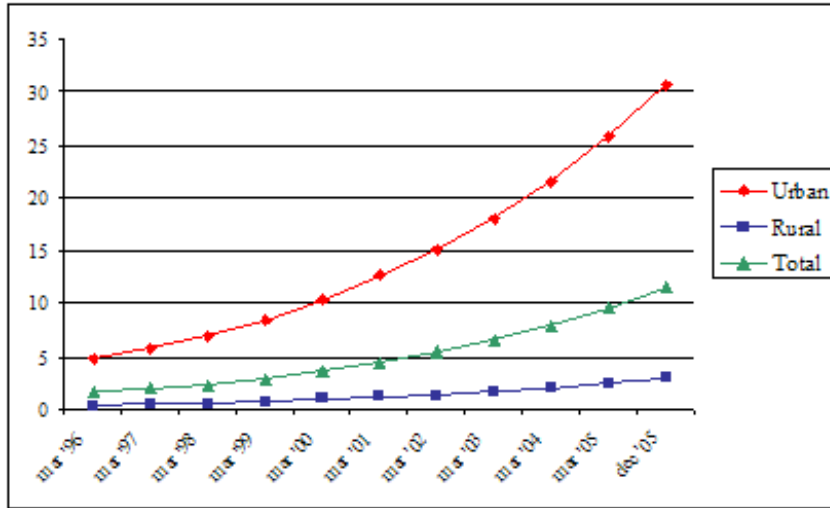


Figure 2: Fixed Lines and Mobiles (source: DOT)

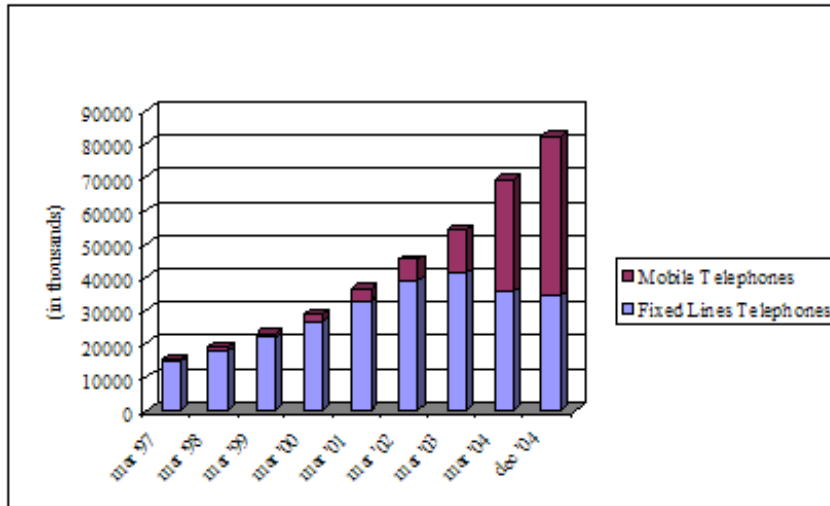


Table 1: The Universal Service Fund

Year	Opening balance	Funds Collected	Funds Allocated	Closing Balance
2002-03	0	1653,61	300	1353,61
2003-04	1353,61	2143,22	200	3296,83
2004-05	3296,83	3457,73	1314,59	5439,98
2005-06	5439,98	3533,29	1766,85	7206,42

Source: DOT. Values are in crores: 1 crore=10.000 rupies

other observers have repeatedly expressed concerns about the high level of taxes on the Indian telecommunication industry, which could be an obstacle to further growth of the sector. For assessing the relevance of this argument and measuring the degree of inefficiency of the tax system, it is important to consider two different potential distortion introduced by taxation policies. The first acts through demand: taxes introduces a deadweight loss which depends on the relative elasticity of taxed and subsidized activities. The second passes through supply: taxes tend to reduce the profits of the providers potentially harming investment capabilities. In this sense, the net effect depends on the relative efficiency of private and public investment. Our empirical analysis aims to shed some light on the determinants of demand and investment behaviors.

## 2 The data

The panel is built using two main sources. For the telecommunications variables, the data come from the Department of Telecommunications (DOT) of India Annual Reports from 1994 to 2004 and from the International Telecommunication Union (ITU). They also contain some demographic variables such as population and population density (population per square kilometer). Other sociodemographic variables are obtained elaborating data from the decennial Census surveys. In reason of their slow dynamics, the annual values have been reconstructed interpolating the available decennial trends<sup>2</sup>.

Data on access to other infrastructures are available on the website of the Planning Commission (PlannComm) of the Indian government <http://planningcommission.nic.in>, but only for selected years.

Data on competition are collected by the Indian Regulator TRAI. Finally, some data on investment (capital outlays) are published by the incumbent operators (BNSL and MTNL). The series from 1998 is available at <http://www.indiastat.com>.

## 3 Demand for telecommunication services: log-linear specification

To start our analysis on the demand for telecommunications in India, we first estimate a simple log-linear demand equation. At this stage, we use the number of main lines per 100 population as a proxy for telephone usage. This does not corre-

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<sup>2</sup>We consider the possibility of adding data from the National Sample Surveys. They are collected in different years but they are not directly comparable to Census data, especially in reason of smaller samples. For this reason, we did not to include them in the series.

Table 2: Variable Description and Sources

Name	Description	Source
del	direct exchange lines per 100 people	DOT
wl	waiting lists per 100 people	DOT
pen	direct exchange lines + waiting list per 100 people	DOT
hpen	household penetration (% of households with a fixed line)	DHS+
p	average revenue per direct exchange lines in real prices	DOT
month	monthly subscription in real prices	ITU
cellpen	cellular penetration (cellular phones per 100 people)	DOT
area	State area in square kilometer	Census
ruraldel	share of rural direct exchange lines	
density	population per square kilometer	DOT
y	per capita real gross domestic product in real prices	Indiastat
liter	literacy rate	Census
castes	rate of population in scheduled castes or tribes	Census
migration	rate of immigrants	Census
elect	rate of households with access to electricity	Census
roads	roads length per 1000 square kilometers (1996)	PlannComm
post	post offices per square kilometer (1998/1999)	PlannComm
capacity	total capacity of local public switching exchanges	DOT
inv	capital outlays (BNSL) in real prices	Indiastat

spond to household penetration or even residential lines. However, since main lines are reported on yearly basis in most country, this allow us to have a fist assessment of the determinants of demand and to compare it with cross country studies. In the next Section we will build a measure for household penetration using some recent household-level data. As it is standard, we assume that demand for telephone mainlines is a function of price, income and other variables controlling for poverty and living conditions.

$$\log(\text{pen}_{it}) = \beta_0 + \beta_1 \log(p_{it}) + \beta_2 \log(y_{it}) + \beta_3 X_{it} + \varepsilon_{it}$$

The left hand side variable  $\text{pen}$  is given by the sum of main lines and waiting list (per 100 people). The inclusion of waiting lists tries to capture some of the demand which is not satisfied due to supply side constraints (unfortunately, some of the demand is probably completely discouraged in case of very poor supply, but we cannot control for that).  $p$  is the indicator of the price level,  $y$  is per capita income and  $X$  represents control variables (sociodemographic characteristics and, possibly, fixed effects and time dummies). All variables are taken in logs, excluding dummies. As a proxy for the level of the price  $p$ , we use the average revenue per main line. We start estimating model with OLS, including time dummies, population density (*density*) and sociodemographic variables such as the literacy rate (*liter*) and the percentage of inhabitants belonging to scheduled castes and tribes (*castes*). Population density controls at the same time for difference in costs for less populated areas and for possibly different demand pattern in rural and remote areas. Literacy rates have been used in several study to capture the level of life which, especially in developing countries, is often not well described from the mere per capita GDP. Scheduled castes and tribes register people traditionally considered ‘outcastes’, relegated to marginal occupations and victims of social exclusion. These groups are now accorded a special status under the Constitution, trying to reduce their socioeconomic disadvantage. The percentage of people belonging to scheduled castes and tribes can be interpreted as a proxy for poverty, describing the impact of belonging to less favored segments of the population. This is also a rough way to distinguish minority ethnic groups, which may have different consumption behaviors (with similar intent, empirical works about the United States control for different ethnic groups).

One of the classical problems in this kind of estimation is the potential endogeneity of the price. Unfortunately, the available data make it difficult to find instruments for the price. In India, the basic tariffs (access, monthly rent) are regulated at the central level, which reduces the problem of price endogeneity (this tariffs are not subject to idiosyncratic shocks at the State level). Nevertheless, the average revenue per line does not depend only on these tariffs, but also on the patterns of usage and the different tariff plans, which we cannot observe. In order to reduce the impact of the endogeneity problem, we first instrument the price with its lagged value. The estimation of the elasticity of demand shows no bigger variation with

respect to the all exogenous specification. The coefficient slightly increases in absolute value. Alternatively, we use as an instrument the rural percentage of existing lines (*ruralshare*). This variable is not available for all States and periods, reducing the number of observations in the regression. Nevertheless, it is potentially a good instrument. First, it is a proxy for costs, which can capture some supply side characteristics. More interestingly, price regulation imposes different tariffs for the rural areas. This price regulation is decided at the central level and homogeneous across the country (and thus not endogenously determined in itself)<sup>3</sup>.

The basic OLS regression is given in Column (1) of Table 3. The price elasticity is estimated at  $-0.397$  and income and sociodemographic variables appears very important in explaining demand for main lines. Column (2) reported the same estimation with the price instrumented by its lag value.

In order to exploit the panel nature of the data, we introduce fixed effects in order to account for other, time invariant, unobserved heterogeneity. The problem is that the sociodemographic variables display a very little time variation, making it difficult to estimate their impact in a fixed effect specification. Column (3) of the table 3 reports the results of the fixed effect regression. The price elasticity of  $-0.499$ . Sociodemographic characteristics are highly non significant and have implausible signs. We then estimate the same model with random effects, presented in Column (4). This gives a price elasticity of  $-0.599$  and reasonable coefficients for the sociodemographic characteristics. We then perform a panel robust version of the Hausman test for fixed versus random effects<sup>4</sup>. The test does not reject the hypothesis of random effects (at the 5% level). Even if the coefficient estimates are sensibly different in the two estimations, due to the high standard errors the test cannot reject the presence of random intercepts. In Column 5 of Table 3 we present the instrumental variable regression using the proportion of rural lines as an instrument: the coefficient for price is sensibly higher than in the OLS regression. Interestingly, a similar magnitude is obtained when we control for the possibility of a fixed effect for homogeneous *groups* of States as measured by the belonging to a Circle type (Circles classification is discussed in Section 1.2). This strategy allows to control for differences among heterogeneous groups of States, which share some unobservable profitability and market characteristics. Introducing fixed effects for the Circles allows to introduce meaningful fixed effect and at the same time to estimate the impact of the variables characterized by small time variation. In the estimation, we cannot separate the Metros from the States they belong to, because all socioeconomic variables are collected at the State level. We then put fixed effects for the Circle types (A, B or C respectively) and include the Metros in the Circles of the respective States (Delhi, which constitutes at the same time a separate State and a metro Circle, is put in the same groups as the A-Circles).

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<sup>3</sup>Although this is probably a weak instrument, the standard statistics give encouraging results. The Durbin-Wu-Hausman do not reject the null of exogeneity. The first stage F statistics is equal to 45.26 and the partial R-squared 0.25

<sup>4</sup>We perform a robust Hasman test based on the auxiliary regression model as suggested in Wooldridge

The results of this fixed effect estimation are given in Column 6 of Table 3. After controlling for these fixed effect, the price elasticity is a bit higher (-0.65) than in the other specifications. The magnitude of the other explanatory variables remains comparable.

In all our specification the price elasticity is fully significant and sensibly bigger than the ones estimated for developed countries. This is different with respect to the results of Garbacz and Thomson (2005), which find that price elasticity is not significant for their panel of countries. In their estimations, the price elasticity for the group of developing countries is not very different than the one of developed ones. Our evidence about India seems on the contrary to confirm the idea that price elasticity in LDC is more important than in developed ones. Moreover, due to the difficulty to build good instruments for the price, we can expect the price coefficient to be even underestimated (which would reinforce the finding). Taking into account the fact that tariffs in India are rather small as compared to the ones of other countries in the same income group, one could expect the price and income elasticities to play an even larger role in other developing countries.

As in other studies, the importance of income effects is confirmed. Moreover, other variables describing the level of life more accurately than the mere GDP measure seem to play an crucial role in explaining the demand for telecommunications. The impact of literacy is positive and large. Belonging to scheduled castes or tribes is shown to negatively affect demand for telecommunications access.

Another interesting empirical question is the impact of mobile telephony diffusion on the development of the fixed network. This is particularly important in India, where the growth of mobile telephony in the last years has been impressive. Still, mobile phones are mainly available in the big cities. Our panel includes data until 2004, the year in which mobile phones outnumbered fixed lines. Most of the sample precedes the diffusion of mobiles and then refers to a period in which telecommunications service was only provided by the mean of fixed lines. Nevertheless, we have sufficient observations to get some evidence on the impact of mobile technology on the diffusion of fixed lines.

In order to assess the impact of the mobile sector, lacking information about prices at the State level, we introduce the level of cellular penetration (*cellpen*) as an explanatory variable in equation describing demand for fixed lines. Two opposite effects can play. On the one hand, mobile phones can be perceived as a substitute for telephone lines. On the other hand, mobile and fixed telephony have some complementarity and, more importantly, there might be network effects between fixed and mobile infrastructures. The results of the regression including mobile phones are given in Columns (7) and (8). In the regression, *cellpen* appears to be highly collinear with the time dummies starting from year 2000. As explained in Section 1.2, after the New Telecommunication Policy, a change in the access policies favored the diffusion of mobiles. This can explain the existence of two ‘time periods’. We then replace year dummies with a dummy for the beginning of the NTP (i.e. equal to 1 for the years following 1999). The coefficient of cellular pen-

Table 3: Log-Linear Demand Estimation

variable: pen	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
p	-0.397*** (0.107)	-0.431*** (0.125)	-0.603*** (0.157)	-0.723*** (0.219)	-0.637** (0.251)	-0.640*** (0.115)	-0.565*** (0.107)	-0.703*** (0.105)
y	1.181*** (0.069)	1.170*** (0.070)	-0.700 (0.409)	0.616*** (0.188)	1.111*** (0.087)	1.031*** (0.073)	1.174*** (0.075)	1.082*** (0.073)
density	0.137*** (0.020)	0.125*** (0.020)	-1.796* (0.951)	0.157** (0.063)	-	0.104*** (0.049)	0.143*** (0.024)	0.117*** (0.025)
liter	0.734*** (0.194)	0.765*** (0.203)	0.067 (0.572)	0.986 (0.697)	0.726** (0.288)	0.850*** (0.186)	0.831*** (0.220)	0.928*** (0.211)
castes	-0.145*** (0.052)	-0.166*** (0.052)	0.609 (0.498)	-0.073 (0.236)	-0.231*** (0.056)	-0.172*** (0.049)	-0.151** (0.058)	-0.178*** (0.053)
cellpen	-	-	-	-	-	-	0.021** (0.009)	-
cellpen*circle-A	-	-	-	-	-	-	-	-0.012 (0.011)
cellpen*circle-B	-	-	-	-	-	-	-	0.028*** (0.009)
cellpen*circle-C	-	-	-	-	-	-	-	0.042** (0.010)
p endogenous	no	yes	no	no	yes	no	no	no
(instrumented by lag)	no	yes	no	no	no	no	no	no
(instrumented by rural share)	no	no	no	no	yes	no	no	no
state-level fixed effects	no	no	yes	no	no	no	no	no
state-level random effects	no	no	no	yes	no	no	no	no
circle-level fixed effects	no	no	no	no	no	yes	no	no
time dummies	yes	yes	yes	yes	yes	yes	no	no
NTP dummy	no	no	no	no	no	no	yes	yes
observations	200	180	200	200	152	200	200	200

\*\*\* significant at 1% level, \*\* significant at 5% level, \* significant at 10% level.

etration is positive, though rather small. This means that a network effect exists at the aggregate level. We then explore the possibility that this network effect could be different at different stages of telecommunications development. To allow for a nonlinearity of this effect, we interact the variable *cellpen* with the dummies for circle types. The positive effect is confirmed in Circles of type B and C, which are the one with lower penetration. Network externalities and complementarities between the services seem to be more important where coverage is poor. On the contrary, for A-Circles the coefficient is negative, showing a tendency to substitution, but non significant.

Unfortunately, from the existing data, it is not possible to study cross-price elasticities in order to address the question of potential substitutability in usage, which possibly introduce a form of competition between fixed and mobile providers.

#### 4 Demand for telecommunication access: a logit specification

In the previous paragraph, we provided a first rough estimation of demand for main lines. This is not an estimation of demand for access. To perform an estimation of access demand it is necessary to build a variable describing household penetration. Households penetration is available for year 1999 in the DH+ Surveys. We use this information to build a measure for household penetration starting from the available data on lines, population and number of households. We are forced to assume that the relationship between main lines per capita and household penetration is stable across time. As a measure of the price of access, we replace the variable used above, i.e. the average revenue per main line, with the monthly charge. In the case of India, these tariffs are regulated at the central level, so there is no cross-section variation (at least in nominal terms). We could also include the connection charge, but this tariff has not been changed during the study period. The good point is that the monthly charge does not suffer from the endogeneity issues discussed above for the average revenue per line: being fixed at the Central level for all States it is not subject to unobservable shocks at the State level. We also run the estimations using the average revenue as in the previous section and all coefficients and elasticities are strikingly close to the ones presented below.

We estimate a logit model in which the binary variable is the decision to connect to the network. The logistic regression model specifies the probability of being connected  $\pi$  as:

$$\pi_{it} = \frac{\exp^{\beta Z_{it}}}{1 + \exp^{\beta Z_{it}}} \quad (1)$$

Where  $Z$  represents the explanatory variables. Equation (1) can be expressed as:

$$\log \left( \frac{\pi_{it}}{1 - \pi_{it}} \right) = \beta Z_{it}$$

In our case, we specify:

$$\log \left( \frac{hpen}{1 - hpen} \right) = \beta_0 + \beta_1 p_{it} + \beta_2 y_{it} + \beta_3 X_{it} + \varepsilon_{it} \quad (2)$$

Where  $hpen$  is the measure of household penetration,  $p$  is the indicator of the price (here the monthly subscription),  $y$  is income and  $X_i$  are the other controls described below).

The problem of estimating this model is that the available observations are grouped data and not household level observations. Logit models with proportion data need a treatment of the heteroskedasticity related to within-cell heterogeneity. Different strategies may be implemented. An OLS estimation of Equation (2) gives a first assessment of the impact of the explanatory variables. In the first estimation, we include the most relevant socioeconomic characteristics ( $y$ ,  $liter$ ,  $castes$ ), and the variable  $density$ . Since the chosen price variable has only time variation, we do not include time dummies. Nevertheless, we observe qualitatively a discontinuity in the rate of growth of penetration for the years 2000s, just following the introduction of the New Telecommunication Policy (NTP). We thus introduce a dummy variable for the year following the NTP.

The least square regression of Equation 2 is proposed in Column 1 of Table 4. To control for heteroskedasticity, the values in parentheses are White heteroskedastic-robust standard errors.

We then perform minimum chi-square estimation (MCSE), which results are given in Column (2). The estimation is carried using a two-step procedure. We first estimate an OLS model explaining  $hpen$  as a function of the explanatory variables. The estimates are then used for computing the weights of the second-stage FGLS estimation, based on the estimated variance of the logit model  $S_{it}$ :

$$S_{it} = \frac{1}{n_{it} \hat{\pi}_{it} (1 - \hat{\pi}_{it})}$$

Where  $n_{it}$  is the number of households grouped in the aggregate observation for State  $i$  at time  $t$ .

Finally, in Column (3) we present the maximum likelihood estimation (MLE) of the grouped model. Although MCSE and MLE have the same asymptotic properties, they are not equivalent in small samples. The log likelihood function for proportion data writes:

$$\log L = \sum_i n_i \log \{ hpen_i \log(\pi_i) + (1 - hpen_i) \log(1 - \pi_i) \}$$

As shown in table (4) the estimated coefficient and standard errors are very closed to the one obtained by MCSE.

Table 4: Household Access Model

variable: $\log\left(\frac{\pi}{1-\pi}\right)$	(1)	(2)	(3)	(4)	(5)	(6)
p (month)	-0.0054*** (0.0011)	-0.0035*** (0.0007)	-0.0032** (0.0009)	-0.0033*** (0.0009)	-0.0041*** (0.0007)	-0.0031 (0.0009)
y	0.00009*** (0.00001)	0.00007*** (0.000009)	0.00006*** (0.00001)**	0.00006*** (0.00001)	0.00003** (0.00001)	0.00006*** (0.00001)
density	0.00004 (0.00003)	0.00004* (0.00002)	0.00004 (0.00002)	0.00007** (0.00003)	-0.003** (0.00007)	-0.000003 (0.00003)
liter	0.0313*** (0.005)	0.387*** (0.004)	0.410*** (0.004)	0.042*** (0.0043)	0.024*** (0.004)	0.044*** (0.004)
castes	-0.004 (0.003)	-0.012*** (0.004)	-0.106*** (0.004)	-0.010*** (0.004)	-0.009** (0.004)	-0.008** (0.004)
elect	-	-	-	-	0.017 (0.0022)	-
roads	-	-	-	-0.00001 (0.00001)	-0.00002** (0.00001)	-
post	-	-	-	-	0.010 (0.0015)	-
migrants	-	-	-	-	-	0.025 (0.010)
logit LS	yes	no	no	no	yes	no
MCSE	no	yes	no	yes	no	yes
MLE	no	no	yes	no	no	no
observations	220	220	220	160	120	100

\*\*\* significant at 1% level, \*\* significant at 5% level, \* significant at 10% level.

In all the estimations, the coefficients are interpreted as quasi-elasticity. In the logit model, the derivative of the probability of having telephone service with respect to an explanatory variable  $x_i$  is given by:

$$\frac{\partial \pi_{it}}{\partial x_i} = \beta_i \pi_{it} (1 - \pi_{it})$$

From this expression one can derive the relevant elasticities. Computing the price elasticity at the sample mean, we find a coefficient of  $-0.41$ . Elasticity is smaller in States with higher penetration and/or in more recent years. The minimum value is as small as  $-0.10$ . Consistent with the finding of Section 3, the average values are sensibly higher than the ones estimate for developing countries, but seems to be rapidly decreasing when penetration improves. More strikingly, teledensity is affected by income and other sociodemographic characteristics. Income growth and increases in education may be the engines of telecommunications growth. Elasticities with respect to representative variables are given in table 5. An interesting point is that, when controlling for income and other sociodemographic characteristics, the impact of the variable population density is small or non significant. One interesting point is to know if demand in rural and remote areas is qualitatively different. Rural areas are characterized by extremely low levels of penetration, but this could depend on the fact that income and wealth are lower in rural areas. Moreover, the limited penetration could be explained by supply side constraint. In itself, all other things been equal, the remoteness of the area should rather have a positive impact on demand. Telecommunications have a large value to otherwise isolated areas. We explore this hypothesis introducing road density in the regression. The only data available is the roads per 1000 square km in 1996/97. We then use this as a regressor. We also control for access to other infrastructures (road density could be positively correlated with access to telecommunications simply because it is a proxy for the development of the general infrastructures of the region). As shown in Columns 4 and 5 this guess is confirmed by the data. Telecommunications serve as a substitute for road connection and they are particularly valuable in low density areas. The low level of teledensity in these regions seems to depend on wealth or supply side limitation, more than on specific demand patterns. This stresses an important point: in developing countries telecommunications can act as a substitute for other, missing, infrastructures, reducing isolation and promoting the exchange of information which is vital to many economic and noneconomic activities. For instance, small agriculturers in remote areas can find information about prices and stocks: this give a large value to telecommunication services, especially when the alternative (travel time) is very expensive. Finally, we find that the number of immigrants positively affects the demand for telecommunication: increased labor mobility creates new need for telecommunication services. To control for possible endogeneity (the high immigration State could be the more developed and then the ones with higher teledensity), we replaced the variable migration with the share of emigrants (in this case, people tend to emigrate from poorer States). The result is the same, all things being equal an

high number of emigrants increases demand for lines. This confirms the interpretation that labor mobility increases the value of telecommunication services.

Table 5: Elasticities

variable	average	min	max	'01-'04
p(month)	-0.41	-0.65	-0.10	-0.31
y	0.62	0.15	1.05	0.65
liter	2.35	1.62	3.13	2.40
castes	-0.23	-0.68	-0.06	-0.22

Elasticities are computed from the MCSE estimations presented in Table 4, Column (2).

Introducing mobile phones penetration, we find again that the network effect is higher in lower penetration Circles. On the contrary, in A-Circles, the impact of mobile on fixed penetration is not significant or negative (depending on the specification), meaning that some substitution between fixed and mobiles platforms may be going on in the more developed areas. Unfortunately, from the existing data, it is not possible to study cross-price elasticities in order to address the question of potential substitutability in usage, which could introduce a form of competition between fixed and mobile providers.

## 5 Diffusion of telecommunications: a logistic diffusion approach

The issues related with telecommunication diffusion and network effects present some dynamic aspects which are not captured by the models estimated above. In particular, the individual decision to connect on the size already reached by the network itself as well as on the development of complementary network goods (the diffusion of mobile phones, for instance). Several recent papers study mobile telecommunications diffusion and try to assess the impact of fixed lines on the development of the mobile network. Contrarily to these contributions, we look here at the diffusion process governing the fixed lines. We thus characterize the determinants of fixed lines diffusion and the impact of mobile penetration on the development of the fixed network. We estimate two alternative specifications of the diffusion process. We assume that that telephone penetration tends towards an equilibrium level  $pen^*$  following a logistic process. In the first specification the rate of convergence is kept constant. The equilibrium level is assumed to depend on price, income and sociodemographic characteristics. The first difference equation is a linearized Gompertz model, given by:

Table 6: Household Access Model with Mobiles

variable: $\log\left(\frac{\pi}{1-\pi}\right)$	(1)	(2)	(3)	(4)	(5)	(6)
p (month)	-0.0056*** (0.0012)	-0.0039*** (0.00008)	-0.0012*** (0.001)	-0.0041*** (0.001)	-0.0029*** (0.0009)	-0.0025*** (0.0010)
y	0.00008*** (0.00001)	0.00007*** (0.00001)	0.00005*** (0.00001)	0.00008*** (0.00001)	0.00008*** (0.00002)	0.00007*** (0.00001)
density	0.00005* (0.00003)	0.00005** (0.00002)	0.00004 (0.00002)	-0.000007 (0.00003)	0.0005 (0.00002)	0.0005*** (0.00002)
liter	0.0364*** (0.005)	0.393*** (0.004)	0.44*** (0.005)	0.035*** (0.0041)	0.036*** (0.004)	0.038*** (0.0038)
castes	-0.014 (0.003)	-0.011** (0.005)	-0.014*** (0.004)	-0.012*** (0.003)	-0.013*** (0.004)	-0.012*** (0.003)
cellpen	-0.017 (0.023)	-0.016 (0.018)	-0.001 (0.207)	-	-	-
cellpen*circle-A	-	-	-	-0.034 (0.022)	-0.028 (0.018)	-0.030** (0.013)
cellpen*circle-B	-	-	-	0.161*** (0.052)	0.157*** (0.039)	0.147*** (0.044)
cellpen*circle-C	-	-	-	0.326* (0.002)	0.146 (0.230)	0.227* (0.131)
logit LS	yes	no	no	yes	no	no
Min Chi-Sq	no	yes	no	no	yes	no
MLE	no	no	yes	no	no	yes
observations	209	209	209	209	209	209

\*\*\* significant at 1% level, \*\* significant at 5% level, \* significant at 10% level.

$$\log(\text{pen}_{it}) - \log(\text{pen}_{it-1}) = \alpha[\log(\text{pen}_{it}^*) - \log(\text{pen}_{it-1})]$$

The equilibrium penetration  $\log(\text{pen}^*)$  as a linear function of demand determinants:

$$\log(\text{pen}_{it}^*) = \beta \log(X_{it})$$

In our model,  $X_{it}$  is given by price, income, mobile phone penetration and possibly other sociodemographic variables.

The results of the estimation are given in Table 7. Price, income and sociodemographic characteristics have the expected signs. The estimated coefficients for the cellular penetration are positive. Moreover, decomposing the effect of cellular penetration in the different Circles, we find back the main conclusion described above for the static specification. The network effect appears more pronounced in low penetration Circles and mild evidence of substitution is found for Circles of type A.

We now estimate a more general diffusion process, which writes:

$$\text{pen}_{it} = \frac{\text{pen}_{it}^*}{1 + \exp(-a_{it} - b_{it} t)} \quad (3)$$

This model is more flexible and allows for nonconstant diffusion parameters. Diffusion follows a logistic process.  $a_{it}$  represents the location parameter: it shifts the diffusion function without affecting the S-shape.  $b_{it}$  is the speed of the diffusion process. Contrarily to the linearized model used above, we specify the market potential as a fixed share of the total population (to be estimated). We could include other variables such as prices and income, but this complicates the estimation of the nonlinear model (see Gruber and Verboven (2001)). We thus prefer to include all sociodemographic variables and the penetration of mobile phones in  $b$ . In the location parameter  $a$ , we include fixed Circle effects (i.e.  $a_{it} = a_i$ ), allowing location to depend on the circle types<sup>5</sup>. The model is estimated with nonlinear least squares, after adding an error term to Equation 3. The results are given in Table 8. All variables have the expected sign. As for the diffusion of mobile telephones, we still find a positive, though non significant network effect. In Column (2) the effect of mobile penetration is once again interacted with Circle dummies. The results confirm the analysis above: in A-Circles cellular penetration has a negative impact of mobiles on the speed of diffusion of fixed lines. In the other Circle types the estimated network effect is positive.

The application of the two proposed diffusion models confirms the findings of the previous specifications. Mobile phones do not act as a substitute for fixed lines

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<sup>5</sup>Other specification has been tested, for instance including the NTP dummy in both  $a_{it}$  and  $b_{it}$ . The inclusion of the NTP dummy allows to see if the policy change created a 'jump' and/or an acceleration of the diffusion process. Both coefficient were not significant and the other estimates were not particularly affected.

Table 7: Diffusion Equation 1: Linearized Gompertz Model

variable: $\log(pen_{it}) - \log(pen_{it-1})$	(1)	(2)	(3)	(4)	(5)
log(p)	-0.073** (0.032)	-0.067** (0.032)	-0.091** (0.053)	-0.082** (0.035)	-0.076** (0.032)
log(y)	0.131*** (0.038)	0.090*** (0.033)	0.139*** (0.038)	0.097*** (0.033)	0.118*** (0.038)
log(liter)	0.118 (0.081)	0.095 (0.068)	0.121 (0.084)	0.108 (0.071)	0.132* (0.080)
log(castes)	-0.042** (0.020)	-0.030*** (0.017)	-0.044** (0.020)	-0.032* (0.017)	-0.039* (0.019)
log( $pen_{it-1}$ )	0.119*** (0.023)	0.080*** (0.021)	0.128*** (0.024)	0.090*** (0.022)	0.109*** (0.023)
log(cellpen)	0.017 (0.020)	-0.036* (0.027)	-	-	0.0003 (0.0003)
log(cellpen)*circle-A	-	-	-0.001 (0.004)	-0.011** (0.004)	-0.032** (0.012)
log(cellpen)*circle-B	-	-	0.004 (0.004)	-0.007 (0.005)	-
log(cellpen)*circle-C	-	-	0.003 (0.004)	0.006 (0.004)	-
observations	171	171	171	171	171
time dummies	no	yes	no	yes	no

\*\*\* significant at 1% level, \*\* significant at 5% level, \* significant at 10% level.

Table 8: Diffusion Equation 2: Logistic Regression

variable: $pen_{it}$	(1)	(2)	(3)
pen*	0.162*** (0.015)	0.184*** (0.025)	0.182*** (0.025)
p	-0.0000005 (-0.000006)	-0.000004 (-0.000007)	-0.0000009 (-0.000006)
y	0.00002*** (0.000003)	0.00002*** (0.000003)	0.00002*** (0.000003)
liter	0.0092*** (0.001)	0.0086*** (0.001)	0.0087*** (0.0010)
castes	0.0015 (0.0007)	0.001 (0.007)	0.001* (0.0006)
cellpen	-0.010 (0.009)	-	0.010 (0.007)
cellpen*circle-A	-	-0.018*** (0.005)	-0.028*** (0.006)
cellpen*circle-B	-	0.009 (0.09)	-
cellpen*circle-C	-	0.073** (0.036)	-
observations	190	190	190

\*\*\* significant at 1% level, \*\* significant at 5% level, \* significant at 10% level.

in low penetration Circles. Signals of substitution appears in when the mobile network become more developed. This could mean that, for low level of penetration, the network effect is more important and mobiles and fixed lines have a complementary development. In a more mature phase, consumers start substituting fixed with mobile services. There is no evidence, though, that mobiles diffusion is displacing fixed lines in low penetration Circles.

## 6 Supply of telecommunications: investment

We now estimate a supply equation similar to the one proposed in Roller and Waverman (2001). The endogenous variable is the state level of investment. We estimate the following equation:

$$\log(inv) = \beta_0 + \beta_1 \log(area_i) + \beta_2 \log wl_{it} + \beta_3 \log(p_{it}) + \beta_4 X_{it}$$

Where *area* is the geographic area of the State, *wl* is the waiting list (which aims to represent potential demand) and *X* are other control variables. In particular, we put as a control variable the number of competitors of the regulated firm in the fixed segment. This allows to assess the direct impact of competition in the fixed lines segment. In the previous section, we also considered the impact of mobile telephony on fixed lines, finding evidence of network effects in low penetration Circles and some substitution in more developed markets. Acknowledging that, even in the presence of a network effects, mobiles could exert some competitive pressure on the fixed operators, we also estimate the model including the number of mobile operators in the different Circles. All results are qualitatively the same.

One problem is that only the public incumbent publishes data on investment (in particular, State-wise capital outlays). The estimation gives nevertheless some interesting insights on the investment behavior in the different States/Circles (see Table 9). Consistent with the findings of previous studies, we find a positive impact of geographic area. Moreover, the regression show a positive and significant impact of *wl*: investment is demand responsive. We also find a positive and significant impact of competition. The coefficient of the price is negative, which would mean that higher average revenues discourage investment. This puzzling result was also present in Roller and Waverman (2001), and partially solved in the specification which takes into account fixed effects (partially in the sense that the sign of the coefficient changes only in the case of US and Canada, which are "dummied out" in the specification and not for the other group of countries). Also in this case, the measure of prices probably introduces endogeneity problems. For these reason, we replace the average price with other profitability measures. Circle dummies capture some characteristics related to the profitability of investment. We also add population density, which could affect the average main lines profitability. After

Table 9: Investment Equation 1

variable: inv	(1)	(2)	(3)
p	-0.297** (0.157)	-	-
wl	0.433*** (0.031)	0.213*** (0.033)	0.239*** (0.034)
area	0.318*** (0.048)	0.348*** (0.036)	0.356*** (0.038)
density	-	0.405*** (0.051)	0.440*** (0.52)
comp	0.403*** (0.054)	0.083 (0.062)	-
comp*circle-A	-	-	0.306*** (0.037)
comp*circle-B	-	-	0.226*** (0.054)
comp*circle-C	-	-	0.147 (0.103)
circle-level fixed effects	no	yes	no
observations	115	133	133

\*\*\* significant at 1% level, \*\* significant at 5% level, \* significant at 10% level.

adding this new controls, the competition variable turns out not to be significant. One possible explanation is that in general we observe both more investment and more competition in more profitable Circles. To disentangle the effect of competition from the profitability characteristics of the Circles, we build new variables interacting competition with the different circle categories. We now estimate:

$$\log(inv) = \beta_0 + \beta_1 \log wl_{it} + \beta_2 \log(area_i) + \beta_3 \log(density_{it}) + \sum_j \beta_j comp * circle_j$$

Where  $circle_j$ ,  $j \in \{A, B, C\}$  are dummies for the circle classification. The results are given in Column 2. We see that competition has a positive impact on investment in type A and B Circles (which are the ones with higher expected profitability) but it is non significant in C-Circles (the low penetration ones).

We finally perform a similar regression using the equipped capacity as a measure of investment. These data, published by the Department of Telecommunications, include the capacity provided by the private undertakings. They take into account private entry and, contrarily to capital outlays used above, do not refer only to the public incumbent. The results, presented in Table 10 are directly comparable to the ones in 9. All the significant coefficients, and in particular the one describing the impact of competition, have the same sign and similar magnitude. The coefficient for competition interacted with C-Circles is even negative in this

Table 10: Investment Equation 2

variable: capacity	(1)	(2)
wl	0.122*** (0.043)	0.151*** (0.045)
area	0.348*** (0.029)	0.361*** (0.048)
density	0.550*** (0.059)	0.614*** (0.077)
comp	0.027 (0.033)	-
comp*circle-A	-	0.552*** (0.056)
comp*circle-B	-	0.319*** (0.103)
comp*circle-C	-	-0.115 (0.137)
time dummies	yes	yes
circle-level fixed effects	yes	no
observations	197	197

\*\*\* significant at 1% level, \*\* significant at 5% level,

\* significant at 10% level.

regression (and still non significant).

This result seems to suggest that the existence of competition stimulates investment in more profitable areas, but not in regions with less developed markets. This contradicts the idea that the protection of its monopoly position is at the origin of the low levels of investment of the incumbent. This can be the case in more profitable areas, but in low profitability ones entry has no significant impact on investment. The benefits of competitive pressure are thus concentrated in the Circles with the highest expected profitability. This confirms the idea that market driven investment tends to concentrate in profitable areas, potentially increasing the gap in penetration between profitable and less profitable segments of the market. Public intervention is needed to stimulate investment in low penetration areas. An efficient allocation of the resources collected through the universal service levy could play an important role.

## 7 Conclusion

This chapter performs an empirical analysis of the Indian telecommunications market. First, several specification of the demand for fixed lines have been estimated. The results show that (access) price elasticity is much bigger than in developed

countries, although decreasing with time and smaller in highest penetration circles. Moreover, literacy rate and other sociodemographic variables have a large impact on demand: they are important engines of telecommunication development.

As for the relationship between fixed and mobiles telephones, we find that a positive network externality is present in low penetration areas (Circles of types B and C). On the contrary, where the telecommunications market is more developed (Circles of type A and Metros), we find evidence of substitution. We can conclude that the network effect between mobiles and fixed phones is very important at the first stages of telecommunications diffusion. In more mature markets, a substitution effect arises. The evidence of substitution in most developed areas challenges the possibility for cross subsidization of less developed circles with higher taxes in the most developed ones. Not only in higher penetration circles the entry of basic services competitors tends to erode the margins ('cream skimming') reducing the scope for cross subsidization, but in addition mobiles are direct competitors of the fixed lines.

Finally, considering two different investment equations, we show that the introduction of competition have boosted investment in the circles with higher penetration. In the circles characterized with very low penetration, there is no significant impact of entry on investment. For stimulating investment in less developed areas some public intervention seems to be necessary: an efficient allocation of the USO funds is here crucial. A true competition for the market and an efficient subsidization policy (public funds assigned through non discriminatory auctions) could be a response to this problem.

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