CHAPTER 1.11

Digital Inclusion and Economic Development: A Regional Analysis from Brazil

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Information and communication technologies (ICTs) in general, and broadband in particular, have been studied extensively in the economic literature as a potential source for raising employment and economic growth. However, some gaps in the literature remain unfilled, motivating the present research.

Although the bulk of the literature has focused on either country-aggregate or firm-level studies, subnational-regional analyses of the digital divide and the impact of broadband on local productivity are still scarce. An ongoing debate concerns whether or not broadband may enable better opportunities for businesses and individuals in isolated and underdeveloped regions, which are usually affected by regional digital divides. If the economic impact of broadband was found to be bigger in peripheral regions (in contrast to their impact in the center of the country), then a strategy of reducing regional digital divides might help to stimulate economic cohesion across the territories of a country. In contrast, if productivity growth driven by broadband is found to be greater in the center, then it might exacerbate regional disparities. As a result, understanding regional differences in the economic impact of broadband seems key to analyzing the effects of promoting the regional digital inclusion—that is, of extending connectivity to isolated and underdeveloped territories within a country.

Despite their recent economic growth, BRIC countries remain well above Organisation for Economic Co-operation and Development (OECD) averages in terms of inequalities.[1] Income per capita regional disparities have increased in India and China in recent years. In contrast, to some degree in Russia and especially in Brazil, urban-rural inequalities have recently decreased, but they remain high. Transverse and complementary policies will become crucial for BRIC countries to reduce those internal disparities. The present research constitutes an effort to disentangle the impact of broadband on regional productivity and to analyze the suitability of ICT policies in helping lagging regions overcome their disadvantages. The empirical analysis will focus on Brazil,[2] a country in which, despite its recent growth, high levels of inequality persist, and where the income per capita of a leading region is more than three times higher than the national average.

The results presented in this chapter provide evidence that broadband seems to be yielding the highest productivity gains for the less-developed regions in Brazil. This evidence highlights the importance of broadband for regional development, from which some policy implications can be derived. Cohesive policies should promote the development of ICTs in lagging

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regions with the aim of favoring their attractiveness as a location for business, and, in turn, should promote the development of territorial equilibrium—in other words, these policies should help level the playing field among regions.

Apart from national plans, regional governments should promote local policies especially designed to consider their specific socioeconomic and geographic features in order to maximize the deployment of broadband and its economic impact. Deployment can be facilitated by promoting competition in a suitable framework, preventing overlapping regulation among different government levels, and avoiding public initiatives that can generate a crowding-out effect on private investments. In isolated or inaccessible areas, public-private cooperation is important for the development of the sector, and universalization policies might become crucial.[3] Regulatory flexibility will become important for promoting broadband commercial plans affordable to the base of the socioeconomic pyramid. Digital inclusion agendas should also promote ICT skills and the use of ICTs by small- and medium-sized enterprises. These policy derivations are especially important for BRIC countries because they may contribute to reducing their regional inequalities.

LITERATURE REVIEW

In the last few years, most ICT-derived contributions to productivity have come from the development of broadband Internet connections. According to Jordán and De León (2011) and Mack and Faggian (2013), broadband now constitutes a key part of the infrastructure necessary for development, in much the same way that previous advances such as railroads, roads, and electricity became fundamental requirements for development. Recent empirical analysis has concentrated on analyzing the impact of broadband on economic growth at a country level.[4] At a regional level, research has been much scarcer and refers mostly to the United States.[5]

An ongoing debate in the literature is related to the economic impact of broadband for regions in the process of closing their digital divides; determining this impact requires analyzing the link between the new technologies and underdeveloped regions. Some researchers believe that ICTs may open possibilities that will allow remote regions to overcome traditional disadvantages associated with their isolation. 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 being one result of an eventual widespread deployment of ICTs.[6] According to this view, distance may be less important and peripheral regions may benefit from opportunities that were not previously available.[7] The presence of broadband itself may facilitate the development of poor regions, enhancing some degree of territorial equilibrium.[8] Isolated regions may present some advantages—such as lower wages and property costs—that can be fully exploited if good broadband infrastructure is available.

Other authors argue that the presence of network externalities suggests that regions or countries with higher penetration levels tend to exhibit a larger contribution of broadband to economic growth than regions with lower penetration. If high-income economies are those with higher penetration, disparities across regions might be increased. Katz (2012), however, suggests a nonlinear (or inverted U-shape) relationship between broadband penetration and output. Beyond the issues of network externalities and nonlinear impact, the degree of the impact of broadband on productivity may depend on a variety of local attributes, including sectorial structure, demography, human capital, and so on.

All the previous arguments may imply that broadband should have a positive impact on productivity, but this impact may differ across regions, even within the same country. Performing an analysis in a country as big as Brazil, which exhibits important regional inequalities, may provide a better understanding of the regional dimension of the impact of broadband on productivity, and may also contribute to evaluating its suitability as an instrument for regional cohesion.

THEORETICAL MODEL AND EMPIRICAL SPECIFICATION

The empirical specification presented here is based on a theoretical model where economies are supposed to produce according to a Cobb-Douglas production function with various input factors (physical capital stock, labor, and human capital). Total factor productivity (TFP) is stipulated to be related to some region-specific characteristics and is assumed to depend positively on the level of broadband infrastructure. The empirical specification can be expressed as:[9]

$$\ln\left(\frac{Y}{L}\right) = \Gamma_0 + \Gamma_1 \ln \Omega(X) + \Gamma_2 \ln(\text{broadband}) + \Gamma_3 h$$

where

Γ_i = parameters needed to estimate results,
Y = output,
$\Omega(X)$ = region-specific characteristics,
broadband = broadband subscriptions per 100 inhabitants,
L = labor, and
h = the efficiency of a unit of labor (as in Hall and Jones 1999).

The specification in the above equation may be useful for obtaining a common regional measure of the impact of broadband on productivity, but it is not able to account for differences in impact across regions. As stated in the literature review, the impact of broadband may differ, depending on the degree of development of the region. For the purposes of the empirical

Table 1: Descriptive statistics, five-year sample (2007–11)

Variable	Mean	Minimum value of sample (region, year)	Maximum value of sample (region, year)	Number of observations
Productivity: GVA per worker in Brazilian reais, 2000 constant prices	14,490.23 [7,371.61]	5,180.35 (Piauí, 2007)	46,762.56 (Distrito Federal, 2010)	135
Literacy rate, population over 15 years old	88.25 [6.29]	74.26 (Alagoas, 2008)	96.84 (Distrito Federal, 2009)	135
Fixed broadband penetration: no. of subscriptions > 512 kp/s per 100 inhabitants	2.97 [3.21]	0.04 (Amapá and Roraima, 2007)	15.47 (Distrito Federal, 2011)	135
Speed, weighted average in mb/s	4.41 [2.82]	1.32 (Rondônia, 2007)	13.83 (Rio de Janeiro, 2011)	135
Agriculture sector, % of regional GVA	0.09 [0.07]	0.00 (Distrito Federal and Rio de Janeiro, 2007, 2008, 2009, 2010, 2011)	0.29 (Mato Grosso, 2008–09)	135
Services sector, % of regional GVA	0.31 [0.05]	0.22 (Acre,2007; Amazonas and Pará, 2010)	0.47 (São Paulo, 2011)	135
Urban population, % total population	51.63 [6.70]	36.23 (Maranhão, 2011)	65.96 (Distrito Federal, 2007)	135
Youth workforce, % working age population (18–29 years old)	0.45 [0.04]	0.32 (Rio de Janeiro, 2011)	0.56 (Roraima, 2007)	135

Sources: Author's analysis based on data from the following sources: GVA per worker, Agriculture sector, Services sector, and Youth workforce: IBGE database; Fixed broadband, Speed: Telebrasil; Literacy rate, Urban population: IPEA database.
Note: The standard deviations appear within square brackets.

estimation, regions are classified according to their level of development. As a result, in further estimations TFP is expressed as depending on broadband penetration associated with the level of development of the region, plus further factors that may have an influence on the economic impact of broadband.

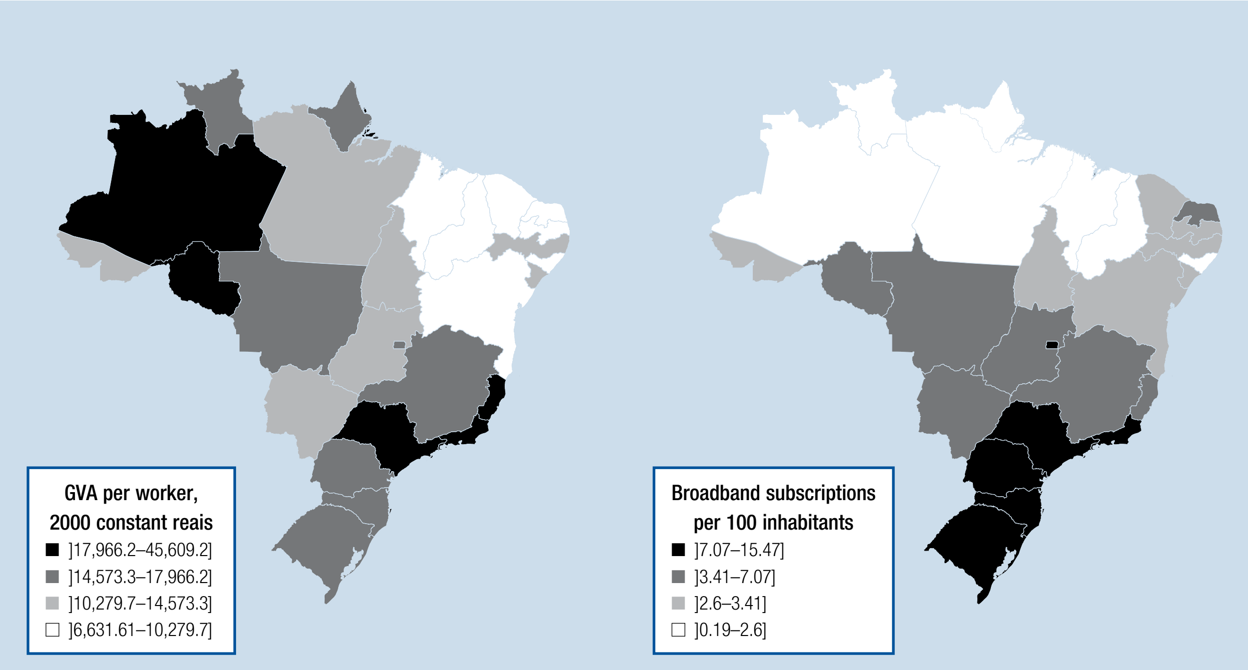
The empirical model to be estimated consists of a panel with regional fixed effects, which provides the advantage of accounting for all time-invariant heterogeneity across regions. A common critique of ICT and broadband estimations is that results may determine correlation rather than a causality effect on productivity. Some authors use instrumental variables to tackle these endogeneity issues. Following Czernich et al. (2011), the empirical specification builds on the idea that most common broadband rollouts—that is, asymmetric digital subscriber line (ADSL) or cable modem—rely on the copper wire of pre-existing voice-telephony networks. As noted by Czernich et al., the required access to an existing infrastructure built for other purposes, such as that of fixed telephony, make this a suitable instrument. The instrument in this case is the number of voice-telecommunication fixed-access lines per 100 inhabitants five years earlier than the year of the current data—the period considered is 2007–11. For each of those years, we have five-year lags of this variable (2002–06). In addition, because broadband deployment may depend on demographic factors, population density is added as an instrument, but to do this we use variables from the beginning of the last century (census data from 1920 to 1950) in order to avoid any possibility of endogeneity bias. The instruments were lagged considerably to avoid any possibility of being affected by contemporary shocks.

DATA AND EXPLORATORY ANALYSIS

This section summarizes the description of the variables used in the empirical analysis, which covers the period 2007–11.[10] Output is measured through gross value-added (GVA), deflated to 2000 constant Brazilian real prices. *Broadband* is defined as Internet access provided at a certain level of speed capacity. The International Telecommunication Union (ITU) and the OECD both define broadband as those connections with speeds above 256 kilobits per second (kb/s). Telebrasil (the Brazilian Association of Telecommunications) classifies Internet connections by speed, considering a threshold of 512 kb/s. As a result, for the purposes of this research, the analysis considers connections that reach speeds of 512 kb/s or more—this constitutes a more realistic approximation for broadband than that of 256 kb/s, which hardly serves for most applications nowadays. The quality of the connectivity may play an important role in regional inequalities. Available data from Telebrasil allow for considering differences in average bandwidth speeds across regions. Average fixed broadband download speed is constructed with data that classify subscriptions into different groups depending on their speed.[11]

Data on labor and on human capital were obtained from the Brazilian government's Instituto de Pesquisa Econômica Aplicada (the Institute of Applied Economic Research, or IPEA) and the Instituto Brasileiro Geografia e Estatística (the Brazilian Institute of Geography and

Figure 1: GVA per worker (left) and broadband penetration (right), 2011



Source: Author's analysis based on data on GVA per worker from the IBGE database; data on broadband from Telebrasil.

Statistics, or IBGE) databases. After considering a variety of alternatives, literacy rate is used as a measure of human capital. To control for TFP differences across regions, the percentage of urban residents over the total population and the sectoral composition of the economy, measured as the percentage of agriculture and services across the whole regional GVA, are used. To control for differences in demography structure, the percentage of the working-age population under 29 years old is used (termed "youth workforce" in the tables). For the empirical estimations, a dummy variable is added for the 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 global recession.

Descriptive statistics are shown in Table 1. Important differences arise in productivity levels across regions, with Brasilia (Distrito Federal) appearing as the region with the highest productivity. Brasilia presents some peculiarities. It was founded in 1960 in order to move the capital to a central location. The difference in productivity between Brasilia and its closest followers is substantial, possibly partly because of differences in its sectoral composition (its main economic activities are public administration and services) and partly because Brasilia is a city in a small federal district, while the other regions constitute states. At the other extreme, the lowest productivity region is found in Piauí, which had a GVA per worker in 2011 that reached only 14 percent of that found at the capital level.

Broadband penetration averages three subscriptions per 100 inhabitants across the five-year sample, with Brasilia again being the region that reaches the highest penetration in 2011, with a penetration level of 15.47 subscriptions per 100 inhabitants (almost 50 percent of its households). There seems to be a considerable regional digital divide: poor states, such as Amapá, reached a broadband penetration of only 0.19 in 2011 (fewer than 1 percent of households).

Figure 1 summarizes territorial disparities across regional productivity and broadband penetration. Although there is not a clear center-periphery pattern of the regional distribution of productivity, most lagging regions appear to be concentrated in the northeast. On the other hand, 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 or in the northwest (especially Amazonas, an industrial state).

A more pronounced spatial pattern is evident for broadband penetration than for productivity, with Brasilia and the southern regions reaching the highest penetration levels while the northern regions appear to be lagging behind in terms of connectivity. Billón et al. (2009) report a similar pattern in 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 ICTs.

RESULTS

The empirical analysis consists of the econometric estimation of the proposed model for diverse

Table 2: Estimation results of the base model

Variable	Estimation [1]	[2]	[3]	[4]
Literacy rate, population over 15 years old	0.0197† [0.0083]	0.0218‡ [0.0070]	0.0118* [0.0069]	0.0188‡ [0.0065]
ln(broadband)	0.0364‡ [0.0125]	0.0368‡ [0.0103]	0.0553‡ [0.0127]	0.0714‡ [0.0255]
Agriculture sector, % of regional GVA	—	0.1511 [0.2748]	—	0.0007 [0.4277]
Services sector, % of regional GVA	—	–1.0189† [0.4073]	—	–1.1862‡ [0.3359]
Urban population, % total population	—	–0.0133‡ [0.0023]	—	–0.0146‡
Youth workforce, % working age population (18–29 years old)	—	0.1316 [0.4562]	—	1.1027 [0.7561]
Dummy variable for year 2009	—	–0.0122* [0.0070]	—	–0.0133 [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
Number of observations	135	135	132	132
R^2	0.50	0.66	0.46	0.61
Method	Ordinary least squares	Ordinary least squares	Instrumental variable	Instrumental variable

Sources: Author's elaboration based on data from the following sources: Agriculture sector, Services sector, GVA per worker, and Youth workforce: IBGE database; Fixed broadband, Speed: Telebrasil; Literacy rate, Urban population: IPEA database.
Notes: — = not applicable. Robust standard errors appear in square brackets.
Significance level: * = 10 percent, † = 5 percent, ‡ = 1 percent.

Table 3: Regional classification according to productivity

Low-productivity regions	Medium-productivity regions	High-productivity 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 based on productivity levels (GVA per worker); data from the IBGE database.

specifications.[12] Table 2 reports estimations assuming no regional differences. Results provide evidence of the positive impact of broadband on productivity that is robust to the addition of control variables and the use of instruments to take into account endogeneity. Instrumental variable estimates point out that, if anything, the incidence of broadband is even higher than in estimations that do not use this approach (i.e., that are ordinary least squares estimations). This outcome is in line of the results obtained by Bertschek et al. (2013) and Czernich et al. (2011), who both report that ordinary least squares estimates may be downward biased.

Once the impact of broadband on productivity is verified, it is interesting to determine whether that impact is uniform across states. To take into account differences in the impact of broadband, regions are classified into several groups according to their level of development: low-productivity (LP), medium-productivity (MP), and high-productivity (HP) regions. Brazil's 27 states can be easily divided into three groups of nine regions each, according to the average productivity levels in the sample. Regions' classifications are shown in Table 3.

The next estimations are performed using ordinary least squares methods because these provide a more conservative approach than instrumental variables do, and ordinary least squares can serve as a lower bound. Estimation [1] in Table 4 considers uniquely the level of development as a source for differences in the impact of broadband. Every region benefits from broadband (because Φ is significant and equals 0.014),

Table 4: Results allowing for variations in the region groups

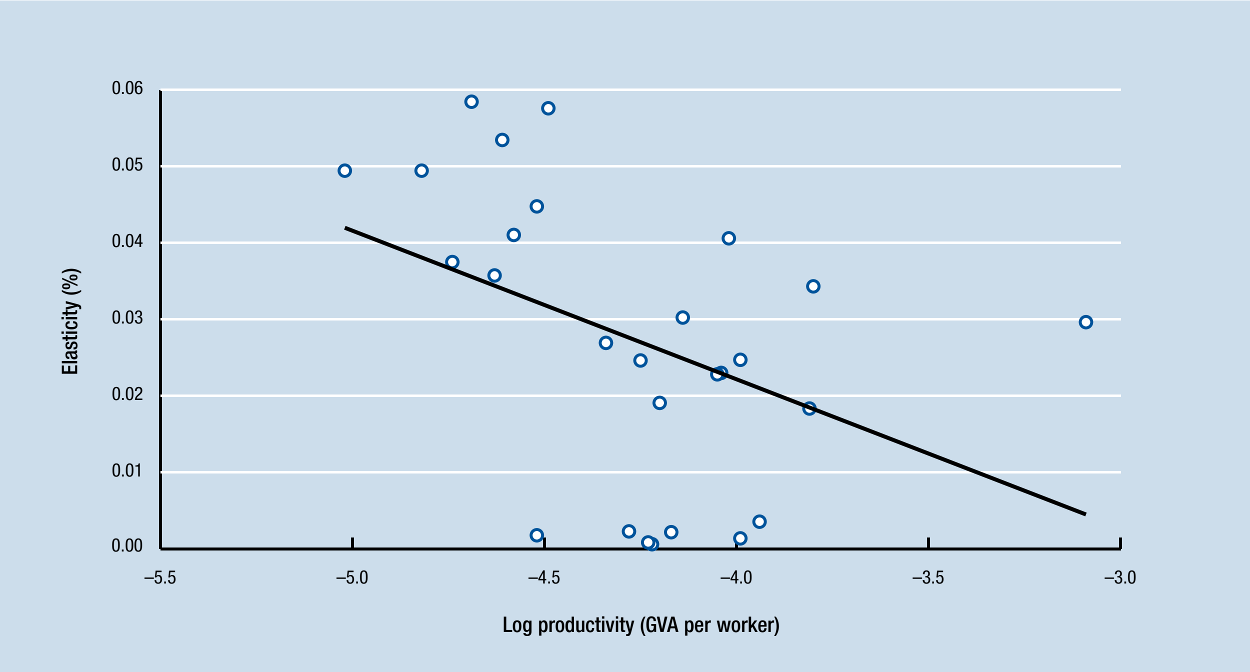
	Estimation			
Variable	[1]	[2]	[3]	[4]
Literacy rate, population over 15 years old	0.0111 [0.0079]	0.0114 [0.0076]	0.0129 [0.0076]	0.0131* [0.0072]
ln(broadband)	0.0258† [0.0120]	0.0161 [0.0123]	–0.0014 [0.0130]	–0.0055 [0.0130]
LP*ln(broadband)	0.0462† [0.0171]	0.0495‡ [0.0165]	0.0513‡ [0.0135]	0.0527‡ [0.0129]
MP*ln(broadband)	0.0076 [0.0191]	0.0117 [0.0178]	0.0197 [0.0157]	0.0209 [0.0157]
Quality*ln(broadband)	— —	0.0002† [0.0001]	— —	0.0001* [0.0001]
Commerce*ln(broadband)	— —	— —	0.0356‡ [0.0122]	0.0363‡ [0.0125]
Info services*ln(broadband)	— —	— —	0.0309† [0.0145]	0.0277* [0.0150]
Finance*ln(broadband)	— —	— —	0.0132 [0.0151]	0.0080 [0.0156]
Other services*ln(broadband)	— —	— —	–0.0089 [0.0156]	–0.0107 [0.0167]
Implied ϕ	0.0142	0.0089	–0.0008	–0.0030
Implied ϕ LP	0.0254	0.0272	0.0282	0.0290
Implied ϕ MP	0.0042	0.0064	0.0108	0.0115
Implied γ	0.0061	0.0063	0.0071	0.0072
Implied δ Quality	—	0.0001		0.0001
Implied δ Commerce	—	—	0.0196	0.0200
Implied δ Info services	—	—	0.0170	0.0152
Implied δ Finance	—	—	0.0073	0.0044
Implied δ Other services	—	—	–0.0049	–0.0059
Fixed effects	Yes	Yes	Yes	Yes
Number of observations	135	135	135	135
R^2 (within)	0.55	0.57	0.61	0.62
Method	Ordinary least squares	Ordinary least squares	Ordinary least squares	Ordinary least squares

Sources: Author's elaboration based on data from the following sources: Literacy rate: IPEA database; broadband data: Telebrasil; GVA per worker: IBGE database.
Notes: LP = low-productivity regions; MP = medium-productivity regions; Quality is approximated by the square of the average speed. Commerce, Info services, Finance, and Other services refer to the GVA data for specific sectors; these are dummy variables that take a value of 1 for those regions that appear at the top third of the sample in the percentage of GVA attributed to those sectors. — = not applicable. Robust standard errors appear in square brackets.
Significance level: * = 10 percent, † = 5 percent, ‡ = 1 percent.

but less-developed regions appear to obtain much larger productivity gains (because Φ_{LP} is significant and equals 0.025). This may suggest that the impact of broadband on productivity declines as regions become more developed.

Estimation [2] allows broadband quality differentials to have an influence on productivity. Quality is approximated by the square of average speed, following Rohman and Bohlin (2012). Results suggest that less-developed regions experience a higher economic impact from broadband. Speed seems to be important, since the associated parameter is significant at the 5 percent level. Estimation [3] considers the sectoral composition. As stated by the literature, services-related sectors are expected to benefit more from broadband than more traditional sectors such as agriculture, construction, and industry. The IBGE provides GVA data for specific services, such as commerce, information services, the financial sector, and others. To find out if regions with a relatively high concentration of these sectors achieve a greater economic impact from broadband, dummy variables are interacted with penetration levels. The respective dummies take a value of 1 for those regions that appear at the top third of the sample in the percentage of GVA attributed to those sectors. Results again confirm that the regions that are the most underdeveloped appear to obtain a higher impact from broadband, while some interesting results arise from the services activities in interaction with broadband. As expected, regions that are relatively intensive in commerce or in information services seem to yield higher productivity returns for broadband. In contrast, no

Figure 2: Productivity variation after a 10 percent increase in broadband penetration



Source: Author's elaboration based on data from the IBGE database, the IPEA database, and Telebrasil. Elasticities were estimated using the parameters estimated in Estimation [4] of Table 4 as described in the text. Variables for the analysis were from 2011.

significance was found for the interaction of broadband and intensiveness in the financial sector or other services sectors. These results seem to be verified when introducing all regional differences (Estimation [4]), after which productivity-broadband elasticity measures can be computed for each region (using 2011 data). The results, displayed in Figure 2, suggest important regional differences of productivity growth after an increase of 10 percent in broadband penetration.

As represented in the scatterplot of the figure, low-productivity regions appear to reach higher elasticities after considering other attributes such as sectoral composition and broadband speed. It is important to try to address why the least-developed regions get more economic impact from broadband than other regions. A possible explanation is that the technological change derived from broadband deployment in a poor region seems to represent a bigger difference (the change is greater) than the same change provides 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 more profound. Perhaps high-productivity regions in Brazil 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 certainly enable better opportunities for business and individuals in underdeveloped regions, which may contribute to overcoming their traditional disadvantages. Broadband infrastructure, combined with lower wages and other costs, may help to increase the competitiveness in more underdeveloped regions, reducing agglomeration forces at the center of the country. Even if further research is required, this evidence may suggest that a strategy of reducing regional digital divides may help to stimulate economic cohesion across the territories of a country.

CONCLUSIONS

This chapter provides evidence that the highest productivity gains from broadband in Brazil appear to be found in the country's less-developed regions. Although a convergence analysis remains out of the scope of this chapter, these results suggest that broadband connectivity might constitute a factor that enhances regional cohesion in the country. In that sense, a digital inclusion strategy across territories may contribute to economic cohesion.

These results do not contradict those studies that argue about the relationship of network effects and the presence of a critical mass for broadband externalities, because, as seen in Figure 1, the poorest regions in Brazil are not those with the lowest connectivity levels.

Some policy implications can be derived from this work. The importance of broadband for regional development makes it clear that all levels of government should follow policies that encourage network deployments. Barrios and Navajas (2008) assert the importance of adopting, together with country-level initiatives, regional policies, because the nature of technological change and innovation have a strong regional component that requires public policies to take this into account when they are designed. 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. Regional policies should also promote ICT skills and the use of ICTs by small- and medium-sized enterprises.[13]

In this context, investment in broadband infrastructure is critical, in terms of both coverage and speed. As maintained by Crandall et al. (2007), it is essential that regulatory policies not reduce investment incentives for carriers. In particular, policymakers should adopt measures that promote, or at least do not inhibit, the growth of broadband. In densely populated areas, private competition will certainly provide the required incentives that will lead to higher investments and better connectivity. In contrast, in remote areas that have low levels of population density or are affected by adverse geographical conditions, public intervention will become vital for infrastructure deployment. In those cases, universalization policies might become crucial. As noted by Frieden (2005), broadband investment requires important levels of public-private cooperation. These policy derivations are especially important for BRIC economies, because broadband investment may contribute to promoting the development of territorial equilibrium within those countries, reducing regional inequalities.

NOTES

1 The BRIC countries are Brazil, Russia, India, and China. See the BRICS Policy Center website at http://bricspolicycenter.org/.

2 The Programa Nacional de Banda Larga, Brazil's National Broadband Plan, which was launched by the Government of Brazil, is out of the scope of this chapter because it did not begin implementation until mid-2011.

3 Universalization policies are those from Universal Fund Services, for instance. These are efforts promoted by governments to extend connectivity to regions where the market is not profitable for private companies. A Fund is established, and usually a private company executes those resources.

4 Koutroumpis 2009; Qiang et al. 2009; Czernich et al. 2011.

5 Lehr et al. 2005; Crandall et al. 2007; Mack and Faggian 2013.

6 Cairncross 2001.

7 Negroponte 1995; Kelly 1998; Quah 2000; Bonaccorsi et al. 2005.

8 Suriñach et al. 2007.

9 The production function is $Y_{it} = A_{it}K^{\alpha}_{it}L^{\beta}_{it}H^{\gamma}_{it}$, where TFP is expressed as $A_{it} = \Omega_{it}(X)BB^{\phi}_{it}$. The lack of available data for state-level physical capital stocks in Brazil required some assumptions and rearrangements to derive the empirical specification. These are omitted to save space, but are available from the author at juan.jung@ahciet.net upon request.

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

11 Telebrasil offers data on fixed broadband across the following speed intervals: (1) 512 kb/s to 2 mb/s; (2) 2 mb/s to 34 mb/s; and (3) higher than 34 mb/s. The formula for computing average download speed for region *i* at time *t* is

$$SPEED_{it} = 1.25 \times \left[\frac{BB(1)_{it}}{BB_{it}}\right] + 18 \times \left[\frac{BB(2)_{it}}{BB_{it}}\right] + 50 \times \left[\frac{BB(3)_{it}}{BB_{it}}\right].$$

Assigned speed values for (1) and (2) correspond to the midpoint of the corresponding speed interval. Speed for the interval (3) is right-censored, and the selection of 50 mb/s is somewhat arbitrary, although results are not sensible to different approximations. The equivalence formula is 1 mb/s = 1,024 kb/s.

12 To recover the structural parameters, it will be assumed $\alpha = 0.45$, following Feenstra et al. (2013) estimations of labor share in the income and supposing constant returns to scale.

13 Barrios et al. 2008.

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