Telecommunications Police

Evolution and determinants of digital divide in Brazil (2005-2013)

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Abstract

During the last decades, the widespread growth of information and communication technologies (ICT) has posed incentives to broaden the participation of individuals in social, political and economic dimensions of life. However, utilization of ICT also involves access to technology and infrastructure, and acquisition of skills to deal with innovations and, thus, digital literacy is, primarily, a complementary good. The digital divide expresses inequalities in access and utilization of ICT among individuals and populations in different countries. The study adopts inequalities indexes of Internet access and mobile phone ownership to measure use of ICT goods, accounting for the digital divide in Brazil. The inequality indexes are also split according to main determinants using four nationally representative survey data from 2005 to 2013. Results indicate that the digital divide among individuals is decreasing quite fast among Brazilians over time. However, there is room for policies of mass access to ICT goods based on mobile Internet broadband access. In addition, digital illiteracy, evaluated by lack of education, is one of the main determinants of the digital divide in the country, especially among elderly individuals.

Keywords: Internet, digital divide, inequality, access, mobile.
JEL classification: O10; O20; O38.

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1. Introduction

The recent widespread growth of information and communication technologies (ICT) poses incentives to broaden the participation of individuals in social, political and economic dimensions of life; including the access to key information and the opportunities of social interaction that include education, leisure and working activities. However, the access to ICT presupposes the access to technology and infrastructure, and also acquisition of skills to deal with innovations of the digital world (Prieger, 2013; Wirthmann, 2010 & 2012).

Several studies show the role of socioeconomic, cultural and geographical characteristics in determining the level of technological advances among countries worldwide. The definition of digital divide refers to "*the 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*" (Organisation for Economic Co-operation and Development [OECD], 2001, p. 5), and it represents the measurement of inequalities in accessing and using ICT among individuals and populations in different countries (Dasgupta, Lall, & Wheeler, 2011; Pantea & Martens, 2013; Vicente & López, 2011; Zhang, 2013).

Zhao, Collier, and Deng (2014) point out that digital divide literature usually investigates two dimensions: digital divide among countries (*international digital divide*) or among individuals/groups of individuals within a country (*domestic digital divide*). Regarding the first dimension, evidence shows that there is significant gap between developing and developed countries due to socioeconomic factors, mainly due to differences in income and educational attainment. In relation to the second dimension, studies tend "*to focus on specific groups of people within a nation who appear especially disadvantaged by the digital divide (...) people on low incomes, people with limited education or low literacy levels, ethnic minorities, the unemployed, the elderly, people in isolated or rural areas, people with disabilities, single parents, and women and girls*" (Zhao et al., 2014, p. 40).

Dewan and Riggins (2005) unfold the digital divide in other two dimensions: inequality in access to ICT and inequality in capacity of ICT utilization; that is, differences in reaching technological innovations and in ability to use technological devices. Other authors point to the utilization of the Internet on mobile phones as alternative to reduce the inequality in Internet access (DiMaggio, Hargittai, Celeste, & Shafer, 2004; Wirthmann, 2012), since differences in

access to ICT have been declining faster in relation to mobile devices than other technologies (technological convergence) (UNCTAD[1]).

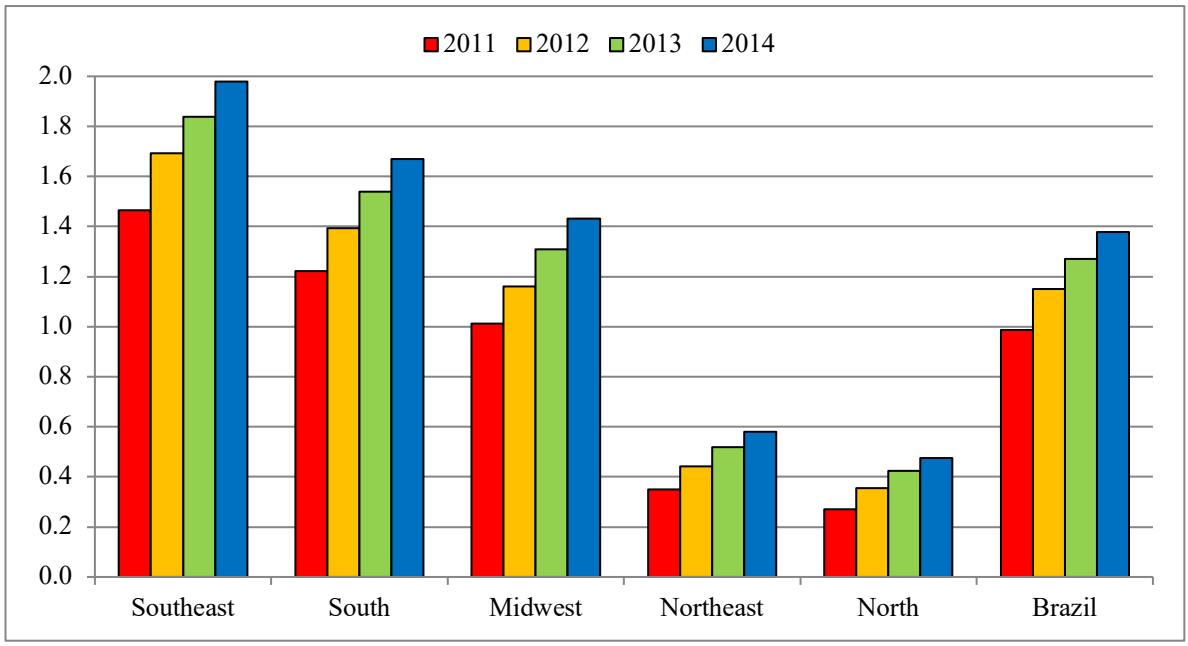
The present study follows Zhang (2013) to evaluate the Brazilian domestic digital divide, adopting the inequality index to analyze the relationship between income, Internet access and mobile phone access in the Brazilian population. The inequality of ICT access is estimated controlling for geographical, socioeconomic and demographic characteristics, using nationally representative data. The National Household Sample Survey (Pesquisa Nacional por Amostra de Domicílio, PNAD), from the Brazilian Institute for Geography and Statistics (Instituto Brasileiro de Geografia e Estatística, IBGE) in 2005, 2008, 2011 and 2013, contains information of individuals and households, including ICT goods utilization. Also, inspired by Dewan and Riggins' (2005) dimension of inequalities in ICT access and capacity of usage, the study includes logistic models to evaluate the disaggregation of digital divide among individuals in Brazil.

The estimates account for weighted measure of Internet use among different individuals (see James, 2008). Differences in population size between countries and variations in income among individuals with access to Internet within countries matter for the proposed concept of digital divide. Also, the influence of digital illiteracy on ICT access is investigated in the case of elderly individuals (older than 60 years).

Although there is scarcity of information about the digital divide and its determinants in Brazil, it is known that there is a positive trend in Brazilian's access to multimedia broadband communication in recent years, as well as in its regions (Fig. 1).

Fig.1. Brazilian broadband multimedia communication accesses per capita, according to state. 2011-2014.

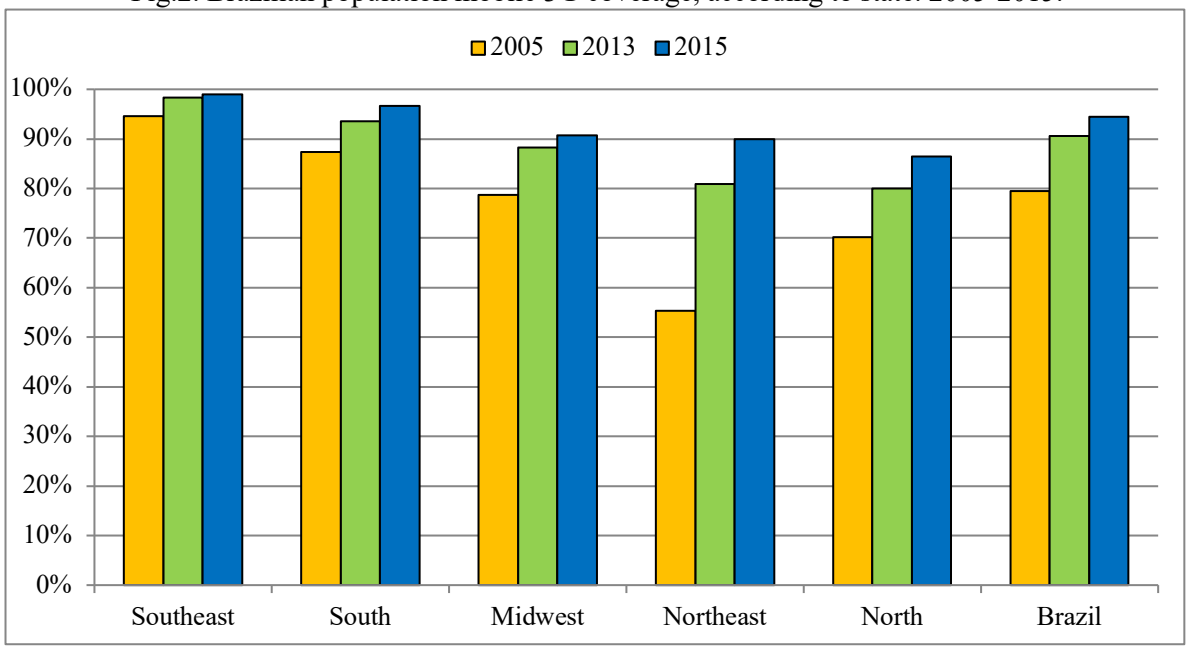
[1] Text available at http://unctad.org/en/PublicationsLibrary/dtlstict2013d8_en.pdf [06/05/2016].



Source: Authors using data of the Brazilian Telecommunications Agency (ANATEL).

The proportion of population covered by mobile 3G according to Brazilian regions from 2005 to 2015 has been increasing also (Fig. 2). It is important to highlight that, although 4G technologies have been disseminated since 2013, Brazilian regions have not still completely replaced 3G technology with full coverage. The data show evidence that more developed regions (Southeastern and Southern Brazil) has higher access to ICT goods in comparison to other regions.

Fig.2. Brazilian population mobile 3G coverage, according to state. 2005-2015.



Source: Authors using data of the Brazilian Telecommunications Agency (ANATEL).

In addition to the introduction, the article includes four additional sections. Section 2 presents the literature review on the determinants of the digital divide among populations and individuals worldwide. Section 3 outlines the databases and discusses the methodological strategy adopted in the study. Section 4 presents the results. Section 5 summarizes the main conclusions of the study.

2. Literature review

2.1. Digital divide in Brazil and Latin America

According to World Bank data, the Latin American and Caribbean countries' populations had increased Internet access in 2014, with 44.0% of the population having access to computers, 50.2% having Internet subscriptions, 9.8% having broadband subscriptions, and there being 115 subscribers of mobile per 100 people.

In comparison to the population of North America (82.1%, 87.3%, 31.5%, and 117, respectively), and Europe and Central Asia (74.4%, 79.2%, 23.7% and 126, respectively), the evidence suggests reduction of the technological gap between regions worldwide with regard to mobile technologies; however, there are still disparities in relation to broadband, Internet and computers access (Balboni, Rovira, & Vergara, 2011). In Brazil, 52.0% of the population has access to computers, 57.6% have Internet subscription, 11.7% have broadband subscription, and 139 are subscribers of mobile per 100 people.

According to Lutz-Baliamoune (2003), information and communication technology markets in Latin American countries are characterized by lack of competitiveness. However, the expansion of mobile telephony in Brazil is very striking: according to data from Instituto Brasileiro de Geografia e Estatística (IBGE, 2015), 72.8% of the population above 10 years old owned a mobile phone in 2013.

Furthermore, Internet service was available for at least 90% of the population living in 18 Brazilian states and Brazilian country capital in 2015, and the remaining states had Internet services coverage ranging from 71% to 88% of the population (Agência Nacional de Telecomunicações [ANATEL], 2016). Despite the optimistic scenario, high prices of mobile phones with Internet applications (smartphones and mobile 3G/4G) are still prohibitive and restrict the expansion of the Internet in prepaid sector of the mobile broadband market.

Macedo (2010) analyzes determinants of broadband access of the Brazilian municipalities and finds a positive impact of social wellbeing indicators (health, education and income per capita) on broadband access. Balboni et al. (2011) stress the need for additional empirical studies and use of individual-level data to evaluate the extent and the characteristics of the digital divide in Latin American and Caribbean countries.

2.2. Determinants of digital divide

Several studies investigate determinants of digital divide among countries worldwide and among individuals within countries. Results of the studies indicate that the main factors associated with individual and household-level inequalities in ICT access are: income, age, educational attainment, area of residence, and occupation.

Singh (2004) analyzes determinants of Internet use in Canada using a logit model applied to individual-level data. The results indicate that age (individuals in age brackets 15-34 and 35-54 years old), family income, educational level, and family of single parents with children present positive impact on Internet access.

Cerno and Amaral (2006) use a probit model in two stages to correct for selection bias in order to estimate determinants of Internet demand in Spain, and find that income has positive effect and age has negative effect. Chakraborty and Bosman (2005) propose the utilization of the Lorenz Curve and the Gini coefficient for measurement of inequality in personal computer ownership in the United States, using data at national, regional and state levels based on the Census between 1994 and 2001.

Vehovar, Sicherl, Hüsing, and Dolnicar (2006) criticize the utilization of bivariate comparisons for assessment of digital divide, proposing three different approaches to its measurement: the use of loglinear modeling to address interactions among determinants of the digital divide, the proposition of a synthetic composite indicator for digital divide measurement, and the use of time-distance methodology to investigate evolution in digital divide.

Demoussiss and Giannakopoulos (2006) use a probit model to estimate the determinants and the extent of use of Internet access in European countries. The results point to the fact that Internet use is associated with income, age, sex and family size. The Internet

utilization is lower among dial-up users, although it is not affected by costs of the dial-up connection.

Dudek (2007) uses a qualitative response model (probit) for Polish individual-level data with a set of usual explanatory variables adopted in studies involving the determinants of residential Internet access (income, gender, ethnic group, educational level, age, location of residence, and presence of children). The study shows that income, educational level and presence of children have a positive effect on residential Internet access. Rural dwellers and female-headed households are less likely to have residential access.

Wirthmann (2010) analyzes individual-level databases in order to verify differences among individuals in relation to access and use of ICT, providing valuable information for the application of measures on policy level. Montagnier and Wirthmann (2011) address digital divide among households and individuals by analyzing ICT usage patterns in 18 European countries, Korea and Canada. The authors show inequalities in computer and Internet access as result of socioeconomic characteristics through logistic regression and multi-linear regression models. Income, age, occupation, presence of children in the household, and living in urban areas are the most important determinants of Internet access. The intensity of Internet utilization is influenced by educational attainment, being student and income (in Europe) or broadband access (in Korea).

Vicente and López (2011) measure digital divide across and within 27 countries of the European Union, showing that, besides income, cultural and institutional factors may be determinants in ICT adoption. The European Commission (2012) adopts models of binary choice to estimate frequency of Internet use based on individual and household-level data from Europe Union, Norway and Iceland. There are positive associations of Internet use in relation to: i) younger individuals; ii) males; iii) urban regions; iv) higher income levels; v) employment and participation in the workforce; vi) non-shared Internet access (residential), and vii) broadband.

Loo and Ngan (2012) investigate the impact of mobile communications on digital divide in China. The authors show that mobile or wireless telecommunications present higher potential of narrowing digital divide in developing countries due to lower costs in comparison to fixed-line telephone services and personal computers. In addition, adoption of proactive government measures granting free access to broadband in mobile devices promotes a decrease in digital divide in China after 2005.

Çilan and Özdemir (2013) analyze domestic digital divide in Turkey using Latent Class Analysis. The results indicate that most of the Turkish population present low information technology competence, being recommended implementation of State policies designed to encourage elderly individuals to use ICT and to enhance educational attainment of people with low levels of education.

Prieger (2013) describes the extent of digital divide among urban and rural areas in the United States, indicating that rural areas present a higher number of slow-speed connection providers in comparison to urban areas, which have larger number of high-speed fixed and mobile providers. Moreover, there is an important influence of household demographics on mobile broadband usage gap.

Pantea and Martens (2013) examine the digital divide in the five largest European Union economies in relation to Internet use, considering general utilization and specific purposes (leisure, improving human capital and obtaining goods and services). The authors show a reversion in income-based digital divide referring to Internet use, indicating high intensity of use by low-income individuals. Also, higher education levels present negative impact on the use of Internet for leisure purposes and positive impact for educational purposes.

Albuja, Navas, Paguay, Moreno, and Nájera (2015) propose a technological Gini coefficient to identify and analyze the access to ICT inequality in Ecuador, and use expenditure in ICT services to indicate the consumption flow of ICT products and services, taking into consideration socioeconomic level. They propose public policies towards promotion of affordability capacities of citizens to ICT access in the country.

The present study investigates empirically the evolution in inequality of access to information and communication technologies among Brazilian individuals, based on the information on Internet utilization during the last three months and the ownership of mobile phone in the period from 2005 to 2013. Additionally, the analysis seeks to indicate the main determinants of digital divide in Brazil, including socioeconomic and demographic characteristics that may impose barriers to ICT access in the population.

2.3. Impact of elderly digital illiteracy on digital divide

Although it is clear that digital illiteracy represents an important obstacle to implementing digital inclusion policies, it should be noted that it does not necessarily refer to

an intergenerational gap in ICT abilities. Lutz-Baliamoune (2003) argues that utilization of mobile does not depend on literacy; however, it is important to notice that the study generally refers to mobile use for voice services. Thus, smartphones present additional challenges in terms of utilization regarding digital literacy due to supplementary applications, especially among elderly individuals.

In Brazil, approximately 86% of the adult population indicated mobile phone ownership in 2015 (Pew Research Center, 2016), being smartphone ownership rate approximately 41% among Brazilian adult population, highly concentrated among younger individuals (61% among individuals between 18 and 34 years old) with higher educational attainment (64%) and higher income (54%).

According to Santos, Azevedo, and Pedro (2013, p. 179), digital literacy is important because it allows access to opportunities and favorable experiences in social, economic, political, health and cultural areas, and brings individual and collective benefits.

Goldani (2004) points out that the Brazilian population is aging rapidly: elderly population increased from 4% of the total population in 1940 to 8.6% in 2000. Brazil is expected to have approximately 31 million elderly people by 2020. Unlike the case of Japan, where digital literacy depends on training for elderly individuals, according to survey conducted by the Japanese Government (Japan, 2001), the digital illiteracy in Brazil seems to be linked with absence of basic educational attainment. A significant part of the Brazilian elderly individuals is illiterate, thus, it seems reasonable to infer that increases in digital literacy will come along with increases in educational attainment, the first step to improvements in Internet access among elderly.

Educational attainment is reported to have positive effects on the spread of computers, and Internet use is particularly high among individuals with college degree (Davies, Pinkett, Servon, & Wiley-Schwartz, 2003). Educational attainment also affects individuals' access to information technologies (IT) and Internet (Selwyn, Gorard, & Williams, 2001). In the case of Brazil, using individual and household-level databases from PNAD (National Household Sample Surveys), Neri (2003) finds that adults with 12 years or more of study are the most likely to use personal computer (PC) and to have access to the Internet.

In a cross-sectional study, Pick and Azari (2008) find that government spending on education is positively related to ICT usage in both developed and developing countries.

Hoffman and Novak (1999 & 2012) indicate that the gap caused by differences in educational attainment among individuals is narrowing, considering the increase in proportion of less educated individuals among Internet users.

In Brazil, it is worth pointing out that there is higher prevalence of illiteracy and lower educational attainment among elderly individuals. Thus, digital exclusion among elderly may be higher due to lack of access to basic education in the past, especially considering that most of the Brazilian population was illiterate until 1950 (Goldani, 2004; Faria, 1991). The digital illiteracy problem among elderly individuals is a well-established phenomenon in the digital divide literature (Cerno & Amaral, 2006; Demoussis & Giannakopoulos, 2006; Japan, 2001; Singh, 2004).

2.4 Hypotheses

The hypothesis of the study refers to the evolution and the determinants of digital divide in Brazil between 2005 and 2013, considering that the digital divide is represented by proxy variables related to ICT utilization: Internet connection and mobile phone ownership.

In the context of the investigation, the main hypothesis is that there have been significant decreases in digital divide in the Brazilian population during the period analyzed, mainly due to increasing income per capita and educational attainment. The assumption is that digital divide determinants in Brazil are related to two dimensions; capacity of ICT utilization (individuals' characteristics: gender, age group, ethnic group, and educational attainment as a proxy for digital illiteracy), and access to ICT (external factors: household income per capita, occupation status, households with children and with elderly, household size, number of household residents, area of residence, and location of the household).

The assumption that population educational level can be a good proxy for digital illiteracy in the Brazilian case is based on Neri (2003) and McCowan (2007). This because of the low educational level and quality among Brazilians are still a challenge to be overcome and digital illiteracy is just one piece of illiteracy.

3. Data and methodological strategy

3.1. Data

The study uses individual-level data representative of the Brazilian population from the National Household Sample Surveys (PNAD), conducted by IBGE during 2005, 2008, 2011 and 2013, in order to estimate the evolution of Internet access and personal mobile phone ownership. Individuals were asked about any access to the Internet in the last three months and mobile phone ownership for individual use. The datasets also include households and individuals' characteristics that comprise the main determinants of Internet utilization services and mobile phone ownership, as highlighted by the literature (Table 1).

Table 1. Survey data - Brazilian individual's variables, according to year. 2005-2013.

Variable		Year								Total
		2005		2008		2011		2013		
Individuals	(obs.)	327,884		316,763		285,555		290,112		1,220,314
	(%)	26.87		25.96		23.40		23.77		100.00
Sex										
Male	(%)	48.22		48.21		48.05		48.19		48.17
Female	(%)	51.78		51.79		51.95		51.81		51.83
Age										
<15	(%)	11.59	*	11.23	*	10.59	*	9.89	*	10.86
15-59	(%)	77.10	*	76.35	*	76.01	*	75.58	*	76.29
>60	(%)	11.31	*	12.43	*	13.40	*	14.53	*	12.85
Ethnicity										
White	(%)	46.12	*	44.77	*	44.40	*	42.54	*	44.52
Non-white	(%)	53.88	*	55.23	*	55.60	*	57.46	*	55.48
Educational attainment										
Adults (+21 years old)	(years)	6.63	*	7.05	*	7.28	*	7.58	*	7.12
Elderly (+60 years old)	(years)	3.55	*	4.03	*	4.35	*	4.66	*	4.15
Household income per capita	(US$)	297.47	*	348.15	*	377.57	*	415.64	*	357.46
Household size	(n)	3.81	*	3.70	*	3.60	*	3.50	*	3.66
Type of family										
Family with children	(%)	59.83	*	56.42	*	53.72	*	51.65	*	55.57
Family with elderly	(%)	25.43	*	26.47	*	27.39	*	28.75	*	26.95
Employment status										
Employed	(%)	95.25	*	96.24	*	96.57	*	96.86	*	96.20
Student	(%)	1.74	*	1.22	*	1.02	*	0.91	*	1.24
Retired	(%)	0.10	*	0.06	*	0.06	*	0.06	*	0.07
Unemployed	(%)	4.75	*	3.76	*	3.43	*	3.14	*	3.80
Region										
North	(%)	12.91	*	12.57	*	15.17	*	15.84	*	14.05
Northeast	(%)	31.73	*	31.88	*	29.18	*	28.76	*	30.46
Southeast	(%)	29.30	*	29.41	*	28.59	*	29.13	*	29.12
South	(%)	15.33	*	15.09	*	16.33	*	15.94	*	15.65
Midwest	(%)	10.73	*	11.05	*	10.73	*	10.33	*	10.72
Area of residence										
Urban	(%)	84.06	*	84.67	*	85.51	*	85.10	*	84.81
Rural	(%)	15.94	*	15.33	*	14.49	*	14.90	*	15.19
Internet access										
Yes	(%)	23.96	*	41.19	*	53.83	*	58.03	*	43.52
No	(%)	76.04	*	58.81	*	46.17	*	41.97	*	56.48
Personal mobile phone										
Yes	(%)	37.92	*	55.20	*	69.81	*	75.54	*	58.81
No	(%)	62.08	*	44.80	*	30.19	*	24.46	*	41.19

Source: Authors using data of the Brazilian Institute for Geography and Statistics (IBGE).
Obs.: (*) At least 5% statistical significant differences among years.

The methodological approach of the study uses Deaton's (1997) strategy to convert individual income into household income per capita in adult equivalents, in order to split income available according to the household expenditure needs of each age group. Individuals younger than 14 years old are computed a weight of 0.75, in order to generate an equivalence scale (e_h):

$$e_h = (A_h + \Phi K_h)^{\theta} \qquad \text{Eq. (1)}$$

Where: A_h represents the number of adults in the household h, and K_h represents the number of children in the household h. The parameters Φ and θ should be equal to 0.75, the weight previously defined by Deaton (1997). Considering that Internet access depends on the structure of services supply in a large country like Brazil, a check on Internet services available for each state of the country is performed.

3.2 Methodological strategy

To explore evolution of digital divide and its determinants in Brazil, the investigation follows Zhang (2013) in using an inequality index, but using a concentration index instead of the Gini index. The analysis performed focus on income-related inequality in access to information and communication technology (ICT) goods in Brazil. The concentration curve (L), the concentration index (CI), and the horizontal concentration index (HI) are computed to identify inequality on Internet access and mobile phone ownership, considering proxy measurements of ICT goods.

Then, logistic regressions are estimated using the concentration index of ICT goods as dependent variable against independent variables representing individual characteristics and external factors related to ICT access, including socioeconomic, demographic and geographical variables. Following Wagstaff, van Doorslaer, and Watanabe (2003), the study presents disaggregation of the concentration index among the main determinants. However, as Dewan and Riggins (2005), the determinants are split into two dimensions of the inequalities in ICT: access to ICT goods and capacity of ICT usage, corresponding to external factors and individual characteristics according to Wagstaff et al. (2003), in order to identify the contribution of education, the proxy measure adopted to represent digital illiteracy.

The concentration curves (L) display the cumulative share of ICT access (*y*), that is, Internet connection and mobile phone ownership, accounting for the cumulative proportion of individuals of a population ranked from the poorest to the richest (Kakwani, 1980).

On the other hand, the concentration index (CI) allows to measure inequality according to socioeconomic position of individuals. The graphic of its curve shape is illustrative of inequality patterns among individuals. The concentration index (CI) may be written as:

$$CI = \frac{2}{n\mu} \sum_{i=1}^{N} y_i \, R_i - 1 \qquad \text{Eq. (2)}$$

Where μ is the mean of y and R_i is the fractional rank of the i^{th} person in the income distribution, and N is the sample size.

Finally, it is possible to estimate the horizontal inequality (HI) index to address measurement of inequality between groups of individuals with different personal characteristics regarding capacity of ICT usage, calculated from the difference between the concentration index (CI) and the concentration index for the called individuals' capacity of ICT usage (CN), controlled by individual characteristics:

$$HI = CI - C_N \qquad \text{Eq. (3)}$$

In addition, the concentration index may be disaggregated in terms of its determinants by using a set of independent variables that affect access to ICT goods, according to individual characteristics and external factors (Wagstaff et al., 2003). The CI disaggregation is estimated using a logit model with the concentration index as dependent variable. The model defines y^* as latent non-observed variable that describes the utilization of ICT goods by the individual, where β_k is the coefficient of explicative variable k and ε is an error term:

$$y^* = \beta_1'.x + \beta_2'.w + \varepsilon \qquad \text{Eq. (4)}$$

Matrix x includes a set of variables of individual characteristics and matrix w includes other independent variables associated with external factors. It is possible to show that (Wagstaff et al., 2003):

$$IC = \frac{1}{\mu}\sum_k(\beta_k \, \bar{x}_k)C_k + \frac{GC}{\mu} \qquad \text{Eq. (5)}$$

Where $\mathrm{GC} = \frac{2}{\mathrm{N}}\sum_{\mathrm{i}=1}^{\mathrm{N}} \varepsilon_{\mathrm{i}}\mathrm{R}_{\mathrm{i}}$ is the generalized concentration index for the residual (ε) and $\bar{x}_k$ is the mean of x_k. Two different specifications of logistic model are tested in order to verify

main determinants of access to ICT goods of the Brazilian population. The observed information of y is defined by:

$$y = 1 \Leftrightarrow y^* > 0 \;\; \& \;\; y = 0 \Leftrightarrow y^* \leq 0 \qquad \text{Eq. (6)}$$

As already described, the dependent variable (y) in each model describes whether the individual had access to two types of ICT goods: i) Internet connection, and ii) mobile phone ownership.

The coefficients (β_k) of the non-linear logistic regression model (logit) are estimated, as Dewan and Riggins (2005) indicated, against individuals' capacity of ICT utilization (x) and other external factors that determine access to ICT goods (w).

Matrix x includes gender, age group, ethnic group, and educational attainment to measure individuals' capacity of ICT usage. Matrix w includes household income per capita, occupation status, households with children and with elderly, household size, number of persons in the households, area of residence (rural or urban), and location of the household (region and state) to measure access to ICT goods.

Logistic regression models exclusively for elderly individuals (older than 60 years) are also estimated, in order to account for elderly's digital illiteracy, evaluated using educational level.

4. Results

The Brazilian population's characteristics show trends related to occurrence of demographic transition, marked by increasing proportion of elderly individuals, decreasing number of families with children, and reduction of average number of household members (shown in Table 1). Simultaneously, there are evidences of improvements in socioeconomic trends during the last decade: higher rates of educational attainment, employment and urbanization among Brazilian individuals. Regarding utilization of ICT, there is significant increase in Internet access and mobile phone property throughout the period investigated.

The results of logistic regressions referring to determinants of Internet access throughout the period investigated show that, in general, younger, white and educated individuals, having a higher income levels, and living in larger households (measured by household size) influences positively the likelihood of Internet access (Table 2).

However, there are significant changes occurring between 2005 and 2013, especially related to the probability of Internet utilization by women and families with children, which presents changes in effects (from negative to positive) along the decade. There are evidences of intense Internet usage among youngsters (individuals younger than 15 years old), especially students. Apart from that, individuals living in rural areas have reduced probability of Internet access, possibly due to lack of infrastructure.

Elderly individuals also have lower access to the Internet; however, it is important to point out that the effect has been reducing during the period analyzed, especially due to improvements in educational attainment levels among older individuals (shown in Table 1). That is, considering the convergence of effects from coefficients of age (individuals younger than 15 year old and individuals older than 60 years old) and educational attainment (years of education), the impact of digital illiteracy in Brazil seems to be significantly attached to lack of access to formal education, instead of difficulties in accessing or using the Internet.

The effect is particularly applicable to the probability of Internet access among elderly individuals, considering that the study analyzes combined effects of age and education by adopting an interaction variable in the model (Table 5, Appendix), in order to test for nonlinear effects of adequacy of educational attainment according to age of the individual. The indicator of educational attainment per age represents an indicator positively correlated with ICT utilization, since education influences positively ICT utilization and age influences negatively ICT utilization. The inclusion of the interaction term of education per age shows positive impact on Internet access probability; however, it significantly reduces the direct effects of age and educational attainment.

Table 2. Estimates of logistic regression for Internet access in Brazil. 2005-2013.

Year	2005	2008	2011	2013
Dep. Variable	Internet Access	Internet Access	Internet Access	Internet Access
Female	-0.073***	-0.046***	-0.007	0.037***
	(0.011)	(0.009)	(0.009)	(0.008)
Age<15	1.560***	1.854***	1.615***	1.360***
	(0.023)	(0.020)	(0.021)	(0.022)
Age>60	-0.817***	-0.726***	-0.682***	-0.621***
	(0.036)	(0.027)	(0.024)	(0.021)
White	0.253***	0.197***	0.237***	0.249***
	(0.018)	(0.015)	(0.015)	(0.016)
Education (years)	0.259***	0.241***	0.232***	0.219***
	(0.003)	(0.002)	(0.002)	(0.002)
Household size	0.155***	0.186***	0.214***	0.218***
	(0.007)	(0.006)	(0.007)	(0.008)
Household with children	-0.186***	-0.105***	-0.001	0.111***
	(0.021)	(0.018)	(0.020)	(0.020)
Household with elderly	-0.245***	-0.237***	-0.300***	-0.353***
	(0.025)	(0.021)	(0.021)	(0.021)

Household income	1.237***	1.033***	0.974***	0.983***
	(0.015)	(0.013)	(0.014)	(0.014)
Employed individual	-0.081**	0.256***	0.212***	0.201***
	(0.038)	(0.035)	(0.037)	(0.036)
Student	1.318***	1.555***	1.581***	1.530***
	(0.052)	(0.064)	(0.080)	(0.084)
Retired	-0.285	-0.565**	-0.447*	-0.313
	(0.233)	(0.239)	(0.245)	(0.214)
Rural	-1.284***	-1.289***	-1.429***	-1.260***
	(0.068)	(0.046)	(0.035)	(0.032)
Constant	-10.610***	-8.582***	-7.579***	-7.367***
	(0.098)	(0.099)	(0.093)	(0.094)
R^2	0.3861	0.3371	0.3425	0.3274
Observations	326,085	315,492	284,870	289,261

Obs.: * p<0.05; ** p<0.01; *** p<0.001. Standard errors in parentheses. State and region dummies included.

It is possible to identify similar effects observed in Internet access referring to the evolution and the main determinants of mobile property. Higher income and higher education influence positively the probability of mobile phone ownership in Brazil, as well as being male, white and employed or student (Table 3).

The main differences refer to results for young individuals (aged under 15 years old), who are less likely to have mobile phones (probably due to parental concerns), and for household size, showing that individuals living in households with higher number of family members are less likely to have a mobile phone. The last result is particularly interesting as it refers to potential strategies of public policy directed at massive Internet access based on mobile phone property.

However, there is increasing probability of mobile phone ownership among individuals in households with children and individuals with higher educational attainment, while the effect of income and ethnicity are declining along the period analyzed. There are evidences of declining effects of certain determinants of mobile phones property (sex and being elderly) along time. The probability of having a mobile phone has been increasing among the Brazilian population in general (shown in Table 1), turning into a device commonly available in comparison to other ICT devices, due to declining prices and its utility on daily tasks.

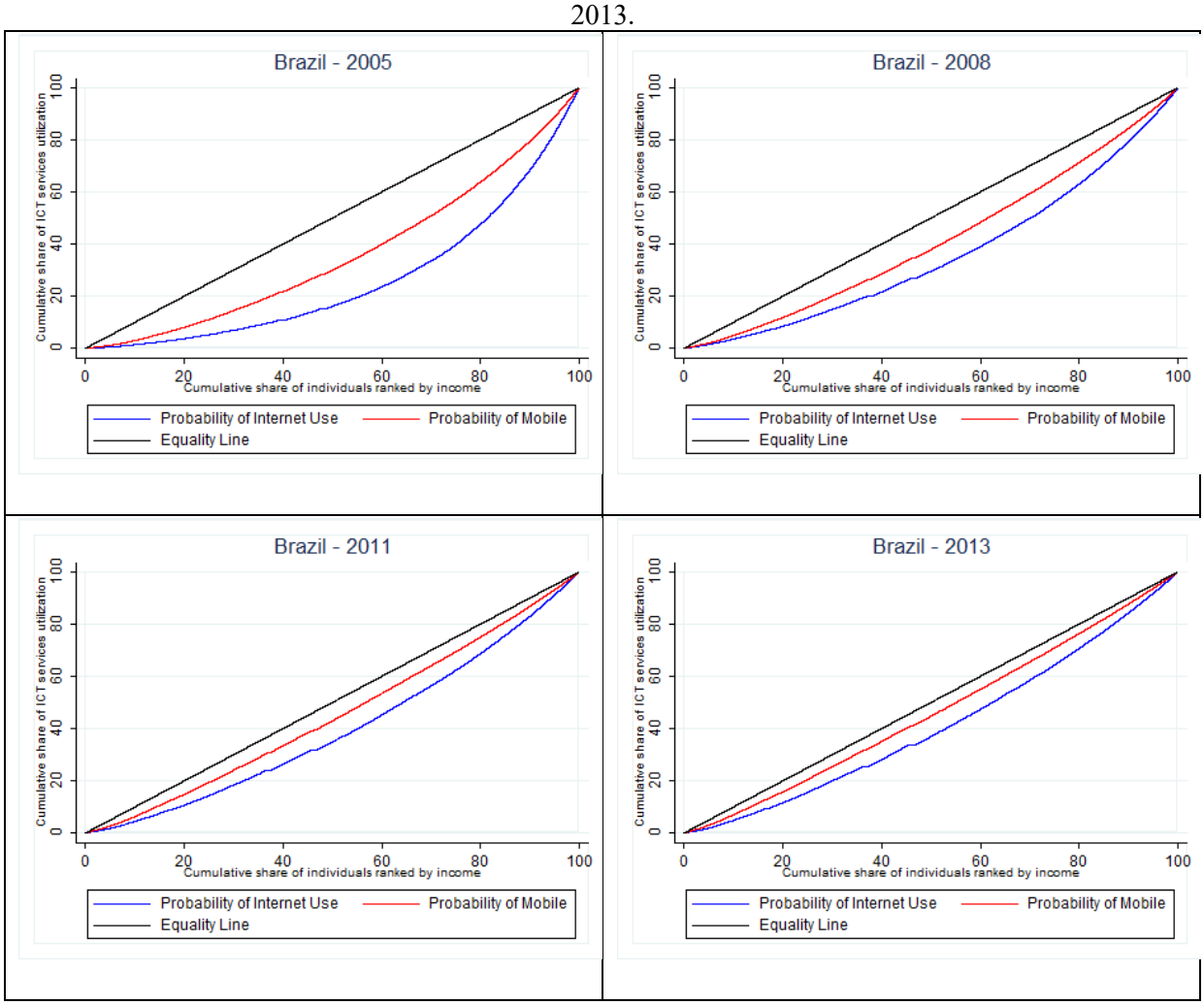
[Insert Table 3]

An important evidence to be highlighted in the estimates of mobile phone ownership refers to barriers in access to certain ICT goods due to income, educational attainment and, possibly, limitations of the electronic device for specific uses (e.g., Internet access), especially

among elderly individuals. The results show that the probability of mobile phone property has been increasing along the period analyzed, including decrease in negative effect of being elderly and increase in positive effect of education, indicating that mobile utilization may involve higher complexity in comparison to Internet access.

Furthermore, the results shed light on the promotion of education as public policy strategy to foster access to information and communication technologies using mobile services, because Brazilian elderly individuals have significantly lower educational attainment than younger individuals (shown in Table 1). According to the data, trends of increasing educational attainment of the Brazilian population may help overcome the problem of digital illiteracy, although there is ongoing debate on the quality of education in Brazil.

Fig.3. Evolution of concentration curves of Internet utilization and mobile property in Brazil. 2005-2013.



Inequalities in personal mobile phone ownership are decreasing sharply over time, especially in comparison to inequalities with regard to Internet access in Brazil. The digital

divide among Brazilian individuals may be minimized by the convergence in ICT access due to acquisition of electronic devices at lower prices, according to the evolution of inequalities in Internet access and mobile property in Brazil between 2005 and 2013 (Fig. 3).

Table 3. Estimates of logistic regression for mobile phone property in Brazil. 2005-2013.

Year	2005	2008	2011	2013
Dep. Variable	Mobile	Mobile	Mobile	Mobile
Female	-0.232***	-0.083***	-0.017	0.020*
	(0.011)	(0.010)	(0.011)	(0.012)
Age<15	-0.510***	-0.899***	-1.162***	-1.157***
	(0.019)	(0.018)	(0.019)	(0.018)
Age>60	-1.077***	-1.000***	-0.973***	-0.960***
	(0.024)	(0.022)	(0.023)	(0.022)
White	0.071***	0.055***	0.041***	0.012
	(0.013)	(0.014)	(0.015)	(0.015)
Education (years)	0.154***	0.153***	0.157***	0.171***
	(0.002)	(0.002)	(0.002)	(0.002)
Household size	-0.082***	-0.087***	-0.107***	-0.116***
	(0.004)	(0.004)	(0.005)	(0.005)
Household with children	0.189***	0.292***	0.368***	0.394***
	(0.013)	(0.015)	(0.017)	(0.018)
Household with elderly	-0.249***	-0.333***	-0.427***	-0.463***
	(0.017)	(0.017)	(0.02)	(0.02)
Household income	0.768***	0.714***	0.614***	0.622***
	(0.010)	(0.010)	(0.011)	(0.011)
Employed individual	0.200***	-0.002	0.104***	0.131***
	(0.030)	(0.033)	(0.039)	(0.044)
Student	0.443***	0.216***	0.040	0.152*
	(0.045)	(0.054)	(0.071)	(0.078)
Retired	0.086	-0.003	-0.081	0.161
	(0.180)	(0.224)	(0.243)	(0.229)
Rural area	-0.703***	-0.755***	-0.903***	-0.912***
	(0.040)	(0.040)	(0.031)	(0.030)
Constant	-4.376***	-3.552***	-2.407***	-2.112***
	(0.061)	(0.069)	(0.072)	(0.082)
R^2	0.2503	0.2442	0.253	0.265
Observations	326,085	315,492	284,870	289,261

Obs.: * p<0.05; ** p<0.01; *** p<0.001. Standard errors in parentheses. State and region dummies included.

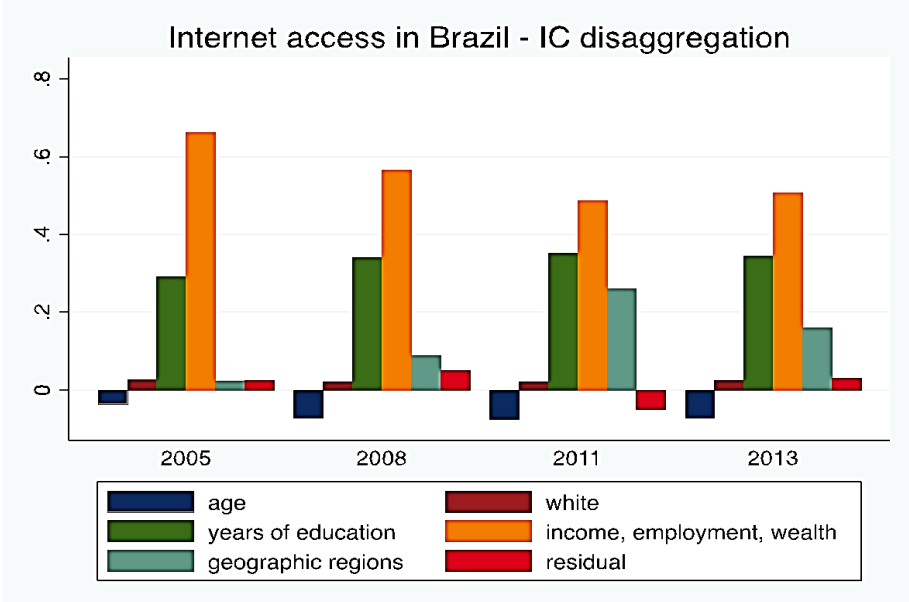
The datasets from the Brazilian Institute for Geography and Statistics allow the disaggregation of the effects from diverse determinants of the concentration index (CI) for Internet access and mobile ownership. That is, it is possible to identify the main groups of determinants in inequalities regarding the digital divide among Brazilian individuals: household income per capita and educational attainment (Figs. 4-5).

Educational attainment, considered one of the main dimensions of capacity of ICT utilization, presents an increasing trend along the period analyzed. Thus, access to information and communication technology may be improved significantly by promoting education in Brazil.

However, it is important to point out that employment and number of household members are also important determinants of the inequalities in access to ICT; although the impacts in inequality coefficients related to income, employment and number of household members have been declining during recent years (Figs. 4-5).

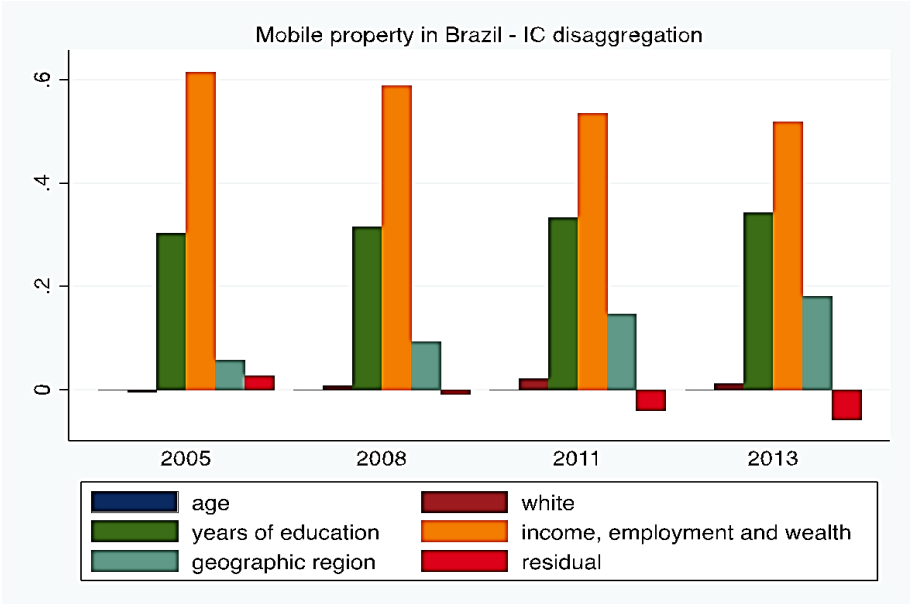
The results may be related to the digital convergence due to reduction of prices of ICT goods, one of many consequences of technological convergence/evolution, allowing improvement of access among poorest individuals in the Brazilian population along time.

Fig.4. Main determinants of Concentration Index for Internet access in Brazil. 2005-2013.



Additionally, geographic localization (including state and urban/rural areas) shows an increasing trend as determinant of inequalities on Internet access and mobile property. The results indicate that, although statistics from the Brazilian Telecommunications Agency (Agência Nacional de Telecomunicações, ANATEL) demonstrate growing broadband access and 3G coverage, there are still significant infrastructural differences according to regional location.

Fig.5. Main determinants of Concentration Index for mobile property in Brazil. 2005-2013.



Coefficients of concentration indexes (CI) and horizontal inequality (HI) indicate that inequality is decreasing both on Internet access and on mobile property along time (Table 4). Recently, mobile ownership reaches a significantly lower degree of general inequality (CI_{2013}=10%) in comparison to Internet access (CI_{2013}=19%).

Except personal characteristics that may limit the capacity of ICT utilization, HI indicators bring evidence of inequalities referring to external factors, that is, excluding the effects of individual's skills (especially educational attainment in the case of the Brazilian population).

The coefficients of concentration indexes (CI) and horizontal inequality (HI) for elderly individuals are also presented in order to verify the impact of ageing on Internet access and on mobile property, promoting an intergenerational digital divide in Brazil. It is possible to note higher coefficients for elderly individuals, especially referring to the general determinants of ICT access (concentration indexes), connected with low level of education.

Referring to personal capacity of ICT utilization, represented by the difference between concentration index and horizontal inequality, it is possible to notice convergence of inequality coefficients for mobile phone ownership between the general population and elderly individuals; showing that mobile phone property is limited by external factors more than by personal skills among the whole Brazilian population.

Regarding Internet access, the results confirm recent concerns with regard to elderly digital illiteracy. Although formal education has been increasing among elderly individuals

along the period analyzed, educational attainment is still significantly lower among elderly in comparison to the general Brazilian population. Lower educational attainment associated with lower household income per capita are important limiting factors to Internet access among elderly individuals, due to costs and skills required to obtain broadband connection in Brazil.

Table 4. Evolution of Concentration Index and Horizontal Inequality Index in Brazil. 2005-2013.

Internet access				
Full sample	2005	2008	2011	2013
Concentration Index	49%	31%	22%	19%
Horizontal Inequality	35%	22%	16%	14%
Elderly	2005	2008	2011	2013
Concentration Index	65%	53%	41%	35%
Horizontal Inequality	46%	38%	29%	24%
Mobile phone property				
Full sample	2005	2008	2011	2013
Concentration Index	31%	20%	12%	10%
Horizontal Inequality	21%	13%	8%	6%
Elderly	2005	2008	2011	2013
Concentration Index	41%	29%	18%	15%
Horizontal Inequality	22%	17%	9%	7%

Comparing inequality levels between Internet access and mobile phone property, it is possible to verify that Internet access presents higher concentration indexes due to socioeconomic determinants in Brazil than mobile ownership during the period analyzed (Table 4, Fig. 3). The result reinforces the potential for adoption of mass Internet access policy based on granting free wireless broadband access in public places, which has been proposed by governments of certain Brazilian cities, grounded on examples from other countries.

Another public policy strategy that may disseminate mass Internet access among the Brazilian population and promote equality in information and communication technology utilization might be the implementation of incentives (subsidies or tax discounts) for household Internet subscription and/or acquisition of personal mobile phone with Internet connection (smartphone), although its utilization may present certain limitations in comparison to computer-based access to the Internet.

The identification of technological convergence patterns on mobile ownership in Brazil, similar to other countries (Khalil & Kenny, 2008), may support evidences of reduction in the digital divide among the Brazilian population, particularly referring to socioeconomic obstacles, excluding digital illiteracy. Aspects related to personal capacity of ICT utilization

should be addressed specifically through education policies, including assessment of education quality.

5. Discussion

The main goal of the paper is to perform an empirical investigation on the evolution of the digital divide among Brazilian individuals, including its main determinants, using valuable survey data representative at national level from 2005, 2008, 2011 and 2013. Inequality in Internet access and mobile phone property among individuals of the Brazilian population represent the digital divide in using information and communication technologies (ICT) goods available in Brazil.

The study also seeks to fill the gap in empirical studies using individual and household-level data on Internet access and personal mobile phone property in Latin American countries, according to recommendations published by the United Nations (Balboni et al., 2011).

Two dimensions of the digital divide are investigated in the study: inequality in access to ICT and inequality in capacity of ICT utilization. The results of logistic models estimated using the Brazilian datasets allow the disaggregation into main determinants of inequality indexes for ICT access. The evolution of the digital divide assessed by inequality indexes and its disaggregation suggests that: i) education is the main barrier for personal capacity of ICT goods utilization, being connected to digital illiteracy; and ii) income, employment and number of household members are major barriers to access ICT goods.

However, the impact of external barriers to ICT access has been declining in recent years; whilst effect of educational attainment remains expressive throughout time. The results show that education accounts for the majority of inequalities in personal skills for ICT utilization, that is, improvements in education policy represent an effective strategy to reduce the digital divide among individuals of the Brazilian population in the long run by reducing barriers related to digital illiteracy, evidence that is supported by Davies, Pinkett, Servon, and Wiley-Schwartz (2003).

Regarding the challenges of ageing, digital illiteracy has been considered the main restriction for ICT utilization among elderly individuals (Goldani, 2004; Cerno & Amaral, 2006; Demoussis & Giannakopoulos, 2006; Faria, 1991; Japan, 2001; Singh, 2004). The results of the study suggest that digital illiteracy, measured by years of education, has negative impact

on Internet access among elderly individuals; however, the effect of ageing is declining in Brazil along the period from 2005 to 2013.

Furthermore, the effect of ageing is significantly higher in reference to mobile phone property in comparison to Internet access, showing that computer-based Internet access may be more useful for elderly individuals than mobile-based Internet access. The barriers to mobile phone property among elderly individuals in Brazil concentrate on external factors linked to ICT goods acquisition, according to horizontal inequality coefficients estimated.

That is, low income and high costs to purchase mobile phones and possibly difficulties in using applications in smartphones affect the ability to overcome the digital divide among elderly individuals; especially considering extended uses of smartphones other than voice services, activities that need large screens. However, the impact of ageing in digital divide tends to decline along time in Brazil due to effect of schooling, because the educational attainment of younger individuals is higher than the educational achievements observed currently among elderly individuals in Brazil.

Although barriers of access to ICT have been declining due to digital convergence and prices reduction, the findings of the investigation corroborate that adoption of short-term public policy for promoting mobile Internet access is suitable for Brazil, according to the proposal of the Knowledge Society. Although there are limitations to Internet access by mobile phone for certain purposes, the supply of free Internet access in public places may promote reduction in digital divide observed with regard to Internet access among diverse socioeconomic groups in the Brazilian population.

Additionally, the study allows the analysis of possibilities to increase equality in access to information and communication technologies in the country through public policies based on incentives for household Internet subscription and/or acquisition of personal mobile phones with Internet connection, especially based on reduction of taxes on ICT goods, since there are still high taxes in Brazil applied to ICT products, which are considered to be similar to games and entertainment goods (i.e., sin taxes).

In sum, the study brings important evidences of evolution and determinants of the digital divide in Brazil, providing contributions to support the development of innovative strategies in ICT policy that address the reduction of inequalities in access to ICT and the minimization of inequalities in capacity of ICT utilization. The evidences suggest that there is

room for short-term policy for promotion of mass Internet utilization in Brazil, in order to reduce the share of digital divide in ICT access attributable to costs of ICT goods acquisition. A limitation of the study refers to the utilization of educational level of individuals as a measure of digital literacy. However, it is important to point out the absence of other proxy variables in Brazilian databases representative at population level. In addition, as the Brazilian educational level and quality are still low, it is reasonable to pose that it accounts for the major part of difficulties in digital literacy yet.

Mobile technology is improving quickly, outgrowing some of its important limitations related to Internet utilization. Considering that the purpose of mass Internet access is to incentive the spread of information, the adoption of public policies that encourage mobile Internet access may also enhance individuals' social support network and economic opportunities. Mobile broadband access enables individuals to have access to relevant information and communication tools that may be carried out with fairly regular quality of access anywhere, at any time.

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Appendix

Table 5. Estimates of logistic regression for Internet access in Brazil, including interaction variable between age and education. 2005-2013.

Year	2005	2008	2011	2013
Dep. Variable	Internet Access	Internet Access	Internet Access	Internet Access
Female	-0.009***	-0.008***	-0.002*	0.004***
	(0.001)	(0.001)	(0.001)	(0.001)
White	0.039***	0.038***	0.038***	0.036***
	(0.002)	(0.002)	(0.002)	(0.002)
Age	0.0005***	-0.0004***	-0.0017***	-0.0022***
	(7.4e-05)	(8.4e-05)	(9.3e-05)	(9.8e-05)
Years of education	0.010***	0.004***	0.012***	0.016***
	(0.0004)	(0.0004)	(0.0004)	(0.0003)
Years of education per age	0.606***	0.987***	0.752***	0.569***
	(0.013)	(0.013)	(0.012)	(0.013)
Household size	0.0160***	0.0213***	0.0256***	0.0270***
	(0.0008)	(0.0009)	(0.0011)	(0.0013)
Household with children	-0.0066**	0.0104***	0.0202***	0.0309***
	(0.00264)	(0.00271)	(0.00291)	(0.00296)
Household with elderly	-0.049***	-0.039***	-0.044***	-0.052***
	(0.00287)	(0.00307)	(0.00299)	(0.00302)
Household income	0.171***	0.176***	0.152***	0.148***
	(0.00175)	(0.00175)	(0.00175)	(0.00176)
Employed individual	-0.0358***	0.0022	-0.0052	-0.0005
	(0.00432)	(0.00583)	(0.00609)	(0.00591)
Student	0.129***	0.137***	0.118***	0.113***
	(0.00772)	(0.00908)	(0.00935)	(0.00881)
Constant	-0.929***	-0.865***	-0.584***	-0.519***
	(0.0175)	(0.0156)	(0.0132)	(0.0137)
R^2	0.366	0.398	0.409	0.389

Observations	326,085	315,492	284,870	289,261

Obs.: * p<0.05; ** p<0.01; *** p<0.001. Standard errors in parentheses. State and region dummies included.