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Broadband Market Sizing in Brazil

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Abstract

The objective of this study is to predict the potential broadband market in Brazil. This is done by combining information from two national databases: the 2010 census and the 2015 PNAD (National Household Survey). The 2015 PNAD is used to estimate the probability of the household accessing internet by broadband technology, using a logit regression. The broadband market is predicted using the estimated model with the same covariates found in the 2010 census. The prediction indicated a potential market of 45 million households, an additional of 6 million households in relation to the current situation. The new size of the broadband market is estimated if there is a 10% increase in the average penetration of broadband services in the main metropolitan areas. In this scenario, the new market covers 50.7 million households.

Key words: broadband, internet, logit regression, potential market, prediction

JEL: L51, L96.

1. Introduction

Broadband technology is nowadays considered to be indispensable in the society we live in. It brings overarching benefits, encompassing telephone services, computer networks, satellite connections, to cite a few. As a result, broadband expansion takes on a significant economic effect, as pointed out by several studies (Stiroh, 2002; Czernich et al., 2009; Qiang & Rossotto, 2009; Katz, 2008 and 2012; inter alia). The economic impact of broadband expansion has also been estimated in Brazil and has been deemed just as positive, as highlighted by Macedo and Carvalho (2010a; 2010b). Quite recently, Carvalho, Mendonça, and Silva (2017) have investigated this impact and demonstrated that a 1% expansion in broadband access pushes the gross domestic product (GDP) up by 0.077%, showing a heterogeneous behavior across Brazilian regions.

Despite the perceived importance of broadband access in Brazil, a lot still has to be done, unlike landline phone services, which have already been universalized. Data from the Brazilian Telecommunications Regulating Agency (Anatel) show that broadband service infrastructure is still poor in Brazil. For instance, 2,325 Brazilian municipalities do not have access to fiber backhaul (Note 1), and 58% of them are located in the northern and northeastern regions, which means that 14% of the Brazilian population is not covered by this service. Even in those municipalities with access to fiber backhaul, broadband service quality is below expectations. On average, broadband speed in the 2,221 municipalities with access to fiber backhaul is 5 Mbps (Note 2). The northern and northeastern regions have the lowest speeds.

Bearing in mind the current situation of broadband services in Brazil, it should be noted that the Brazilian broadband market is clearly limited, not because of a slowdown in demand, but because of the current status of its infrastructure. It is then conjectured that there exists a large potential for expansion of this service on the demand side if broadband access is expanded. Not only public policy managers, but also telephone companies should take a close interest in broadband expansion. The former should do that because universalization of this service is supposed to meet some prioritization criteria, and market sizing is one of them. The latter, because profitability should, in principle, be associated with the level of demand.

The aim of the present study is to estimate the size of the potential broadband market in Brazil. Given that broadband provides direct usefulness to users, in addition to allowing access to other important services, we use internet access for broadband market sizing. Sizing is estimated based on the prediction of the total number of households that could have broadband internet access.

In addition, the sizing of the broadband market is estimated if there is a 10% increase in the mean penetration of services in the major metropolitan areas in Brazil. The estimation results indicate that the potential expansion of broadband access (fixed broadband or 3G and 4G on cell phones) covers 45 million households, i.e., an increase of nearly six million households when compared to the current scenario. With a 10% increase in broadband access in major metropolitan areas, there is a new potential market for 50.7 million households, i.e., an increase greater than 10 million households.

This paper is structured into four sections, aside from the introduction. Section 2 briefly presents a literature review on the demand for broadband services. It is important to bear in mind that our study, for reasons that will be explained later, does not refer strictly to the estimation of the demand function. The term "sizing" seems more appropriate to our goals. Section 3 describes the methodology used, showing the procedures that will be used in Section 4 for the estimation of the probability model for broadband access and prediction of broadband market sizing. Section 5 contains the final remarks.

2. **Literature Review**

The object of analysis herein is the broadband market sizing in Brazil. In principle, it could be reasonable to associate this topic with studies on the demand for broadband services available in the literature. This, however, is not perfectly correct, as we do not have the representative variable for broadband price at a disaggregate level that is compatible with the databases used in this paper. To overcome this drawback, our paper should be construed as an exercise for predicting the potential broadband market. Anyway, it is reasonable to associate the research subject with the literature on demand for broadband services.

The determinants of demand for broadband services have been poorly investigated in the literature. Koutroumpis (2009) estimated a simultaneous equations model to assess the supply and demand for broadband services, including data from 22 OECD countries. Macedo and Carvalho (2010) apply a similar model to that estimated by Koutroumpis, using data on Brazilian states. In the models estimated by Macedo and Carvalho (2010), the variable demand is defined as "density expressed as number of broadband accesses per 1,000 inhabitants" (*op. cit.*, p. 13). The explanatory variables of demand were: price; GDP *per capita*, and human capital (measured in years of schooling among adults). According to the authors, the larger the human capital, the larger the demand for broadband internet services.

Macedo and Carvalho (2010) also observed an inverse relationship between price and demand. The service was quite elastic for price movements, as described in the literature of that study. In the models that included human capital, the results were satisfactory (positive and significant sign), showing that the more educated individuals are, the higher the demand for broadband access. The international literature proposes the same variables for the assessment of the broadband demand function. Röller and Waverman (1996) estimate the demand for telecommunications infrastructure in which price and real GDP are explanatory variables.

Cadorna et al. (2007) assess the residential demand for internet access in Austria, with a focus on broadband connections. The authors used a nested logit model, which is a discrete choice model. They used data from a survey of more than 4,000 households about the type and characteristics of internet connection and about the characteristics of residents. Modeling was done using a utility function for internet access, according to which the utility obtained by a consumer for using a specific product depends on the characteristics of the product and of the consumer (Cadorna et al., 2007). The authors assume that consumers purchase the internet access plan that provides them with the best utility. The variables related to the product include the different types of technology – Digital Subscriber Line (DSL), broadband, cell phone, etc. –, and price and household characteristics were age, level of education, and household size. The results of that study show that the demand for broadband internet is elastic. Access services are quite elastic (elasticity > 2.5 for DSL, cable, and cell phone) in areas where several types of broadband access (DSL, cable, and cell phone) are available. This could indicate that different broadband access technologies are close substitutes near substitutes.

Finally, the study by Wohlers, Abdala and Kubota (2009) is noteworthy. Those authors demonstrate that broadband access is a product whose demand is quite sensitive to price movements, as also pointed out by Ávila (2008) and Guedes et al. (2008).

3. Methodology

As mentioned in the introduction, the aim of this study is to predict the size of the potential broadband market in Brazil based on the total number of households estimated to have access to the internet, and to establish the new size of the broadband market if the average penetration of services in the major metropolitan areas increases by 10%. To achieve that, we used information from two databases: the 2010 census and the 2015 PNAD (National Household Survey), both conducted by the Brazilian Institute of Geography and Statistics (IBGE). The 2010 census data are used for predictions, whereas the 2015 PNAD is used to estimate a model that associates the dependent variable related to broadband access to the possible predictor variables. Thus, the first step consisted of the selection of compatible predictor variables from the 2010 census and the 2015 PNAD.

The choice of the variables was based on the study by Cadorna et al. (2007), whose scope and methodology has a lot in common with our study. Those authors estimate the residential demand for internet access in Austria, focusing on broadband connections and using a discrete choice nested logit model. However, unlike Cadorna et al. (2007), who use the characteristics of residents as dependent variable, this study utilizes the physical and socioeconomic characteristics of households as predictor variables, determining whether the household has a broadband connection.

The compatible predictor variables chosen from the 2010 census and 2015 PNAD are listed next (Note 3).

- Urban: whether the household is located in the urban area (dummy);
- TV: whether the household has a TV set (dummy);
- Landline: whether the household has a conventional landline (dummy);
- Fridge: whether the household has a refrigerator (dummy);
- Rental: whether the household has been rented (dummy);
- Density: number of residents per room;
- Rooms: number of rooms;
- Residents: number of residents;
- H-income: household income of all residents; and
- Rental$: monthly rent paid in the reference month.

We used the 2010 census for the predictions because it provided information about the households and this information could be expanded through weights established for the Brazilian territory as a whole. However, as the 2010 census had little information on internet use, the econometric model for assessing broadband access had to be estimated based on the 2015 PNAD, which contains more up-to-date and in-depth information about broadband services. Figure 1 shows the depth of information on internet access (broadband) based on the 2015 PNAD data. This database does not allow for disaggregate data on municipalities, states, metropolitan areas, non-metropolitan urban areas, and rural areas.

32.4 The household internet access is via:			
a. 3G or 4G?	**02424**	2 □ Yes	4 □ No
b. dial-up connection (as in a regular phone call)	**02425**	2 □ Yes	4 □ No
c. Broadband (ADSL, VDSL, cable TV, fiberoptic cable, satellite or some type of radio, such as WI-FI and WiMAX?	**02426**	2 □ Yes	4 □ No
(Go to 32a)			

Figure 1. 2015 PNAD: internet access

Source: 2015 PNAD survey/IBGE.

In order to use the census variables appropriately in a model whose parameters are estimated based on PNAD data, it is necessary that the variables of this database be on the same scale as that of the census, i.e., that they be rescaled. The 2015 PNAD variables were rescaled to the 2010 census data by using, for each variable, the transformation seen in equation (1), which is a translation of 2015 PNAD variables. That was done by equating the normalized variables for both databases.

$$x_{2010} = \left((x_{2015} - \bar{x}_{2015})/\sigma_{2015}\right) * s_{2010} + \bar{x}_{2010} \quad (1)$$

Where:

x_{2015} is the rescaled variable *x* of the 2015 PNAD;

$\overline{x}_{2015}$ is the mean for variable *x* of the PNAD;

s_{2015} is the standard deviation of variable *x* of the PNAD;

x_{2010} is variable *x* of the 2010 census;

$\overline{x}_{2010}$ is the mean for variable *x* of the census; and

σ_{2010} is the standard deviation of variable *x* of the census.

The subsequent step refers to the estimation of the model. The dependent variable Y_i is a dummy defined as follows: $Y_i = 1$ if household *i* is connected to broadband internet, i.e., if the household satisfies item c of Figure 1, and $Y_i = 0$, otherwise.

Since variable Y_i is within the interval between 0 and 1, we cannot use the linear regression model as it is commonly used. In such cases, where the dependent variable is qualitative, we should limit the behavior of *Y* by way of a function Φ, which denotes probability of the household having broadband connection. We then have:

$$\Pr(Y_i = 1 \mid X) = \Phi(\beta_0 + \beta_1 x_{1i} + \cdots + \beta_N x_{Ni} + \varepsilon_i) \tag{2}$$

The probability of household *i* having broadband connection, $\Pr(Y_i = 1|X)$, is given by a nonlinear function on interval $[0,1]$, whose argument is expressed by the linear relationship $\beta_0 + \beta_1 x_{1i} + \cdots + \beta_N x_{Ni} + \varepsilon_i$, where x_{ji} is predictor variable *j* associated with household *i*, β_j is the parameter of this variable, whereas ε_i is the disturbance of the nonlinear regression.

In this study, we used the logistic distribution function (Note 4) (Greene, 1993; Johnston & Dinardo, 1997; Maddala, 1983; Kutner et al., 2005; Stock & Watson, 2004) to represent Φ, such that $\Phi = 1/1 + e^{-x}$. Then we obtain:

$$\Pr(Y_i = 1) = p_i = \frac{1}{1+e^{-(\beta_0+\beta_1 x_{i,1}+\beta_2 x_{2,i}+\cdots+\beta_N x_{i,N})}} \tag{3}$$

Expression (3) can be written as follows:

$$\ln\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 x_{i,1} + \beta_2 x_{2,i} + \cdots + \beta_N x_{i,N} \tag{3'}$$

The logistic regression model is estimated based on maximum likelihood.

The subsequent step consists of the description of the procedures related to broadband market sizing. To do that, we estimated equation (3) using the 2015 PNAD data only for households where broadband access was available. After that, we used the regression estimated the predicted probability for each of all 2010 census households to having access to the internet. The size of the potential broadband market (Market) for the whole Brazilian territory, i.e., the estimated number of households that could have a demand for internet is calculated by the weighted sum (Note 5) of these probabilities, as follows.

$$Market = \sum_{j}^{5570} \sum_{i=1}^{N_j} Internet_{i,j} \times HH\ \ weight_i \tag{4}$$

$$Internet = \Pr(Y_i = 1 \mid X) = \Phi\left(\hat{\beta}_0 + \sum_{l}^{L} \hat{\beta}_l x_{li}\right) \tag{5}$$

Where:

N_j=Number of households sampled in municipality *j=1,...,5570;*

$\text{Internet}_{i,j}$ is the estimated probability of household *i* in municipality *j* demanding for internet services;

HH weight_i is the weight of household *i* in the 2010 census.

x_{li} is the variable *l* of household *i*. The variables are listed above (Note 6). The variables were obtained from the 2010 census;

$\hat{\beta}_l$ is the estimated coefficient of variable *l*. The coefficients were estimated based on the 2015 PNAD data.

4. Estimation of Potential Broadband Market Size

In this section, we present the estimation results for the model proposed in Section 3, as well as the predicted value of the potential broadband market size for Brazil. Table 1 shows the logistic regression results with significant variables (Note 7). Note that, unlike the linear regression, the coefficients of the logistic regression cannot be interpreted directly in the equation as the marginal effect of the regressor variable (Note 8). Table 1 also shows McFadden's R^2($R^2 McF$), whose interpretation is analogous to the R^2 in linear regression (Note 9).

Table 1. Logistic regression result

Regressors	Coefficient	Standard error	P-value [1]
Intercept	-4.385	0,233	0.000
Urban	1.133	0.091	0.000
TV	0.459	0.115	0.000
Landline	1.071	0.024	0.000
Fridge	0.625	0.182	0.000
Rental	-0.164	0.056	0.001
Density	-0.377	0.104	0.000
Rooms	0.116	0.011	0.000
Residents	0.202	0.021	0.000
H-income	0.0002	0.000	0.000
Rental$	0.001	0.000	0.000
$R^2 McF$		0.193	

Source: Data compiled by the authors.

Note. [1]Confidence interval (CI): 95%.

As previously outlined, the aim of our study is to predict the size of the broadband market, and that is why sizing was denoted by a predictor variable rather than by an explanatory variable. Therefore, the estimated regression should be understood as a regression related to the reduced form of the model, and not to the structural form. Thus, a statistic of interest would be the odds ratio. The chance of an event occurring is defined as the ratio between the probability of an event occurring and the probability of the event not occurring. It indicates when the probability of an event occurring is a number of times larger than the probability of the event not occurring. The odds ratio is calculated between two groups for a given event, and it is defined as the probability of an event occurring in one group and the probability of the event occurring in the other group (Note 10).

Table 2 results can be interpreted using the concepts described for the odds ratio. In the case of the variable Urban, which indicates whether the household is located in the urban area, the odds ratio was 3.1, which means that when the household is in the urban area, the probability of this household having internet access is three times higher than when the household is located elsewhere, with all household characteristics, such as income, number of rooms, rental price, presence of TV set, etc, kept unchanged. The same interpretation can be made for when the household has landline phone because, in this case, the probability of having broadband connection is almost three times higher than when the household does not have a landline phone.

Table 2. Odds ratio

Regressors	Odds ratio
Intercept	0.0124
Urban	3.1043
TV	1.5832
Landline	2.9195
Fridge	1.8692
Rental	0.8481
Density	0.6856
Rooms	1.1229
Residents	1.2247
H-income	1.0002
Rental$	1.0007

Source: Data compiled by the authors.

The probability of broadband connection in households with a TV set is 58% higher than for households without a TV set, and this probability is 86% higher for households with a refrigerator than for those without one, considering, in both cases, that the characteristics of the other explanatory variables remain unchanged. In the case of a household being rented or not, the parameter should be interpreted inversely. Thus, 1/0.84 = 1.17, i.e., when the household is not rented, the probability of broadband connection is 17% higher than otherwise.

For sizing of the broadband market, we are going to use the methodology described in Section 3. In line with this methodology, we use the 2015 PNAD to estimate the logit model, whose results are displayed in Table 1. A preliminary exercise predicts that 28.1 million households have broadband access. The prediction for the whole Brazilian territory is made based on the 2010 census, also in line with the methodology described. For municipalities that did not exist in 2010, an imputation was made based on the towns/cities to which the new municipalities belonged. The final effects were found to be residual. The potential broadband market in Brazil is estimated at 32.6 million households. Northern and northeastern Brazilian states (Pará, Amapá, Amazonas, Tocantins, Maranhão, and Piauí) can potentially double or triplicate the number of households if broadband access is expanded. The predictions are well depicted in the figures shown in the appendices. We show the potential demand for the five major municipalities in each state.

Table 3. Estimated market size by State and in the five major municipalities

North region				
State	Municipality	Market 2015 (no. of households)	Mean – state	Total of major 5 municipalities
Rondônia	Ariquemes	22,111	6,857	199,819
	Cacoal	19,832		
	Ji Paraná	30,328		
	Porto Velho	106,862		
	Vilhena	20,685		
Acre	Cruzeiro do Sul	12,423	5,781	97,924
	Feijó	3,592		
	Rio Branco	72,530		
	Sena Madureira	5,444		
	Tarauacá	3,935		
Amazonas	Coari	10,464	10,028	461,211
	Itacoatiara	13,561		
	Manacapuru	12,680		
	Manaus	410,470		
	Parintins	14,036		
Roraima	Boa Vista	71,112	6,248	82,126
	Cantá	1,750		
	Caracaraí	2,869		
	Mucajaí	2,553		
	Rorainópolis	3,842		
Pará	Ananindeua	101,805	8,852	549,675
	Belém	317,046		
	Castanhal	34,345		
	Marabá	46,106		
	Santarém	50,373		
Amapá	Laranjal do Jari	7,214	8,163	117,597
	Macapá	85,488		
	Oiapoque	3,387		
	Porto Grande	2,651		
	Santana	18,856		
Tocantins	Araguaína	36,860	2,143	143,753
	Gurupi	20,694		
	Paraíso do Tocantins	11,441		
	Porto Nacional	11,381		
	Palmas	63,378		

Northeast region				
State	Municipality	Market 2015 (no. of households)	Mean – state	Total of major 5 municipalities
Maranhão	Caxias	26,079	4,699	350,375
	Imperatriz	53,966		
	São José de Ribamar	23,331		
	São Luís	219,047		
	Timon	27,952		
Piauí	Floriano	11,517	2,324	236,802
	Parnaíba	28,094		
	Picos	14,816		
	Piripiri	10,774		
	Teresina	171,602		
Ceará	Caucaia	62,978	8,659	785,222
	Fortaleza	591,065		
	Juazeiro do Norte	51,598		
	Maracanaú	42,651		
	Sobral	36,931		
Rio Grande do Norte	Caicó	14,579	3,900	347,246
	Parnamirim	53,026		
	Mossoró	59,171		
	Natal	203,046		
	São Gonçalo do Amarante	17,424		
Paraíba	Bayeux	19,743	3,202	325,735
	Campina Grande	85,883		
	João Pessoa	176,465		
	Patos	21,562		
	Santa Rita	22,081		
Pernambuco	Caruaru	68,301	9,219	752,573
	Jaboatão dos Guararapes	143,932		
	Olinda	87,153		
	Paulista	69,069		
	Recife	384,117		
Alagoas	Arapiraca	42,863	5,632	306,440
	Maceió	226,221		
	Palmeira dos Índios	13,470		
	Penedo	10,817		
	Rio Largo	13,069		
Sergipe	Aracaju	147,566	5,357	230,500
	Itabaiana	17,736		
	Lagarto	16,381		
	Nossa Senhora do Socorro	33,128		
	São Cristóvão	15,689		
Bahia	Camaçari	58,613	6,707	1,050,455
	Feira de Santana	127,961		
	Itabuna	47,807		
	Salvador	748,360		
	Vitória da Conquista	67,715		

Southeast region				
State	Municipality	Market 2015 (no. of households)	Mean – state	Total of major 5 municipalities
Minas Gerais	Belo Horizonte	704,767	5,511	1,280,809
	Betim	93,723		
	Contagem	161,636		
	Juiz de Fora	146,013		
	Uberlândia	174,670		
Espírito Santo	Cachoeiro de Itapemirim	50,934	11,564	479.804
	Cariacica	88,938		
	Serra	107,787		
	Vila Velha	124,990		
	Vitória	107,155		
Rio de Janeiro	Duque de Caxias	203,517	45,294	2.623.286
	Niterói	153,789		
	Nova Iguaçu	186,240		
	Rio de Janeiro	1,826,935		
	São Gonçalo	252,805		
São Paulo	Campinas	323,367	17,582	4,347,983
	Guarulhos	314,732		
	Santo André	204,614		
	São Bernardo do Campo	223,497		
	São Paulo	3,281,774		
South region				
State	Municipality	Market 2015 (no. of households)	Mean – state	Total of major 5 municipalities
Paraná	Curitiba	620,516	6,918	1,029,459
	Londrina	144,174		
	Maringá	107,061		
	Ponta Grossa	78,686		
	São José dos Pinhais	79,021		
Santa Catarina	Blumenau	101,562	6,212	534,528
	Criciúma	58,700		
	Florianópolis	148,055		
	Joinville	158,152		
	São José	68,058		
Rio Grande do Sul	Canoas	90,009	5,645	835,224
	Caxias do Sul	127,110		
	Pelotas	86,307		
	Porto Alegre	460,469		
	Santa Maria	71,329		

Let us have a look at the impact of broadband expansion on the market. This expansion could occur on the supply side, with larger network availability or lower prices for the services. Let us assume a 20% increase in the mean penetration of services in the major Brazilian metropolitan areas. Using the 2015 PNAD data and bearing in mind the methodology described in Section 3, we obtain the intercept of the logistic regression to include the 20% increase. We then apply the modified equation for the remaining municipalities using the 2010 census data. The new potential market would cover a total of 40.6 million households.

5. Final Remarks

This study aimed to assess the potential size of the Brazilian broadband market. This connection system does not yield direct utility for the final consumer, but it allows having access to extremely important services, such as internet. As pointed out, for broadband market sizing, we used internet access as a parameter. Internet access can be obtained by other means, such as cell phones. It is important to highlight that broadband expansion in Brazil has some setbacks, as a large number of municipalities still have a poor infrastructure for implementation of the system. This results in higher costs. Fortunately, there are some alternatives at hand, and one of them is the use of cell phone technology. Therefore, the replication of the sizing exercise should include not only broadband services, but also internet access through 3G and 4G technologies.

Using the same method described in Section 3 and applied in Section 4, we found around 28.1 million households with broadband access to the internet in the 2015 PNAD data. Sizing of the Brazilian market covers around 39.1 million households with broadband internet access or 3G and 4G cell phone technology.11 If we recalculate our predictions, assuming a 10% increase in internet access (broadband or 3G and 4G on the cell phone) in forthcoming years, the new potential market will cover 50.7 million households with internet access, an additional expansion of approximately six million households.

References

Anonymous. (2010). Aumento da penetração do serviço de acesso à internet em banda larga e seu possível impacto econômico: Análise através de sistema de equações simultâneas de oferta e demanda. Brasília: Ipea, 2010. *Texto para Discussão n. 1495*.

Anonymous. (2012). *The impact of broadband on the economy.* [s.l.]: ITU, 2012.

Ávil, A. F. (2008). *Banda larga no Brasil: Uma análise da elasticidade preço-demanda com base em microdados.* 2008. 54 f. Monografia (Graduação) – Faculdade de Economia, Administração e Contabilidade, Universidade de Brasília, Brasília, 2008.

Cadorna, M., Schwarz, A., Yurtoglu, B., & Zulehner, C. (2007). Demand estimation and market definition for broadband internet services. *Journal of Regulatory Economics*, *35*(1), 70-95. https://doi.org/10.1007/s11149-008-9076-x

Carvalho, A. Y., Mendonça, M. J., & Silva, J. J. (2017). *Avaliando os efeitos dos investimentos em telecomunicações sobre o PIB. Brasília: Ipea, 2017* (Texto para Discussão, no prelo).

Czernich, N. et al. (2009). *Broadband infrastructure and economic growth.* Center of Economic Studies (CESifo), 2009, Working Paper, n. 286. https://doi.org/10.2139/ssrn.1516232

Greene, W. H. (1993). *Econometric Analysis* (2nd ed., p. 791). New Jersey: Prentice Hall.

Guedes, E. et al. (2008). *Avaliação dos impactos da cisão das operações de STFC e SCM em empresas distintas*. [s.l.]: Tendências Consultoria Integrada. (Nota Técnica).

Johnston, J., & Dinardo, J. (1997). Econometric Methods.

Katz, R. (2008). *The economic and social impact of telecommunications output: Empirical evidence in the US and Europe.* European Telecommunications Network Regulatory Economics Task Force, 2008, Brussels. Presentation… Brussels: ETNO, 2008. Retrieved from https://www8.gsb.columbia.edu/citi/sites/citi/files/files/theeconomicandsocialimpact.pdf

Koutroumpis, P. (2009). The Economic impact of broadband on growth: A simultaneous approach. *Telecommunications Policy, 33*(9), 471-485. https://doi.org/10.1016/j.telpol.2009.07.004

Kutner, M. et al. (2005). *Applied linear statistical models* (5nd ed.). New York: McGraw-Hill Irwin.

Macedo, H., & Carvalho, A. (2010). *Aumento do acesso à internet em banda larga no Brasil e sua possível relação com o crescimento econômico: Uma análise de dados em painel.* Brasília: Ipea, 2010a. (Texto para Discussão, n. 1494).

Maddala, G. (1983). *Limited dependent and qualitative variables in econometrics* (pp. 257-91). New York: Cambridge University Press. https://doi.org/10.1017/CBO9780511810176

Qiang, C., & Rossoto, C. (2009). Economic impacts of broadband. In *Information and communications for development 2009: Extending reach and increasing impact* (pp. 35-50).Washington: World Bank, 2009.

Röller, L. H., & Waverman, L. (1996). *Telecommunications infrastructure and economic development: A simultaneous approach*. Social Science Research Center Berlin, Discussion Paper, n. 722.

Stiroh, K. (2002). Information technology and the U.S productivity revival: What do the industry data say? *American Economic Review, 92*(5), 1559-1576. https://doi.org/10.1257/000282802762024638

Stock, J. H., & Watson, M. W. (2004). *Econometria*. Adison Wesley.

Wohlers, M., Abdala, R., & Kubota, J. (2009). Banda larga no Brasil: por que ainda não decolamos? *Radar – Tecnologia, Produção e Comércio Exterior,* (5), 9-15. Retrieved from http://repositorio.ipea.gov.br/bitstream/11058/5429/1/Radar_n5_Banda%20larga.pdf

Notes

Note 1. Backhaul is a piece of equipment that connects to the core of the internet service provider's network. This connection can be via fiberoptic cable, radio, satellite, or other technologies.

Note 2. Brazil is one of the countries with the lowest broadband speeds.

Note 3. Other variables were included in the regression analysis. However, they were not statistically significant.

Note 4. We could have used the probit model, where function Φ is represented by a normal cumulative distribution.

Note 5. This is the methodological note from the 2010 census: "In a survey with probabilistic sampling, each unit selected from the sample also represents other units that make up the target population. Thus, a factor of expansion or weight was associated for each household unit selected from the 2010 census. This weight was obtained by adjusting the initial weight given by the inverse effective sampling fraction, which is the total number of households in the census divided by the number of households selected for the sample in a given geographical area." Available from: http://www.ibge.gov.br/apps/snig/v1/notas_metodologicas.html

Note 6. See footnote 6.

Note 7. See footnote 6.

Note 8. The marginal effect in the logit model $\partial p_i / \partial x_{ij} = \Phi^{'}(X\beta)\beta_j$, where $\Phi^{'}$ is the derivative of $\Phi^{'}$ relative to variable x_{ij}.

Note 9. R^2McF is defined as $R^2McF = 1 - (\ln(LM/\ln(L0))$, where LM is the value of the likelihood function of the regression, whereas $L0$ is the value of the same function without any predictor.

Note 10. For instance, when the odds ratio of a given event between women (group 1) and men (group 2) is 0.5, this means that the probability of the event occurring in the women's group is 50% lower than in the men's group.

Note 11. For municipalities that did not exist in 2010, an imputation was made based on the towns/cities to which the new municipalities belonged (residual final effects)