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> Internet and economic activity in Colombia, 2007-2011: An analysis of municipalities and 23 main cities

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Abstract

The importance of broadband as a factor of development has only recently become a topic of study. Internationally, it has been found that broadband access to broadband tends to have a positive effect on economic growth or economic activity in a country. This study describes recent patterns of broadband access in Colombia for 23 main cities as well as on a more general level. Econometric exercises sought to determine how broadband and the Internet affect some economic variables and manufacturing productivity. The results indicate a positive relationship between broadband and proxies for economic activity for three (3) different levels of download speed. Although for some variables the sensitivity of the economic variable to percentage changes in the broadband penetration is relatively low, the evidence allows room for public policy. However, public policy must be complemented by other policy actions. The plan *Vive Digital* addresses just one aspect of the policy measures needed to widen the impact of broadband in Colombia.

1. INTRODUCTION

Broadband and its impact on the social, economic and political activity of a country has been the subject of numerous studies. One of the many aspects of broadband that has been discussed is what broadband means. In the following section, in order to set the framework for the study, we present some definitions, which will have important implications and to which we will return throughout this investigation.

One of the earliest and most commonly used definitions of broadband was provided by the Computer Science and Telecommunications Board (CSTB) of the United States. "Broadband: Bringing Home the Bits" (2002, p. 62-81) states that an accurate definition should include the different interest groups or parties that will benefit from broadband: consumers, service providers, content and application developers, regulators and policymakers and public interest groups. The term's definition identifies the kinds of applications that consumers are most likely to define as useful and desirable; it determines the benefits different segments of the public anticipate as a result of being able to access to the broadband services. Broadband, for this institution, is designed as a set of service performance characteristics, for example, speed, latency or a measure of how long it takes to send a packet over the network, symmetry in the downstream and upstream capacity, always-on access, shared connectivity and addressability. CSTB put forth two definitions based on that performance. The first one says that "*Local access link performance should not be the limiting factor in a user's capability for running today's applications*" and the second says "*that broadband services should provide sufficient performance—and wide enough penetration of services reaching that performance level—to encourage the development of new applications*" (CSTB, 2002, p. 1-2).

The book "Broadband in Europe: How Brussels can Wire the Information Society" edited by Maldoom, Marsdeen, Sidak and Singer (2005, p. 3), suggests that broadband "provides users with always-on, high-speed connections to access the Internet and transfer data … adding that the term is used widely as an abbreviation for high-speed Internet access … (and that) the extensive and growing array of broadband products available in the EU member states, for example, in terms of transmission speeds, demonstrates the need for a flexible definition of broadband in any market analysis."

Kelly and Rossotto emphasize the core concepts of the International Telecommunications Union (ITU) Broadband Commission which focus on

broadband as an always-on service with high-capacity, able to carry lots of data per second. They assert that they regard "broadband more holistically, as a high-capacity ICT platform that improves the variety, utility, and value of the services and applications offered by a variety of providers in benefit of users, society, and many sectors of the economy. From a policy perspective broadband should be seen largely as a platform for ICT, which has the potential to influence the whole economy, acting as a General Purpose Technology (GPT) that is used as a key input across sectors." (2012, p. 3-4)

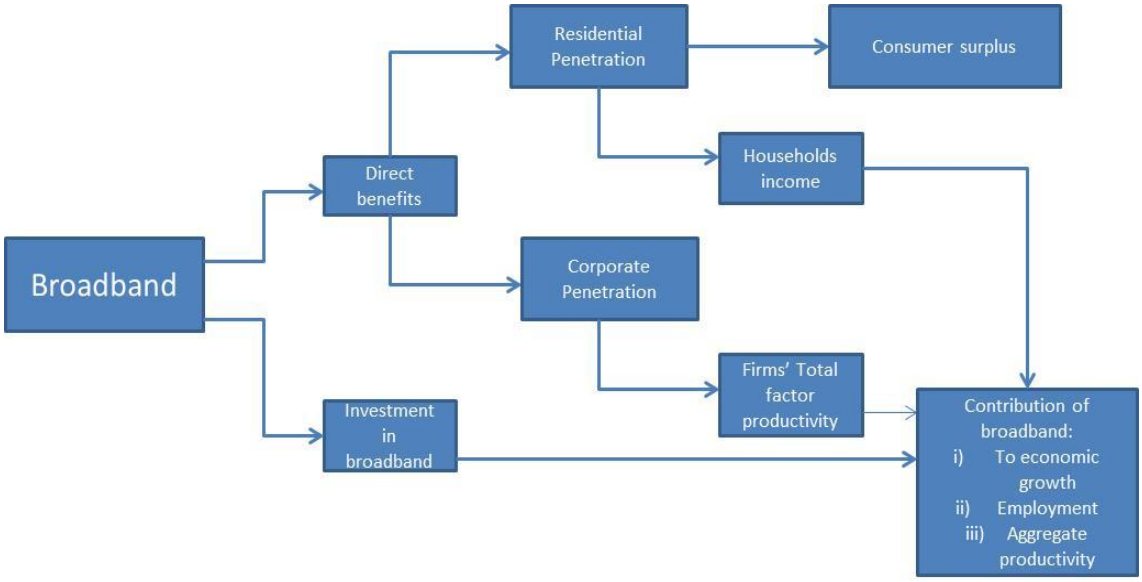
Finally, ITU's Broadband Commission for Digital Development published a recent report entitled "Broadband: A Platform for Progress," which includes an analysis of what would be the most appropriate definition of broadband. The report presents three options. The first is to define quantitative indicators, meaning in terms of bandwidth and technologies. The second is with qualitative indicators in terms of possible applications to be used. And the third one is a combination of the first two. The report outlines the arguments in favor of and against the first two options, and concludes with what is referred to as a "working definition" that defines broadband as an "always-on, high-capacity service" (ITU-Unesco, 2011: 16-19).

In general since the publication of the CSTB report in the 2002, a consensus has been reached that broadband is a technology that allows multiple *always-on,* two-way high-speed access with new and varied applications.

2. BIBLIOGRAPHIC REVIEW

Broadband access and use and its impact on social and economic activity is today the subject of numerous studies and, in some ways, of relative controversy. The initial studies regarding possible effects of *broadband* on economic activity date from 2001 (Crandall and Jackson, 2001) using hypothetical or forward-looking assumptions formulation methodologies. The literature that discusses the subject is broad and recently several documents summarizing the literature have been published, among which "Impact of broadband on the economy" (ITU-Unesco, 2012a) prepared by Katz is worth highlighting.[1] This paper takes as its starting point the analysis of the impact of broadband on economic activity in Diagram 1, reproduced below.

Diagram 1. Economic impact of broadband



Source: Katz (2011)

The diagram illustrates how the deployment of broadband affects economic agents and their results and also synthesizes most of the research that has been carried out to date that seeks to quantify the economic impact of broadband. As seen in the diagram, availability, access and use of broadband tends to generate direct benefits for families and businesses at a micro and macro level. In this summary, we focus on

[1] *Our bibliographical review will focus on studies and reports related to the empirical econometric exercises that we develop in this paper and is based mainly on the ITU document "Impact of broadband on the economy," 2012, and another document published by the same institution, Broadband: a Platform for Progress, a Report by the Broadband Commission for Digital Development, which analyzes in a succinct manner 107 different studies or reports that show the impact of broadband on some variable of the economic activity.*

the impact that broadband has on economic growth, employment, entrepreneurship and productivity.

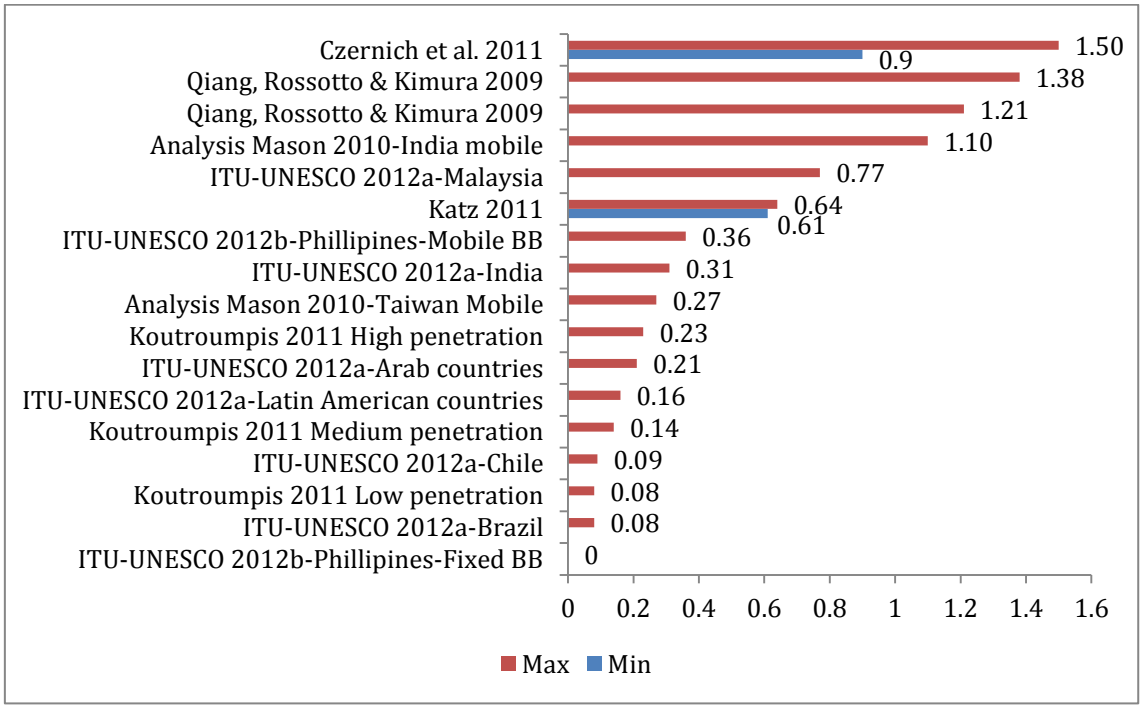
2.1 Impact on economic growth

The impact of broadband on economic activity can occur (and be analyzed) at a micro or macro level. According to the bottom link in Diagram 1 and to macroeconomic analyses, studies have taken a group of countries or within a country the states, regions, or cities that comprise it, and have sought to measure the impact of the provision of broadband on economic growth, employment, productivity, or some other important economic variable. (Ford and Koutsky, 2005; Gillet, Lehr, Osorio and Sirbu, 2005; Sacramento Regional Research Institute, 2007; Crandall, Lehr and Litan, 2007; LECG, 2009; Qiang, Rossotto and Kimura, 2009; Kandilov and Renkow, 2010; Koutroumpis, 2009; Czernich, Falck, Kretschmer and Woessmann, 2011; and Kolko, 2012, among the most widely quoted and studied). In these studies, generally, a Cobb-Douglas production function is used in which the dependent variable is GDP growth, or some other economic measure and explanatory variables such as investment in broadband are introduced, or a proxy for broadband, the capital stock different from broadband, the workforce, or proxy variables, the level of human capital and in a few cases, institutional and regulatory variables for broadband, and other control variables, generally time or regional dummies.

Three of the cited studies illustrate this approach. Koutroumpis (2009), Czernich, Falck, Kretschmer and Woessmann (2011) and Kolko (2012). The first includes 22 European countries during the period 2002-2007 and looks at the effect of the change in broadband access, or broadband growth over economic growth, the second study uses a sample of 25 European countries for the period 1996-2007 and analyzes the effect of broadband penetration on economic growth, and the third study uses a combination of counties and zip codes in the United States for the period 1999-2006 and examines how changes in the *number* of broadband providers affects employment growth at a more local level. The three studies from the outset warn about the potential problems of endogeneity, heterogeneity and other factors that may affect the direction and level of impacts; and they all seek to overcome these problems by introducing instrumental variables and by testing the robustness of the results. The impact of broadband on economic growth has varied from study to study, which can be explained by the greater or lesser degree of stringency of the econometric techniques used, the years included, the choice of the initial year of the study, the number and relevance of control variables, and the

final number of country-year observations. Figure 2 illustrates the most important results.

Figure 2. Estimated Impact on GDP of a 10% increase in the provision of broadband



Source: Various authors

As noted, the impact of a 10% increase in the broadband deployment or investment on GDP growth has fluctuated between 0%—found for the study of Katz in the Philippines—to a 1.53% for European countries, in the study by Czernich et al. A common aspect of the results that has been emphasized by scholars is that investment in broadband *does* have positive effects on economic growth. This result has been the main argument made to support or encourage national broadband deployment plans worldwide.[2] There are, however, several differentiating elements in terms of the results. The first is the wide variability of the impacts, even in the case of studies that analyze a similar number of countries. For example, Koutroumpis (2009) examines 22 European countries and Czernich et al. (2011) added only three more European countries. The difference in the average results of the impact of broadband in the two studies (0.25% vs 1.5%, respectively) is too broad. Both studies have advanced econometric exercises. What explains this ample difference?

[2] *Castalia, (2008), OECD (2008), Qiang (2010), Kim, Kelly, y Raja (2010), Barrantes (2011), and Kelly and Rossotto (2012) analyze broadband plans in developing and developed countries. On the other hand, Puig de la Bellacasa and Hernández (2010) studied the different models of government intervention and financing in the deployment of broadband in some countries.*

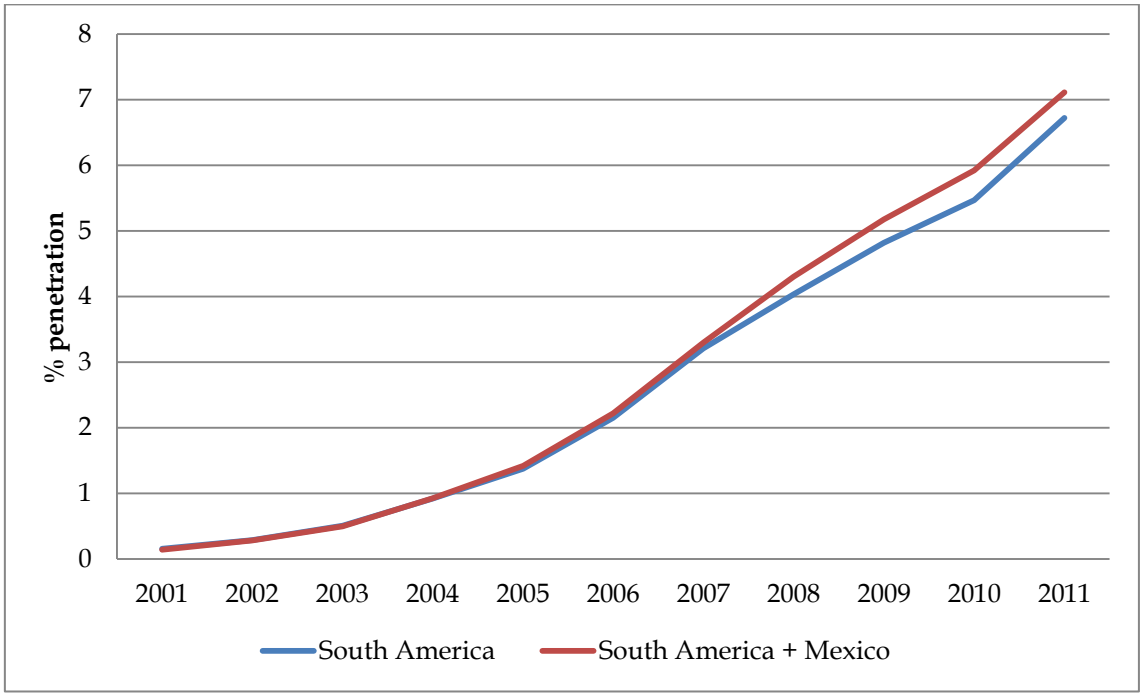
One reason could be the period of analysis. Czernich et al. begin their study in 1996, a year before broadband was installed in the first country (Canada in 1997), while Koutroumpis uses data starting in 2002. The period of analysis could be a factor since it may or may not capture the effect of the diffusion of broadband. In some countries, where there are still no government broadband plans, the deployment of broadband has been faster than in others where there has been. A second potential differentiator is the indicator of broadband utilized. In the case of the studies of Koutroumpis and Czernich et al., the indicator is the total number of broadband subscribers per 100 inhabitants. Research (Lehr et al., 2006) for the United States has used the presence of at least one Internet service provider broadband in an area code as an indicator, which may *not* capture accurately the true level of broadband penetration. A third differentiating factor is the use of control variables, and the use of techniques that control for fixed effects, or unobserved characteristics that may affect the relationship between broadband and economic growth. Koutroumpis employs a limited number of variables, i.e., labor force and capital stock unrelated to ICT and controls for country and year fixed effects. Meanwhile, Czernich et al. controlled by the growth rate of the ratio of total capital stock to GDP, a human capital variable, a population variable of age, and like Koutroumpis included controls for country and year fixed effects. Qiang et al. (2009) includes a similar number of control variables as those used in the study of Czernich et al. and defines a base year of GDP as a control. The estimates calculated by Katz for the ITU paper (2012a) for a set of Latin American countries, Arab countries, China, Indonesia, Malaysia and the Philippines include annual or quarterly data; the variables used, as well as the selected period of study, vary from country to country according to the availability of information. Among others, Katz (2011) used an initial economic performance variable, human capital, population size, urban density, illiteracy, business dynamics without controlling (apparently) for fixed effects of periods and regions or states.

It is evident from the abovementioned studies that there is a positive relationship between the variation or growth of broadband, measured in some way, and GDP growth, either within a country or using a set of countries. It is also evident that the size of the impact varies depending on the particular study. It is worth emphasizing a central point analyzed econometrically and discussed in Koutroumpis, Czernich et al., and Qiang et al., and discussed briefly by Katz in the ITU report (2012), which is the (average) level of broadband penetration in countries or regions studied. Koutroumpis introduces dummies for three levels of penetration: below 20%, between 20% and 30% and over 30% (broadband per 100 inhabitants).

Czernich et al. added dummy variables to account for broadband penetration levels of 10% or over 20%.[3] What these three studies seek to establish is whether there is a critical mass of broadband penetration at which point the investment in broadband does really impact other economic activity and if the relationship between broadband growth and economic growth is nonlinear. From these studies it is clear that the relationship is: i) nonlinear for all levels of penetration, and ii) the relationship is apparently statistically and economically significant *if and only if* it exceeds a certain threshold, which is apparently either 10% according to Czernich et al., or 30% according to Koutroumpis. How important is a critical mass in order to determine the impact of broadband on economic activity?

[3] *Quiang et al. introduce the average broadband penetration for two groups of countries: high income and low and middle income. The exercise may mix high-income countries but low penetration levels and vice versa. Moreover, Fornefeld, Delaunay and Elixmann (2007, p. 104) also claim that the impact of broadband is higher in countries with greater development and penetration of broadband.*

Figure 3. Broadband penetration (%) in South America plus Mexico



Source: ITU – Unesco 2011

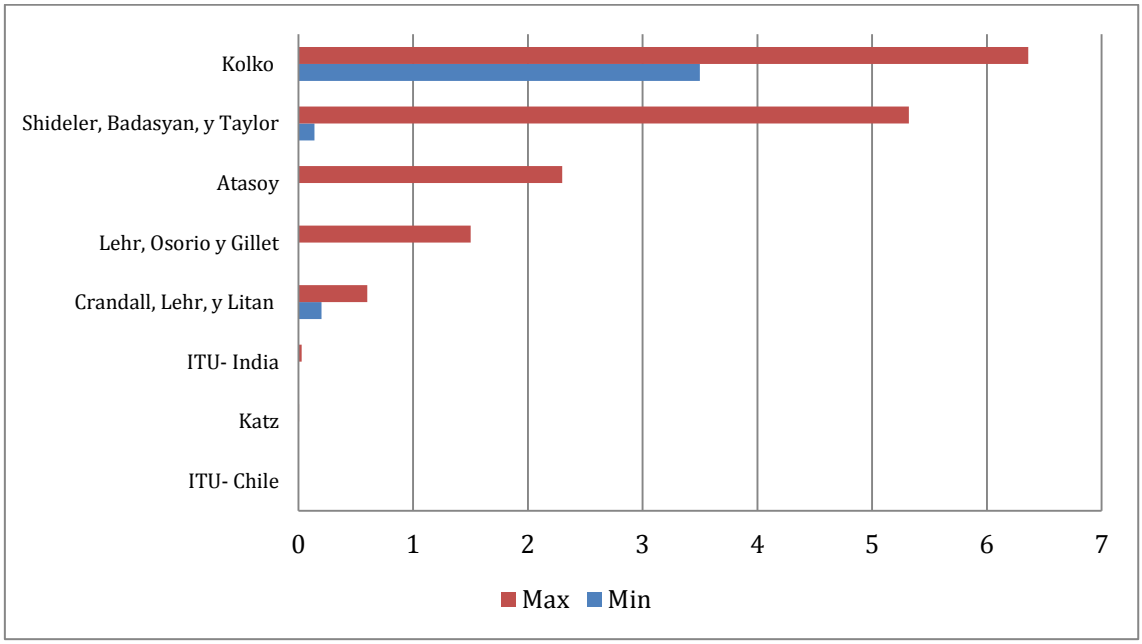
It is not easy to give an accurate or even adequate response to that question. But if this were true, it is clear that the *real* impact that broadband investment or deployment may have on economic growth in developing countries remains to be seen. Figure 3 shows the average percentages of broadband penetration in South America, excluding Venezuela, in blue and South America plus Mexico marked in red. Data provided by ITU reflect a low level of broadband penetration in the region.[4] Up until 2010, only two countries—Chile and Uruguay—passed 10% and only Argentina followed a year later. The percent contribution of broadband to economic growth in Katz was calculated between the periods 2001-2003 and 2004-2006, during which they were well below 5%, nowhere close to the critical mass of 10% quoted by Czernich et al. if broadband were to have noticeable effects on economic activity. In addition, given that the regressions did not control for country or time fixed effects, the calculations made could be over-estimated or even result in the impact being found null or statistically insignificant. This does not mean there is no impact on growth, but that "the increase in penetration in low penetration areas takes much longer to materialize in economic growth because these economies require a longer period of time to develop and fully utilize the technology" (ITU-Unesco, 2012a, p. 26).

[4] *Additionally, the use of broadband information between different studies could present a problem of comparability in terms of what is being assessed as broadband.*

2.2 Impact on employment generation and entrepreneurship

Diagram 1 illustrates that another variable of economic activity that may be impacted by broadband deployment is employment. Several econometric studies have analyzed the potential impact of broadband on employment (Lehr, Osorio, Gillet and Sirbu 2005; Crandall, Lehr and Litan, 2007; Shideler, Badasyan and Taylor, 2007; Kandilow and Renkow, 2010; Atasoy, 2011; Kolko, 2012; ITU-Unesco, 2012b). With the exception of the study by Katz for the ITU (2012a), most studies analyze the relationship between broadband and employment for the United States. The results have generally shown a positive association between growth in the deployment of broadband and employment growth.

Figure 4. Estimated impact on employment of a 10% increase in broadband supply



Source: Various authors

There are several elements worth keeping in mind when analyzing these results. The first is that the effects on employment growth in emerging countries like India and Chile were almost negligible. Other calculations made by Katz (not presented in this paper) showed a reduction in the unemployment rate. Less satisfactory results found for these countries may be influenced by the *aggregation* of data unlike in the studies conducted in the United States where the effect of changes in broadband on employment growth were done at the county level, or zip codes allowing finer analysis. However, except for the work of Crandall et al.,

broadband measurement is rather questionable. The authors use: a) the change in the number of Internet service providers (Kolko), b) the area within a county where there is at least one service provider (Shideler et al.), c) the proportion of the population by county within an area in which there is at least one broadband provider in a county (Atasoy). In all three cases, the authors argue that what is important is *the availability* of a service provider, not the service adoption by economic agents. The way that broadband is being quantified may be leading to an overestimation of its impact on employment growth.

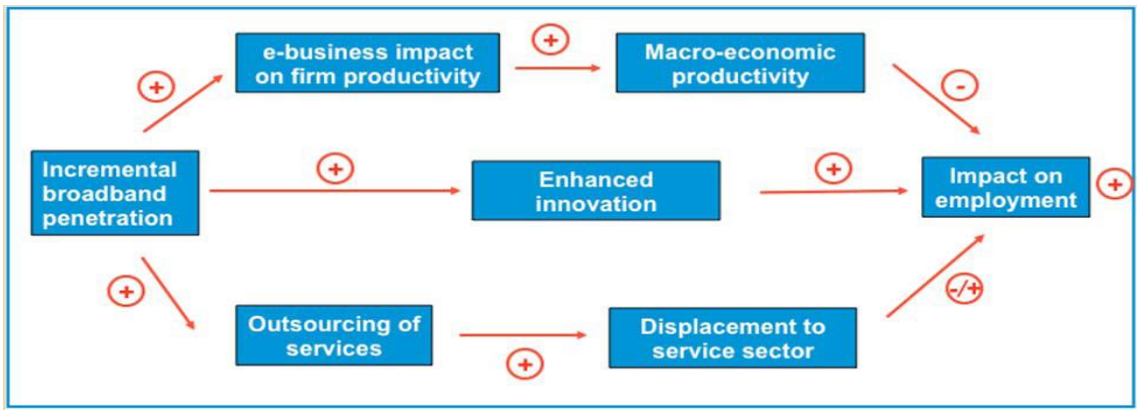
Studies for the United States present information regarding the impact of broadband on economic activity and results vary from one study to another. For the period 2003-2005, Crandall et al. (2007) found that broadband positively affected employment (statistically significant) in manufacturing, occupational and health services and social care. Meanwhile Shideler et al. (2007) in their study for the state of Kentucky show that the positive impact of broadband was in mining, construction, information, waste management and rehabilitation services.

Atasoy (2010) found that although a large number of sectors experience increased employment levels, the largest effects occur in sectors with a high proportion of skilled labor such as professional, technical, financial and information services and that the expansion of broadband has a negative effect on industries with low-skilled human capital or routine jobs such as sales and services (retail, entertainment and the like) with job functions that are easily replaced or displaced by the emergence of broadband. Kolko (2012) finds that the relationship between the change in the number of broadband providers and growth in employment is higher in areas of public services, information, finance and insurance, technical, professional and scientific services, and company support services, among others. However, when controlling for population growth, sectors such as manufacturing, educational services, arts, entertainment and recreation stop having statistical significance. Though weak, the impact found between broadband and economic activity in the areas of greatest technological development could confirm the complementarity between ICT and human capital (Bresnahan, Brynjolfsson and Hitt 2002, Brynjolfsson and Hitt, 2000).

An under-analyzed aspect in macro-level econometric studies of the impact of broadband on employment how that process comes about. The following diagram, taken from ITU, 2012, suggests that increases in broadband impact employment positively or negatively through its effect on the productivity of the company directly, as a result of innovation or hiring external processes or outsourcing. As noted, the relationship

between broadband and employment is complex since the effect can be positive or negative.

Diagram 5. Impact mechanisms of the Internet on employment



Source: ITU – Unesco (2012a: 16)

Few of the cited studies that have evaluated the effect of broadband on employment are controlled by: i) the effect of productivity, ii) by the number of establishments, or iii) by their size. For example, Kolko, 2012, found in separate regressions that the relationship between the variation in broadband was *positively* related to: a) growth of employment in all establishments, b) establishment growth, and c) positively with the change in the size of the companies for the period 1992-1999, but negatively for the period of 1999-2006. The author does not elaborate much on the results of (a) and (b), and interprets (c) by stating that broadband initially favored large firms and then later medium and small firms, which is consistent with the empirical evidence of high initial costs adoption of this technology and their subsequent decline. The employment dynamics found are important because they may reveal patterns that may occur in other developing economies like Colombia, a market dominated by micro, small and medium enterprises. Kolko also found a positive relationship between the rate of broadband and a variable called "*changes in employment due to the creation and destruction of establishments*."

Atasoy (2011) in his basic specification finds a strong positive relationship between the proportion of the employed population and broadband. Subsequently, the study also includes both the rate of domestic growth and the number of establishments. The relationship between the variables of interest remains robust and the coefficient of the variable of establishments remains positive. The author recognizes that employment growth may be the result of an increase in the number of firms or of the increase in the rate of recruitment by existing firms in a specific county. To verify this hypothesis, Atasoy ran regressions between broadband and

the number of establishments and average number of employees per establishment; in both cases, he found a positive and statistically significant relationship suggesting that at a county level broadband increases not only the number of establishments but also their average size. Finally, in these last specifications, when the variable of broadband interacts with the measurement of human capital, the positive coefficient found suggests that the effect of broadband on employment and firm size is higher in firms with greater human capital.

The effect of broadband on employment or firm creation requires even more studies to draw robust conclusions. As has been mentioned, Kolko found positive and negative relationships; Atasoy found that the average firm size increases along with more broadband and better human capital. In both cases, however, the authors did not examine in detail whether broadband generates more entry than exit of businesses due to the increased presence or broadband availability; and furthermore, they also fail to isolate the effects of broadband on employment or entrepreneurship from the effects of productivity generated by companies prior to the availability of broadband. In the United States (and other developed countries) there is some concern that broadband is displacing skilled labor jobs in their countries to developing countries through offshore outsourcing. This problem of outsourcing should be lower in developing countries like Colombia, and even better it could be a possible source of employment generation.

2.3 Analysis and comments

Arguments in favor of national broadband investment plans in developed and developing countries alike have been based on the results of econometric exercises such as those presented earlier that relate some measure of broadband with economic variables such as economic growth, employment, entrepreneurship or productivity, the lion's share of which have recorded *apparent positive impacts*. However, a number of authors have criticized the fervor over the positive results found to date.

The critical remarks were:

I. The Internet, and more specifically broadband, which is a relatively new technological phenomenon, has been flagged as a General Purpose Technology (GPT). Studies of GPTs, such as steam power, electricity, among many others, have shown that their effects on economic growth and other variables are over a long term period, so impact results obtained for broadband to date are at best

preliminary and subject to further verification (Wallsten, 2010; Lehr, 2012).

II. To date, the data collected at macro and even micro levels are insufficient to quantify their actual impact on economic activity variables (Howell and Grimes, 2010; Kenny, 2011; Kenny, 2012; Lehr, 2012).

III. More detailed studies have shown that company's productivity gains occur when a company goes from *not* using the internet to using it, and not in terms of Internet use (narrowband or low speed access) to broadband or higher speed access (Grimes, Ren, and Stevens, 2012). The shift from using normal band to broadband does not generate profits.

IV. Some studies use the number of residential broadband subscriptions or connections as the source of analysis of the impact but there are no strong theoretical arguments indicating that these have any impact on net economic activity. If broadband has an effect on economic activity, it should be measured at the enterprise level (Wallsten, 2010).

V. The biggest problem faced in studying the impact of broadband on economic activity lies in *how to measure the Internet* or broadband which in itself is problematic since measure its economic impacts, we must first measure the Internet, "which is problematic because the Internet is itself changing *… and as it evolves … What will matter is how different firms, workers, or consumers utilise the Internet and measuring that is inherently more difficult.*" (Lehr[5], 2012, p. 5; Holt and Jamison, 2009).

VI. The impact of broadband found on economic activity is only relevant when there is a critical mass of diffusion or adoption, therefore, its impact on developing countries, which have not yet reached that level, would (or could) be null or minimal at the most (Koutroumpis, 2009; Fornefeld, Delaunay and Elixmann, 2007; Belloc, Nicita, and Rossi, 2012; Czernich Falck, Kretschmer, and Woessmann, 2011).

[5] *Aptly, this analyst notes that "We will need even more granular data at the level of the business location, or individual units, or even better, the level of activity of workers in order to understand how the Internet is used in productive activities. This is because the Internet enables the creation of virtual organisations and flexible outsourcing of business activities, blurring the boundaries between firms and markets…"*

VII. Although no direct studies are presented in this paper, the literature investigating the effect of ICT on productivity in companies has found that the successful applications of ICTs—of which broadband is an enabler—require new organizational structures to manage the steady procession of new generations of equipment and software. (Brynjolfsson and Saunders, 2010; Howell and Grimes, 2010)

2.4 Hypothesis derived from past studies

a) Increases in broadband penetration can have positive effects on economic variables.

b) The effects may be more likely for those populations where there is a greater critical mass of ICT adoption, more advanced industries or economic sectors, and higher levels of human capital and absorptive capacity.

c) The type of broadband usage most likely to impact economic indicators is broadband used by businesses.

d) Broadband usage by manufacturing companies tends to impact positively labor productivity.

3. Internet-Broadband Adoption Trends in Colombia

As mentioned in the introduction of this paper, there are several definitions of broadband. In Colombia, the then Telecommunications Regulatory Commission (CRT for its acronym in Spanish), issued in 2007 Resolution 1740 in which Article 1.8 defined what it understood broadband to be: *"the transmission capacity with sufficient bandwidth to permit combined provision of voice, data and video, over wired or wireless delivery. For marketing purposes, it should be noted that a connection will be considered to be "broadband" only if its effective access speeds meet the following minimum values:*

Direction of connection	Effective minimum speed
ISP toward user or *downstream*	512 Kbps
User toward ISP or *upstream*	256 Kbps

Internationally, with the aim of making comparisons, speeds of 256 Kbps have been used. In this study, the speeds used are equal to or greater than 256 Kbps, 512 Kbps, and 1024 Kbps, which is what the official current defining speed for broadband in Colombia, in order to present different views of the state of broadband adoption in Colombia.

A novelty of our study is the presentation of the first data on broadband penetration not only at the household level or total subscribers per 100 inhabitants, but also for all business subscribers or at the enterprise level. In this section of the paper, two data sources will be used: a) data from the Integrated Survey of Households (GEIH for its acronym in Spanish), which from 2009 to 2011 included a module of ICT, and since 2006 a question about Internet access at home, b) data from the Colombia's ICT Ministry that collects user information by type, i.e., residential or business, and Internet download speed (broadband). The first sub-section discusses broadband use among the business sector and by families or households using data from the Ministry of ICT. The second section will examine the patterns of ICT use in households, focusing on the Internet. Unfortunately, GEIH's information regarding Internet access and use does not include a breakdown by bandwidth used in the home.

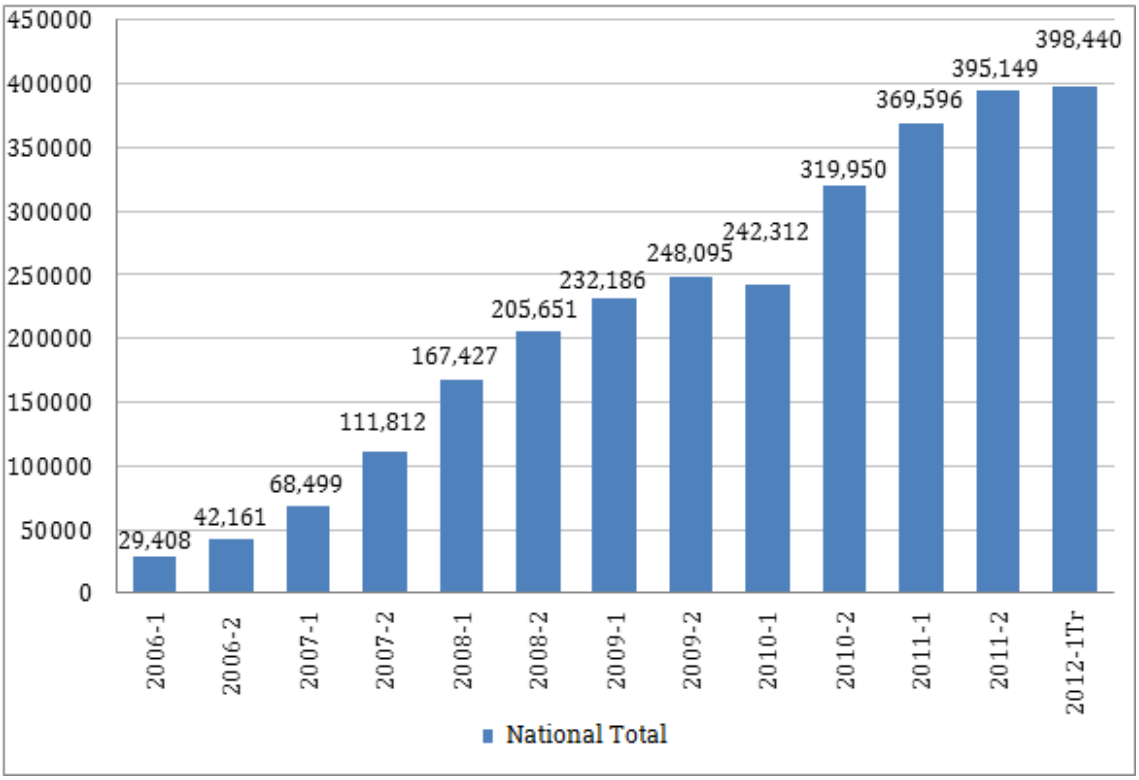
3.1 Expansion of Broadband based on ICT Ministry figures

3.1.1 Patterns of broadband adoption in Colombia's business sector

Information about Internet users by user type, level of download speed, type of technology and other data dates from 2002 when the CRT issued Resolution 502 indicating the methodology to be followed by all Internet service providers (ISP) for presenting information on a quarterly basis. All operators were therefore obliged to give information to the CRT and then to the Ministry of ICT. However, it is possible that there were periods when one or more operators *may have failed to send it*. This database is the source of information presented below.

In Colombia, as of December 2002, there were a total of 1623 subscribers to dedicated Internet services (DSL, cable, copper or fiber connections) with a download speed of at least *512 Kbps* (CRT, 2002, Appendix 4). From that report issued by CRT, how many of them were businesses cannot be determined, but given the high cost of installation (minimum of about US$ 265) and the monthly subscription fee (minimum US$ 3403) is quite likely that this total corresponds to the number business subscribers. The vast majority of subscribers (368000), at that time, corresponded to dial-up Internet users with much lower access speeds. Since then, the number of business subscribers to broadband Internet with speeds above 512 Kbps has increased substantially. In late 2006, business subscribers totaled 42161 and by 2011 the figure had multiplied about thirteen times to reach 398000 (Figure 6).

Figure 6. Number of business broadband subscribers (512 Kbps or higher). National total



Source: SIUST, Ministry of ICT, Colombia.

An important aspect of *broadband* access used by businesses in Colombia has been its concentration in some areas of the country and more precisely, its distribution in cities and departments, and growth rates. The answer is in Table 1.

Table 1. Distribution of business broadband subscriptions (≥ 512 Kbps) by department

Department	2006-2	2007-2	2008-2	2009-2	2010-2	2011-2
Antioquia	21.6%	16.1%	14.1%	12.7%	13.2%	14.5%
Arauca	0.01%	0.1%	0.1%	0.2%	0.2%	0.3%
Atlantico	1.8%	4.3%	5.7%	6.3%	5.9%	5.2%
Bogota d. C.	68.8%	58.3%	47.3%	42.7%	37.6%	35.3%
Bolivar	0.4%	0.6%	1.8%	2.5%	3.2%	3.2%
Boyaca	0.7%	0.3%	0.8%	0.9%	1.2%	1.3%
Caldas	0.5%	0.3%	1.5%	2.5%	1.5%	1.5%
Casanare	0.1%	0.1%	0.2%	0.3%	0.5%	0.6%
Cauca	0.1%	0.3%	0.4%	0.6%	0.8%	0.7%
Cesar	0.1%	0.2%	0.7%	0.7%	1.1%	1.0%
Choco	0.0%	0.0%	0.1%	0.2%	0.3%	0.3%
Cordoba	0.3%	0.4%	0.8%	0.9%	1.6%	1.7%
Cundinamarca	1.2%	2.5%	3.2%	3.4%	3.5%	3.5%

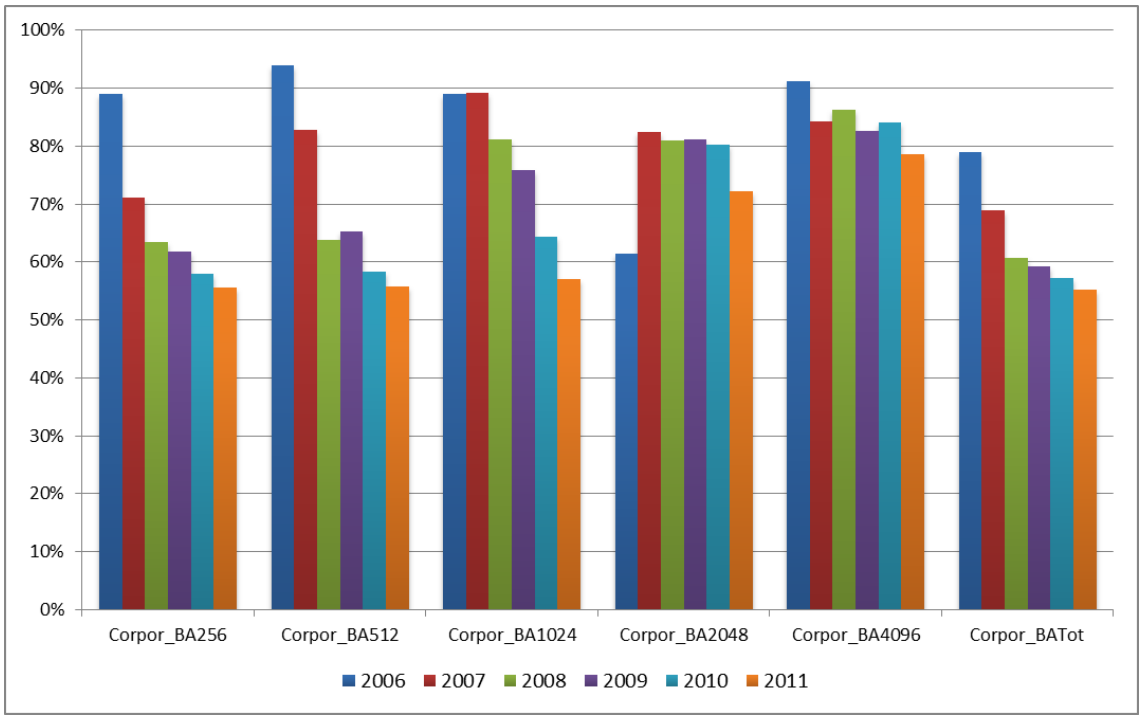
Huila	0.1%	0.4%	1.0%	1.2%	1.4%	1.4%
Guajira	0.02%	0.1%	0.3%	0.5%	0.6%	0.5%
Magdalena	0.1%	0.2%	1.1%	1.1%	1.4%	1.4%
Meta	0.0%	0.6%	1.5%	1.3%	1.6%	2.1%
Nariño	0.2%	0.6%	0.8%	1.1%	1.3%	1.4%
Norte de santander	0.1%	0.4%	1.5%	1.9%	2.4%	2.3%
Putumayo	0.00%	0.1%	0.1%	0.1%	0.1%	0.2%
Quindio	0.1%	0.2%	0.9%	1.0%	1.3%	1.2%
Risaralda	0.6%	1.4%	2.1%	2.2%	2.2%	2.4%
Santander	0.3%	6.4%	3.7%	4.7%	5.7%	6.1%
Sucre	0.1%	0.1%	0.3%	0.3%	0.6%	0.7%
Tolima	0.5%	0.4%	1.1%	1.4%	2.0%	2.0%
Valle del cauca	2.6%	5.5%	9.4%	9.1%	8.6%	8.9%
Otros */	0.02%	0.1%	0.1%	0.1%	0.2%	0.5%

*/ It includes: Amazonas, Guainia, Guaviare, Caqueta, San Andres and Providencia, Vaupes and Vichada.
Source: Ministry of ICT

Table 1 reveals that in 2006 broadband at a corporate level was concentrated in two areas in Colombia, the country's capital, Bogota, with 69% of total subscriptions and the department of Antioquia with 21.6%. The remaining departments recorded only 10% or less of the 4200 broadband subscriptions. This high concentration begins to change in late 2008 when the two areas hold 60% of total broadband. In 2011, of almost 400000 corporate broadband subscriptions, only 50% corresponded to areas other than Bogota and Antioquia. The departments of Valle, Santander and Atlantico stand out. Although the percentages of concentration are disproportionate, it is only a reflection of the concentration of business activities in industry, commerce and services in those departments. Therefore, the digital divide in broadband use at the departmental level reflects the inequality of economic development in the country.

Figure 7 shows the pattern of concentration of broadband in the country's four major cities: Barranquilla, Bogota, Cali and Medellin. As shown, at all levels of bandwidth, no less than 55% of business subscriptions are concentrated in those cities. The concentration is much higher for downstream speeds greater than or equal to 2048 Kbps; even in 2011, they were higher than 72%.

Figure 7. Concentration in the four major cities of corporate subscriptions by broadband speed



Source: Ministry of ICT

The above analysis shows an unequal distribution of the number of business broadband subscribers at the departmental and city level. However, the above data do not provide a perspective as to how low or high broadband business penetration is for a particular department or city. In an effort to build a proper indicator of broadband penetration in the Colombian business community, the authors resorted to the following analytical exercise. First, broadband is mostly fixed broadband. Second, any subscriber — whether a business or a family — must have a computer in order to use broadband.

Third, any user, or at least the vast majority of these users, must have the electrical service in their business or home. If the above exercise is approximately correct, it would be correct to take as the number of business firms in a city or municipality the total number of electrical power business customers reported to the Superintendency of Public Services (SSPD for its acronym in Spanish) in its user database (known for its Spanish acronym SUI). The reader should keep in mind that in order to function as a business, every business unit should have electricity service, whether or not it has access to broadband. One caveat should be mentioned. SSPD does not perform a quality control of the information provided, and as a result there may be breaks in the periodic data presented in its database, which in turn generates jumps in the

penetration indicator. Notwithstanding this drawback, the broadband penetration indicator is, to our knowledge, the first to consider this an appropriate universe of firms in a geographical or territorial unit. The indicator is:

$$Rate\ of\ Penetration_i = \frac{Number\ of\ broadband\ business\ subscriptions_i}{Number\ electricity\ business\ users_i}$$

where i represents the city i.

Table 2 presents the penetration rates of broadband (≥ 512 Kbps) at the enterprise level, by department, by departmental capitals and other municipalities in the department between 2006 and 2011. Several aspects are worth highlighting. First, the penetration of broadband in the Colombian business community is *moderately* high, in particular at the level of the capital cities. Second, the country's capital, which has the largest number of connections and the largest business community, has maintained high penetration rates, moving from 13% of its businesses with broadband connections in 2006 to 65% in 2011. Third, capital cities like Cartagena, Barranquilla and Santa Marta, located in the Colombian Caribbean coast, had reached very high penetration rates by 2011. Given the potential problems of the quality of information contained in the SSPD database, these figures may be lower. Fourth, there is a strong broadband digital divide between departmental capitals and other municipalities; with the exception of a few cases (Boyaca and La Guajira), the penetration rate in capital cities in 2011 was higher by several multiples than rates in the remaining municipalities of a department. Why is corporate broadband penetration moderately high? In addition to the potential problems of incomplete reporting by energy companies, there is the fact that the indicator of electrical power business customers includes the universe of large and medium enterprises, some small companies but very few Colombian microenterprises. If this is true, Colombia's Vive Digital plan could be an alternative to expand penetration in these microbusiness segments.

Table 2. Broadband penetration rate (>512) in the business sector

Department	2006	2007	2008	2009	2010	2011
ANTIOQUIA	7.79%	14.11%	23.16%	23.01%	30.03%	39.74%
Medellin	18.51%	31.42%	37.07%	38.33%	42.67%	51.92%
The rest	0.51%	1.38%	16.95%	15.74%	27.29%	39.34%
ATLANTICO	3.05%	19.01%	49.12%	56.97%	41.52%	80.54%
Barranquilla	3.92%	23.06%	59.32%	65.54%	42.41%	94.85%
The rest	0.01%	0.95%	3.72%	4.90%	4.38%	8.79%
BOGOTA, D. C.	13.92%	29.89%	45.11%	46.00%	54.01%	64.87%
BOLIVAR	1.29%	4.95%	39.74%	34.74%	55.76%	69.66%
Cartagena	1.98%	7.56%	62.27%	50.27%	80.09%	101.80%
The rest	0.00%	0.06%	1.79%	2.54%	6.40%	8.53%
BOYACA	1.39%	1.35%	11.16%	7.93%	13.50%	17.33%
Tunja	5.94%	3.35%	22.67%	17.21%	27.28%	29.89%
The rest	0.22%	2.91%	29.70%	20.97%	38.74%	52.61%
CALDAS	0.94%	1.67%	7.25%	27.06%	19.56%	24.29%
Manizales	1.80%	2.81%	10.28%	27.84%	31.92%	37.89%
The rest	0.05%	0.50%	4.13%	26.31%	7.26%	10.81%
CAQUETA	0.13%	3.80%	15.82%	12.32%	19.95%	21.23%
The rest	0.03%	3.36%	1.16%	1.16%	2.29%	2.87%
CAUCA	0.59%	2.13%	6.32%	8.72%	12.84%	15.34%
Popayan	1.05%	3.57%	9.74%	12.55%	18.33%	21.88%
The rest	0.14%	0.50%	2.59%	4.53%	7.11%	9.00%
CESAR	0.51%	3.67%	27.52%	20.90%	29.38%	35.03%
Valledupar	0.75%	4.75%	39.90%	29.26%	52.24%	60.74%
The rest	0.07%	0.97%	6.61%	5.56%	15.26%	20.15%
CHOCO	0.17%	0.82%	11.71%	10.07%	12.82%	16.67%
Quibdo	0.30%	2.15%	18.18%	14.43%	26.14%	30.78%
The rest	0.00%	0.00%	1.46%	2.50%	4.35%	6.20%
CUNDINAMARCA	1.67%	7.06%	14.29%	16.77%	21.94%	25.95%
CORDOBA	1.09%	3.40%	16.38%	13.31%	30.46%	40.65%
Monteria	1.61%	5.36%	28.56%	21.55%	41.94%	51.71%
The rest	0.96%	2.50%	9.75%	7.55%	26.74%	42.89%
HUILA	0.29%	3.15%	23.94%	19.12%	28.75%	32.95%
Neiva	0.50%	5.13%	39.19%	28.90%	43.85%	51.44%
The rest	0.08%	1.23%	8.94%	9.61%	15.22%	15.65%
LA GUAJIRA	0.12%	1.67%	25.95%	17.87%	29.27%	30.49%
Riohacha	0.28%	3.03%	28.96%	26.50%	42.92%	50.60%
The rest	0.17%	2.50%	57.78%	28.02%	51.96%	57.19%
MAGDALENA	0.35%	2.91%	36.50%	25.44%	43.05%	52.25%
Santa Marta	0.56%	4.64%	31.32%	37.90%	62.73%	76.17%
The rest	0.04%	0.11%	2.89%	2.98%	8.44%	13.06%
META	0.12%	3.33%	15.87%	14.68%	21.39%	30.70%
Villavicencio	0.17%	5.11%	21.00%	17.26%	24.10%	37.73%

The rest	0.02%	0.03%	3.93%	5.80%	9.69%	11.44%
NARIÑO	0.25%	3.06%	21.95%	15.90%	24.06%	29.76%
Pasto	0.38%	5.09%	33.36%	22.93%	33.87%	37.36%
The rest	0.04%	0.19%	1.50%	1.73%	3.04%	8.37%
NORTE SANTANDER					30.21%	34.71%
Cucuta					39.64%	45.40%
QUINDIO	0.43%	1.96%	25.13%	18.43%	27.78%	32.76%
Armenia	0.70%	3.29%	18.32%	14.16%	22.97%	30.37%
The rest	0.19%	0.14%	3.99%	3.18%	5.59%	6.16%
RISARALDA	1.37%	7.65%	25.26%	21.57%	27.62%	37.93%
Pereira	1.81%	9.74%	33.27%	27.73%	36.45%	50.26%
The rest	0.33%	2.16%	6.79%	5.77%	8.04%	12.81%
SANTANDER	0.84%	14.93%	16.36%	19.83%	30.15%	37.95%
Bucaramanga	14.25%	19.82%	20.06%	26.97%	38.11%	46.34%
The rest	12.83%	9.30%	12.43%	12.99%	23.86%	32.49%
SUCRE	0.49%	2.44%	13.69%	10.17%	26.98%	39.76%
TOLIMA	0.17%	1.68%	15.22%	12.22%	21.28%	24.92%
Ibague	0.29%	3.11%	28.35%	22.09%	35.87%	40.35%
The rest	0.06%	0.39%	3.95%	4.13%	9.67%	13.44%
VALLE DEL CAUCA	1.40%	7.96%	26.81%	26.15%	31.24%	39.16%
Cali	2.19%	11.55%	33.55%	32.62%	39.02%	48.21%
The rest	0.35%	1.70%	10.24%	9.59%	12.26%	16.50%
ARAUCA	0.19%	1.56%	14.22%	11.86%	18.35%	27.01%
CASANARE	1.28%	2.37%	11.69%	11.95%	19.33%	26.99%
GUAVIARE	0.29%	0.59%	0.82%	0.44%	0.19%	0.29%
PUTUMAYO	0.09%	2.04%	9.35%	7.24%	10.41%	13.32%

Source: Authors' calculations based on data from the Ministry of ICT, SSPD and SIU.

Table 3 presents broadband information using as a reference connections with downstream speeds equal to or greater than 1024 Kbps. Several points are worth noting when comparing that information with data from Table 2. First, the percentage of enterprises with broadband equal to or higher than 1024 Kbps is relatively high, especially in 2010 and 2011. International data for broadband penetration in businesses at a regional or city level are not available to make comparisons but the great effort on behalf of the business community, especially large and medium enterprises, to have connections with higher bandwidth is evident. Second, even though Bogota has maintained high levels of penetration, the catch-up process happening in other cities is clear. Again, Barranquilla, Cartagena and Santa Marta on the Caribbean coast represent this process. Third, in general, there is a pronounced backwardness among companies located in towns other than the capital cities to connect at download speeds of 1024 Kbps. Fourth, the digital divide between the capital cities and the rest of a department's cities is observed in most departments.

A slightly different view is shown in Table 14 in the Annex. It presents information about an alternative broadband penetration indicator for enterprises with ≥ 512 Kbps access speeds in capital cities and at a departmental level. The indicator is the number of corporate broadband subscribers per 1000 inhabitants. The country's capital ranked first with nearly 19 corporate subscriptions per 1000 inhabitants. However, the capital cities do not have, with this indicator, higher penetration rates than the rest of municipalities in each department. For example, Cali and Medellin have lower indicators than the rest of the municipalities in the Valle del Cauca and Antioquia. A plausible explanation is that the high concentration of population in the capital cities increases the denominator of the indicator, consequently, decreasing penetration. The corporate digital divide between major cities and between each one of those cities with the rest of its municipality does not seem so high; however, the reader should keep in mind the most concentrated population levels in the departmental capitals.

Table 3. Broadband penetration rate (>1024) in the business sector

Department	2006	2007	2008	2009	2010	2011
ANTIOQUIA	1.50%	2.39%	21.47%	22.51%	28.35%	37.62%
Medellin	3.63%	5.50%	35.31%	37.56%	42.10%	51.62%
The rest	0.03%	0.05%	14.75%	15.34%	23.93%	34.78%
ATLANTICO	2.44%	6.37%	36.91%	26.43%	28.84%	75.03%
Barranquilla	3.14%	7.64%	44.82%	30.65%	29.77%	88.69%
The rest	0.01%	0.41%	2.55%	2.04%	2.73%	7.85%
BOGOTA, D. C.	2.23%	13.30%	22.21%	41.65%	52.34%	64.52%
BOLIVAR	0.63%	1.51%	3.13%	12.72%	38.49%	68.71%
Cartagena	0.97%	2.31%	4.52%	18.50%	56.19%	100.47%
The rest	0.00%	0.03%	0.52%	0.84%	3.50%	8.36%
BOYACA	1.32%	0.29%	0.47%	2.25%	8.00%	16.90%
Tunja	5.79%	0.71%	0.78%	5.95%	20.31%	29.39%
The rest	0.09%	0.63%	1.44%	4.90%	18.84%	51.06%
CALDAS	0.17%	0.23%	1.91%	21.23%	17.78%	24.07%
Manizales	0.32%	0.34%	3.51%	26.53%	31.38%	37.70%
The rest	0.02%	0.12%	0.30%	15.94%	4.25%	10.56%
CAQUETA	0.04%	0.49%	0.00%	2.88%	13.99%	20.86%
The rest	0.00%	0.10%	0.16%	0.47%	0.91%	1.42%
CAUCA	0.26%	0.54%	2.86%	4.58%	9.31%	14.57%
Popayan	0.48%	1.00%	4.31%	7.21%	14.51%	20.69%
The rest	0.06%	0.06%	1.28%	1.76%	3.93%	8.64%
CESAR	0.23%	1.15%	0.42%	5.35%	17.96%	34.50%
Valledupar	0.36%	1.61%	0.34%	7.74%	35.37%	60.03%
The rest	0.02%	0.20%	0.38%	1.19%	5.89%	19.64%
CHOCO	0.10%	0.10%	0.08%	2.23%	7.75%	16.24%

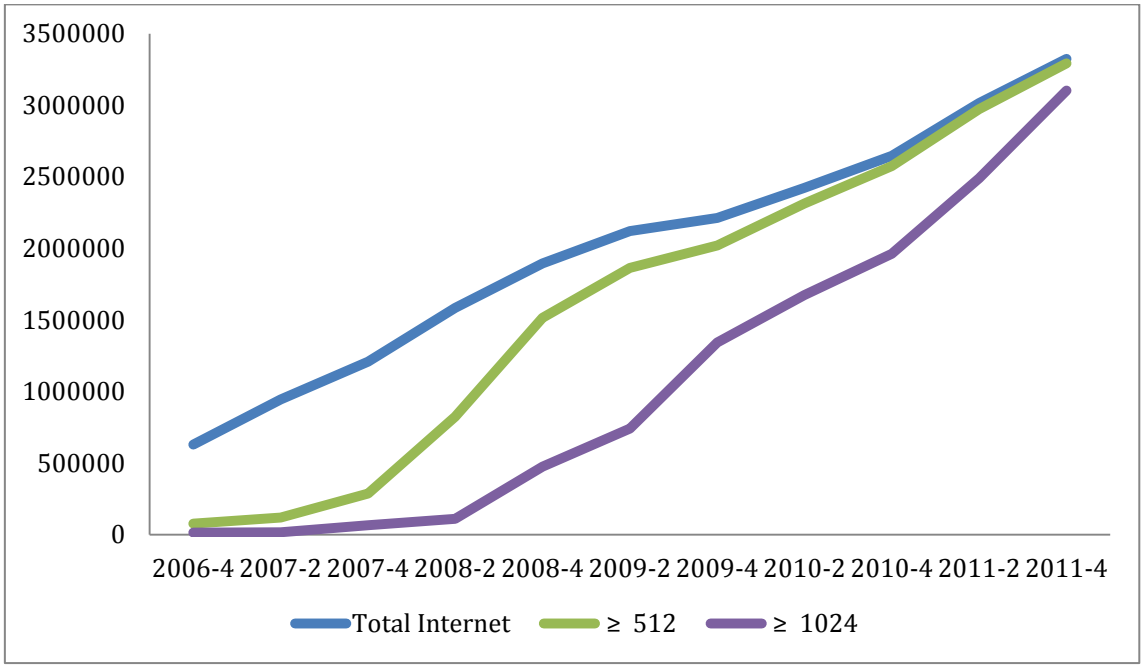
Quibdo	0.20%	0.31%	0.17%	3.23%	16.91%	30.34%
The rest	0.00%	0.00%	0.00%	0.55%	1.56%	5.68%
CUNDINAMARCA	0.31%	2.87%	6.87%	10.99%	19.31%	25.51%
CORDOBA	0.30%	1.21%	0.98%	2.71%	15.75%	30.63%
Monteria	0.62%	2.04%	1.38%	4.90%	26.36%	45.93%
The rest	0.11%	0.76%	0.92%	1.03%	9.16%	25.36%
HUILA	0.16%	0.61%	1.63%	8.94%	20.45%	32.06%
Neiva	0.26%	1.10%	2.70%	13.72%	31.69%	49.93%
The rest	0.06%	0.15%	0.59%	4.28%	10.31%	15.36%
LA GUAJIRA	0.02%	0.31%	0.48%	3.83%	14.75%	29.63%
Riohacha	0.11%	0.74%	0.66%	5.36%	26.31%	48.89%
The rest	0.00%	0.32%	0.99%	6.34%	21.53%	55.89%
MAGDALENA	0.28%	0.68%	1.02%	6.81%	29.08%	51.61%
Santa Marta	0.45%	1.09%	0.80%	10.07%	44.86%	75.23%
The rest	0.04%	0.04%	1.01%	0.88%	3.22%	12.89%
META	0.08%	0.32%	2.12%	6.25%	18.09%	30.38%
Villavicencio	0.11%	0.50%	0.45%	7.12%	20.37%	37.44%
The rest	0.02%	0.28%	2.89%	2.70%	8.20%	11.22%
NARIÑO	0.12%	1.77%	0.77%	7.14%	16.85%	29.28%
Pasto	0.20%	3.01%	0.57%	10.48%	24.09%	36.76%
The rest	0.01%	0.03%	0.68%	0.61%	1.78%	8.22%
NORTE SANTANDER					20.21%	34.27%
Cúcuta					27.16%	44.93%
QUINDIO	0.09%	0.28%	1.10%	7.86%	17.62%	32.33%
Armenia	0.50%	0.67%	1.04%	6.50%	14.84%	28.27%
The rest	0.06%	0.03%	0.53%	0.71%	2.72%	6.13%
RISARALDA	0.18%	1.93%	6.54%	10.37%	24.03%	37.17%
Pereira	0.26%	2.65%	9.47%	13.53%	32.65%	49.43%
The rest	0.02%	0.37%	0.91%	2.59%	6.07%	12.37%
SANTANDER	0.41%	1.84%	2.26%	6.62%	18.78%	30.64%
Bucaramanga	8.31%	2.35%	2.25%	8.68%	21.78%	33.95%
The rest	4.99%	1.25%	2.25%	4.67%	16.83%	29.69%
SUCRE	0.05%	0.67%	0.41%	2.23%	15.77%	32.41%
TOLIMA	0.09%	0.45%	0.98%	3.10%	14.46%	24.56%
Ibague	0.17%	0.85%	1.16%	5.46%	26.26%	39.85%
The rest	0.03%	0.10%	0.92%	1.21%	4.69%	13.16%
VALLE DEL CAUCA	0.48%	2.10%	11.22%	11.63%	26.07%	35.67%
Cali	0.71%	2.99%	14.26%	13.18%	34.41%	43.87%
The rest	0.16%	0.51%	4.06%	5.59%	8.38%	15.08%
ARAUCA	0.00%	0.17%	0.76%	2.17%	10.67%	26.55%
CASANARE	0.09%	0.31%	0.44%	2.93%	13.37%	26.33%
GUAVIARE	0.00%	0.07%	0.19%	0.00%	0.00%	0.12%
PUTUMAYO	0.00%	0.33%	2.43%	1.61%	4.78%	13.06%

Source: Authors' calculations based on data from the Ministry of ICT, SSPD and SIU

3.1.2 Broadband adoption patterns in Colombia's residential sector

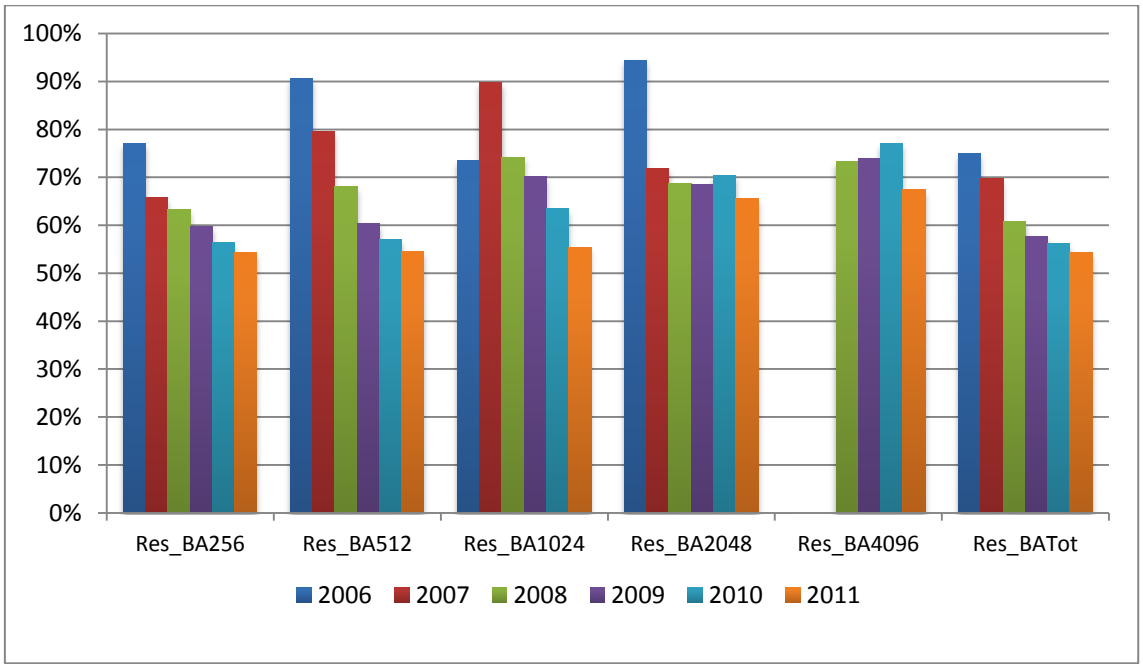
Research conducted internationally on broadband penetration has used the presence of an ISP in a given area or, more commonly, the total of residential subscribers normalized based on total population as an analysis variable, which is known as penetration per 100 inhabitants. In the following section, the authors present indicators for broadband penetration (normalized for 512 Kbps and 1024 Kbps), initially, for the number of residential subscribers reported by electrical power companies. Our procedure replicates what was done for the business sector. In the case of households, in general, there is only one connection per household, which must have at least one computer, and requires at least one electricity connection. Subsequently, we present the normalized indicator per 1000 inhabitants.

Figure 8. Total number of Internet and broadband subscribers



Source: Ministry of ICT

Figure 9. Concentration of residential subscribers in four cities



Source: Ministry of ICT.

Figure 8 presents information for the total number of Internet connections, the total number of connections faster than 512 Kbps and Figure 9 shows the percentage of those connections concentrated in the cities of Barranquilla, Bogota, Cali and Medellin, considered to be the four cities with the largest population and highest level of economic activity.

From these graphs, several patterns emerge. The first is that there has been a steady annual growth in the number of households with Internet since the first half of 2007, in general, which starting in the first half of 2008 is explained by the number of subscribers with broadband connection speeds of at least 512Kbps. Based on the information of the Ministry of ICT, it is not possible to separate out the number of Internet subscribers that went from having a narrowband connection to a broadband connection from the number of new subscribers that entered the market. On the other hand, Figure 9 shows a high, although slightly decreasing concentration of broadband in the four largest cities. By 2011, even at download speeds of 256 Kbps, the country's capital, Barranquilla, Cali and Medellin represented more than half of the connections. Concentration levels in those cities exceeded 65% for bandwidths above 2048 Kbps download.

Table 4. Broadband penetration rate above 512 in residential units

Department	2006	2007	2008	2009	2010	2011
ANTIOQUIA	0.30%	0.39%	17.47%	20.1%	27.4%	36.1%
Medellin	0.71%	0.87%	27.94%	30.78%	38.93%	49.89%
The rest	0.02%	0.03%	14.69%	19.23%	29.66%	37.80%
ATLANTICO	0.63%	1.63%	13.16%	17.2%	15.3%	32.1%
Barranquilla	1.28%	2.88%	22.16%	27.47%	17.42%	44.02%
The rest	0.00%	0.29%	3.77%	7.12%	10.16%	20.15%
BOGOTA, D. C.	1.44%	7.39%	33.46%	39.54%	44.98%	52.11%
BOLIVAR	0.06%	0.17%	6.09%	12.1%	16.1%	22.7%
Cartagena	0.12%	0.31%	11.08%	21.06%	29.05%	41.48%
The rest	0.00%	0.00%	0.46%	1.56%	2.48%	4.19%
BOYACA	0.03%	0.04%	1.57%	3.5%	5.1%	7.9%
Tunja	0.10%	0.15%	5.56%	14.25%	20.16%	26.80%
The rest	0.05%	0.05%	2.07%	4.10%	6.14%	9.61%
CALDAS	0.00%	2.14%	8.76%	14.3%	18.2%	23.4%
Manizales	0.00%	5.32%	19.05%	32.54%	38.16%	47.88%
The rest	0.00%	0.05%	3.18%	3.35%	8.15%	11.66%
CAQUETA	0.04%	0.06%	2.10%	4.7%	6.4%	6.5%
The rest	0.00%	0.03%	0.60%	0.91%	1.61%	1.70%
CAUCA	0.00%	0.02%	1.30%	5.3%	7.4%	9.1%
Popayan	0.00%	0.09%	4.20%	18.13%	25.94%	32.44%
The rest	0.00%	0.00%	0.62%	2.00%	2.50%	3.30%
CESAR	0.04%	0.08%	5.83%	6.8%	9.1%	12.4%
Valledupar	0.08%	0.15%	11.88%	13.08%	20.68%	26.14%
The rest	0.01%	0.03%	1.10%	2.11%	2.70%	4.87%
CHOCO	0.03%	0.03%	2.65%	6.7%	7.8%	10.2%
Quibdo	0.06%	0.07%	4.54%	11.46%	13.87%	18.31%
The rest	0.00%	0.00%	0.81%	1.82%	1.71%	2.26%

CUNDINAMARCA	0.10%	1.10%	6.92%	9.1%	11.9%	18.0%
CORDOBA	0.03%	0.07%	2.74%	4.0%	6.9%	8.7%
Monteria	0.06%	0.08%	6.93%	9.66%	14.26%	18.61%
The rest	0.04%	0.11%	1.26%	2.19%	6.22%	7.43%
HUILA	0.05%	0.04%	6.76%	9.5%	12.0%	15.8%
Neiva	0.10%	0.08%	17.20%	23.01%	28.41%	37.02%
The rest	0.03%	0.02%	1.65%	3.81%	4.58%	5.27%
LA GUAJIRA	0.04%	0.04%	3.11%	6.3%	8.7%	11.6%
Riohacha	0.08%	0.06%	5.75%	10.78%	15.46%	22.61%
The rest	0.03%	0.03%	2.15%	4.61%	5.92%	8.15%
MAGDALENA	0.06%	0.04%	4.65%	7.5%	11.2%	16.6%
Santa Marta	0.16%	0.09%	10.20%	15.73%	23.97%	34.98%
The rest	0.00%	0.00%	0.60%	1.15%	1.62%	4.34%
META	0.64%	1.49%	10.43%	14.6%	17.8%	20.9%
Villavicencio	0.93%	2.27%	16.64%	21.43%	26.68%	32.02%
The rest	0.24%	0.34%	2.26%	6.17%	6.66%	5.82%
NARIÑO	0.03%	0.03%	2.71%	4.9%	5.9%	8.8%
Pasto	0.09%	0.11%	8.67%	15.25%	19.08%	26.71%
The rest	0.00%	0.00%	0.21%	0.76%	1.23%	2.63%
NORTE SANTANDER					14.2%	17.6%
QUINDIO	0.03%	0.05%	9.64%	16.9%	21.0%	26.8%
Armenia	0.06%	0.08%	7.73%	13.24%	16.76%	21.20%
The rest	0.02%	0.03%	2.91%	6.06%	8.33%	12.11%
RISARALDA	0.00%	1.73%	16.47%	21.4%	20.3%	23.5%
Pereira	0.00%	3.00%	22.60%	28.53%	22.78%	23.05%
The rest	0.01%	0.54%	13.64%	18.69%	22.89%	33.15%
SANTANDER		2.15%	8.84%	18.9%	24.1%	30.9%
Bucaramanga		8.16%	22.05%	38.25%	45.90%	56.62%
The rest	0.08%	0.09%	7.27%	18.41%	25.81%	32.40%
SUCRE	0.04%	0.05%	2.71%	3.7%	6.9%	9.3%
TOLIMA	0.04%	0.05%	5.28%	9.7%	12.1%	16.1%
Ibague	0.08%	0.11%	12.44%	22.56%	28.60%	36.76%
The rest	0.01%	0.01%	1.03%	2.39%	3.10%	6.10%
VALLE DEL CAUCA	0.05%	1.66%	13.00%	15.9%	20.7%	30.3%
Cali	0.09%	1.88%	20.92%	19.85%	26.53%	40.91%
The rest	0.02%	1.74%	5.25%	11.78%	16.30%	24.51%
ARAUCA	0.04%	0.04%	3.43%	5.2%	6.7%	8.3%
CASANARE	0.06%	0.11%	2.53%	6.8%	8.4%	10.8%
GUAVIARE	0.00%	0.00%	0.00%	0.057%	0.010%	0.010%
PUTUMAYO	0.04%	0.03%	2.72%	5.7%	6.7%	8.1%

Source: Authors' calculations based on data from the Ministry of ICT, SSPD and SIU

Table 4 shows broadband penetration (≥ 512 Kbps) in major departmental capitals and other municipalities. In general, if the indicator residential electrical power customers is accurate, the first thing one can observe is a slight generalized pattern of digital divide between the country's largest

capital cities and the smallest, and between capital cities and the other municipalities throughout the country (see for example the differences between Bogota and Riohacha or Tunja). Secondly, the country's capital has a high level of broadband penetration, 52% in 2011, and capital cities like Medellin, Barranquilla and Cali have made significant progress to close the gap recorded in 2007. In addition, intermediate cities like Cartagena, Popayan and Pereira have also made advances in broadband penetration. Third, in several departments such as Boyaca, Choco, Cauca, Cesar and Sucre, the penetration in municipalities other than the capital city is extremely low.

A different perspective is observed when the broadband penetration indicator of 512 Kbps download per 100 inhabitants is used, which is employed by various ITU reports. Table 5 presents this information at the level of departmental capitals and the rest of municipalities but for every 1000 inhabitants. Clearly, different results are revealed. First, penetration rates are low compared with international standards. For example, in 2011, only Bogota exceeded ten connections per 100 inhabitants (0r 100 per 1000 pop.). Secondly, again the higher population concentration in the departmental capitals produces a lower indicator in those cities for most departments than in the rest of the municipalities grouped together. In third place, the digital divide between departments and between capital cities is now wider.

Table 5. Broadband penetration rate above 512 per 1000 inhabitants

Department	2006	2007	2008	2009	2010	2011
ANTIOQUIA	0.12	0.17	6.89	9.2	19.9	29.8
Medellin	0.19	0.26	7.74	9.0	11.4	14.7
The rest	0.03	0.05	24.09	32.1	49.5	67.2
ATLANTICO	0.16	0.40	3.56	6.1	9.0	13.1
Barranquilla	0.24	0.60	4.45	5.8	7.1	8.6
The rest	0.00	0.57	7.76	15.4	22.1	32.7
BOGOTA, D. C.	3.20	16.33	74.82	89.9	104.0	122.4
BOLIVAR	0.07	0.08	0.73	1.7	2.4	3.7
Cartagena	0.02	0.06	2.28	4.7	6.1	8.2
The rest	0.00	0.00	0.57	2.0	3.2	5.3
BOYACA	0.23	0.24	0.64	1.3	1.8	2.7
Tunja	0.02	0.03	1.33	3.5	5.1	6.9
The rest	0.06	0.06	2.58	5.3	8.0	13.3
CALDAS	0.07	0.60	3.84	5.5	9.2	12.9
Manizales	0.00	1.37	4.97	8.7	10.3	13.1
The rest	0.00	0.06	4.56	4.9	11.9	17.6
CAQUETA	0.09	0.14	0.69	1.4	2.0	13.9
The rest	0.00	0.02	0.45	0.7	1.2	1.4

CAUCA	0.05	0.06	0.44	1.6	2.3	3.0
Popayan	0.00	0.02	1.01	4.4	6.5	8.3
The rest	0.00	0.00	0.36	1.3	1.6	2.1
CESAR	0.06	0.07	1.31	2.3	3.5	5.8
Valledupar	0.02	0.03	2.15	2.6	4.1	5.1
The rest	0.01	0.04	1.40	3.1	4.2	7.4
CHOCO	0.11	0.11	0.68	1.5	1.8	2.4
Quibdo	0.01	0.02	1.13	2.9	3.7	5.1
The rest	0.00	0.00	0.41	0.9	0.9	1.3
CUNDINAMARCA	0.18	0.72	4.47	5.8	7.6	10.2
CORDOBA	0.06	0.11	1.37	2.3	5.3	6.5
Monteria	0.01	0.02	1.68	2.4	3.5	4.3
The rest	0.04	0.10	1.24	2.4	6.5	8.2
HUILA	0.10	0.10	1.76	3.0	4.0	5.2
Neiva	0.02	0.02	4.19	5.8	7.4	9.9
The rest	0.03	0.02	1.90	4.5	5.4	6.0
LA GUAJIRA	0.08	0.08	2.08	4.5	6.3	8.9
Riohacha	0.01	0.01	0.87	1.8	2.2	2.8
The rest	0.03	0.03	2.14	4.9	6.3	7.3
MAGDALENA	0.07	0.07	1.32	2.3	3.1	4.3
Santa Marta	0.03	0.02	2.63	4.5	5.6	6.5
The rest	0.00	0.00	1.09	2.2	3.2	5.4
META	0.32	0.45	3.35	5.8	6.9	7.6
Villavicencio	0.22	0.55	4.20	5.4	6.8	8.5
The rest	0.26	0.38	2.96	7.3	8.6	8.1
NARIÑO	0.08	0.09	0.42	0.8	1.0	1.6
Pasto	0.02	0.02	1.90	3.4	4.3	6.1
The rest	0.00	0.00	0.14	0.5	0.8	1.9
NORTE SANTANDER	0.16	0.16	1.31	2.7	4.5	6.0
Cucuta	0.02	0.03	2.19	4.4	5.5	6.7
QUINDIO	0.11	0.12	5.69	10.9	14.0	19.1
Armenia	0.02	0.02	2.03	3.5	4.5	5.8
The rest	0.01	0.02	5.28	10.9	15.2	22.4
RISARALDA	0.06	0.80	11.49	14.2	17.0	26.0
Pereira	0.00	0.73	5.61	7.6	8.6	11.3
The rest	0.02	0.91	23.82	33.4	41.3	61.9
SANTANDER	0.19	0.42	1.89	4.5	6.0	8.2
Bucaramanga	0.03	1.80	4.51	8.5	10.9	14.4
The rest	0.08	0.14	9.48	29.2	41.1	56.5
SUCRE	0.08	0.16	5.19	7.4	13.7	18.5
TOLIMA	0.09	0.09	1.27	2.6	3.5	6.3
Ibague	0.02	0.02	2.78	5.1	6.8	9.1
The rest	0.02	0.02	1.36	3.2	4.3	8.8
VALLE DEL CAUCA	0.07	1.24	4.67	16.8	22.6	34.2
Cali	0.02	0.40	4.58	6.1	7.1	9.3

The rest	0.04	2.88	8.87	21.2	29.6	44.6
ARAUCA	0.13	0.13	2.82	4.6	6.3	8.3
CASANARE	0.21	0.26	1.80	4.3	5.4	6.9
GUAVIARE	0.05	0.06	0.06	0.1	0.1	0.1
PUTUMAYO	0.10	0.09	2.06	4.2	5.2	6.5

Source: Authors' calculations based on data from the Ministry of ICT

3.2 Some socioeconomic patterns of broadband expansion with indicators from the Integrated Household Survey

The expansion of the Internet through the different socioeconomic strata presents important gaps that should be highlighted. Colombia's socioeconomic strata range from the number one, the lowest socioeconomic conditions, to the number six, the highest. As explained by a DNP document (2008) called "Evaluation of socioeconomic stratification as a classification tool for users and a tool for allocating subsidies and contributions to household public services",

In Colombia, socioeconomic stratification is a property classification system used as geographical tool to target differential tariff for household public services through a demand-side subsidy scheme. Historically, six strata have been used, defined according to the characteristics of the housing and its surrounding environment as an indirect indicator of the economic capacity of its inhabitants. Thus, the quality of housing is used as an approximation to the inhabitants' quality of life..

In 2009, the Household Integrated Survey (GEIH) carried out by Colombia's National Administrative Department of Statistics (DANE for its acronym in Spanish) began gathering information on information communications technology in a special module called ICT. However, since its inception, the GEIH included the question: "Which of the following services or goods does this household have?" in the household data module with "Internet services" as one of the possible responses. Based on responses to the question, Table 6 presents average percentage of households that indicated "Internet services" in response to the question for the periods 2007-2008 and 2009-2011, discriminating by socioeconomic strata for the total, all 23 main cities in Colombia, the total for the so-called municipal head or urban area, and the total for the rest.

The first result that stands out is the difference in the percentage of households with Internet access in the home for the different socioeconomic strata. If we take the national total, the average household Internet access for stratum 6 (or 5 in some cases), i.e., greater economic resources, was about 70 times greater during 2007 and 2008 than stratus 1, the lowest economic resources (Table 6A). This difference later shrank to 20 times for the period 2009-2011. The differences between strata 2 and 3 were not so high and have rapidly dropped in recent years. Relations

between the stratum with the highest average access in the home and stratum 1 have varied between cities with a range of six for Quibdo and a high of 101 for Sincelejo in 2007-2008 and four for Quibdo and 26 to Sincelejo from 2009 and 2011. These low cases could be explained by the very limited supply of these services even to the upper strata of the cities, or the limited utility these high strata households confer to having Internet in the home. The socioeconomic digital divide has narrowed rapidly but it still remains when we look at household penetration in cities.

There are also differences in terms of penetration or Internet access among cities-strata. Cities like Neiva, Valledupar, Santa Marta and Tunja, for example, have lower average rates of households with Internet. A third observation is that the penetration or percentage of households with Internet service in the home in the so-called "rest" of the country is relatively low compared with all of the urban municipal sides. For the most recent period of 2009-2011, levels of residential Internet access for strata 5 and 6 in these locations did not exceed the average of stratum 3 municipal seats. The "rest" is comprised representatively of the nearly 1,000 remaining municipalities. For example, for strata 1 and 2 of the "Rest," Internet penetration was in less than 3% of households. The above does show a large and growing digital divide that the plan Vive Digital seeks to rectify and reduce. A fourth point that stands out from Table 6 is that Internet penetration is not complete yet for socioeconomic strata 5 and 6. The highest percentages for stratum 6 are in Bogota. An explanation for this is may be the absence of any ISP in an area or the low value household members confer the service.

Table 6. Average percentage of households with Internet service

City	2007-2008						2009-2011					
	Stratum						Stratum					
	1	2	3	4	5	6	1	2	3	4	5	6
National	1.1	4.9	18.0	48.3	62.7	76.1	4.2	15.1	36.4	65.6	74.1	83.6
Head	1.6	6.0	18.4	49.2	63.7	76.8	6.0	17.9	37.2	66.7	74.9	85.4
The rest	*0.4*	*0.7*	*3.6*	*10.0*			*1.0*	*2.7*	*7.1*	*19.2*	*34.4*	*27.0*
Bogota, D. C.	4.0	8.2	22.2	64.2	76.1	79.8	11.1	21.9	41.6	79.0	89.2	91.3
Medellin	3.4	10.0	24.9	48.5	67.5	82.1	9.7	24.7	42.7	68.6	75.4	89.4
Barranquilla	1.8	8.0	19.3	43.9	54.5	72.5	7.5	26.6	41.8	65.5	77.1	85.2
Cartagena	1.4	7.1	20.8	52.9	59.1	67.2	5.3	22.2	46.9	70.3	80.1	73.6
Manizales	1.8	6.1	15.5	38.5	43.1	63.8	9.9	24.1	38.4	58.5	64.8	75.6
Monteria	2.2	10.0	20.0	40.4	56.5	74.6	6.3	27.1	41.4	74.0	81.5	78.9
Villavicencio	2.0	4.9	12.8	31.6	46.6	53.9	6.0	14.3	31.4	48.6	69.6	63.3
Pasto	1.7	4.6	14.9	37.6	48.6	10.3	4.5	14.2	32.3	58.0	57.8	
Cucuta	1.4	4.0	15.7	47.8	59.7	29.5	4.6	14.8	39.5	73.1	76.2	
Pereira	1.9	8.9	19.2	35.1	50.6	72.6	8.5	23.6	35.6	52.0	63.1	76.4
Bucaramanga	2.6	7.7	18.0	48.8	63.3	70.1	11.4	27.3	42.2	66.6	79.6	81.3
Ibague	2.1	6.2	16.7	36.4	44.3	35.9	9.5	21.1	41.4	60.5	52.4	80.2
Cali	2.4	6.3	19.7	44.8	55.6	77.2	10.2	18.4	34.7	58.3	65.2	79.9
Tunja	1.5	4.4	12.2	33.4	48.7		5.4	11.4	27.5	46.6	64.4	
Florencia	1.9	10.1	17.7	40.3	57.0	27.6	8.1	23.3	35.4	60.2		
Popayan	0.9	3.5	10.8	30.5	47.3	64.7	3.1	13.1	32.2	53.7	71.3	40.3
Valledupar	1.2	6.6	12.7	29.5	41.7	46.9	5.9	17.1	36.6	54.8	69.4	77.6

Quibdo	3.4	13.4	21.3				11.3	31.4	39.8			
Neiva	2.5	11.1	27.2	41.1	56.7	40.9	9.8	32.4	54.1	65.4	69.1	37.1
Riohacha	1.7	9.6	21.1	34.2	52.2		5.8	24.7	41.2	53.1	40.3	87.8
Santa Marta	1.4	3.5	9.2	23.8	43.3	51.7	5.0	18.1	29.5	49.4	61.7	62.5
Armenia	2.5	6.1	14.6	31.9	48.1	61.6	6.4	18.4	33.8	56.4	70.7	80.7
Sincelejo	0.7	6.6	16.8	36.8	67.7	63.2	3.0	18.9	41.5	61.3	74.9	77.5
Total 23 cities	2.3	7.8	20.7	51.0	64.0	77.0	8.4	22.0	40.1	68.8	75.5	85.8
Urban without 23 cities	*1.0*	*3.3*	*10.3*	*31.1*	*47.6*	*3.5*	*3.6*	*11.1*	*26.2*	*50.9*	*54.6*	*72.8*

Source: DANE, GEIH.

3.3 Telecenters and Internet cafes as Internet access mechanisms

In 2000, the government of Colombia began to foster the development of so-called social telephony under the Compartel program, which focused on providing telecommunications services, initially fixed telephone services in rural towns and municipalities throughout the country. The program emphasizes that "universal access policy should tend toward the installation of public or community telephones and telecommunications centers that make it possible for communities to have telecommunications services within a reasonable distance of their homes." This set the foundation for universal access rather than universal service, aimed at generating non-residential access to basic telephony and other telecommunications services with three main goals: “provide community-based telecommunications services to the highest number of locations without access to these services,” “improve service coverage in those towns with inadequate or no coverage,” and “promote the development of telecommunications services in rural areas in order to increase their competitiveness.”

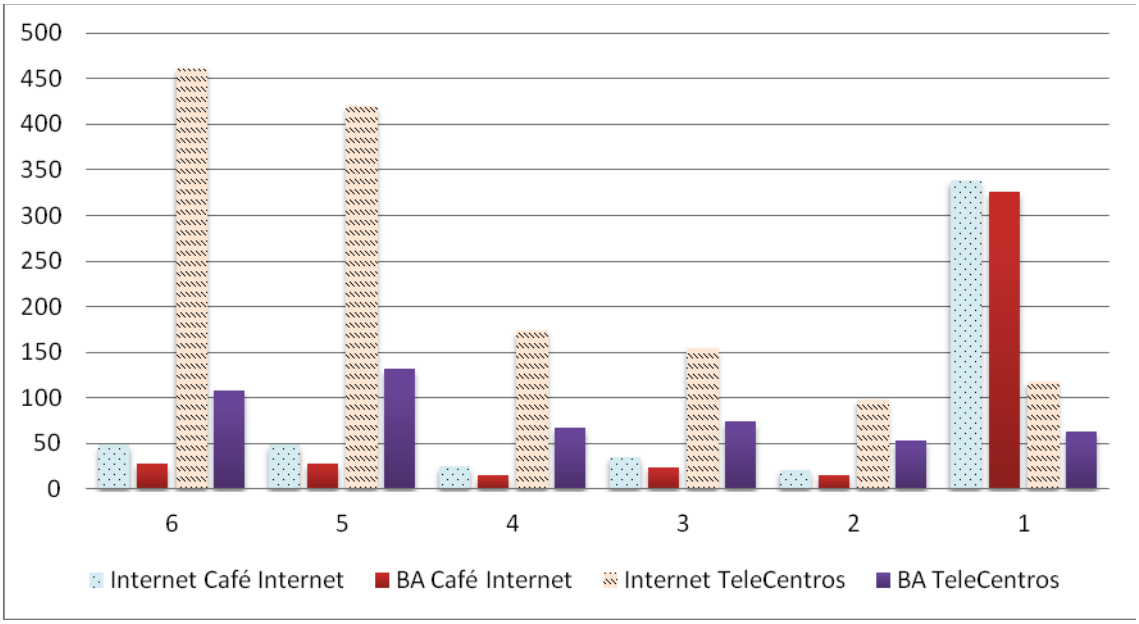
A formal evaluation of the program[6] indicated that at the time of the report 670 Compartel points with Internet access had been installed in about 7400 locations benefitting nearly four million inhabitants. In 2007, the National Council of Economic and Social Policy (CONPES for its acronym in Spanish) in document Nr. 3457 compiled more information about the program, showing that by 2009 Telecenters 1490 telecenters with download speeds no greater than 128Kbps were (or should be) created. CONPES emphasized that "by 2006, the program achieved community Internet access in 100% of the municipal seats in the country."

Figure 11 shows the average number of telecenters and Internet cafes in seven groups of Colombian municipalities. The purpose of the chart is to illustrate the number of *community* Internet access points in the country's municipalities. Existing information from SIUST of the Ministry of ICT includes data about telecenters only from 2007. The classification of municipalities into seven groups based on the classification established by Act 617 of 2000, which divides municipalities into seven categories based on their population and income not designated or reserved for specific purposes (Special Category and Categories 1-6). The categories are:

[6] *See CONPES 3171 of 2001.*

- Special category includes capital municipalities or districts with more than 500000 inhabitants
- First - Municipalities with populations between 100001-500000
- Second - Municipalities with populations between 50001 – 100000
- Third - Municipalities with populations between 30001-50000
- Fourth - Municipalities with populations between 20001-30000
- Fifth - Municipalities with populations between 10001-20000
- Sixth - Municipalities with population under 10000.[7]

Figure 10. Number of telecenters and Internet cafes by type of municipality



Although illustrative, the figure shows two important aspects of the development of the Internet in smaller populations. The first is that these two mechanisms of community access—Internet cafes and Telecenters—are more numerous in the smaller towns, in the spirit of the COMPARTEL program. The second is that there is still very little known about the broadband available through these mechanisms. While it is true that the

[7] *The average of municipalities, 2006 to 2011 by category is: a) Category 6, 389 municipalities, b) Category 5, 291 municipalities, c) Category 4, 120 municipalities, d) Category 3, 98 municipalities, e) Category 2, 54 municipalities, f) Category 1, 48 municipalities, and g) Special Category 9 municipalities or district capitals.*

COMPARTEL program has fueled the use of Internet across the country, the emergence of broadband (download speeds of at least 256 Kbps) is still very low in those same locations. The Vive Digital plan aims to expand broadband access and help reduce the digital divide in residential access (or in the home) seen today in the country as shown in the previous section.

3.4 Internet, computers and ICT

GEIH provides additional information on home ownership of at least a computer and access to other ICTs. Table 7 shows the average of these indicators for the 23 main cities in Colombia without discriminating by socioeconomic status. A first point to be noted is that, mixing all households, Bucaramanga and Medellin displace Bogota in ranking of the average number of households with computers. A second point is that average number of households with internet access per city is more or less similar, except for Riohacha, Quibdo and Florencia. Next, we see that the average number of households that own a computer is higher than the average number of households with Internet access for all 23 cities. This is important because policy discussions often note that one of the barriers to Internet access is a lack of computer ownership. Clearly, it would seem not to be the case, although it is possible that an explanation for the higher average number of computers owned is due to high ownership in higher-income socioeconomic strata. Finally, there is the ICT index, calculated as the average of the presence or ownership in the home of a) landline, b) cable TV, c) Internet d) computer, and e) at least one cell phone. Cities such as Bucaramanga, Cali, and Medellin had the highest average, around 3.8. In several cities, the indicator did not exceed the three points

3.5 Analysis of broadband penetration results

Broadband penetration, measured at bandwidth levels greater than 512 or 1024 Kbps, has progressed at accelerated growth rates over the last five years in Colombia. Advances have been made in residential and business penetration indicators alike. At a residential and business level, increased ICT penetration has followed demographic and business development trends experienced by the Colombian cities during the last 30 years. Bogota, Medellin, Cali and Barranquilla concentrate the largest number of broadband subscribers in both user segments. However, it is worth noting the progress observed in cities like Cartagena, Santa Marta, Manizales and Pereira at the residential level and in the department of Santander, in general, at the enterprise level. Unfortunately, progress in terms of penetration levels has been uneven, demonstrating that, in general,

household and business broadband access in municipalities has continued to lag behind departmental capitals, deepening existing economic inequalities.

Table 7. Access to Internet, computers and ICTs

City	GEIH		
	Internet	Computer	ICTs
Armenia	23.4%	33.9%	3.4
	10.1%	6.7%	0.2
Barranquilla	21.9%	26.4%	2.9
	9.8%	7.8%	0.3
Bogota, D. C.	31.1%	43.1%	3.6
	10.1%	7.0%	0.3
Bucaramanga	32.9%	40.6%	3.8
	14.2%	10.8%	0.3
Cali	25.1%	37.7%	3.7
	8.5%	6.3%	0.2
Cartagena	21.4%	27.6%	3.0
	10.8%	8.7%	0.3
Cucuta	16.9%	23.4%	3.0
	8.7%	7.2%	0.2
Florencia	12.6%	24.9%	2.9
	5.5%	4.6%	0.2
Ibague	20.9%	32.7%	3.3
	11.7%	9.3%	0.3
Manizales	29.4%	41.7%	3.7
	14.0%	10.5%	0.3
Medellin	32.6%	42.6%	3.9
	10.9%	8.8%	0.3
Monteria	17.0%	22.1%	3.1
	9.3%	7.6%	0.2
Neiva	23.9%	34.1%	3.3
	12.9%	10.4%	0.3
Pasto	17.0%	33.6%	3.0
	8.4%	5.0%	0.2
Pereira	26.6%	34.7%	3.7
	11.2%	9.0%	0.2
Popayan	19.1%	35.0%	3.2
	10.0%	7.0%	0.2
Quibdo	12.0%	20.3%	2.9
	7.0%	7.7%	0.2
Riohacha	13.1%	17.6%	2.8
	7.0%	6.2%	0.3
Santa Marta	17.3%	25.3%	3.0

	9.8%	9.1%	0.2
Sincelejo	13.7%	18.7%	3.1
	8.1%	5.9%	0.2
Tunja	18.9%	35.0%	3.1
	10.1%	5.7%	0.2
Valledupar	14.6%	21.3%	2.8
	8.7%	8.1%	0.3
Villavicencio	18.4%	31.0%	2.9
	9.9%	6.6%	0.2

Note: The first row represents the anual average from 2006 to 2011. The second one is the standard deviation.
Source: DANE-GEIH.

Using the GEIH data as a reference, there are large differences that persist: a) between socioeconomic strata in the cities, b) between urban or municipal urban and rural areas or the 'Rest' of the country and c) between strata within each city. The differences show a wide digital gap that favors the richest cities and the highest strata.

One mechanism that has mitigated the overwhelming digital divide is the existence of internet cafes and telecenters throughout small and medium towns and villages. However, even after 10 years of government plans availability of broadband (a download speed of 512 kbps or more) is still limited or inexistent for most of the country's population.

4. INTERNET AND ECONOMIC DEVELOPMENT: SOME RESULTS FOR COLOMBIA

In the previous section, the authors highlight the digital divide in residential and business broadband access in Colombia, although this has been declining in recent years in cities and within strata in some cities. In this section we tackle several empirical exercises using econometric techniques in an effort to verify the connection between the use of broadband and some variables proxies for the economic activity. In order to carry out this empirical exercise, multiple databases are used, including the Integrated Survey Household (GEIH) and ICT Ministry data. In addition to these two databases, supplementary information was obtained from DANE and the National Planning Department (DNP for its acronym in Spanish) for information related to the municipalities' fiscal performance.

Certain limitations reduce the scope of this investigation. The first has to do with the different time periods covered by the information available in the aforementioned databases. For example, GEIH is quarterly, as is the ICT Ministry data, but the others have biannual or annual periodicity. In second place, while the ICT Ministry database's reporting period is quarterly, it does not publish all the necessary information for every quarter, which makes it necessary to use the information corresponding to biannual periods in most cases. On a third note, GEIH, which provides basic and ample information for the more advanced econometric exercises, only gives information for a total of 23 cities, the ones with largest economic and social development in the country. For the rest of municipalities, the econometric exercise is more limited given the lack of data, and so the authors perform a similar exercise between the Internet or broadband and the economic variables for the rest of the municipalities other than those 23 cities. Finally, the Internet access information reported by GEIH for households does not discriminate bandwidth.

4.1 The relationship between broadband and economic activity in 23 cities

The availability of information allows for two groups of econometric exercises which we describe in detail, noting the respective models and variables used. The first exercise takes quarterly GEIH information for 23 cities from the year 2006-2011 to a set of socioeconomic variables for households in Colombia. One of the survey questions refers to the presence of, or access to, the Internet at home. The survey does not ask

about the available bandwidth in the home. Internet access is one of the explanatory variables of interest in all of exercises in this study, which the authors complement with bandwidth data reported in the ICT Ministry's database for these 23 cities.

The procedure for the creation of economic indicators used in the econometric exercises follows. For example, city salaries: for a city, for example Armenia, assume that 900 households were surveyed. For these households, the average salary for the adults who make up that household is assumed and a "median household" is constructed. Then, the "average household wages" found in that city are added up and an average calculated. Biannual and annual salary data is the average salary of the adults in the households per city. For each case, citywide expansion factors calculated by DANE are used. The results are then representative of citywide averages.

The model uses a double logarithmic specification that makes it possible to interpret the results as response elasticities.

$$lny_{i,t} = \alpha + \beta lnX_{i,t} + Z_{i,t} + CI_{t=2005} + (\rho_i + \varepsilon_{i,t})$$

Where *y* is a variable that represents certain economic variables, *i* is the city or municipality, and *t,* the year. Among the economic variables available through GEIH are: a) The logarithm of the real wage; b) the percentage of employed persons; c) the logarithm of average household income; d) the logarithm of the average price of housing values; e) the logarithm of the level of municipal tax revenue;[8] f) the logarithm of the number of enterprises. Because there is not a *direct* variable for the number of firms in each city, the number of business subscribers to electricity services supplied by the SSPD is used as a proxy; it is a variable referred to in this paper as *company*.

The *variable of interest, X,* is Internet access, the average number of households per city that indicated they have Internet access.[9]

The Z vector is comprised of socioeconomic variables such as: a) Average household education for members aged 0-55 years; b) an index of public

[8] *The authors excluded house tax from the total tax revenues since the total of residential subscribers is used as an IV. This variable could potentially be correlated with house taxes.*

[9] *Other variables used are: the logarithm of broadband subscribers (≥ 256 Kbps, ≥ 512 Kbps, ≥ 1024 Kbps) from the Ministry of ICT.*

services in the home; c) the percentage of households that work in the manufacturing, services, financial, and real estate sectors (Kolko, 2012); d) if the head of the household works in an office and not in the street or elsewhere; e) the number of households, estimated based on the residential electrical power customers; f) number of students; and g) the municipal population density. All the variables are entered into logarithms.

As control variables for the initial development situation up to 2005 (*CI*) the authors propose: i) the use of the municipal tax revenue taken from the National Planning Department, ii) the number of corporate establishments that cover activities in industry, commerce and services. As in the previous case, the level variables are entered into a logarithm. Finally, note that all monetary variables have been deflated using 2008 as the base year and the Consumer Price Index, CPI, published by DANE.

Given the nature of the panel of data, panel data econometrics with random effects is used.[10] The choice of random effects, instead of fixed effects, is to be able to control for initial development conditions present in each of the different units, in this case, cities. The use of fixed effects simply removes that initial condition. Although there has been much debate about which of the two effects should be chosen, it is worth noting Green (2008), who said "*The crucial distinction between fixed and random effects is whether the unobserved individual effect embodies elements that are correlated with the regressors in the model, not whether these effects are stochastic or not.*" In this case, the authors consider that there are differences between cities that may influence the economic variable chosen, so the use of the random effects is justified.

Before proceeding with the findings, it is necessary to discuss the interpretation of relationships. As Kolko (2012, p. 101) correctly points out, it is necessary to take into account the potential endogeneity problems of the indicators of broadband penetration and control for heterogeneity of the units of analysis.

In the first place, we can say that if there is a positive relationship between an indicator of broadband and a proxy for economic activity, this does not mean that broadband causes the economic activity being measured. This endogeneity problem is alleviated with the use of a valid instrument. As explained by econometric texts (Angrist and Pischke 2008) a good instrument is one that is correlated with the endogenous variable that is assumed (broadband measure) but is not correlated with the

[10] *All econometric exercises were run using the xtivreg command from Stata.*

dependent variable, in our case, the proxy for economic activity. Kolko (2012) suggested the use of the average slope of local terrain as an instrument of broadband penetration. In his article, he notes that the topography appears to negatively affect the deployment of broadband. To complete his analysis, he analyzes the exclusion restriction of using the slope as an instrument. He analyzes factors associated with mountainous terrain as a place of amenity, transportation costs, variation in climate, and economic structure of the counties and controls for some of these factors. Is the slope of local terrain at a municipal level a good instrument? Kolko's study and the explanations given in the footnote on page 14 appear to be sufficient. It should be noted that the expected relationship may depend on the technologies used to provide Internet service. If they are satellite or something similar, the relationship could be positive.

In this study, the authors did not have all of the exclusion controls used by Kolko, except for a restricted measure of the structure of economic activity. To supplement these controls, the authors used two additional instruments. The first is the number of households that reported having fixed telephony in the 2005 Census. The second additional instrument is the ratio of residential subscribers to electrical power which one would think would be positively related to broadband indicators and not necessarily with economic activity variables. This second instrument is more controversial as the expectation would be that as economic activity increases, so would the number of residential subscribers.

A second problem is the heterogeneity in the use of broadband by businesses in a given locality. In places where there is a strong base of businesses that make more use of information and communication technologies and where there is generally more qualified human capital in the use of these technologies, it is expected that they would make more use of broadband and therefore the penetration indicator would be higher. In the two econometric exercises of this study, the authors controlled for this heterogeneity. In the exercises that are limited to 23 cities in the GEIH data, the authors introduced in vector Z the average response pertaining to the economic activity of the head of each household. Activities with widespread use of ICT and higher levels of labor force training, such as manufacturing, services and tourism, were grouped together.

4.1.1 Annual results: Internet and Economic Activity

Table 8 presents the results of relating the indicator of Internet access (average) per town and six (6) indicators of economic activity. For each indicator of economic activity two exercises are presented. The first numbered as (1) presents the results of panel data regressions with

random effects, correcting for endogeneity using the above instruments. The second, marked as (2), presents the results of the panel data regression with random effects not corrected for endogeneity. Several points are worth mentioning. The first is that regardless of controls for potential endogeneity of the dependent variable (average household access to the Internet), there is a positive association between this variable and the six economic variables. Since we use double logarithmic specifications, the coefficients represent elasticities or the degree of sensitivity of a variable to a percentage change of 1% in the Internet access. Thus, for example, a 1% increase in average of internet connections in the 23 cities generates a percentage increase of 0.08% in the employment rate. If a city has an average occupancy rate of 80%, an increase of 1% in the number of households connected to the Internet would raise the occupancy rate to about 80.1%. The greatest impact in terms of elasticity is obtained with tax revenues. In all cases, the sensitivity of economic variables is *still* relatively low.

The second aspect to highlight is the direction of potential endogeneity bias. In some cases, such as the estimated price of housing and wages, endogeneity bias tends to overestimate the magnitude of the coefficient. However, for the remainder of the four economic variables, by controlling for endogeneity, slightly higher coefficients are obtained. Third, the variance explained by the model adopted varies between 27% and 98% implying that different specifications could be used. Finally, the first column from right to left shows the results of the first stage of the regressions. The authors point out that there is a negative relationship between the average slope of local terrain and variable of the Internet, which confirms that the higher the (average) slope of the terrain, the more difficult it is to have Internet connections. The other two instruments have high statistical significance, but the sign of one of them, the variable of an existing fixed telephone landline in 2005, has the opposite expected sign.

Table 8. Internet impact on some economic variables. Panel data. Random effects with IV.

Variables	Dependant variables												
	Ln Price of household		Ln Lease		Ln Salary		Ln % Employment		Ln Tax revenues		Ln Firms		LnInternet
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(3)
lninternet	0.210**	0.325***	0.406***	0.286***	0.171*	0.235***	0.0762***	0.0157**	0.608***	0.475***	0.305***	0.115***	
	(0.0940)	(0.0228)	(0.0670)	(0.0209)	(0.0961)	(0.0373)	(0.0230)	(0.0064)	(0.1030)	(0.0368)	(0.0882)	(0.0210)	
Public utility index	-0.0358	-0.0460	0.0078	0.0313	0.0139	0.0069	0.0206**	0.0277**	-0.0040	-0.0369	-0.237***	-0.113*	0.108
	(0.0390)	(0.0520)	(0.0278)	(0.0404)	(0.0399)	(0.0448)	(0.0096)	(0.0111)	(0.0478)	(0.0673)	(0.0670)	(0.0583)	(0.0887)
Average education 0-55 years	0.293***	0.164***	-0.0597	0.0600	0.0356	-0.0215	-0.0707***	-0.0054	-0.177*	-0.0365	-0.254*	0.0080	0.977***
	(0.0894)	(0.0419)	(0.0637)	(0.0367)	(0.0914)	(0.0566)	(0.0219)	(0.0109)	(0.1020)	(0.0634)	(0.1320)	(0.0444)	(0.1020)
Economic sectors using ICTs	0.569	-0.374	-0.773	0.181	-1.438*	-1.758***	-0.587***	-0.077	-1.581*	0.684	0.506	0.856*	7.797***
	(0.7920)	(0.4680)	(0.5640)	(0.4140)	(0.8090)	(0.6320)	(0.1940)	(0.1240)	(0.8920)	(0.7140)	(0.8390)	(0.4860)	(1.3420)
Ln firms	0.158**	0.07100	-0.03790	0.116*	0.149**	0.11600	-0.0320*	-0.00970	-0.05360	0.05650			0.572***
	(0.0727)	(0.0855)	(0.0519)	(0.0693)	(0.0743)	(0.0791)	(0.0178)	(0.0193)	(0.0883)	(0.1170)			(0.1750)
Ln tax revenues 2005	-0.1200	-0.0314	0.0869	-0.0107	-0.1070	-0.0708	0.0404**	-0.0084	0.642***	0.582***	0.451***	0.237*	-0.537***
	(0.0800)	(0.1010)	(0.0570)	(0.0684)	(0.0817)	(0.0717)	(0.0196)	(0.0180)	(0.0950)	(0.1120)	(0.1350)	(0.1320)	(0.1390)
Ln firms 2005	0.0844	0.2080	0.0351	-0.0847	-0.0589	-0.0288	0.0547***	0.0108	0.1390	0.0427	0.564***	0.469***	-0.566***
	(0.0852)	(0.1280)	(0.0607)	(0.0830)	(0.0871)	(0.0788)	(0.0209)	(0.0212)	(0.1040)	(0.1350)	(0.1300)	(0.1650)	(0.1500)
Ln population density	-0.0603***	-0.0418	-0.0034	-0.0218	-0.0028	0.0029	0.0040	-0.0002	0.0618***	0.0333	0.0404	0.0448	-0.0845*
	(0.0169)	(0.0390)	(0.0121)	(0.0245)	(0.0173)	(0.0214)	(0.0042)	(0.0061)	(0.0214)	(0.0394)	(0.0386)	(0.0529)	(0.0466)
Ln middle and high school enrollments	-0.0215	-0.1670	-0.0460	0.0352	0.1160	0.0724	-0.0559*	0.0208	0.327**	0.332**	-0.2240	0.1340	0.583*
	(0.1220)	(0.1130)	(0.0870)	(0.0861)	(0.1250)	(0.1040)	(0.0299)	(0.0238)	(0.1470)	(0.1460)	(0.1980)	(0.1300)	(0.3090)
Constant	15.00***	16.96***	13.66***	11.84***	13.64***	14.50***	0.733**	-0.295*	3.105*	1.3210	4.697**	0.6900	-15.11***
	(1.4460)	(0.6830)	(1.0310)	(0.5610)	(1.4780)	(0.8400)	(0.3540)	(0.1650)	(1.6480)	(0.9580)	(1.9360)	(0.7910)	(1.3110)
Ln households													0.612**
													(0.2420)
Ln fixed phone lines 2005													-0.583***
													(0.2010)
Ln average slope of terrain													-0.0744*
													(0.0423)
Observations	124	124	124	124	124	124	124	124	119	119	124	124	124
Number of groups	23	23	23	23	23	23	23	23	23	23	23	23	

Sargan-Hansen statistics	16,801		10,523		0,219		9,104		3,14		17,85		
Instruments	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no	
r2_w	0.8927	0.9124	0.8706	0.8935	0.4433	0.4524	0.1179	0.1588	0.8289	0.8574	0.4271	0.515	
r2_b	0.7285	0.7139	0.7867	0.7568	0.5985	0.609	0.4279	0.4967	0.9932	0.9906	0.9601	0.956	
r2_o	0.7977	0.7991	0.8313	0.8254	0.4798	0.4891	0.2715	0.3821	0.9878	0.9868	0.9547	0.9542	0.6742

Note: Standard errors in parentheses. * Significant to 10%; ** to 5%; *** to 1%.
(1): It refers to regressions of panel data, random effects with IV.
(2): It refers to regressions of panel data without IV.
(3):It refers to the first stage of OLS regression between the variable of broadband and the instruments and other exclusion controls.

A third point is that the elasticities are less than the unit and the highest sensitivity to both broadband indicators is obtained on municipal tax revenues.

4.1.2 Summary of exercises in 23 cities

The econometric analysis was carried out based on panel data with random effects controlling for the potential endogeneity of the study's broadband indicators and heterogeneity in the use of ICT in the 23 Colombian cities studied.

Does broadband impact economic activity and what is the transmission mechanism? The findings for the 23 departmental capitals and the national capital, using average municipal Internet access as the indicator, aim to illustrate if there is a positive relationship even in the case that the sensitivity of economic variables to the Internet does not seem very high. The specification used cannot discern how Internet access in the home impacts economic activity indicators.

4.2 Broadband and economic activity in every municipality nationwide

How have broadband and download speeds impacted economic activity when a larger number of municipalities are included? The initial objective of this paper was to evaluate the economic impact of the creation of a nationwide optical fiber network as part of the Vive Digital initiative launched by the Colombian government in November 2010. Given the short time to assess how the creation of this network is related to economic activity, the goal became to evaluate the relationship between broadband penetration and economic activity variables between 2006 and 2011. As shown in section 3 of this document, there is a significant digital divide between the departmental capitals and between departmental capitals and other towns in the same departments.

The model used in this section is equal to the one used in the previous section. It is a double logarithmic specification to interpret the results as response elasticities.

$$lny_{i,t} = \alpha + \beta lnX_{i,t} + Z_{i,t} + CI_{t=2005} + (\rho_i + \varepsilon_{i,t})$$

4.2.1 Economic variables –y–

The different econometric exercises evaluated in the first part of this paper, as well as the exercise in the previous subsection, have included *granular information* for economic variables, such as estimated housing prices, cost of leases, average household income and wages, and changes in employment, among others. This analysis has been possible given the information recorded by the GEIH. Economic information with a higher level of territorial aggregation, such as departments, is also available but the aggregation in a territorial unit is so broad and heterogeneous that it is hard to draw fine conclusions about the relationship between broadband and economic activity. With the exception of studies in the United States, where granular information is available by zones or zip codes, little research has been done to capture that relationship among a larger number of small towns. Data for economic variables such as occupancy level, local GDP, leasing, housing prices, etc., for a territorial unit such as municipalities are nonexistent in Colombia.

An alternative to this lack of data is to use indirect information that could somehow be a good proxy for economic activity. In this regard, the National Planning Department (DNP), a so-called super ministry that reports directly to the office of the president, has been producing an annual fiscal performance index based on "the Law 617 of 2000 (that) in Article 79 established that the National Planning Department DNP will publish in media of wide national circulation, at intervals specified in the regulations, and at least once a year, the results of the evaluation of the management of all the territorial entities, including its overseeing agencies, according to the methodology established to this" (DNP 2005). The construction of this fiscal performance index uses information about the revenue and expenditures from all the country's municipalities as filed on their fiscal statements. The available information covers the period 2000 to 2011. Some variables of this information serve as economic variables in our wider econometric analysis. The variables include: a) total municipal revenue, b) total tax revenue collected from industry and commerce, and c) the total property tax revenue.

A city's progress in terms of economic activity, which would be measured directly by the growth of GDP, employment rate, the number of new establishments or their growth, could be approximated with the use of any of the factors (a), (b) and (c). For example, ceteris paribus, industry and commerce tax levied on industrial, commercial and service sectors by each of the districts and municipalities where they carry out their activities grows to the extent that local businesses grow; real-estate values increase as construction grows and property values rise. Therefore,

the first variable is each municipality's total tax revenue. With the intention of using the number of households in each municipality as an instrument of the variables for broadband, property tax revenue is subtracted from total tax revenue. This variable is available for (almost) all 1123 municipalities. A second economic variable is the number of electrical power business customers, which could approximate the number of existing firms in a municipality in a given year.

There is a caveat worth noting. Data regarding municipal tax revenue and number of electrical power business customers may be subject to errors. In the case of electrical power customers, given the nature of self-reported information from electricity providers, it is clear that there could be a high likelihood that the information contains errors. More than that, because it includes all of the 1,000 municipalities in the country, the report of customers in very small municipalities may contain other information problems and be a less valid proxy for the number of existing firms in a locality. Tax revenue information is less likely to contain errors given the basic sources are the Municipal Comptroller and DNP. At the level of very small municipalities, it is impossible to indicate whether the proxy is close to measuring economic activity when governance in these locations may be lower. That is, phenomena of corruption, administrative disorder or a lack of properly trained personnel may lead to revenues not reflecting the real economic activity. Conversely, one might expect that in larger municipalities that regulatory controls and governance would be greater so that tax revenues would move in line with economic activity trends.

4.2.2 Explanatory variables

As explanatory variable of interest, vector X, the number of Internet subscribers by type of bandwidth for all 1123 municipalities published biannually by the ICT Ministry are used. Subscribers are based on whether they are residential, corporate, call centers, internet cafe and others. To standardize the indicator, the number of residential and corporate broadband subscribers (≥ 256 Kbps, ≥ 512 Kbps, etc.) was divided by the population multiplied by 1000 in each municipality in order to have an indicator comparable to that used in the majority of international studies on the subject.

A second disadvantage of this analysis of the 1123 municipalities, as discussed with respect to the economic variables, is the availability of appropriate control variables, the vector Z. The only ones available are: a) the population by municipality or population density, b) the number of students enrolled in school, and c) the number of residential subscribers at the municipal level, which is used as an instrument. As for variables

that capture the initial conditions of economic development—*CI*, the following are available for 2005: i) population, ii) the municipality tax revenue reported by DNP, iii) education rate reported by the General Census of 2005, and iv) the total business units reported by the General Census of 2005.

Finally, the broadband variables are instrumented with the variable for average terrain undulation height[11] in a locality, with the variable number of residential electrical power customers and the number of phones available as of 2005. Similarly, we control for fixed effects at a departmental level including a dummy per department in every regression.

4.2.3 Annual results

The following two subsections present the results of econometric analysis that links the penetration of the corporate and residential broadband with two proxies of economic activity. The first subsection presents the results of the variable for tax revenues (excluding property taxes) and the second, for the company proxy. It is important to highlight that the 1123 municipalities in the country for which the authors could collect complete information to estimate the relationship between broadband and economic activity, somewhere between 759-1027 municipalities ended up being included in the regressions, which undoubtedly is a representative sample of Colombian municipalities.

4.2.4 Broadband and tax revenue

Table 9 shows the results of the regressions with random effects of the relationship of the penetration of the residential broadband variables and Table 10 the penetration of corporate broadband of 256 Kbps with municipal tax revenues. In both tables, column (1) refers to the results of the relationship of instrumented variable for bandwidth and column (2) with the same variable not instrumented. Column (3) refers to the first stage of the instrumented regression.

[11] *This variable is instead used because the slope is not available for all municipalities.*

Table 9. Impact of residential broadband penetration on tax revenue

Variables	Dependant variables								
	Ln Tax revenues		Ln Broadband penetration	Ln Tax revenues		Ln Broadband penetration 512	Ln Tax revenues		Ln Broadband penetration 1024
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Ln Residential broadband penetration 256Kbps	0.0322**	0.0135***							
	(0.0128)	(0.0019)							
Ln Residential broadband penetration 512Kbps				0.0272***	0.0122***				
				(0.0101)	(0.0017)				
Ln Residential broadband penetration 1024Kbps							0.0248**	0.0111***	
							(0.0101)	(0.0016)	
Ln Total municipal revenues 2005	1.215***	1.215***	0.697***	1.222***	1.219***	0.575***	1227***	1.221***	0.475***
	(0.0364)	(0.0308)	(0.0575)	(0.0374)	(0.0308)	(0.0605)	(0.0361)	(0.0308)	(0.0594)
Ln Education enrollment rate 2005	0.103	0.217	1.981***	0.107	0.222	1.928***	0.125	0.223	1.818***
	(0.28)	(0.20)	(0.24)	(0.28)	(0.20)	(0.26)	(0.27)	(0.20)	(0.25)
Ln Urban population	0.483***	0.486***	0.738***	0.493***	0.486***	0.690***	0.492***	0.490***	0.546***
	(0.063)	(0.042)	(0.054)	(0.061)	(0.042)	(0.057)	(0.058)	(0.042)	(0.056)
Ln Middle and high school enrollments	0.0474***	0.0661***	0.0828	0.0481***	0.0661***	0.0162	0.0541***	0.0678***	-0.112*
	(0.014)	(0.011)	(0.066)	(0.014)	(0.011)	(0.069)	(0.013)	(0.011)	(0.068)
Ln Households			0.276***			0.319***			0.271***
			(0.062)			(0.065)			(0.064)
Ln Fixed phone lines 2005			-0.108***			-0.120***			-0.147***
			(0.034)			(0.036)			(0.035)
Ln terrain undulation			-0.00869			-0.00934			-0.0132*
			(0.008)			(0.008)			(0.008)
Constant	-3.407***	-4.276***	-27.71***	-3.530***	-4.336***	-26.68***	-3.719***	-4.383***	-24.05***
	(1.275)	(0.947)	(1.166)	(1.299)	(0.947)	(1.227)	(1.231)	(0.946)	(1.206)
Department fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
IV	yes	no		yes	no		yes	no	
Observations	5069	5463	5141	5069	5463	5141	5069	5463	5141

R-squared			0.394			0.306			0.21
Number of municipalities	1000	1027		1000	1027		1000	1027	

Note: Standard errors in parentheses. * Significant to 10%; ** to 5%; *** to 1%.
(1): It refers to regressions of panel data, random effects with IV.
(2): It refers to regressions of panel data without IV.
(3): It refers to the results of the first stage of OLS regression between the variable of broadband and the instruments and other exclusion controls.

It is clear from both tables that there is a statistically significant positive relationship between the indicators of corporate broadband penetration with the variable for tax revenue, regardless of the download speeds. Elasticity is still low but shows that to the extent that the percentage of broadband penetration rises, the percentage of tax revenues increases. It is observed that for both penetration measures, when this variable is instrumented, sensitivity increases slightly, indicating a need to control for endogeneity. Moreover, the effect of the instrument of the terrain slope (undulation height) on the variable for broadband penetration was negative as expected, but it was statistically significant in only one case in each table.

Table 10. Impact of business broadband penetration on tax revenue

Variables	Dependant variables								
	Ln Tax revenues		Ln Broadband penetration	Ln Ingresos Tributarios		Ln Broadband penetration 512	Ln Tax revenues		Ln Broadband penetration 1024
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Ln Business broadband penetration 256Kbps	0.0441***	0.0188***							
	(0.015)	(0.003)							
Ln Business broadband penetration 512Kbps				0.0369***	0.0200***				
				(0.013)	(0.002)				
Ln Business broadband penetration 1024Kbps							0.0294**	0.0177***	
							(0.013)	(0.002)	
Ln Total municipal revenues 2005	1.218***	1.219***	0.546***	1.222***	1.222***	0.506***	1.230***	1.226***	0.412***
	(0.052)	(0.031)	(0.042)	(0.047)	(0.031)	(0.044)	(0.038)	(0.031)	(0.044)
Ln Education enrollment rate 2005	0.035	0.226	1.367***	0.047	0.229	1.515***	0.112	0.230	1.625***
	(0.406)	(0.202)	(0.177)	(0.358)	(0.202)	(0.184)	(0.275)	(0.202)	(0.186)
Ln Urban population	0.529***	0.481***	0.610***	0.530***	0.478***	0.587***	0.501***	0.483***	0.507***
	(0.089)	(0.042)	(0.040)	(0.075)	(0.042)	(0.041)	(0.060)	(0.042)	(0.042)
Ln Middle and high school enrollments	0.0402***	0.0669***	(0.047)	0.0430***	0.0653***	(0.074)	0.0526***	0.0656***	-0.140***
	(0.013)	(0.011)	(0.048)	(0.013)	(0.011)	(0.050)	(0.014)	(0.011)	(0.050)
Ln Households			0.122***			0.156***			0.141***
			(0.045)			(0.047)			(0.048)
Ln Fixed phone lines 2005			-0.102***			-0.118***			-0.135***
			(0.025)			(0.026)			(0.026)
Ln Terrain undulation			-0.00988*			(0.009)			-0.0110*
			(0.006)			(0.006)			(0.006)
Constant	-3.303*	-4.462***	-12.59***	-3.413**	-4.483***	-13.23***	-3.870***	-4.516***	-12.75***
	(1.870)	(0.944)	(0.850)	(1.652)	(0.943)	(0.884)	(1.273)	(0.944)	(0.893)
Department fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
IV	yes	no		yes	no		yes	no	
Observations	5069	5463	5141	5069	5463	5141	5069	5463	5141

R-squared			0.366			0.313			0.223
Number of municipalities	1000	1027		1000	1027		1000	1027	

Note: Standard errors in parentheses. * Significant to 10%; ** to 5%; *** to 1%.
(1): It refers to regressions of panel data, random effects with IV.
(2): It refers to regressions of panel data without IV.
(3): It refers to the results of the first stage of OLS regression between the variable of broadband and the instruments and other exclusion controls.

4.2.5 Broadband and the number of companies

Tables 11 and 12 present the regressions between the two indicators of broadband penetration and the proxy for companies. The presentation of results is similar to those in Tables 9 and 10.

Table 11. Impact of residential broadband penetration on the number of companies

Variables	Dependant variables								
	Ln Businesses		Ln Broadband penetration	Ln Businesses		Ln Broadband penetration 512	Ln Businesses		Ln Broadband penetration 1024
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Ln Residential broadband penetration 256Kbps	0.468***	0.0267***							
	(0.0433)	(0.0027)							
Ln Residential broadband penetration 512Kbps				0.378***	0.0255***				
				(0.0312)	(0.0024)				
Ln Residential broadband penetration 1024Kbps							0.360***	0.0209***	
							(0.0353)	(0.0023)	
Ln Total municipal revenues 2005	0.906***	0.898***	0.697***	1.028***	0.905***	0.575***	0.886***	0.909***	0.475***
	(0.0937)	(0.0321)	(0.0575)	(0.0921)	(0.0321)	(0.0605)	(0.0603)	(0.0321)	(0.0594)
Ln Education enrollment rate 2005	0.482	0.410*	1.981***	0.699	0.419*	1.928***	0.357	0.426*	1.818***
	(0.68)	(0.22)	(0.24)	(0.67)	(0.22)	(0.26)	(0.38)	(0.22)	(0.25)
Ln Urban population	0	0.759***	0.738***	0	0.760***	0.690***	0.331***	0.768***	0.546***
	(0.153)	(0.044)	(0.054)	(0.145)	(0.044)	(0.057)	(0.083)	(0.044)	(0.056)
Ln Middle and high school enrollments	(0)	0.213***	0.0828	(0)	0.212***	0.0162	0.160***	0.217***	-0.112*
	(0.050)	(0.016)	(0.066)	(0.044)	(0.016)	(0.069)	(0.041)	(0.016)	(0.068)
Ln Households			0.276***			0.319***			0.271***
			(0.062)			(0.065)			(0.064)
Ln Fixed phone lines 2005			-0.108***			-0.120***			-0.147***
			(0.034)			(0.036)			(0.035)
Ln Terrain undulation			-0.00869			-0.00934			-0.0132*
			(0.008)			(0.008)			(0.008)
Constant	2	-4.402***	-27.71***	(1)	-4.496***	-26.68***	0	-4.645***	-24.05***
	(3.204)	(1.040)	(1.166)	(3.121)	(1.039)	(1.227)	(1.853)	(1.040)	(1.206)
Department fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Instruments	yes	no		yes	no		yes	no	
Observations	5108	5120	5141	5108	5120	5141	5108	5120	5141

R-squared			0.3940			0.3060			0.2100
Number of municipalities	1006	1008		1006	1008		1006	1008	

Note: Standard errors in parentheses. * Significant to 10%; ** to 5%; *** to 1%.
(1): It refers to regressions of panel data, random effects with IV.
(2): It refers to regressions of panel data without IV.
(3): It refers to the results of the first stage of OLS regression between the variable of broadband and the instruments and other exclsion controls.

Again, there is a positive relationship between the penetration of residential or corporate broadband and the proxy for businesses. The elasticity or sensitivity of this variable is greater than that obtained from tax revenues, though it is still relatively small.

Table 12. Impact of business broadband penetration on the number of companies

	Dependant variables								
	Ln Businesses		Ln Broadband penetration	Ln Businesses		Ln Broadband penetration 512	Ln Businesses		Ln Broadband penetration 1024
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Ln Business broadband penetration 256Kbps	0.484***	0.0399***							
	(0.057)	(0.004)							
Ln Business broadband penetration 512Kbps				0.426***	0.0406***				
				(0.047)	(0.003)				
Ln Business broadband penetration 1024Kbps							0.204***	0.0332***	
							(0.042)	(0.003)	
Ln Total municipal revenues 2005	0.560***	0.904***	0.546***	0.583***	0.909***	0.506***	0.514***	0.916***	0.412***
	(0.044)	(0.032)	(0.042)	(0.040)	(0.032)	(0.044)	(0.027)	(0.032)	(0.044)
Ln Education enrollment rate 2005	0.062	0.422*	1.367***	0.066	0.422*	1.515***	0.173	0.426*	1.625***
	(0.239)	(0.223)	(0.177)	(0.219)	(0.223)	(0.184)	(0.145)	(0.223)	(0.186)
Ln Urban population	0.253***	0.751***	0.610***	0.299***	0.752***	0.587***	0.429***	0.761***	0.507***
	(0.060)	(0.044)	(0.040)	(0.052)	(0.044)	(0.041)	(0.034)	(0.044)	(0.042)
Ln Middle and high school enrollments	0.395***	0.214***	(0.047)	0.422***	0.210***	(0.074)	0.619***	0.213***	-0.140***
	(0.033)	(0.016)	(0.048)	(0.031)	(0.016)	(0.050)	(0.022)	(0.016)	(0.050)
Ln households			0.122***			0.156***			0.141***
			(0.045)			(0.047)			(0.048)
Ln Fixed phone lines 2005			-0.102***			-0.118***			-0.135***
			(0.025)			(0.026)			(0.026)
Ln Terrain undulation			-0.00988*			(0.009)			-0.0110*
			(0.006)			(0.006)			(0.006)
Constant	(0.777)	-4.720***	-12.59***	(1.158)	-4.730***	-13.23***	-2.863***	-4.821***	-12.75***
	(1.216)	(1.038)	(0.850)	(1.100)	(1.038)	(0.884)	(0.759)	(1.039)	(0.893)
Department fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Instruments	yes	no		yes	no		yes	no	
Observations	5108	5120	5141	5108	5120	5141	5108	5120	5141

R-squared			0.366			0.313			0.223
Number of municipalities	1006	1008		1006	1008		1006	1008	

Note: Standard errors in parentheses. * Significant to 10%; ** to 5%; *** to 1%.
(1): It refers to regressions of panel data, random effects with IV.
(2): It refers to regressions of panel data without IV.
(3): It refers to the results of the first stage of OLS regression between the variable of broadband and the instruments and other exclusion controls.

4.3 Global analysis of the results

What conclusions can be drawn from the econometric studies using data from the GEIH and Ministry of ICT? What policy implications can be formulated?

In general, the first conclusion is that the results are relatively robust when considering the relationship between economic variables and the two penetration indicators for corporate broadband at download speeds of 256 Kbps or higher. For higher speeds, i.e., 512 Kbps or 1024 Kbps, economic significance is reduced slightly but this is explained by the lower levels of penetration, or the lower critical mass obtained. Even controlling for the potential endogeneity of broadband penetration, relationships are positive so it can be said that the higher the corporate and residential broadband penetration is, the higher the performance of the economic indicators is. The second point of importance is that there appears to be little difference between having Internet access and Internet access with faster download speeds. While it is true that a higher bandwidth makes it possible to use more advanced applications online, what seems to matter is the possibility to access the Internet, even if to carry out very basic activities. This is confirmed in the second exercise performed for 1100 municipalities, many of which have significant backwardness in issues regarding education, infrastructure, public service and governance. The inhabitants of many of these municipalities have not yet assessed the potential of the Internet and it is possible that Internet use is mostly for communication via emails, news or entertainment.

The results partially confirm that there is room for public activity. In this regard, the authors note that the effect of these projects that have been implemented over the last five years in Colombia were deployed in order to improve the capacity of ICT adoption in the country and have been successful in bringing fiber to certain cities, or expanding Internet coverage. One of these initiatives that represents these efforts to bring broadband to the different regions of the country is COMPARTEL. Recently, its efforts were reaffirmed by the Vive Digital plan of the ICT Ministry and the iNNova plan under Colombia's Ministry of Commerce, Industry and Tourism. The Fiber Optic Network Plan should include clear mechanisms that allow Internet service providers (ISPs) to be able to provide their services in the different localities throughout the country. The strengthening of competition among broadband service providers becomes a critical mechanism to encourage the use of broadband throughout society and, in particular, the productive sector, which is ultimately the generator of economic progress. Finally, it is clear that at the level of lower density populations with less economic development,

disparities or gaps have deepened. It is urgent that local governments engage more local resources and greater efforts to enhance the possibilities of ICT adoption in homes and businesses. Specifically, even if a municipality is connected to the national fiber optic network, but it is not clear to the general population, particularly businesses what the benefits of Internet access are, then the Vive Digital plan to bring fiber optic network to 700 new municipalities will have little or no impact. The number of educational institutions with broadband (512 Kbps or more) in the small towns throughout the country is currently very low. Colombia's Ministry of Education should provide mechanisms for all *public educational institutions* to access broadband services of 1024 kbps or higher.

4.4 Broadband and business productivity

The importance of information technology and communications (ICT) for economic activity and in particular for business productivity has been extensively studied (Brynjolfsson and Hitt, 2000; Bresnahan, Brynjolfsson and Hitt 2002, Brynjolfsson and Hitt, 2003; Giuri, and Zinovyeva Torrisi, 2008; Arvanitis and Loukis, 2009; Badescu and Garcés-Ayerbe, 2009, Brynjolfsson and Saunders, 2010; Balboni, Rovira and Vergara, 2011). The evidence overwhelmingly shows that ICT does have a positive impact on business productivity. ICT has been measured in terms of the monetary sums of investment in these technologies, ICT capital stock, among others. However, few studies have been done that show the relationship between Internet access and broadband and industrial productivity. Among the few studies that in one way or another directly employ Internet access, or the percentage of employees with Internet access, and broadband and its relation to productivity or dissemination, are, Arvanitis (2005), Battisti, Hollesnstein, Stoneman, Woerter, 2007, Hollesnstein and Woerter, (2007), Nurmilaakso (2009), and more recently Grimes, Ren, and Stevens (2012), discussed in previous sections.

In this section we present an econometric exercise that relates internet access, some broadband proxies and productivity for the years 2006 and 2007[12] in a Cobb-Douglas production function. To this end we make use of information from the Annual Manufacturing Survey, (EAM for its acronym in Spanish) in its special ICT module.

4.4.1 Model, variables and econometric technique

The specification of the model is:

[12] *More recent data from EAM go up to 2010. However, the ICT module is under revision.*

$$ln\left(\frac{y_{i,t}}{L_{i,t}}\right) = \alpha + \beta K + \gamma Internet_{i,t} + \phi CH_{i,t} + +\Lambda X_{i,t} + \tau Uso_{i,t} + \varepsilon_{i,t}$$

The dependent variable is the average labor productivity where L represents the number of employees of the company. K is the capital, proxied by the capital stock or investment. CH_profesional is the natural logarithm of workers with university degrees or higher in the production area; CH_técnico is the natural logarithm of workers with technical degrees, also in the area of production, Internet is the percentage of workers that use the Internet; BA is a proxy for broadband; X is a vector of control variables as a dummy for whether the firm belongs to an industry of high, medium or low technology. All monetary variables are deflated to 2008.

The EAM survey provides information about whether a business has Internet access. The authors constructed a dummy that takes on the value of one (1) if a company claims to have internet, and zero otherwise. However, the statistical results are unreliable for 2007 data. It was found that the percentage of companies that reported having internet in 2007 fell to less than half of those that reported having internet in 2006, an implausible situation. To overcome this impasse, they proceeded to construct a proxy for information with the question, "Indicate what activities or services the company uses Internet for?" The authors constructed a dummy for the first option, Internet for communication, that takes on the value of one (1) if the company said it used internet for that purpose, and zero otherwise. The result was good showing an increase of about 4%.

BA is a proxy for broadband constructed in the following manner. In the first instance, the remaining options of the question "Indicate what activities or services the company uses Internet for?" were used from the previous question: i) online banking or other financial products, ii) transactions with government agencies, iii) Customer Service, and iv) Distribution of products online. However, the indicator year-to-year presented serious problems. For that reason, the variable was constructed using the responses with regard to which areas of the company use the Internet, i.e., production and sales. The dummy takes on the value of one if the firm reports using the Internet in both areas and zero otherwise. The results were satisfactory. The author's assumption was that in order to

engage in these two types of online activities, it is necessary to have a higher bandwidth[13] of at least 256 Kbps.

Because there are two years of data, the authors use panel data, a technique that allows better control of endogenous factors present in these studies. As explained in multiple studies, it is possible that the companies that have higher productivity are the ones that (more often) decide to adopt or make use of the Internet. Using panel data with random effects ensures better control for unobservable variables such as corporate governance, different enterprise technologies, among others.

4.4.2 Results

Table 13 presents the impact of broadband and the Internet on labor productivity. The authors focus on the variables of interest: broadband and the Internet. As seen in Table 13, the broadband proxy has a positive relationship with labor productivity while the Internet variable has a negative—but not significant—impact. This finding should be highlighted in that it illustrates that a company's access to the Internet does not per se generate productivity gains, while access to higher bandwidth does produce significant benefits in the authors' model. The assumption that the Internet is only available in a company's sales and production areas, the broadband proxy, suggests that only when the Internet is linked to more advanced activities within the company does it have a positive effect on productivity.

[13] *The ICT module of EAM and EAS collects information regarding the bandwidth that firms report having. Dane however has not made those variables available. In general, all the ICT information contained in that module is under revision.*

Table 13. Broadband Impact on average labor productivity 2006-2007

Impact of broadband on Manufacturing Industry: 2006-2007		
	(1) Internet	(2) Broadband
Log employment	-0.357***	-0.398***
	(0.042)	(0.042)
Log capital stock	0.093***	0.089***
	(0.014)	(0.013)
Export firm	0.117***	0.104**
	(0.045)	(0.045)
Foreign capital	0.096	0.096
	(0.065)	(0.064)
Log number of professionals and technicians in production	0.042**	0.038*
	(0.019)	(0.019)
Log number of blue-collar workers	-0.097***	-0.081**
	(0.034)	(0.034)
Firm with access to internet	-0.042	
	(0.052)	
Firm with access to broadband		**0.104*** **
		(0.038)
Constant	10.756***	10.866***
	(0.156)	(0.156)
Observations	9244	9244
Number of firms	4622	4622

Note: Robust standard errors in parentheses. * significant to 10%, ** to 5%, *** to 1%

Our assumption does not mean that if a company is using Internet in the management area, it is because the firm does not need high speed of download. What the authors mean is that in order to have a more granular measure, if Internet is used in those two areas, then it must be broadband.

5. CONCLUSIONS

This study investigated for the first time the relationship between broadband access and economic activity at the level of households and companies in Colombia. In this first instance, we have presented broadband and Internet access patterns and found a high digital divide between: a) economic strata, b) cities of greater economic development, and c) capital cities and the rest of the municipalities of a department. The data show that in the 23 departmental capitals, the most developed in Colombia, households in the higher-income socioeconomic strata have access to the Internet; and, in cities with higher average incomes, households across all strata have proportionally greater access to the Internet than in cities with lower incomes. At the departmental level, the capital city tends to have more residential broadband access than other municipalities in the same department.

Subsequently, we investigated how broadband with download speeds of 256 Kbps or higher related to economic activity variables. The central question of this research is: How does broadband impact the economic activity? To answer this question, the authors used proxy variables such as average family income levels, average lease fees or the estimated price of housing extracted from GEIH data, and the number of companies and municipal tax revenue. The findings, based on the variable of interest of broadband or Internet, had the expected sign and high statistical significance for business penetration indicators for six (6) economic indicators: estimated price of housing, average salaries, lease fees, number of businesses and tax revenues.

A more-limited exercise in scope but wider in terms of its territorial coverage was done for about 1123 municipalities. This exploratory exercise looked to see how broadband data supplied by the ICT Ministry explain or impact a pair of proxy economic activity variables: a) municipal tax revenues, b) the number of electrical power customers. Again, the results were *positive* for residential and corporate broadband indicators with high statistical significance at download speeds of level 256Kbps.

Finally, the authors made an initial attempt to see how broadband access affected labor productivity in Colombia's manufacturing industry in 2006 and 2007. To this end, due to a lack of data, they built some variables that approximate broadband and Internet access. Using a standard Cobb-Douglas production function, the authors found that their broadband indicator has a positive and statistically significant effect on the average labor productivity, a situation that does not occur with the Internet

indicator. This suggests that the *limited* existence of broadband generates positive effects on productivity but this effect can be diluted as it becomes effective for the entire manufacturing industry, a situation that had almost been reached in 2006 and 2007. Another interpretation is that the measurement of broadband, restricted to sales and production areas of a company, is what makes it possible to have positive effects on productivity. In either case, it will require many more years and more information on broadband and its use within the areas of a company.

What policy implications can be drawn from the results of this study? Numerous studies reviewed in the earlier sections of this study yield results that tend to show positive effects of broadband on economic activity. In all cases, the variable of interest for broadband is the total or residential access to it. The results found in this study with different econometric specification confirm these findings, which suggest that there is ample room for public policy. In particular, it should be noted that there is a wide digital gap which shows a slight deepening especially in the smaller municipalities and those of lower socioeconomic development. The deployment of broadband networks that Vive Digital seeks to implement is a step forward in this regard since it allows, in a near future, closing that gap.

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ANNEX

Table 14. Penetration rate for broadband above 512, corporate sector = ((BB subscribers/pop.)) *1000

Department	2006	2007	2008	2009	2010	2011
ANTIOQUIA	0.18	0.50	1.16	1.05	3.67	6.34
Medellin	0.40	0.77	0.93	1.02	1.18	1.48
The rest	0.07	0.21	2.69	2.65	4.74	7.04
ATLANTICO	0.09	0.28	0.65	0.86	1.20	1.35
Barranquilla	0.06	0.39	1.00	1.23	1.45	1.60
The rest	0.00	0.18	0.67	0.98	1.57	1.54
BOGOTA, D. C.	4.17	9.24	14.16	14.60	16.34	18.69
BOLIVAR	0.07	0.09	0.29	0.30	0.53	0.67
Cartagena	0.02	0.08	0.72	0.64	1.00	1.23
The rest	0.00	0.01	0.19	0.29	0.73	0.94
BOYACA	0.24	0.25	0.55	0.43	0.64	0.81
Tunja	0.17	0.10	0.69	0.53	0.84	0.97
The rest	0.01	0.13	1.35	0.99	1.87	2.71
CALDAS	0.10	0.15	0.50	2.71	1.15	1.70
Manizales	0.05	0.08	0.30	0.84	1.02	1.23
The rest	0.01	0.09	0.78	5.20	1.52	2.33
CAQUETA	0.08	1.13	0.42	0.36	0.53	3.59
The rest	0.00	0.36	0.13	0.13	0.25	0.32
CAUCA	0.06	0.11	0.18	0.24	0.36	0.44
Popayan	0.02	0.07	0.21	0.28	0.42	0.50
The rest	0.01	0.03	0.14	0.25	0.41	0.52
CESAR	0.06	0.12	0.46	0.46	1.06	1.35
Valledupar	0.01	0.06	0.52	0.39	0.66	0.73
The rest	0.01	0.08	0.59	0.52	1.39	1.77
CHOCO	0.11	0.12	0.29	0.30	0.45	0.55
Quibdo	0.01	0.04	0.37	0.30	0.56	0.67
The rest	0.00	0.00	0.10	0.17	0.29	0.42
CUNDINAMARCA	0.24	0.55	1.14	1.47	1.88	2.42
CORDOBA	0.08	0.17	0.79	0.64	1.69	2.53
Monteria	0.02	0.08	0.56	0.42	0.77	0.88
The rest	0.05	0.14	0.67	0.52	1.71	2.55
HUILA	0.09	0.14	0.56	0.66	0.86	1.00
Neiva	0.01	0.11	0.88	0.69	1.04	1.25
The rest	0.01	0.12	0.90	1.01	1.58	1.65
LA GUAJIRA	0.07	0.15	2.59	0.96	1.66	1.70
Riohacha	0.00	0.03	0.32	0.29	0.43	0.45
The rest	0.01	0.09	2.16	1.07	1.81	1.82
MAGDALENA	0.06	0.09	0.44	0.37	0.65	0.82
Santa Marta	0.01	0.06	0.85	0.58	0.90	1.02
The rest	0.00	0.01	0.23	0.27	0.72	1.05

META	0.13	0.19	1.01	1.33	2.12	2.89
Villavicencio	0.01	0.16	0.69	0.59	0.85	1.43
The rest	0.00	0.01	1.25	1.94	3.37	4.28
NARIÑO	0.08	0.12	0.25	0.20	0.26	0.47
Pasto	0.01	0.11	0.68	0.50	0.81	0.88
The rest	0.00	0.01	0.10	0.13	0.24	0.66
NORTE SANTANDER	0.13	0.17	0.56	0.51	0.83	0.98
Cucuta	0.01	0.06	0.78	0.69	1.08	1.25
QUINDIO	0.15	0.19	1.62	1.24	2.07	2.36
Armenia	0.02	0.08	0.56	0.43	0.76	1.12
The rest	0.06	0.05	1.40	1.13	2.06	2.28
RISARALDA	0.12	0.48	1.48	1.45	1.92	2.99
Pereira	0.05	0.29	1.01	0.97	1.21	1.59
The rest	0.09	0.63	2.01	1.97	2.61	3.95
SANTANDER	0.19	0.44	0.70	0.72	1.15	1.60
Bucaramanga	0.01	0.92	0.95	1.32	1.90	2.39
The rest	0.04	1.54	2.09	2.26	4.20	5.90
SUCRE	0.08	0.26	1.36	0.98	2.48	3.58
TOLIMA	0.09	0.13	0.50	0.51	1.06	1.61
Ibague	0.01	0.08	0.71	0.57	0.95	1.10
The rest	0.01	0.06	0.59	0.64	1.57	2.27
VALLE DEL CAUCA	0.09	0.46	1.85	2.03	2.54	3.47
Cali	0.04	0.25	0.77	0.78	0.93	1.14
The rest	0.07	0.38	2.44	2.40	3.06	4.09
Arauca	0.11	0.20	1.11	0.98	1.46	2.21
Casanare	0.23	0.29	0.68	0.76	1.25	1.76
Guaviare	0.08	0.10	0.12	0.12	0.07	0.08
Putumayo	0.08	0.20	0.75	0.60	0.84	1.00

Source: Ministry of ICT and SSPD

Table 15. Relationship between higher and lower stratum

Municipality	2007-2008					2009-2011				
	Stratum					Stratum				
	1	2	3	4	5	1	2	3	4	5
National	70	15	4.2	1.58	1.21	20	6	2.3	1.27	1.13
Head	47	13	4.2	1.56	1.21	14	5	2.3	1.28	1.14
The rest	27	14	2.8			35	13	4.8	1.79	1.00
Bogota	20	10	3.6	1.24	1.05	8	4	2.2	1.16	1.02
Medellin	24	8	3.3	1.69	1.22	9	4	2.1	1.30	1.19
Barranquilla	41	9	3.8	1.65	1.33	11	3	2.0	1.30	1.11
Cartagena	47	9	3.2	1.27	1.14	15	4	1.7	1.14	1.00
Manizales	35	10	4.1	1.66	1.48	8	3	2.0	1.29	1.17
Monteria	33	7	3.7	1.85	1.32	13	3	2.0	1.10	1.00
Villavicencio	27	11	4.2	1.71	1.16	12	5	2.2	1.43	1.00

Pasto	29	11	3.3	1.29	1.00	13	4	1.8	1.00	
Cucuta	41	15	3.8	1.25	1.00	17	5	1.9	1.04	
Pereira	38	8	3.8	2.07	1.43	9	3	2.1	1.47	1.21
Bucaramanga	27	9	3.9	1.44	1.11	7	3	1.9	1.22	1.02
Ibague	22	7	2.7	1.22	1.00	8	4	1.9	1.33	1.53
Cali	32	12	3.9	1.72	1.39	8	4	2.3	1.37	1.23
Tunja	33	11	4.0	1.46		12	6	2.3	1.38	
Florencia	30	6	3.2	1.41	1.00	7	3	1.7		
Popayan	74	18	6.0	2.12	1.37	23	5	2.2	1.33	1.00
Valledupar	39	7	3.7	1.59	1.12	13	5	2.1	1.42	1.12
Quibdo	6	2				4	1			
Neiva	23	5	2.1	1.38	1.00	7	2	1.3	1.06	1.00
Riohacha	31	5	2.5	1.53		15	4	2.1	1.65	2.18
Santa Marta	37	15	5.6	2.17	1.19	12	3	2.1	1.27	1.01
Armenia	24	10	4.2	1.93	1.28	13	4	2.4	1.43	1.14
Sincelejo	101	10	4.0	1.84	1.00	26	4	1.9	1.26	1.04
All 23 cities	33	10	3.7	1.51	1.20	10	4	2.1	1.25	1.14
Head without 23 cities	50	15	4.6		0.07	20	7	2.8	1.43	1.33

Source: DANE-Integrated Household Survey

Table 16. Correlation broadband variables in 23 cities

	1	2	3	4	5	6	7	8	9	10	11	12	13
Internet	1												
Computer	0.89	1											
Business BB 256	0.39	0.42	1										
Business BB 512	0.40	0.43	1.00	1									
Business BB 1024	0.43	0.43	0.95	0.97	1								
Business BB 2048	0.37	0.37	0.84	0.86	0.95	1							
Residential BB 256	0.44	0.47	0.98	0.99	0.97	0.88	1						
Residential BB 512	0.46	0.47	0.94	0.97	0.98	0.91	0.98	1					
Residential BB 1024	0.46	0.45	0.87	0.89	0.97	0.96	0.92	0.96	1				
Residential BB 2048	0.41	0.40	0.81	0.84	0.94	0.99	0.86	0.90	0.97	1			
Community BB 256	-0.06	0.03	-0.14	-0.14	-0.13	-0.10	-0.13	-0.12	-0.11	-0.10	1		
Community BB 512	0.03	0.13	-0.10	-0.10	-0.09	-0.07	-0.09	-0.08	-0.08	-0.06	0.98	1	
Community BB 1024	0.09	0.12	-0.09	-0.08	-0.07	-0.06	-0.07	-0.07	-0.06	-0.05	0.90	0.95	1

Table 17. Correlation Ln broadband variables in 23 cities

	1	2	3	4	5	6	7	8	9	10	11	12	13
Δ Ln Internet	1												
Δ Ln Residential BB penetration	0.23	1											
Δ Ln Residential BB penetration 512	0.49	0.70	1										
Δ Ln Residential BB penetration 1024	0.24	0.48	0.52	1									
Δ Ln Business BB penetration	0.29	0.29	0.33	0.19	1								
Δ Ln Business BB penetration 512	0.48	0.56	0.89	0.32	0.56	1							
Δ Ln Business BB penetration 1024	-0.02	0.09	-0.09	0.57	0.07	-0.20	1						
Δ Ln Residential BB penetration x 100 Pop.	0.25	0.98	0.72	0.49	0.32	0.59	0.10	1					
Δ Ln Residential BB penetration 512 x 100 Pop.	0.49	0.69	1.00	0.52	0.33	0.89	-0.08	0.72	1				
Δ Ln Residential BB penetration 1024 x 100 Pop.	0.24	0.47	0.52	1.00	0.19	0.32	0.57	0.49	0.52	1			
Δ Ln Community BB penetration x 100 Pop.	-0.01	0.26	0.21	0.21	-0.08	0.09	0.13	0.29	0.22	0.21	1		
Δ Ln Community BB penetration 512 x 100 Pop.	0.01	0.15	0.20	0.23	-0.01	0.16	0.21	0.19	0.21	0.24	0.71	1	
Δ Ln Community BB penetration 1024 x 100 Pop.	0.32	0.41	0.46	0.29	0.20	0.45	0.12	0.48	0.47	0.30	0.53	0.61	1

Table 18. Main statistics used in the econometric exercise Broadband and productivity

	N	Average	Deviation	Min	Max
			All the observations		
Log aggregate value over employment	9244	10.0699	1.7101	0	18.3300
Log employment	9244	3.6636	1.1968	0.6931	8.0193
Log capital	9244	9.9135	1.4843	0	15.4859
Export firm	9244	0.2254	0.4179	0	1
Foreign capital	9244	0.0766	0.2659	0	1
Log number of professionals and technicians in production	9244	1.0774	1.2258	0	6.7154
Log number of blue-collar workers in production	9244	3.1430	1.3242	0	7.7685
Firm with access to Internet	9244	0.8746	0.3312	0	1
Firm with access to broadband	9244	0.3096	0.4623	0	1
			2006		
Log aggregate value over employment	4622	10.0034	2.2177	0	18.3300
Log employment	4622	3.6433	1.1800	0.6931	7.9424
Log capital	4622	9.8625	1.4956	0	15.0024
Export firm	4622	0.2391	0.4266	0	1
Foreign capital	4622	0.0754	0.2641	0	1
Log number of professionals and technicians in production	4622	1.0739	1.2189	0	6.7154
Log number of blue-collar workers in production	4622	3.1292	1.3138	0	7.7428
Firm with access to Internet	4622	0.8622	0.3447	0	1
Firm with access to broadband	4622	0.3091	0.4622	0	1
			2007		
log_vaL	4622	10.1363	0.9605	4	14.4030
log_v27	4622	3.6839	1.2131	0.6931	8.0193
log_K	4622	9.9644	1.4713	0	15.4859
Export firm	4622	0.2117	0.4086	0	1
Foreign capital	4622	0.0778	0.2678	0	1
Log number of professionals and technicians in production	4622	1.0809	1.2328	0	5.7203
Log number of blue-collar workers in production	4622	3.1569	1.3345	0	7.7685
Firm with access to Internet	4622	0.8866	0.3171	0	1
Firm with access to broadband	4622	0.3100	0.4625	0	1

Source: EAM - DANE