REGIONAL INEQUALITIES IN THE IMPACT OF BROADBAND ON PRODUCTIVITY. EVIDENCE FROM BRAZIL

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REGIONAL INEQUALITIES IN THE IMPACT OF BROADBAND ON PRODUCTIVITY. EVIDENCE FROM BRAZIL

Juan Jung

Abstract: The aim of this paper is to perform an analysis of the impact of broadband on regional productivity in Brazil, intending to find out if the economic impact is uniform across all territories of the country. The possibility of performing a regional approach, instead of the usual country-level analysis, means an opportunity to disentangle the economic impact of broadband at territories which share a common institutional and regulatory framework as are the regions inside a same country. Results suggest that the impact of broadband on productivity is not uniform across regions, and seemsto be yielding higher productivity gains for less developed regions, a result which is robust after controlling for differences in connection quality, network effects, human capital and sectorial composition. Results further verify that broadband connectivity yields higher economic impact in regions specialized in specific sectors as commerce and information services. Another important result verified in this paper is that faster download speed and critical-mass accounting for network externalities enhance the economic impact of broadband. The fact that most underdeveloped regions in Brazil seem to be benefiting more from broadband may suggest that broadband can constitute a factor favoring regional convergence in Brazil, although further research will be needed to confirm that assertion.

Keywords: Broadband, Information and Communication Technologies, Regional Productivity.

Comments: In 2014 Juan Jung was awarded a Junior Fellowship at Institut Barcelona d'Estudis Internacionals (IBEI) to research regulation of Information and Communications Technology (ICT) in Latin America, granted by Catedra Telefonica de Política y Regulación de las Telecomunicaciones e Internet América Latina – Europa.

1. INTRODUCTION

Information and Communication Technologies (ICT) in general, and broadband in particular, have been extensively studied in the economic literature as a potential source for raising employment and economic growth. There are, however, some gaps in the literature that remain unfilled and that motivate the present research.

In the first place, while the bulk of the literature has focused on either at country-aggregate or firm levels, evidence of subnational-regional analysis of broadband impact on local productivity is still scarce, and mainly limited to the United States. In the second place, those empirical studies that have addressed the regional level usually have replicated the analysis performed at cross-national level, ignoring the regional perspective. For regional analysis, it is a key element to understand if broadband might have a uniform impact on productivity across the regions of a country. In that sense, if the impact of broadband on productivity is found to differ territorially inside a country, then the analysis will have to contemplate the regional dimension, intending to find out why some regions are able to extract more productivity spillovers from technology in comparison with others. The impact of broadband on productivity may depend on a variety of regional attributes, such as sectorial structure, demography, human capital, level of development, among others.

The possibility of working at a regional level provides some advantages. Country-level analysis is usually affected by important heterogeneities across countries in terms of institutions, culture, regulations, etc. Even if some of these heterogeneities are time-invariant (and as a result can be tackled by fixed effects), other may vary over time. In contrast to the country-level approach, regional analysis provides a more homogeneous framework which allows filtering for those potential heterogeneities and as a result it may help to find a more accurate measure of the impact of broadband on productivity.

To find out if there are differences in the regional productivity impact of broadband, additional factors will be considered as potential enablers, like connection quality and critical-mass externalities. The possibility of getting homogeneous data on download speeds provides the possibility of considering quality differentials across regions. A question that motivates this approach is to find out if continuous improvements in speed levels of current connections should also constitute a priority for operators and policy-makers, along with universalization.

The empirical analysis focuses in Brazil, which is an emerging country which has reached important economic growth over the last decades. A recent report by Centre for Economics and Business Research (CEBR, 2013) forecasts that Brazil will become the world's fifth largest economy in 2023, overtaking UK and Germany. In the last few years, this country has reduced significantly the levels of poverty, combining social policies with economic growth. As a result of its potentiality, Brazil has been classified as one of the BRICs (the others being Russia, India and China). A key of this process was the openness of its economy for foreign investment. Since the nineties when many state industries were privatized, the presence of Brazilians multinationals in the world has grown considerably, as well. Its entrance onto the world stage has been reinforced by the high-profile international events that have been or will be hosted in the country: the football World Cup in 2014, and the Olympic Games 2016 in Rio de Janeiro.

Considering the importance of broadband as an essential infrastructure, the Federal Government of Brazil has launched the "Programa Nacional de Banda Larga", with the objective of extending the provision of broadband, especially in regions lacking connectivity. The plan, launched at mid-2010, has a target of reaching 40 million of households connected for 2014, and is acting on several fronts, such as expansion of optic fiber networks and price reduction programs, including the implementation of a "popular broadband" tariff for connections of 1 mbps per 35 Reais per month. The implementation of this plan is out of the scope of this paper because it was not until mid-2011 that it started to be implement in the first towns chosen by the authorities. Despite not being considered in the analysis, the present paper may bring out some inputs to estimate the future economic impact of this initiative across the Brazilian states.

This paper is structured as follows: section 2 resumes a review of recent literature on ICT and broadband economic impact; section 3 presents a theoretical model that serves as the basis for the econometric analysis; section 4 exposes a descriptive analysis of the available data; section 5 presents the main results and discussion; and finally section 6 briefly summarizes the main conclusions of the work, with some remarks and policy discussion.

2. LITERATURE REVIEW

Economic impact of infrastructures has been widely studied in the economic growth literature, following the initial contribution of Aschauer (1989), who included public capital as a productivity determinant. The impact of telecommunications infrastructure has also been studied, being an important contribution Roller and Waverman (2001) in this sense. The diversity of channels through which ICT can contribute to productivity and economic growth has been extensively studied in the literature (for a complete review, see for instance Cardona *et al.*, 2013).

In the last few years most of ICT-derived contribution to productivity has come from the development of broadband high-speed internet connections, which has been classified as a General Purpose Technology (GPT) by some authors (Mack and Faggian, 2013; Czernich *et al.*, 2011). Because of its attributes, some authors state that the new technologies influence productivity beyond the effect of regular capital goods. According to Mack and Faggian (2013), and Jordan and De Leon (2011), broadband now constitutes a key part of the necessary infrastructure for development, in the same way as previous advances such as railroads, roads and electricity. Recent empirical analysis has mainly concentrated on analyzing the broadband impact on economic growth. Czernich *et al.* (2011) study a simple of 25 OECD countries for the period 1996-2007 and find that a 10% of increase in broadband penetration raises annual growth in GDP per capita by 0.9-1.5 percentage points. Koutroumpis (2009) studied a simple of 22 OECD countries for period 2002-2007, finding that a 10% increase in broadband penetration contributed to 0.25% in GDP growth. Qiang *et al.* (2009) found that a 10% increase in broadband penetration contributed to more than 1% of increase in per capita GDP growth. As it can be seen, most empirical analysis seems to contemplate the broadband incidence on GDP growth rather than on productivity.

At a regional level, research has been much scarcer, and mostly referred to United States. For instance, Crandall *et al.* (2009) study the effects of broadband deployment on output and employment in US states for the period 2003-2005. They find a positive association of employment and broadband use in several industries, but were unable to find a significant association between output and broadband. Mack and Faggian (2013) analyze the regional impact of broadband provision for US counties, finding that it had a positive impact on productivity only when accompanied with high skills. Lehr *et al.* (2005) studied the impact of broadband at US communities, finding out a positive impact of broadband on economic growth.

An ongoing debate in the literature is related to the link between the new technologies and underdeveloped regions. It is believed that ICT may open possibilities for isolated regions to overcome traditional disadvantages associated to their remote location. As a result, new technologies and internet diffusion could reduce the role played by agglomerations. Some authors even talk about the "death of distance" as a result of an eventual widespread deployment of ICT services (Cairncross, 2001). According to this view, distance would be less important and peripheral regions would benefit from opportunities that were not available before (Bonaccorsi *et al.*, 2005; Quah, 2000; Kelly, 1998; Negroponte, 1995).

In some cases, the presence of broadband infrastructure facilitates the development of poor regions, enhancing some degree of territorial equilibrium (Suriñach *et al.*, 2007). Isolated regions may present some advantages as lower wages and property costs, which can be fully exploited if good broadband infrastructure is available. In that case, it can attract companies to locate in the region the localization of companies which can suffer from congestion costs in more developed regions, increasing demand and activity in isolated regions. This might lead to a positive spiral of increased activity that may help even people who is not a user of broadband.
Even if not related to regional analysis, Thompson and Garbacz (2011) find that

broadband has a relatively more favorable economic impact in low-income countries than in high-income countries. In the same fashion, Qiang *et al.* (2009) suggest that the growth effects of broadband, as well as those of other technologies, is higher in low-income countries than in high-income economies. According to Fernández-Ardèvol *et al.* (2011), the economic impact of mobile phones was larger in Latin America than in OECD countries.

On the other hand, other authors argue that the economic impact should be bigger in high income economies. For instance, Katz (2012) stated, for a country-level analysis that economies with lower broadband penetration tend to exhibit a lesser contribution of broadband to economic growth. The reason for this statement is linked to network externalities resulting from larger broadband penetration. This critical-mass effect might lead to increasing returns to broadband penetration. Other authors argue that ICT can exacerbate disparities between regions, both inside and across countries, because regions may differ not only in ICT endowments, but also in the possibilities to make a productive use of it (Gareis and Osimo, 2004). Billón *et al.* (2009) argue that agglomerations and internet may be complementary instead of substitutes. According to Bonaccorsi *et al.* (2005), disparities and inequalities seemed to be reinforced, rather than reduced, by ICT diffusion. Along with that, the importance of complementarities (i.e., ICT and human capital), sectorial composition and institutional framework may contribute to a higher economic impact in more developed economies. At the same time, the decrease of the role of distance as a result of the new technologies may be over-optimistic, referred to earlier, as only codified knowledge can be transmitted through ICT, meaning that for tacit knowledge diffusion distance will remain to be relevant.

A relatively unstudied aspect of broadband impact is that related to differences in its quality (downloading speed). A recent paper by Rohman and Bohlin (2013), based on a sample of 34 OECD countries during the period 2008-2010, suggests that doubling the broadband speed contributes to 0.3% growth compared with the growth rate in a base year. This is because low transmission capacity and speed of dial-up internet severely limit access to content-dense applications. Howell and Grimes (2010) argue that fast internet access is considered a productivity-enhancing factor. As a result, quality of connections should also be considered as a potential factor which may contribute to regional differences in the economic impact of broadband.

All the previous arguments may give an insight that broadband should have a positive impact on productivity, and that impact may be different across regions, even inside the same country. The possibility of performing the analysis in a big country as Brazil, which exhibits important regional inequalities, may provide a better understanding of the regional dimension of the impact of broadband in productivity, and may contribute to evaluate its suitability as an instrument for regional cohesion.

3. THEORETICAL MODEL AND EMPIRICAL SPECIFICATION

In this section we build our model on the basis of an augmented Solow (1956) framework, where economies are supposed to produce according to a Cobb-Douglas production function with various input factors:

$$Y_{it} = A_{it} K_{it}^{\alpha} L_{it}^{\beta} H_{it}^{\gamma} \qquad [1]$$

Where Y represents output, K is physical capital stock, L is labor and H denotes human capital, approximated as $H = e^h$, where h reflects the efficiency of a unit of labor, in a similar fashion as Hall and Jones (1999). Subscripts i and t denote respectively regions and time period. The term A represents Total Factor Productivity (TFP), which reflects differences in production efficiency across regions. TFP can be expressed as:

$$A_{it} = \Omega_i(X) BB_{it}^{\Phi} \qquad [2]$$

TFP is stipulated to depend on some region-specific characteristics, represented by $\Omega_i(X)$, a term which is influenced either by X a vector of control variables and by time invariant idiosyncratic productivity effects, which may make some regions more productive *per se* because of unobserved heterogeneity. As it is supposed that broadband contributes to increase productivity, and to facilitate the development of new products and process and the adoption of new technologies devised by others, A is assumed to depend positively on the level broadband infrastructure denoted by BB. The stock of broadband infrastructure is used, instead of investment, because users demand infrastructure and not investment *per se* (Koutroumpis, 2009). An expected positive value for Φ may suggest the productivity gains derived from broadband.

The empirical specification will be derived omitting the subscripts for region and time period for the sake of simplicity. The lack of available data for state-level physical capital stocks in Brazil will require of some assumptions and rearrangements to derive the empirical specification. Following economic theory, if markets are competitive, capital earns its marginal product (Romer, 2006). As a result, firms in this economy will acquire physical capital until its marginal productivity equals its price, usually approximated by the real interest rate r :

$$\frac{\partial Y}{\partial K} = A\alpha K^{\alpha-1} L^{\beta} H^{\gamma}$$

From this expression, the demand for physical capital can be derived and expressed as

$$K = \left[\frac{\alpha A L^{\beta} H^{\gamma}}{r}\right]^{\frac{1}{1-\alpha}}$$

Inserting the derived demand for physical capital in [1], yields an expression for output which do not depends on physical capital on the right-hand side:

$$Y = A\left[\frac{\alpha A L^{\beta} H^{\gamma}}{r}\right]^{\frac{1}{1-\alpha}} L^{\beta} H^{\gamma}$$

Performing some further operations, output can be expressed as

$$Y = \frac{\alpha^{\left[\frac{\alpha}{1-\alpha}\right]} A^{\left[\frac{1}{1-\alpha}\right]} L^{\beta\left[\frac{1}{1-\alpha}\right]} H^{\gamma\left[\frac{1}{1-\alpha}\right]}}{r^{\left[\frac{\alpha}{1-\alpha}\right]}}$$

Under the assumption of constant returns to scale for physical capital and labor, the following equality can be expressed: $\alpha + \beta = 1$. Then,

$$Y = \frac{\alpha^{\left[\frac{\alpha}{1-\alpha}\right]} A^{\left[\frac{1}{1-\alpha}\right]} L H^{\gamma\left[\frac{1}{1-\alpha}\right]}}{r^{\left[\frac{\alpha}{1-\alpha}\right]}}$$

The previous expression can be easily manipulated to obtain a measure of labor productivity which does not depend on the stock of physical capital:

$$\frac{Y}{L} = \frac{\alpha^{\left[\frac{\alpha}{1-\alpha}\right]} A^{\left[\frac{1}{1-\alpha}\right]} H^{\gamma\left[\frac{1}{1-\alpha}\right]}}{r^{\left[\frac{\alpha}{1-\alpha}\right]}}$$

Introducing [2], this yields:

$$\frac{Y}{L} = \frac{\alpha^{\left[\frac{\alpha}{1-\alpha}\right]} [\Omega(X) B B^{\Phi}]^{\left[\frac{1}{1-\alpha}\right]} H^{\gamma\left[\frac{1}{1-\alpha}\right]}}{r^{\left[\frac{\alpha}{1-\alpha}\right]}}$$

This expression can be linearized by applying logarithms:

$$\ln\left[\frac{Y}{L}\right] = \left[\frac{1}{1-\alpha}\right]\ln\alpha + \left[\frac{1}{1-\alpha}\right]\ln\Omega(X) + \left[\frac{1}{1-\alpha}\right]\Phi\ln BB + \left[\frac{1}{1-\alpha}\right]\gamma h - \left[\frac{\alpha}{1-\alpha}\right]\ln r$$

The interest rate is the same across the states, because financial markets are integrated inside the country, and as the long-term rate is supposed to vary little over the time period analyzed, it will be assumed as constant. Renaming the constant factor $\Gamma_0 = \left[\frac{1}{1-\alpha}\right]\ln\alpha - \left[\frac{\alpha}{1-\alpha}\right]\ln r$, and the following parameters successively as Γ_i then the empirical specification is:

$$\ln\left[\frac{Y}{L}\right] = \Gamma_0 + \Gamma_1\ln\Omega(X) + \Gamma_2\ln BB + \Gamma_3 h \qquad [3]$$

As a result, the empirical specification will relate labor productivity on the left-hand side to some right-side variables: human capital, broadband penetration and some controls. The parameter α cannot be identified through the empirical specification, so the physical capital share on the income obtained by the Brazilian national accounts used to recover the structural parameters: $\Phi = \Gamma_2\,(1-\alpha)$ and $\gamma = \Gamma_3\,(1-\alpha)$.

The previous specification may be useful to obtain a common-regional measure of the impact of broadband on productivity, but is inappropriate to account for differences of impact across regions. As a result, further strategies require of slight modifications to the TFP term expressed in [2]. As stated in the literature review, broadband may have a different impact depending on the degree of development of the region. Additionally, that economic impact of broadband may vary depending on other factors, such as the quality of the connection, the presence of network externalities, or the sectorial composition. As a result of all that, [2] can also be expressed as:

$$A = \Omega(X)BB^{(\phi+\Phi LP^{LP+\Phi}MP^{MP+\delta Z})} \qquad [2']$$

Where LP and MP represent dummy variables associated to the level of development of the region: Low Productivity and Medium Productivity, respectively. As a result, the base scenario measures the impact of broadband on high productive regions. The term Z reflects further factors which may have an incidence on the economic impact of broadband.

The interpretation of the parameters associated with broadband provides some of the contributions of the model. For instance, if $\Phi_{LP} = \Phi_{MP} = 0$, then the impact of broadband on productivity can be considered as uniform across regions. On the contrary, if $\Phi_{LP} \neq 0$ or $\Phi_{MP} \neq 0$, then research should focus in finding out why some regions appear to be extracting more productivity gains from broadband than others. The parameter δ will reflect the incidence of other factors in interaction with broadband. The procedure to derive the empirical specification and the strategy for recovering structural parameters is similar to that indicated in the base model.

The empirical model to be estimated will consist on a panel with fixed-effects at the state level, which provide the advantage to account for all time-invariant heterogeneity across regions. A common critique of ICT and broadband estimations is that sometimes the results determine correlation rather than a causality effect on productivity, because investment in ICT may be considered a driver, but also a result of productivity and economic growth (Cardona *et al.*, 2013). This possible reverse causality may arise because individuals in high-income economies may also have higher resources to pay for broadband. Some authors exploit the structure of panel data by using lagged variables for ICT (Bloom *et al.*, 2010; Hempell, 2005; Tambe and Hitt, 2001; Brynjolfsson and Hitt, 1995). Other strategies may be structural multi-equation models (Röller and Waverman, 2001; Koutroumpis, 2009), or instrumental variables with a first-stage diffusion equation (Bertschek *et al.*, 2013; Czernich *et al.*, 2011).

Bertschek *et al.* (2013) firm-level analysis uses ADSL availability as an instrument for broadband. Their results suggest that instrumental variables approach resulted in higher coefficients for broadband incidence in productivity, although less precise than OLS as the standard errors increase, leaving broadband as weakly significant. In Czernich *et al.* (2011) country-level analysis uses fixed-line voice telephony and Cable TV pre-existing networks as instruments for broadband. Its estimations suggested that IV results are slightly larger than OLS, concluding that OLS regressions are downward biased.

Following Czernich *et al.* (2011), in the empirical specification builds on the idea that most common broadband roll-out (i.e.: ADSL or Cable Modem) rely on the cooper wire of pre-existing voice-telephony networks. As stated by Czernich, the required access to an existing infrastructure built for other purposes, such as that of fixed telephony, make this a suitable instrument for this estimation strategy. The instrument in this case is the number of voice-telecommunication fixed access lines per 100 inhabitants five years before. In addition, as broadband deployment may depend on demographic factors, population density will be added as instrument, but using variables from the beginning of the last century (census 1920-1950). The instruments were lagged considerably to break any possibility of being affected by contemporary shocks.

4. DATA AND EXPLORATORY ANALYSIS

Table 1 summarizes the description of the variables to be used in the empirical analysis. Output is be measured through Gross Value Added (GVA), which subtracts intermediate inputs from the gross output, which is usually considered a more accurate measure of the actual surplus created (Cardona *et al.*, 2013). The data, extracted from the IBGE database[1] , are deflated to 2000 constant Reais prices.

Considering the importance of ICT to increase competitiveness of territories, inequalities detected in its diffusion can have implications for economic growth, human development and the creation of wealth (Vicente and López, 2011; Billón *et al.*, 2009; ITU, 2006). One of the consequences of the lack of broadband connections is that it generates a new divide between those who have access to a large number of applications, for which broadband is needed, and those who do not have access (Billón *et al.*, 2009).

Previous studies on the determinants of broadband adoption have identified economic wealth as the biggest factor explaining disparities. Another important factor is human capital, especially in the case of internet, which is an interactive technology and in which skills are crucial to take advantage of its potentialities. Population size and its socio-economic features may also contribute to explain disparities (Vicente and López, 2011). Also, empirical data presents an associated age gap, in the sense that younger generations will have bigger demand for new technologies than older people (Chinn and Fairlie, 2007). Population density may also contribute, as the high fixed costs of network deployment make that highly population areas constitute attractive markets for telecommunication providers. Higher degree of services in the sectorial composition can increase the demand for broadband, as a sector which can obtain most productivity gains from the new technologies, especially services sectors which are high intensive in information (Qiang *et al.*, 2009). Local cultural factors might also constitute a significant factor to explain adoption (Billón *et al.*, 2009).

1 For some cases of missing 2010 information, averages among data from 2009 and 2011 were used to fulfill the gaps.

Table 1. Variables for empirical analysis

Variable	Description	Source
Productivity	Gross Value Added per worker in Reais at 2000 constant prices	IBGE
Broadband	Number of subscriptions (>512kbps) per 100 inhabitants	Telebrasil
Literacy rate	Literacy rate of population over 15 years old	IPEA
Speed	Weighted average in mbps	Computed from data of Telebrasil
Agriculture	Percentage of sectorial GVA	IBGE
Services	Percentage of sectorial GVA	IBGE
Urbanism	Percentage of people living on urban areas	IPEA
Youth workforce	Percentage of working-age population under 30 years old	IBGE

Source: Author's elaboration

Even if a wide definition of digital-divide may consider a large number of technology-related variables, in this exploratory section the analysis only considers broadband, as it is the principal scope of this article. There is no public regional data on broadband adoption at the firm level in Brazil. But, as stated by Vicente and López (2011), firm adoption is expected to be highly correlated with the overall spread of broadband across the entire population. As a result, penetration across inhabitants is used in the empirical analysis. Several authors use penetration levels to approximate broadband infrastructure (see, for instance, Koutroumpis, 2009, or Czernich *et al.*, 2011).

Broadband is defined as internet access provided at a certain high level of speed capacity. In Brazil, most internet connections at the end of the 90s and beginning of the 2000s were based on slow dial-up connections, which imposed restrictions for its usability and ability to make full use and take full advantage of internet applications. The introduction of broadband allowed the possibility of exploiting internet full potential. ITU or OECD defines broadband as those internet connections with speeds above 256 kbps. In this case, Telebrasil (the Brazilian Association of Telecommunications classifies internet connections by speed considering a threshold of 512 kbps. As a result, for the purpose of this research, the analysis consider as broadband connections considered those that reach at least 512 kbps or more, which constitutes a much more realistic approximation for broadband than that of 256 kbps, which hardly serves for most applications nowadays.

Available data from Telebrasil allows considering differences in average bandwidths across regions. Fixed broadband download average speed is constructed with data which classifies subscriptions to different groups depending on its speed. In this case, averages for each interval were weighted by the corresponding penetration levels[2].

Data on labor force and on human capital were obtained from IPEA[3] and IBGE databases. As stated by Caselli (2005), data on years of schooling for population over 25 years old may seem appropriate for developed countries with a large share of college graduates, but it is not appropriate for most developing countries. After considering a diversity of alternatives, literacy rate is used as a measure of human capital.

To control for TFP differences across regions, it is included the percentage of urban residents over the whole population, and the sectorial composition of the economy, measured as the percentage of agriculture and services across the whole regional Value Added. To control for differences in demography structure, it is used the percentage of working-age population under 30 years old.

Descriptive statistics are shown in Table 2. Important differences arise in productivity levels across regions, appearing Brasilia (Distrito Federal) as the highest-productivity region. Brasilia presents some peculiarities. It was founded on 1960, in order to move the capital from Rio de Janeiro to a more central location. The difference in productivity levels between Brasilia and its most close followers (Rio de Janeiro and Sao Paulo) is substantial, possibly related of differences Its sectorial composition (its main economic activities are public administration and services) and on the fact that Brasilia is a city in a small federal district, while the other regions constitute states. On the other side, the lowest productivity region is found in Piauí, with a GVA per worker in 2011, which accounted for only 14% of the capital level, and 30% of that of Rio and Sao Paulo.

Broadband penetration averages 3 subscriptions per 100 inhabitants across the 5-year sample, being again Brasilia the one which reaches the highest penetration level in 2011, with a penetration level of 15.47 (almost 50% of its households). There seems to be a considerable regional digital-divide, as poor states, such as Amapá, reached a broadband penetration of only 0.19 in 2011 (less than 1% of households).
Broadband speed appears to be fastest in Rio de Janeiro in 2011, averaging 14 mbps, while lowest levels in that year were reached in Piauí (2.1 mbps), which suggest that the digital-divide is present not only in quantity, but in quality levels as well. The gap in broadband average speed seems to have increased over the years, as the ratio slowest/quickest broadband speed was 0.34 in 2007 and 0.15 in 2011. The considerable differences in broadband speed across states make it important to take into account this fact when analyzing the broadband impact on productivity.

2 Telebrasil offers data on fixed broadband connections across the following speed intervals: (1) 512kbps-2mbps; (2) 2mbps-34mbps; and (3) higher than 34mbps. The formula for computing average download speed for region *i* at time *t* is: $SPEED_{it} = 1.25 * \left[\frac{BB(1)_{it}}{BB_{it}}\right] + 18 * \left[\frac{BB(2)_{it}}{BB_{it}}\right] + 50 * \left[\frac{BB(3)_{it}}{BB_{it}}\right]$. Assigned speed values for (1) and (2) correspond to the half of the corresponding interval. Speed for the interval (3) is right-censored, and the election of 50 mbps is somewhat arbitrary, although results are not sensible to different approximations. The equivalence formula is 1 mbps = 1024 kbps.

3 Instituto de Pesquisa Econômica Aplicada

Table 2. Descriptive Statistics

Variable	Mean	Min	Max	Obs
Gross Value Added per worker	14490.23	5180.35	46762.56	135
	[7371.61]	(Piauí, 2007)	(Distrito Federal, 2010)	
Literacy rate	88.25	74.26	96.84	135
	[6.29]	(Alagoas, 2008)	(Distrito Federal, 2009)	
Fixed broadband	2.97	0.04	15.47	135
	[3.21]	(Amapá and Roraima, 2007)	(Distrito Federal, 2011)	
Speed	4.41	1.32	13.83	135
	[2.82]	(Rondônia, 2007)	(Rio de Janeiro, 2011)	
Agriculture	0.09	0.00	0.29	135
	[0.07]	(Distrito Federal and Rio de Janeiro)	(Mato Grosso, 2008 - 2009)	
Services	0.31	0.22	0.47	135
	[0.05]	(Acre,2007; Amazonas and Pará, 2010)	(São Paulo, 2011)	
Urbanism	51.63	36.23	65.96	135
	[6.70]	(Maranhão, 2011)	(Distrito Federal, 2007)	
Youth workforce	0.45	0.32	0.56	135
	[0.04]	(Rio de Janeiro, 2011)	(Roraima, 2007)	

Source: Author's analysis from the databases described above.

Note: standard deviation in parenthesis.

Human capital levels also exhibit some disparities across states. The highest levels of literacy rate are observed in Brasilia (97%). At the bottom, Alagoas presents the lowest level, with 74%, which means that more than a quarter of the population lack the basic writing and reading skills. Urbanization level also reflects differences across states. Brasilia is the most urban state, in contrast to Maranhao, with only 36% of its population living in urban areas. The age of the working population also presents regional disparities, since almost 50% of the working age population in Marañao in 2011 had 29 or less years old, in contrast to Rio de Janeiro, which presents only 32%.

Sectorial composition is quite diverse across states, as Brasilia and Rio de Janeiro present almost no agricultural activity, while, in Mato Grosso almost 30% of its economy corresponds to agricultural related activities. Almost the half of Sao Paulo's economy can be attributed to services, in contrast to only 0.22% of Amazonas or Pará. IBGE provides data on GVA for 12-sectors, which allows for a more detailed descriptive analysis on the differences in sectorial composition and industrial layout across regions. In Table 3 a chart is added which describes the percentage of GVA attributed to each sector in 2011.

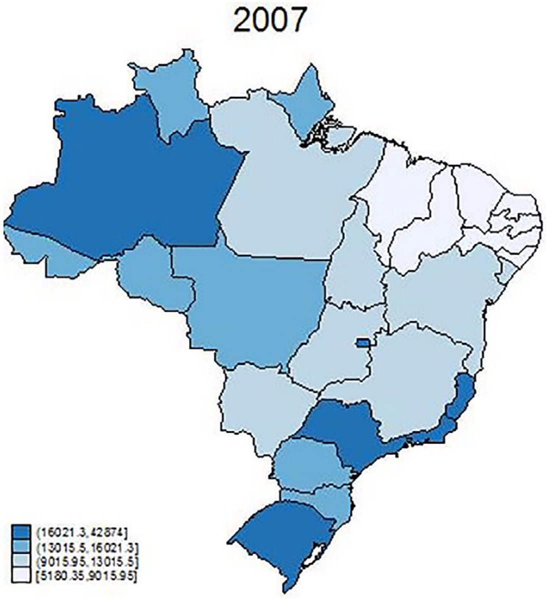
Table 3. Composition of GVA by sector (2011).

Regions	Agricultural sector	Extractive industry	Transformation industry	Construction	Electricity, gas, water, sewage, street cleaning .	Commerce	Transport, storage, post	Information services	Finance, insurance, pensions	Real estate and rentals	Public administration, health, education, social security	Other services
Piauí	7.40%	0.53%	5.65%	7.79%	4.44%	16.03%	3.42%	1.66%	3.71%	7.83%	29.08%	12.47%
Maranhão	17.54%	2.49%	4.41%	8.70%	1.92%	15.10%	6.69%	1.38%	2.77%	7.71%	22.10%	9.19%
Ceará	4.70%	0.51%	10.43%	6.09%	5.19%	15.48%	5.76%	1.91%	5.49%	7.65%	21.97%	14.83%
Paraíba	4.50%	0.62%	8.38%	5.74%	6.75%	13.99%	3.19%	1.87%	4.03%	7.79%	32.30%	10.84%
Alagoas	6.11%	1.19%	13.52%	6.86%	3.63%	15.91%	3.84%	1.69%	3.84%	6.59%	25.89%	10.95%
Rio Grande do Norte	3.74%	8.43%	6.97%	7.25%	1.00%	13.52%	3.30%	1.69%	3.78%	7.44%	28.35%	14.53%
Bahia	7.44%	2.44%	10.43%	8.04%	5.32%	14.28%	4.92%	1.91%	4.47%	8.00%	18.11%	14.63%
Pernambuco	3.45%	0.16%	10.18%	8.60%	5.06%	13.62%	4.37%	2.12%	5.57%	7.95%	23.96%	14.98%
Sergipe	3.53%	7.11%	7.50%	7.66%	6.52%	10.80%	4.81%	2.32%	4.21%	7.80%	27.46%	10.29%
Tocantins	17.12%	0.66%	3.83%	9.01%	7.97%	11.90%	3.14%	0.75%	3.08%	4.70%	29.24%	8.60%
Goiás	12.51%	1.80%	13.80%	7.54%	3.68%	15.17%	4.68%	1.74%	5.17%	7.44%	14.07%	12.41%
Pará	6.06%	27.08%	5.33%	6.25%	3.84%	9.46%	3.87%	1.76%	2.69%	8.03%	17.14%	8.51%
Mato Grosso do Sul	14.04%	1.02%	11.97%	6.90%	2.92%	14.64%	5.55%	1.64%	4.38%	6.79%	19.18%	10.96%
Minas Gerais	9.16%	8.01%	15.26%	6.04%	3.50%	11.27%	5.04%	2.08%	5.13%	8.58%	13.52%	12.41%
Acre	17.65%	0.04%	3.10%	8.59%	1.70%	10.50%	2.42%	1.26%	3.01%	8.50%	35.29%	7.93%
Amapá	3.28%	1.37%	1.86%	3.81%	1.07%	12.43%	3.05%	1.81%	2.22%	10.81%	48.72%	9.58%
Paraná	8.68%	0.22%	17.67%	5.31%	4.08%	16.27%	5.77%	1.94%	7.41%	7.82%	11.81%	13.03%
Roraima	4.53%	0.53%	1.65%	7.91%	1.29%	13.34%	1.94%	1.53%	3.42%	6.40%	49.35%	8.11%
Mato Grosso	24.12%	0.39%	9.98%	4.99%	3.20%	16.65%	5.18%	1.85%	3.44%	6.76%	14.48%	8.95%
Rondônia	20.18%	0.68%	6.43%	11.64%	0.26%	13.49%	2.64%	0.68%	2.82%	6.42%	27.30%	7.44%
Santa Catarina	5.98%	0.56%	22.92%	5.70%	5.89%	15.50%	4.45%	2.13%	4.90%	8.65%	11.93%	11.40%
Espírito Santo	6.22%	22.31%	10.48%	5.41%	0.33%	13.19%	6.95%	1.97%	3.53%	5.09%	13.86%	10.66%
Rio Grande do Sul	9.18%	0.23%	19.07%	4.53%	3.03%	12.74%	5.48%	2.22%	6.33%	6.58%	16.20%	14.41%
Amazonas	6.87%	3.05%	30.55%	5.70%	2.42%	10.59%	4.93%	1.46%	2.46%	5.15%	17.65%	9.17%
Rio de Janeiro	0.43%	14.49%	7.97%	5.71%	2.22%	9.77%	5.43%	4.60%	6.10%	8.43%	18.12%	16.73%
São Paulo	2.11%	0.33%	19.44%	5.17%	2.49%	12.88%	5.58%	4.43%	11.84%	8.45%	9.23%	18.05%
Distrito Federal	0.35%	0.02%	1.81%	3.87%	0.65%	6.39%	2.39%	2.76%	9.67%	6.27%	54.70%	11.12%

As seen in Table 3, there are important differences among regions in terms of GVA composition. For instance, the Pará region is clearly intensive on extractive industry, while Amazonas in industry, and Brasilia in Public Sector. As for the service-related activities (which are important to determine the impact of broadband), there are some differences as well. Mato Grosso, while being an agricultural state, reaches important levels of commerce activity. As for information services, it accounts for a range of GVA which goes from 4.6% (Rio de Janeiro) to 0.68% (Rondonia). Sao Paulo is the clear financial capital (the incidence of financial sector on GVA reaches the highest levels of the country, near 12%), in contrast to most regions in which it does not reaches 5%.

Figure 1 summarizes territorial disparities across regional productivity, defined as GVA per worker. While there is not a clear core-periphery pattern of the regional distribution of productivity, most lagged regions appear to be concentrated in the Northeast. On the other side, most productive regions seem to be located at the Southeast (Rio de Janeiro, São Paulo, Espirito Santo), while there are some centers of development in the South (Rio Grande do Sul) or in the Northwest (especially Amazonas). Amazonas is an industrial state, which has attracted considerable exporting industries in the last decades. Under a scheme of tax incentives, through the duty-free zone in Manaus, Amazonas has attracted manufacturing companies of cell-phones, electronics and motorcycles, among others.

Figure 1. Gross value added per worker in Brazilian states.

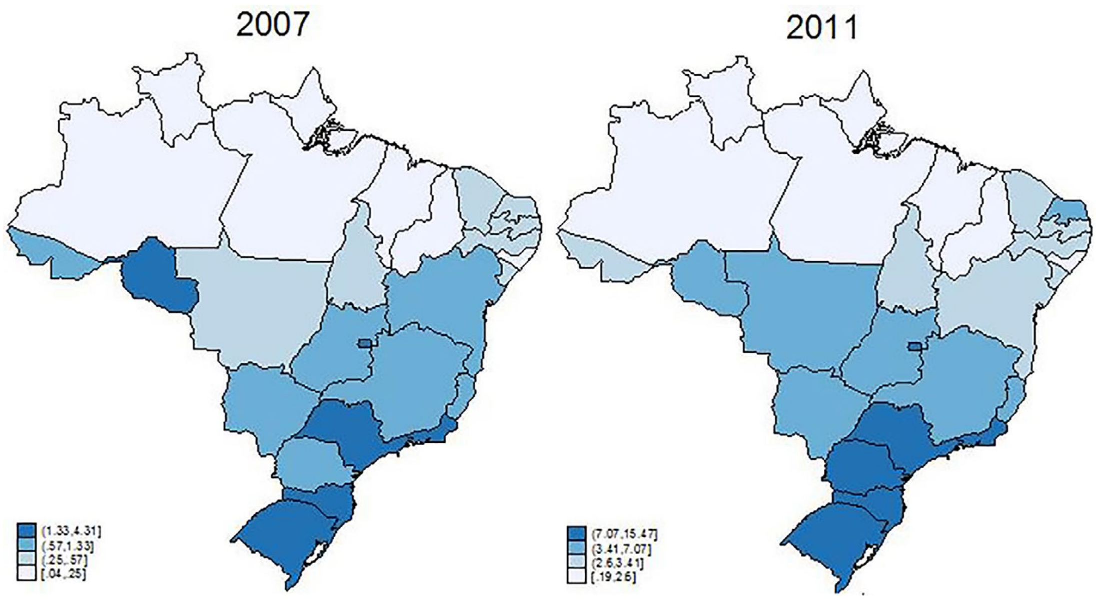


Source: Author’s analysis from the databases described above.

Some of the fastest growing areas in the period are those in low-productive regions in the Northeast (with the exception of Bahia), which may suggest that some process of convergence is being in place. Despite that, the spatial pattern seems to be persistent, with the relative positions remaining almost unchanged between 2007 and 2011. The reason may be that a possible convergence process can take much longer than the analyzed period in this research.

In the case of broadband penetration (Figure 2), there seems to be a more pronounced spatial pattern than in the case of productivity, with Brasilia and the Southern regions reaching the highest penetration levels, while Northern regions appear to be lagging behind in terms of connectivity. Billón *et al.* (2009) report a similar pattern for European regions, as internet adoption followed an uneven spatial pattern with arising agglomeration centers. In a similar fashion, Bonaccorsi *et al.* (2005) state that both developed and developing countries suffer from serious regional disparities in ICT. The digital-divide in Brazil seems to follow a spatial pattern, as broadband penetration is not randomly distributed across space. Northern regions are mainly affected by the Amazonas forest, which probably has affected infrastructure deployment in those states. As a remarkable element, the lagged northeastern regions appear to reach in some cases acceptable levels of connectivity.

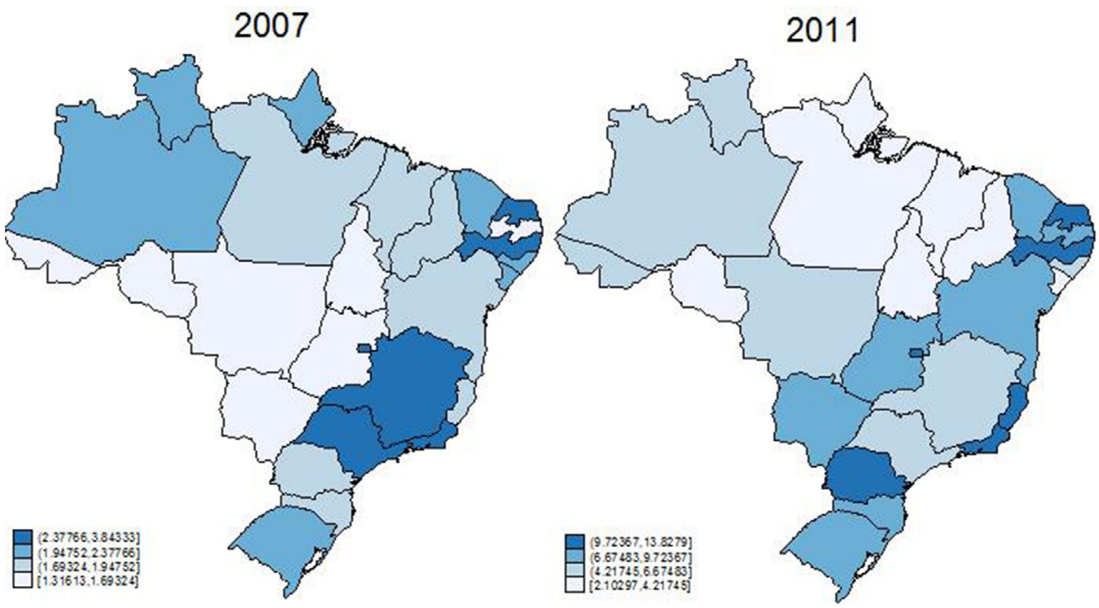
Figure 2. Fixed broadband penetration across Brazilian states



Source: Author's analysis from the databases described above.

In terms of broadband speed, the highest levels are those reached by Rio de Janeiro, Brasilia, Paraná and some of the lagging northeast regions. The fact that some of the low-productive regions exhibited the fastest growth in the period and present reasonable levels of broadband penetration and speed, might contribute to raise the question if the new technologies can have contributed to its recent development.

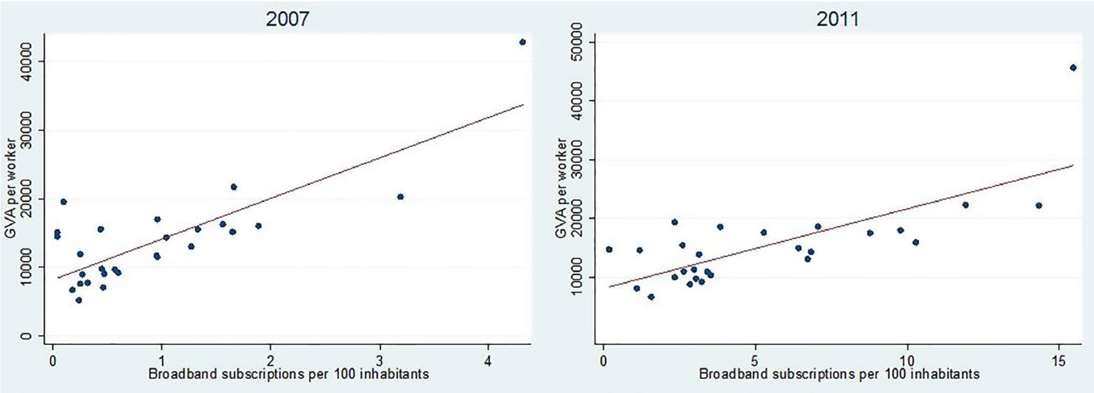
Figure 3. Fixed broadband download speed across Brazilian states.



Source: Author's analysis from the databases described above.

Figure 4 plots broadband penetration and productivity. Even if that correlation does not necessarily indicate causality, it provides evidence of a positive association among both variables, which is stable over the period considered. That is, productivity and broadband penetration tends to appear together.

Figure 4. Correlation between productivity (gross value added per worker) and broadband penetration.



Source: Author's analysis from the databases described above.

5. RESULTS

The empirical analysis will consist on the econometric estimation of the proposed model on diverse specifications. As the empirical specification makes impossible to recover α, this parameter will be determined by the capital share on the income in Brazilian national accounts. In that sense, Feenstra *et al.* (2013), using Penn World Table data, find that the labor share in the income in Brazil averaged 0.55 in the period 2007-2011. Under the assumption of constant returns to scale, this implies α=0.45, which will be used to recover the structural parameters. Table 4 reports estimations of the base model assuming no interaction between broadband penetration and local attributes. All estimations are performed computing heteroskdasticy-robust standard errors.

Table 4. Estimation Results of base model

Estimation	[1]	[2]	[3]	[4]
Literacy rate	0.0197**	0.0218***	0.0118*	0.0188***
	[0.0083]	[0.0070]	[0.0069]	[0.0065]
In(Broadband)	0.0364***	0.0368***	0.0553***	0.0714***
	[0.0125]	[0.0103]	[0.0127]	[0.0255]
Agriculture		0.1511		0.0007
		[0.2748]		[0.4277]
Services		-1.0189**		-1.1862***
		[0.4073]		[0.3359]
Urbanism		-0.0133***		-0.0146***
		[0.0023]		[0.0029]
Youth workforce		0.1316		1.1027
		[0.4562]		[0.7561]
Year 2009		-0.0122*		-0.0133
		[0.0070]		[0.0092]
Implied ϕ	0.0200	0.0202	0.0304	0.0393
Implied γ	0.0108	0.0120	0.0065	0.0103
Fixed effects	Yes	Yes	Yes	Yes
Observations	135	135	132	132
R-sq (within)	0.50	0.66	0.46	0.61
Method	LS	LS	IV	IV

Source: Author's analysis

Note: *p<10%, **p<5%, ***p<1%. Robust standard errors in parenthesis. Instruments for Broadband in IV: telephone fixed voice lines per 100 inhabitants (lagged 5 years), and population density at the beginning of the XX century (census 1920-1950).

Estimation [1] in Table 4 reports Least-Squares results assuming that all region specific differences in TFP, accounted by Ω_i are time-invariant, and are approximated by state fixed effects. Results suggest a positive and significant incidence of human capital on productivity, as expected. Broadband is found to be significant at 1% level, with elasticity levels which suggest that a 10% increase in penetration can be related with a 0.2% of increase in productivity, as denoted by the implied parameter ϕ. As stated by other studies (Czernich *et al.* 2011; Koutroumpis, 2009) broadband effect appears to be contemporaneous to the diffusion of broadband. Although the magnitude is similar to other empirical research in the literature, additional estimations will be performed to evaluate the robustness of the results.

Estimation [2] in Table 4 adds controls to [1], trying to control for the existence of time-varying regional specific differences in Ω_i. As a result, beyond regional fixed effects, further variables might be considered as potential determinants of productivity. Particularly, the following variables are considered: sectorial composition (percentage of agricultural and services activities in local GVA), degree of urbanization, age of the workforce and a dummy variable to account for the economic cycle. As stated by Cardona *et al.* (2013), taking into account business cycle effects is manageable given long enough time periods, which is not the case of this dataset. As a result, a dummy variable will be added for year 2009, in which the Brazilian economy experienced a one-off contraction as a result of the international crises. This variable will absorb external shocks related to the recession. Results in [2] suggest similar coefficients for broadband, suggesting that the impact is robust to controls.

Results for IV estimations are shown in columns [3] and [4] of Table 4. In both cases, the Hansen statistic, which test the exogeneity of the instruments do not reject the null hypothesis of exogeneity. The results from tests for weak instruments also suggest the validity of the chosen instruments. IV estimates point out, if anything, that the incidence of broadband is even higher. This outcome is in line of the results obtained by Bertschek *et al.* (2013) and Czernich *et al.* (2011), who report that OLS estimates may be downward biased. In fact, productivity-broadband elasticity reaches 0.03 in the model without controls and 0.04 when control variables are included. The fact that the coefficients increase from LS to IV, and even increase further when adding controls, provides additional support to the hypothesis that broadband has had a positive impact on productivity in Brazil, suggesting a causality direction in that sense.

Once the impact of broadband on Brazilians productivity seems to be verified, it seems extremely interesting to assess whether the impact is uniform across states, which means to define TFP as in [2´]. To take into account possible differences in the impact of broadband, regions are classified in several groups according to its level of development, measured through labor productivity (GDP per worker). The 27 states can be easily divided into 3 groups of 9 regions, according to the average productivity levels in the sample. Regions' classification is shown in Table 5.

Table 5. Region clustering according to productivity

Low-Productive regions	Medium-Productive regions	High-Productive regions
Piauí	Tocantins	Mato Grosso
Maranhão	Goiás	Rondônia
Ceará	Pará	Santa Catarina
Paraíba	Mato Grosso do Sul	Espírito Santo
Alagoas	Minas Gerais	Rio Grande do Sul
Rio Grande do Norte	Acre	Amazonas
Bahia	Amapá	Rio de Janeiro
Pernambuco	Paraná	São Paulo
Sergipe	Roraima	Distrito Federal

Source: Author's elaboration

The next estimations are performed using Least Squares as they provide a more conservative approach than IV and they can serve as a lower bound. High-productive regions mean the reference category, adding dummy variables LP (for low-productive ones) and MP (for medium-productive regions). The parameters associated to these variables are represented by Φ (base scenario), Φ_{LP} and Φ_{MP}, respectively.

Table 6. Results allowing variations for region groups

Estimation	[1]	[2]	[3]	[4]
Literacy rate	0.0111	0.0098	0.0114	0.0129
	[0.0079]	[0.0077]	[0.0076]	[0.0076]
In(Broadband)	0.0258**	0.0143	0.0161	-0.0014
	[0.0120]	[0.0120]	[0.0123]	[0.0130]
LP*In(Broad-band)	0.0462**	0.0599***	0.0495***	0.0513***
	[0.0171]	[0.0176]	[0.0165]	[0.0135]
MP*In(Broad-band)	0.0076	0.0147	0.0117	0.0197
	[0.0191]	[0.0172]	[0.0178]	[0.0157]
Mass*In(Broad-band)		0.0177**		
		[0.0067]		
Quality*In(-Broadband)			0.0002**	
			[0.0001]	
Commerce*In(-Broadband)				0.0356***
				[0.0122]
Info_servi-ces*In(Broad-band)				0.0309**
				[0.0145]
Finance*In(-Broadband)				0.0132
				[0.0151]
Other_servi-ces*In(Broad-band)				-0.0089
				[0.0156]
Implied ϕ	0.0142	0.0079	0.0089	-0.0008
Implied ϕ LP	0.0254	0.0329	0.0272	0.0282
Implied ϕ MP	0.0042	0.0081	0.0064	0.0108
Implied γ	0.0061	0.0054	0.0063	0.0071
Fixed Effects	Yes	Yes	Yes	Yes
Observations	135	135	135	135
R-sq (within)	0.55	0.57	0.57	0.61
Method	LS	LS	LS	LS

Source: Author's analysis from the databases described above.

Note: *p<10%, **p<5%, ***p<1%. Robust standard errors between brackets.

Estimation [1] in Table 6 considers uniquely the level of development as a source for differences in the impact of broadband on productivity. Results suggest important differences among regions. Every region benefits from broadband (as Φ is significant and equals 0.014), but less developed regions appear to obtain much larger productivity gains through broadband than medium and highly developed regions (as Φ_{LP} is significant and equals 0.025). On average, a 10% increase of broadband penetration developed regions in Brazil seem to increase productivity in 0.14%, while poor regions experience a productivity raise of 0.4%.Additional productivity gains for medium developed regions are positive but no significant. On average, a possible pattern may suggest that the impact of broadband on productivity declines as regions become more developed.

Additional estimations may provide more insights on the impact of broadband on productivity. Estimation [2] allows regions reaching a certain critical-mass to get benefit from network externalities. Lowest thresholds considered by other authors at OECD are were found to be far from Brazilian levels at this stage (for instance, Koutroumpis, 2009, considers as critical the threshold of 20% penetration per inhabitant, while Czernich *et al.*, 2011, measure network externalities from a 10% level). For Brazil, after considering several alternatives, a minimum threshold of 6.25% penetration is adopted, a level which means 20% of households with broadband connection[4]. Regions reaching that threshold are be assigned *Mass* = 1, while regions below, *Mass* = 0.

Estimation [2] in Table 6 suggests that low developed regions are still those that benefit most from broadband. In contrast, the base scenario appears to be not significant, once controlling for critical-mass. Critical-mass appears to be important, as the parameter associated is positive and significant at 5%. This suggests that regions after reaching the stipulated critical-mass increase the impact of broadband on productivity by 0.009. These results cannot be interpreted as that medium and highly developed regions do not obtain benefits from broadband, but those benefits may be mostly associated to network externalities. In contrast, underdeveloped regions get a benefit independently from the critical-mass effect.

Estimation [3] in Table 6 allows broadband quality differentials to have an incidence on productivity. As seen in Figure 3, low productive regions, located at the northeast, reach acceptable average speed levels for its broadband networks, suggesting that this may contribute to these regions extracting more externalities from broadband. To approximate quality, the measure to be used will be the square of average speed, following Rohman and Bohlin (2013). Results suggest that low developed regions remain benefiting from a higher economic impact from broadband than other states. Medium and highly productive regions again reach non-significant levels. Broadband speed seems to be important, since the associated parameter is significant at 5% level. As in the case of critical mass, higher quality may be contributing especially to medium and high productive regions reaching benefits from broadband.

Estimation [4] in Table 6 considers the sectorial composition in interaction with broadband. As stated by the literature, services related sectors are expected to benefit more than broadband, in comparison with more traditional sectors as agricultural, construction or industry. IBGE provides data of GVA of specific services, as commerce, information services, financial sector and others. To find out if regions relatively intensive in these sectors reach higher economic impact of broadband, dummy va-

4 The average size of Brazilian households is 3.2 persons

riables will be interacted with penetration levels. To define the service sector related dummy variables, regions which will take the respective values of 1 will be those which have a higher degree of its economies attributed to those sectors, in comparison with other regions (the top third in each case). Results again confirm that most underdeveloped regions appear to obtain a higher impact from broadband, while some interesting results arise from the services activities in interaction with broadband. Regions which are relatively intensive in commerce activities, or in information services, seem to yield higher productivity returns for broadband. On the contrary, no significance was found for the interaction of broadband and intensiveness on the financial sector or other services.

It is important to try to address why the least developed regions get more economic impact from broadband. A possible explanation can be related to the fact that the technological change derived from broadband deployment in a poor region seems to be much larger than in highly developed regions, which already had good infrastructure and communications endowment. In contrast, for poor regions, the impact on the social and business environment may be bigger. Perhaps high productive regions in Brazil may have already made a difference in their economies because of broadband, which may suggest some degree of diminishing returns.

This evidence suggests that broadband inclusion across all territories in Brazil will surely enable better opportunities for business and individuals in underdeveloped regions and that may contribute to overcome its traditional disadvantages. Broadband infrastructure, combined with lower wages and other costs may contribute to increase the competitiveness in more underdeveloped regions, reducing agglomeration forces at the core. Even if further research is required, this evidence may suggest that a strategy of reducing regional digital divides may contribute to prompt economic cohesion across the territories of a country

6. CONCLUSIONS

This paper has aimed to provide robust evidence on the impact of broadband on productivity and Brazil and, particularly, on the fact that these effects are not uniform across national territories. In fact, at least in Brazil, broadband seems to be yielding the highest productivity gains for less developed regions, a result that is robust to controls for differences in quality, network effects, human capital endowments and sectorial composition.

Even if a convergence analysis remained out of the scope of this paper, these results suggest that broadband connectivity might constitute a factor favoring regional cohesion in Brazil. In the past, Barrios *et al.* (2008) find that ICT investments have contributed significantly to regional convergence in Spain. They also state that the development of ICT activities constitute a potentially good candidate for promoting regional development. In the same line, Ding *et al.* (2008) suggest that telecommunication infrastructure contributed significantly to regional convergence in China, supporting investment policies in telecommunications in lagged regions of developing countries. They state that facilitating telecommunications infrastructure is important for assisting economic growth in the least developed regions of developing countries with poorly developed telecom infrastructure. To confirm that assertion for the case of Brazil, further research will be required, especially when long enough time series data is available to perform a growth-regression analysis.

In any case, broadband connectivity appears to be a source of productivity gains in Brazil, something that provides empirical support to the public program of connectivity "Programa Nacional de Banda Larga", currently being deployed in Brazil.

To conclude, some policy implications can be derived from the analysis. The importance of broadband for regional development makes that all level of governments should follow policies that encourage broadband deployment. Although referring to the case of Europe, Barrios and Navajas (2008) state the importance to adopt, together with country-level initiatives, regional policies, because the nature of technological change and innovation have a string regional component that make that public policies must be designed taking that into account. In Brazil, some states have started to follow this strategy, as for instance Paraná and Amapá which have launched state-based broadband public plans, as aiming to complement the above-mentioned national plan. Barrios and Navajas (2008) highlight the importance that regional cohesion policies consider the relevance of ICT infrastructure, aiming to favor the attractiveness of less developed regions. They even call for differentiated intervention, even among regions within the same countries. Regional policies should also promote ICT skills and the use of ICT by small and medium size enterprises (SMEs) (Barrios *et al.*, 2008).

In this context, investment from service providers in broadband infrastructure is critical, both in terms of coverage and speed. As stated by Crandall *et al.* (2009), it is essential that regulatory policies do not reduce investment incentives for carriers. In particular, policy makers should adopt measures that promote, or at least do not inhibit, the growth of broadband. In density-populated areas, private competition will surely provide the required incentives which will lead to higher investments and better connectivity. In those markets, it will be necessary from federal and state governments to reduce entry barriers and promote investment by incumbents and new service providers. In contrast, in distant areas, with low levels of population density, or affected by adverse geographical conditions, public intervention will definitely become vital for infrastructure deployment. At those cases, universalization policies might become crucial. As stated by Frieden (2005), broadband investment requires of important levels of public and private cooperation.

Policy will also need to promote connectivity from the demand-side. Lower prices are necessary to increase penetration, because, as stated by Galperin and Ruzzier (2013), broadband demand is elastic. Additionally, to maximize demand and social returns to broadband deployment, policymakers should address eventual ICT-related skills among the workforce.

Downloading speed is, as seen before, relevant to enhance the economic impact of broadband, and it will probably become more important in the future, as data traffic through the networks is increasing and will start to strain current infrastructures. Although not addressed by this research, mobile broadband may also constitute an opportunity to close the digital-divide, especially through its potential to connect isolated distant areas (Katz, 2012). In that sense, spectrum allocations will be required to provide necessarily resources for deployment of new generation services as LTE.

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