Universidade do Minho

Escola de Economia e Gestão

Francisca Nogueira da Cunha

The Impact of broadband connection on regional productivity

October of 2021

UMinho | 2021 Francisca Nogueira da Cunha **The impact of broadband connection on regional productivity**

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The impact of broadband connection on regional productivity

Master's Dissertation

Master in Economics

Work done under the guidance of

Professor Doutor João Cerejeira

and

Professora Doutora Sílvia Sousa

October of 2021

DECLARATION

Name: Francisca Nogueira da Cunha

Email: franciscanogueiracunha@gmail.com

Identification Card Number:

Dissertation title: Gross Value Added *versus* Internet Connection

Guidance counsellors: João Cerejeira and Sílvia Sousa

Completion year: 2021

Master Designation: Master in Economics

Universidade do Minho, ___/___/_____

Signature: ____

Acknowledgments

As a colleague said before, I agree that we grow up believing that in our adult life, all the success we achieve comes from our efforts and abilities. However, this is not exactly the case. The following words are for those who made me believe that is not true.

To my parents, Glória and Filipe, who have always believed and supported me unconditionally, called me to reason and congratulated me in due moments. Without them, none of my dreams and ambitions would be possible to achieve.

To my sister, my best friend, Joana. Our connection is greater than everything we have ever lived and idealized. Thank you for always being there, in good and bad times.

To the rest of my family, thank you all for always being available to help me in everything I need.

To my friends, who I believe are the family we have chosen. You inspire me and I hope I can continue to share these moments with you.

To my teachers João Cerejeira and Sílvia Sousa, for their dedication and availability and the help given throughout this last year. Certainly, without their knowledge, working methods and rigor, it would not have been possible to carry out this study.

Now, memories of the best years of my life remain, the path is straight ahead, and I must follow it – the marathon continues.

STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration.

I further declare that I have fully acknowledged the Code of Ethical Conduct of the University of Minho.

Resumo

Ao longo dos anos, o acesso à Internet e o seu impacto são um tema constantemente debatido, ganhando cada vez mais importância. Neste sentido, pretendemos analisar o impacto que o acesso à Internet tem na produtividade.

O Valor Acrescentado Bruto (VAB) pode ser calculado como a produção menos o consumo intermédio. Além disso, a soma do VAB sobre todas as indústrias ou sectores mais os impostos sobre os produtos menos o subsídio sobre os produtos dá o produto interno bruto.

Foram construídos vários modelos, controlando diferentes variáveis como o acesso à Internet e o consumo de eletricidade de média e alta tensão, por exemplo. Estes modelos foram estimados utilizando três técnicas econométricas alternativas: OLS, Efeitos Fixos e Efeitos Aleatórios.

Neste sentido, a base de dados criada para o estudo, de 2013 até 2018, tem dados a nível municipal e a revisão de literatura elaborada diz que existem efeitos positivos na produtividade. Neste sentido, esta descoberta será verificada, utilizando uma metodologia baseada em dados de painel com efeitos fixos. Finalmente, será feita uma distinção entre territórios de baixa e alta densidade. Conclui-se que há um impacto positivo na produtividade quando os acessos à Internet são analisados, principalmente nos acessos não residenciais.

Palavras-chave: Banda larga, Municípios**,** Portugal, Produtividade, VAB

Abstract

Over the years, internet access and its impact are a constantly debated topic and is gaining more and more importance. In this sense, we intend to analyse the impact that Internet access has on productivity.

Gross Value Added (GVA) can be defined as output minus intermediate consumption. Additionally, the sum of GVA over all industries or sectors plus taxes on products minus subsidies on products gives the gross domestic product.

Several models were built, controlling different variables such as internet access and medium and high voltage electricity consumption, for example. These models were estimated using three alternative econometric techniques: OLS, Fixed Effects and Random Effects.

Therefore, the database created for the study, from 2013 until 2018, has data at the municipal level and literature reviewed reveals that there are positive effects. In this sense, this finding will be verified, using a methodology based on panel data with fixed effects. Finally, there will be a distinction between low- and high-density territories. It is concluded that there is a positive impact on productivity when internet accesses are analysed, mainly in non-residential accesses.

Key Words: Broadband, Municipalities, Portugal, Productivity, GVA

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List of abbreviations

ADSL – Asymmetric Digital Subscriber Lines

ANACOM – Autoridade Nacional de Comunicações de Portugal

CIS – Centralised Information System

DESI – Digital Economy and Society Index

DOCSIS – Data Over Cable Service Interface Specifications

DSL – Digital Subscriber Line

EMQs – Extended-Matching questions

EU – European Union

FE – Fixed Effects

FTTP – Fibre to premises

FWA – Fixed Wireless Access

GBPs – Gigabits

GDP – Gross Domestic Product

GVA – Gross Value Added

ICT – Information Communication Technology

INE – Instituto Nacional de Estatística de Portugal

ISDR – Synthetic Regional Development Index

LM – Breusch-Pagan Lagrange Multiplier

LTE – Long Term Evolution

MBPS – Megabits

NGA – Next-Generation Access Networks

OECD – Organisation for Economic Co-operation and Development

OLS – Ordinary Least Squares

PRF – Population Regression Function

RE – Random Effects

SMEs – Small and Medium Enterprises

VHCN – Fixed Very High-Capacity Networks

1. Introduction

During the last few years, the emergence of broadband has brought with it several changes, not only in terms of access to information (and consequently in the cost of acquisition and dissemination of information).

Portugal presents an interesting case because although broadband access has increased notably, there is still a big difference between areas with high and low populations - thus there is a marked regional variation. Due to COVID-19, these differences have become even more visible, and it is necessary to close these existing gaps.

The growing importance of broadband is an unavoidable topic not only for companies but also for individuals. Increasingly, it is important for economic development and greater well-being. In parallel, broadband has also become increasingly cheaper and more accessible. The availability of technology and broadband improves both work and living conditions.

In Portugal, at the end of 2019, 88% of households were customers of the subscription TV signal distribution service and the penetration rate for fixed broadband residential customers was 80,6% per 100 private households, according to ANACOM. Additionally, data traffic consumption has been increasing significantly and fixed broadband Internet traffic increased 53% in the 3rd quarter of 2020 when comparing to the homologous period, due to COVID-19. Just as in Portugal, in Europe, the importance of broadband has also increased, and a fast and reliable broadband connection is crucial. As expected, during the last year, the demand for good and stable coverage increased.

In this regard, the main goal of this investigation is to analyze the broadband impact on productivity in Portugal. What effect does broadband connection have on productivity?

Firstly, an analysis will be made of Portugal and then of the low-density municipalities also in Portugal - by definition, these are those with a population of fewer than 150 inhabitants/km^2.

In this sense, the present work is divided into seven sections. In section 2, literature review, we collected and synthesised relevant information, based on some papers read on this theme. The third section, Broadband Connection: Portuguese and European Context, aims to explain a brief contextualization of Portugal and Europe. In the fourth section, data, presents the description, treatment, and some descriptive statistics of the used database. In the fifth section, methodology, will discuss the techniques which will be used to evaluate the GVA impact, and the empirical results and discussion will to be analysed and on section 6 and, in section 7, the conclusion will be presented, where I will relate all the data obtained from the analysis and interconnect with the literature review.

2. Relevant Literature

This paper aims to study analyze the broadband impact in productivity in low-density areas in Portugal, when also considering other variables, over the years 2013 to 2018. Over the past few years, the importance of broadband has been growing exponentially. This reality has led to an increase in the number of studies and news on the subject, thus allowing a better view of it not only in Portugal, but also at a European level.

The connection through our telephones, in the beginning, could reach 56kbps, which is a little fraction of the velocity we can use nowadays. Only in 1990, the internet gained widespread attention, but in 1970, the first e-mail was registered.

In the early 2000s, broadband acquired a new life and work tasks started to change. Broadband allowed people to make phone calls and be online at the same time. As is expected, in the beginning, broadband was expensive, so the initial usage was very low. These days, almost everyone uses some form of broadband.

In recent years, the capacity of telecommunications and data communication core networks has grown, with speeds increasing from Mbps to Gbps. However, existing access networks are still not sufficient for today's needs.

The main use of broadband is for surfing the internet and exchanging emails. Lately, users have been downloading more movies and making by-pass payments for intellectual property rights.

Additionally, although the broadband market is still expanding, most of the investment comes from national governments because, according to the European Commission (2008), further economic development is expected to be related to broadband. Although some technologies are still being developed, network operators can upgrade cable connections, deploy new copper technologies, install fibre optic networks, roll out wireless networks or opt for hybrid transmission solutions. Investors prefer to wait and be certain about what they will invest in, to have more certainty about the future of technological developments to choose which technology to invest in. In addition, economies of scale can lower the cost of equipment, ensure interoperability, and reduce investment risks, and suppliers can amortise their research and development costs over a much higher volume.

2.1. The impact of broadband on local development

It also aims to understand the impact of broadband on local development, which was identified in different areas, low-density areas, economic growth, labour market, economic sectors and productivity, and personal benefits.

Low-density Areas

More and more scientific literature has been recently produced on the phenomenon in question - the impact of broadband in low-density areas. In 2008, the European Commission adopted a European economic recovery plan and one of the strategies was to promote optimal fiber. It would support the economy in the short term and create essential infrastructures for healthy economic development. Regarding this, they had a goal where, by 2010, Europe had achieved 100% high-speed internet coverage for all citizens and a piece of the investment would be to develop broadband infrastructures in low-density areas to create new jobs and promote companies' expansion (European Commission, 2008).

In the literature, we can observe that a huge number of OECD countries where municipal networks have a role in the provision of broadband access (Ozdemir et al., 2018). Additionally, Briglauer, et al. (2016) found out that treated municipalities – municipalities that received treatment, state aid on broadband coverage in Bavarian municipalities that received approval, from 2010 to 2011 – have significantly higher broadband coverage than comparable non-aided municipalities.

Finally, Fabritz (2013) and Celbis and Crombrugghe (2016), also conclude that, areas with less population are the ones that benefit the most. Besides, the introduction or improvement in rural areas would conduct to the homogenization of technology, institutions, and culture (Celbis and Crombrugghe, 2016) but, on the other hand, it can lead to regional inequalities between regions. In this regard, the impact depends on population density.

Additionally, firms in larger areas are more willing to pay for e-commerce information (Kim and Orazem, 2016) and broadband would also converge urban and rural areas. Besides that, broadband adoption would attract people to live in cities that have the technology (Mölleryd, 2015). Another study (Briglauer, et al. 2016) found out that people would decide to stay (or move) at treated municipalities than left the analysed rural areas. On the other hand, Ozdemir and Gul (2018), determine that some "invisible" factors are not being considered and then can affect the results. In this regard, rural areas are the ones with less population density.

Socioeconomic Growth

Regarding this, most of these studies assume that the presence or even the improvement of broadband is favourable for local socioeconomic growth (Canzian et al., 2015). On the other hand, some authors do not find any evidence that supports the fact that broadband availability increases economic activities (Fabritz, 2013). Besides, Bertschek, Briglauer, Huschelrath, Kauf and Niebel (2016), find a positive effect between the broadband adoption on GDP and GDP growth with country-level data – the same happens in the study of Minges (2015) related to fixed broadband for developed and developing economies. Still, Celbis and Crombrugghe (2016), conclude that broadband would attract resources from other regions, and this would have a strong impact on financial services. They also determine that air transport capacity and human capital contributes as well to the economy. However, a study shows that broadband can harm the rural economy (Kim and Orazem, 2016) because it can close some offices since their products can be replaced by online customer service. Additionally, Toader et al (2018), discovered that a 1 per cent increase in the number of mobile subscriptions resulted in a 0.4 per cent growth in GDP per capita. Similarly, Katz & Callorda (2018) conclude that an increase of 1 per cent in mobile broadband yielded an increase of 0.15 per cent in per capita growth.

An improvement in the telecommunication networks represents an increase in economic growth and economic outcomes (Bertschek, et al. 2016). Regarding this, areas that adopt broadband are more willing to have more opportunities for economic development (Ozdemir and Gul, 2018). On the other hand, Celbis and Crombrugghe (2016), verified that internet infrastructures may provide benefits to the economy through growth, faster convergence to the steady-state and the homogenization of region-specific steady states.

Some studies have shown that fixed broadband has a positive economic impact as having access from a mobile phone – higher than from a computer or a machine (Minges, 2015). Also, annual sales turnover and an increase in value-added are correlated with broadband availability (Fabritz, 2013).

Labour Market

Most of the literature recognises that exists a relationship between the adoption/availability at low-density areas and labour market (Whitacre et. al, 2014). An increase in broadband creates new jobs in rural areas, decreases unemployment (Briglauer, et al. 2016) and these areas become more attractive to work due to this technology (Ozdemir and Gul, 2018). Besides that, increases the competitiveness of local business and attract different consumers and suppliers from distant geographical regions. According to Moinul Zaber, et al. (2017), a positive connection between high-speed broadband and the number of workplaces exists and the fact that people can work from distance easily. Martin Falka and Eva Hagsten (2021) conclude that high-speed broadband access is correlated with the number of establishments in each municipality. Younjun Kim and Peter F. Orazen (2012) considered that exists a positive and significant effect on firm entry in rural markets and metropolitan areas. It is important to add that broadband matters to creative class employees and that an increase in broadband infrastructures can attract creative employees (Conley, 2013).

According to Nicole Gürtzgena, et al. (2021), male job search behaviour increases and, consequently, job applications. The authors concluded that after the first months of men's unemployment, broadband access improves re-employment rates. There is also a positive relationship between technological progress and employment. Therefore, policy should promote Internet technology in industries, especially those closely linked to other industries, to stabilise employment and growth (Huijuan Wanga, et al. 2020). In Germany, evidence was found that there is a negative effect for manufacturers between broadband availability and employment growth and the opposite for service establishments. However, overall, broadband availability has helped create jobs in firms that use broadband intensely (Bistian Stockinger, 2019).

Additionally, Whitacre, Gallardo, Strover (2014) discovered that an increase in broadband availability (not adoption) does not have any impact on either jobs or income. In this case, the authors conclude that it seems to be no impact on the number of employees at the companies in the sample (Canzian, et al. 2015; Bertschek, et al. 2016).

Besides, the German Federal Ministry of Economics and Technology consider broadband creates workplaces and secures jobs because it attracts business to low-density areas (Fabritz, 2013; Celbis and Crombrugghe, 2016). Another conclusion that seems to have a huge impact, is the fact that this technology favours highly skilled workers, which leads to higher wages and employment rates (Bertschek, et al. 2016). In this regard, Shiyi Chen, et al. (2020) demonstrates that exists a positive correlation between high-speed internet and firm's productivity, worker's wage and with the educational qualifications of the workers.

However, it is also demonstrated that an increase in broadband availability will reduce employment (Whitacre, et al. 2014) but high levels of broadband adoption (not availability) in non-metropolitan areas can increase business and jobs – by 2013, Conley has the same conclusion during his work. Also, Briglauer, et al. (2016) conclude that an increase in broadband coverage would increase the size of the residential population that is employed. Olena Ivus and Matthew Boland (2015) found out that the deployment of broadband promoted employment and wage growth while reducing geographical barriers.

Economic sectors and Productivity

Canzian, Poy and Schüller (2015) also conclude that the sector that would benefit the most from this type of technology would be the hospitality sector. Furthermore, the literature reveals that there is not any employment effect in the manufacturing sector. The sector that shows the biggest impact is the service sector and there are positive effects in both sectoral and industrial sectors (Fabritz, 2013). Stefanie A. Haller and Seán Lyons (2014), supports a similar conclusion, where firms in the service sector derive productivity effects from broadband adoption.

As for Robert LaRose, et al. (2007), they note that age and income, but not education or ethnicity, have direct impacts. Efforts that promote the personal benefits of broadband and advanced ICT literacy skills among Internet users are recommended. Age was significantly related to Internet experience, but in the opposite direction to this hypothesis.

Personal benefits

Another scope of analysis is the impacts on productivity, where they find a positive relationship between broadband and productivity (Bertschek, et al. 2016; Celbis and Crombrugghe, 2016). On the other hand, Stefanie A. Haller, and Seán Lyons (2014) conclude that the more productive firms are, the more they use DSL broadband, on average. However, they found no significant connection between broadband adoption on firms' productivity or productivity growth. Additionally, they observe that what matters for productivity are the specific applications that firms will use their internet connection for. In another research, Giulia Canzian, et al. (2019), conclude the firms' revenue and total factor productivity is positively related to the availability of ADSL2+. On the other hand, this study finds no relevant results regarding personnel costs, local employment, and the number of active firms. In this regard, Malin Allgurin (2017), explained that the availability of broadband increases the probability of innovation and, consequently, can achieve more information and knowledge.

Furthermore, Whitacre, et al. (2014), determine a strong relationship between age, population over 45 years old and broadband adoption

Additionally, Fabritz (2013) complement broadband infrastructures lower transport costs and allows agents to work over large distances. In another study, Conley (2013) and Gruber, et al. (2013), conclude that the government lean towards helping rural areas to implement this type of technology and by implementing it, telemedicine, education and choices of goods and services would benefit (Kim and Orazem, 2016).

Finally, more recently, Deloitte (2021) suggests, digitalisation can bring not only new products (and new employment), but can also reshape several economic activities, improving efficiency, effectiveness, productivity among industries. On the other hand, it could increase the quality of living, personal safety for citizens and a more equitable society. Additionally, they conclude that the impact of digitalisation is higher for countries that have a lower digital development. In a general view, sustainable economic growth, a higher quality of living, health and personal safety, a more resilient society and economy, a more equitable society are the four biggest impacts that can exist through digitalisation.

In the above-mentioned analysis, there are several methodologies used, such as the difference in difference, simultaneous equations model and IV estimation, spatial econometric models, and panel data regressions (Attachment 1).

To sum up, these studies conclude that the adoption of optimal fiber would increase employment, productivity, and innovation; reduce the information gap between markets and worldwide; attract firms and new resources to low-density areas and provide access to households at low-density areas and homogenize the cultural pattern.

3. Broadband Connection: Portuguese and European Context

This chapter aims to set the theme in a context, firstly Portuguese and then European context.

3.1. Portugal

ANACOM (Autoridade Nacional de Comunicações) is the national regulatory authority for communications. This authority is a legal person governed by public law, constructed as an independent administrative entity with administrative, financial, and managerial autonomy and its assets. Their mission is to control the communication sector and the provision of assistance to the Government in these areas.

The NGA (next-generation access networks) coverage is under the European Union average.

The Portugal Digital Agenda aims to develop a digital infrastructure in which citizens can access the opportunities offered by technology. This plan has a catalyst dimension and three main pillars of action: Capacity Building and Digital Inclusion, Digital Transformation of companies and the Digitalisation of public services.

According to ANACOM, in Portugal, at the end of 2019, 88% of households were customers of the subscription television signal distribution service and the penetration rate for fixed broadband residential customers was 80,6% per 100 private households. Additionally, the penetration rates of the main telephone accesses reached 49,9 accesses per 100 inhabitants and the penetration of mobile services with actual use reached 120,9 per 100 inhabitants. On the other hand, the postal services registered a decrease of 6,7% in total traffic and an increase of 1,8% in income.

The graphic below demonstrates the percentage of households that have access to the internet through the years, showing the evolution of Portugal and the European Union (including the United Kingdom).

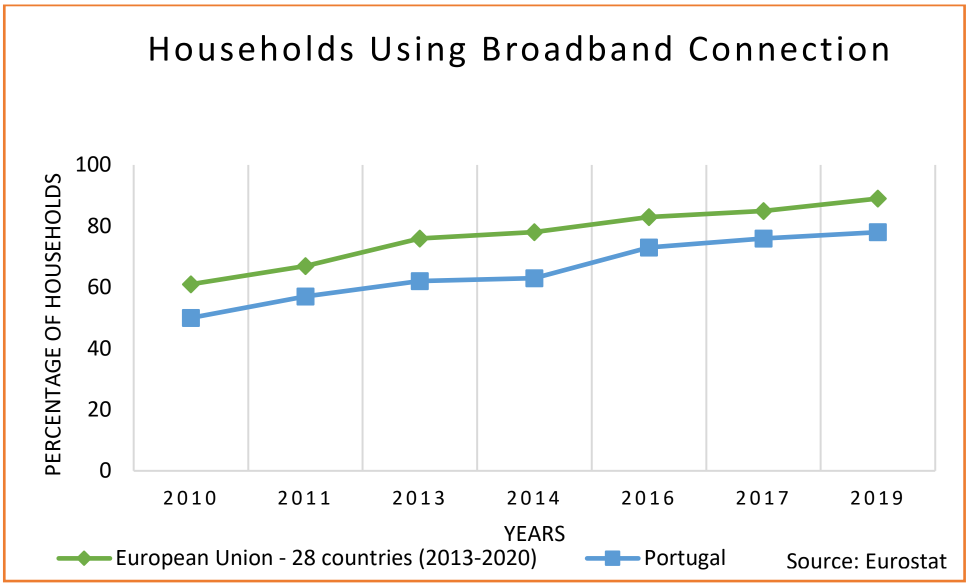

Figure 1: Households using Broadband Connection

According to Eurostat, since 2010, in Portugal, the connection to the internet has been increasing and at the beginning, 50% of households had a connection to the internet and nowadays is about 70%. Relatively to the EU-28, from 2010 until 2019, the percentage of households with broadband access increased around 20p.p.. As can be seen, there is an average difference between Portugal and the EU of, approximately, 10%, which is maintained over time.

There is also very important to understand how broadband influences low-density areas because these municipalities are the ones with the lowest broadband access, and it is important to understand the phenomenon. Moreover, on the study, the broadband impact in low-density areas will be analysed. On the other hand, the graphic below establishes the relation between the penetration rate, municipalities, and time for some low-density areas.

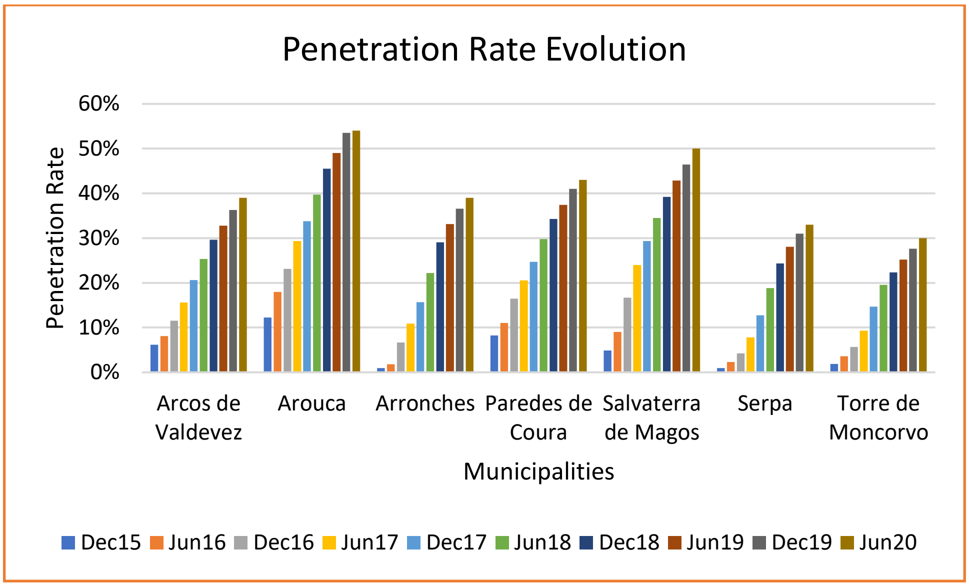

Figure 2: Penetration Rate Evolution (DST)

To get a more detailed view, seven low-density municipalities were observed (Arcos de Valdevez, Arouca, Arronches, Paredes de Coura, Salvaterra de Magos, Serpa and Torre de Moncovo), which had their first operator entering in 2014 and 2015, the second in June 2016 and the last one in January 2018. Furthermore, it is also important to highlight that, at the beginning (2015), the penetration rate per household was 1% at Arronches and Serpa and 12% at Arouca. These values represented the minimum and maximum, respectively. By 2020, the lowest penetration rate was in Torre de Moncovo and it was around 30%. Generally, it is possible to conclude that in every municipality the penetration rate increased considerably but there still exist municipalities of the national territory with coverage of less than 90%, according to DST.

As worldwide, in Portugal data traffic consumption has been increasing significantly and fixed broadband Internet traffic increased 53% in the 3rd quarter of 2020 - due to the pandemic - and that about 83.9% of households had broadband at the end of this period, equivalent to an increase of percentage points over the same quarter. In this sense, it was observed that optical fibre was the main channel for Internet access, reaching 53.8% of the total accesses and, by 2020, the number of accesses supported on optical fibre will increase by 275 thousand accesses, according to ANACOM.

The measures presented for broadband development in Portugal consist in the mapping of broadband infrastructures - Centralised Information System (CIS) - where data on existing infrastructures is stored. In this sense, its main objective is to avoid inefficient duplication and inconveniences for citizens and businesses resulting from constant and extensive underground work.

3.2. Europe

According to the Digital Economy and Society Index (DESI), which follows the global digital development of Europe and the digital competitiveness progress of the EU countries, COVID-19 shown how essential are digital goods nowadays and how networks and connectivity, data, Artificial Intelligence, among others, are essential to a good function of economy and society. These aspects allowed us to continue working in many areas during the pandemic and helped us being aware and updated.

In this regard, a fast and reliable broadband connection is crucial. As expected, during the last year, the demand for good and stable coverage increased.

Firstly, in 2019, Next Generation Access (NGA) coverage is available in 86% of European households. On the other hand, Fixed Very High-Capacity Networks (VHCN) are available in 44% of the households. However, regarding digital skills, only 58% of people have the required skills even though most works need such skills. Nevertheless, companies were already becoming more technological, where before the pandemic, around 38,5% of the big companies already needed advanced cloud services (DESI, 2020).

In terms of connectivity, Denmark is the country with the highest rate, followed by Sweden, Luxembourg, Latvia, and Spain. On the other hand, Greece, Cyprus, and Bulgaria had the weakest rate.

Over the past five years, significant progression, as well as above EU average performance can be observed in Ireland, the Netherlands, Malta, and Spain. In these countries, there are robust policies and targeted investments in the areas covered by DESI. It is also possible to highlight Finland and Sweden, which over the past five years are only slightly above average (as are Belgium and Germany), but are considered leaders in overall digital performance.

On the other hand, Denmark, Estonia, and Luxembourg have shown low progress over the period, with the biggest challenge in Denmark being improving advanced digital skills and in Luxembourg the digitisation of businesses. Additionally, in most of the countries that are below the threshold of the EU average, they have not made much progress. However, it was found that over the years there have been several initiatives in the areas monitored by DESI.

Bulgaria, Greece, Romania, and Italy have the lowest scores on the index and, in contrast, Finland, Sweden, Denmark and the Netherlands have the most advanced digital economies in the EU, followed by Malta, Ireland and Estonia.

As digitalisation increases in businesses, only around 17% of SMEs rely on the advanced cloud and 12% on big data applications, and there is a big gap between large enterprises and SMEs - not only for advanced technology but also for basic digital solutions. In this regard, Malta is the leading country for big data and Finland is the most advanced country in the uptake of cloud services (DESI, 2020).

In the EU, all households have broadband available (considering all the main technologies - DSL, cable, fibre to the premises (FTTP), FWA, LTE and satellite. Fixed technologies have remained unchanged (around 97%) and are considered the primary Internet access at home. Some 44% of households already benefit from very high-capacity network coverage (VHCN) with gigabit connectivity on FTTP and DOCSIS 3.1 networks, up from 29% last year and 4G mobile coverage is almost universal at 99.4% (DESI, 2020).

In rural areas, around 10% of households are not covered by any fixed network and 41% do not have any NGA technology. Coverage in rural areas has been gradually improving.

Compared to last year, mobile broadband availability has increased by two percentage points and is not used to replace fixed technologies.

According to the Digital Economy and Society Index, since 2011, overall fixed broadband coverage has only increased, from 95% to 97% and rural coverage has improved from 80% in 2011 to 90% in 2019.

As for the coverage of next-generation access (NGA) technologies, it has been increasing, reaching 86% in 2019. In rural areas, a very significant increase has been seen, with 9% of households having access in 2011 and 59% in 2019. The leading countries for NGA are Cyprus, Malta, and Belgium.

We denote a very large increase in the overall coverage of the very high-capacity network (VHCN) between 2011 and 2019 from 10% to 44%. There is also an increase in rural areas, but not as significant. In this case, Malta is the leading country, followed by Denmark and Luxembourg. On the contrary, Greece, the United Kingdom and Cyprus are the countries with the lowest VHCN rate.

Regarding 4G, their average 4G availability is 96% and compared to 2016, this has only increased by 3 percentage points, and there are strong differences between rural and non-rural areas, as is the case of Portugal.

According to DESI, by the end of 2020, the Digital Agenda for Europe has a target of at least 50% of households subscribing to ultrafast broadband and this take-up has been growing sharply. In Sweden, Portugal, Spain, and Hungary penetration are highest, with more than 50% of households subscribing to at least 100 Mbps.

For new entrants, compete with incumbents and may use either the incumbent's network or their network to provide Internet access. In Greece, such competition is largely based on regulated access to the incumbent's network. In countries such as Italy, the United Kingdom, Cyprus, Germany, and France new entrants are not only using the incumbents' networks but also their own. In the Eastern European Member States, Belgium, Malta, Portugal and the Netherlands, competition is based on competing infrastructures.

The information presented about Europe was collected because it was considered relevant for a brief contextualisation since the papers analysed refer mostly to European Union countries. Therefore, it can be observed that, although there has been a positive evolution in Internet access in Portugal, there is still a long way to go when we look at other countries.

4. Data

4.1. Database

To answer the research question, what is the effect of broadband connection on productivity, all empirical analyses will be implemented using a database, that has been purpose-built by me for this work, where the information was collected from the National Statistical Institute (INE), with data available from 2013 until 2018. In this way, the variables described throughout this chapter have the same name in the database.

INE is the central body for the production and dissemination of official statistics, which ensures the supervision and technical and scientific coordination of the National Statistical System. The statistics produced are considered a public good and aim to meet users' needs efficiently and without excessive burden on information providers to statistical authorities.

These data are acquired through annual surveys, and they provide a better understanding of some characteristics on a micro and macro level – fundamental for the private and public sector as well as for the citizens in general.

This database contains information on Internet accesses, data on capital quality and human quality, as capital and human proxies, at a municipal level. It should be noted that the database used was constructed for the present study and has never been used in any other.

4.2. Variables and Descriptive Statistics

The database was prepared in Portuguese and therefore the names are in Portuguese. However, throughout this chapter, in the presentation of each variable the corresponding database name will be presented.

This section presents the descriptive statistics for the variables of interest, an annual basis from 2013 to 2019 for municipalities in Portugal, where 278 municipalities were observed. Table 1 and 2 present information about the number of total accesses – that represents the number of broadband internet accesses at fixed location by geographic location and access segment between 2017 and 2018. It should be noted that a distinction was also made between total accesses, *Acesses_total*, residential accesses, *Accesses_res*, and non-residential accesses, *Accesses_nres.*

In the database represented as Total Accesses, Residential Accesses and Non-Residential Accesses.

VARIABLES	(1) N	(2) mean
Accesses_nres	278	1,957.33
Accesses_res	278	10,294.21
Accesses_total	278	12,251.54

Table 1: Accesses (No.) in 2017

VARIABLES	(1) N	(2) mean
Accesses_nres	278	2,118.45
Accesses_res	278	10,857.05
Accesses_total	278	12,975.50

Table 2: Accesses (No.) in 2018

Therefore, from the tables above, the number of observations in the database is 278 municipalities and that the average total accesses in 2018 is higher than in 2017, with the main difference being in non-residential internet accesses. However, it is evident that residential accesses have a greater representation in the number of total accesses.

The interval chosen for the study records only one movement about the evolution of fixed-site broadband internet accesses during the selected period. The evolution has been positive and has always grown over the years.

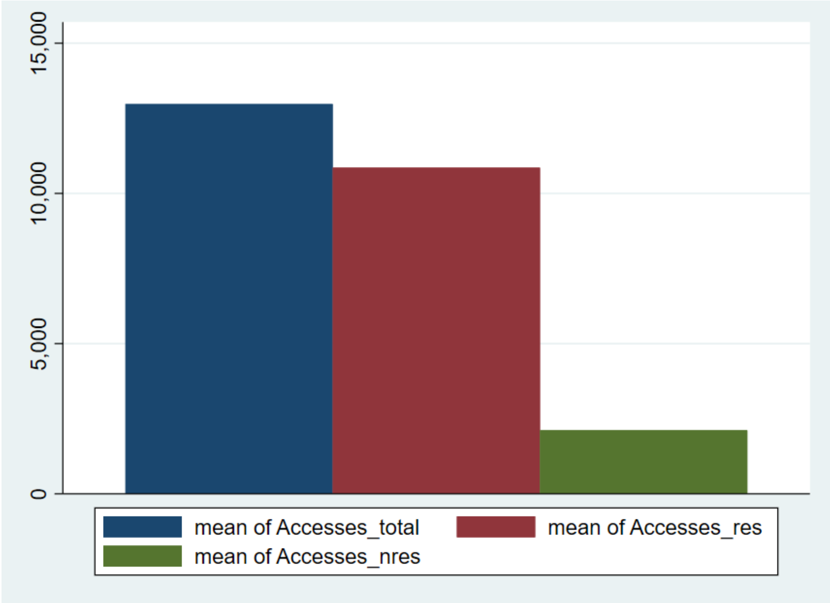

Figure 3: Total Accesses, Residential Accesses, and Non-Residential Accesses, 2018

For an overview, a graph has been constructed where we can observe the total accesses, residential and non-residential in 2018. Therefore, there is a large difference between residential and non-residential accesses, with the average residential access being 9000 the number of broadband internet accesses at a fixed location by geographic location and the average non-residential access being less than 2000.

The database built has variables that allow us to control not only the quality of capital, but also human – used as human and capital proxies.

Firstly, concerning **quality of capital**, data on the number of the consumption of medium and high voltage energy, *Cons_Elet*, was gathered, which allows us to observe at company level this use since it is the companies that use this type of energy. Therefore, the variable then allows us to understand the number of consumers of high and medium voltage electricity. In the database represented as *Cons_Elet.*

VARIABLES	(1) N	(2) Mean
Cons_Elet	278	90.30

Table 3: High and medium voltage electricity consumers (No.) in 2018

In this regard, it can be understood that the number of observations of the variable is 278 and the average number of high and medium voltage electricity consumers is 90.30.

In addition, we added variables to control for **human quality**, one of which allows us to observe the age of the resident population, which in this case is between 14 and 65 years old, *Age2*. Subsequently, we added a variable that allows us to observe employees by education, distinguishing between employees with secondary education, *high_school,* and with higher education, *college*. In the database represented as *GrupoEtario2*, *tco_secundario* and *tco_superior.*

VARIABLES	(1) N	(2) Mean
College	278	1,763.71
high_school	278	2,379.32
Age2	278	62.75

Table 4: Medium values for Human Quality (No.) in 2018

From the above table, it can be concluded that there are, similarly to the other variables, 278 observations. Additionally, it is observed that the average number of employees with higher education in 2018 is 1763.71 and with secondary education is 2379.32, which are relatively low numbers.

Additionally, regarding the variable *Age2* – age range in which the individual is, according to the reference moment – with the proportion of the resident population between the ages of 14 and 65 being, on average, 62.75%. In the database constructed, these values are expressed as a percentage.

From the database used, which considers the continental Portuguese municipalities, it is possible to extract some important data to understand the characteristics of the municipalities that make it up.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	N	Mean	p50	Sd	min	max
GVA	278	344 494.49	76 459.50	1 478 190.28	3 239	23 130 864
Accesses_total	278	12 975.5	4 158.50	26 385.23	338	295 644
Accesses_res	278	10 857.05	3 350.50	21 852.19	279	230 431
Accesses_nres	278	2 118.45	779.50	4 781.26	59	65 213
PService	278	14 012.95	4 437.50	35 353.45	418	496 577
Age2	278	62.75	63	3.99	47.60	72
Cons_Elet	278	90.30	46.50	116.74	5	1 167
High_school	278	2 379.32	655.50	6 985.13	45	102 552
College	278	1 763.71	284	8 335.68	0.00	128 296
Pop_Dens	278	304.65	65.85	844.91	3.90	7 641.90
						[1]

Table 5: Descriptive Statistics of the General Database

As it can be seen in Table 3, 278 municipalities were considered (being that Portugal has 308 when considering Azores and Madeira) between 2013 and 2018.

Regarding the *Pop_Dens* variable, it expresses the intensity of settlement expressed as the ratio of the number of inhabitants of a given territorial area to the surface area of that territory and it is expressed in number of inhabitants per square kilometre. In the database represented as *Densidade Populacional.* From the table, we can see that the population density is, on average, 305 (N°/km^2).

GVA is, by INE definition, the gross production value deducted from the cost of raw materials and other consumption in the production process and the values are gross when consumption of fixed capital is not deducted. In the database represented as *VAB.* According to Table 5, the GVA,

[1] Table 5 summarises the descriptive statistics, describing the characteristics of the variables used from the database used. In this sense, we can observe that 10 variables observed in 278 Portuguese municipalities were considered. Additionally, in column two we can observe the mean value of the variable being considered. In column three, the 50th percentile, that is, the median. The fourth column shows the standard deviation and, finally, columns 5 and 6 represent the minimum and maximum value that the variables under observation reach. Additionally, *GVA* shows the Gross Value Added of non-financial corporations: total and by economic activity sector; *Accesses_total, Accesses_res* and *Accesses_nres* represent broadband internet accesses at fixed location (No.) by geographic location and access segment; *PService* represents the personnel employed (No.) in establishments by geographic location and economic activity, Age, the total resident population and by age groups (%); *Cons_Elet*, consumers of high and medium voltage electricity (No.); *High_School*, employees by secondary education qualifications; College, employees by higher education qualifications and, finally, *Pop_Dens* represents population density (No./km2) by place of residence.

on average is 344,494 thousand euros. Additionally, the minimum value observed is 3,239 thousand euros and the maxium is 23,130,864 thousand euros.

PService represents the number of people employed by establishments by location and economic activity. In the database represented as *PServico.*

It should also be added that in the Descriptive Statistics table, the p50 represents the median, the sd column represents the standard deviation and *min* and *max* are the values for the minimum and maximum that the variable in study can accomplish.

5. Methodology

5.1. Model Specification, OLS Estimation and Problems

This work aims to understand the impact of broadband on productivity is. In this way, a model of the type was drawn up:

$$\log (y_{it}) = X_{it}\beta + \alpha_i + \varepsilon_{it} \qquad (1)$$

where y_{it} corresponds to productivity, that is, Gross Value Added divided by the number of staff employed in the establishments. The vector X_{it} captures the variables chosen at each point in time and the estimated equation also includes the specific characteristics of the population and a disturbance term (ε_{it}), which represents all other factors influencing municipality performance, including measurement errors and which respects the classical assumptions made for the model.

It should be noted that the choices of variables were based on the existing literature, to the extent possible. Therefore, as mentioned above, the variables chosen were accesses (total and distinguished between residential and non-residential), consumption of high and medium voltage electricity (which only businesses use), the qualifications of employees (distinguished between workers with secondary and higher education) and, finally, the resident population aged between 14 and 65.

The OLS (Ordinary Least Squares) is used for estimating the unknown parameters in a linear regression model. The method is used because it allows the analysis of the relationship between a dependent variable and one or more explanatory variables. Before proceeding with the estimation of the model, it is necessary to consider the assumptions and properties of this method. The assumptions of this method refer that the model should be linear in the parameters but may be non-linear in the variables. The explanatory variable is considered deterministic, i.e., it is not random. Hence, the covariance between a random variable and the disturbance term is zero, and the values of X are "fixed in the selection of observations that are part of the sample". The (random) disturbance has zero mean $E\ (u_i\ |X_i) = 0$. Therefore, errors above and below the regression line cancel each other out (Koch, K. R., 2013).

Another assumption of the least-squares method is the absence of autocorrelation between the disturbance terms $cov\ (u_i, u_j\ |X_i, X_j) = 0$, when this does not happen the estimates may be biased due to endogeneity problems. For this reason, the errors are linearly independent, because the error of one observation does not influence the error of another. Violation of this assumption indicates that the important variables are not included in the model, which means that certain variable that is present in the PRF (Population Regression Function), but not in the model that will be estimated. The consequence of not including the important variable depends on the correlation between the omitted variable and other independent variables. If there is a correlation between the omitted variable and any other independent variable, it will influence the regression coefficient produced by OLS. If there is no correlation between the omitted variable and any independent variable it will not produce any serious problem. There is also an absence of correlation between the error and the explanatory variable: $cov\ (u_i, X_i) = 0$. When this assumption fails the variables will be biased, this is an indication that some variable(s) have been erroneously excluded from the equation and the model loses consistency. The number of observations should be greater than the number of parameters to be estimated, that is, the number of observations is greater than the number of explanatory variables. Furthermore, the model should show variability in the values of X, so Var(X) is a finite positive number.

The model is correctly specified when there are no errors or specification biases and no perfect collinearity. This is because there are no perfect linear relationships between the explanatory variables and because an explanatory variable cannot be written as a linear combination of two or more of the remaining variables. The properties of the EMQs, under H1-H6 (linearity, strict exogeneity, non-collinearity, homoscedasticity, absence of autocorrelation and normality of errors), the EMQs $\hat{\alpha}$ and $\hat{\beta}$ are BLUE, that is, Best Linear Unbiased Estimator. Best, because the minimum variance estimators are centric and linear (Gauss Markov Theorem); Linear, because all $\hat{\beta}$ are linear estimators; Unbiased, because, on average, the values of $\hat{\alpha}$ and $\hat{\beta}$ are equal to the true parameter values; and Estimator, because they are estimators of the true parameter values α and β. Additionally, under H1-H6, EMQs have 3 desirable properties such as centricity, efficiency, and consistency. Centricity ensures that both estimators are centric, i.e. $E\ (\hat{\beta}) = \beta$. Efficiency states that EMQs have minimum variance and there is no other with a variance smaller than its own. The consistency of an estimator is verified when it converges to its true value when the amount of data in the sample tends to infinity. $\lim_{n\to\infty} \Pr\ [\ |\hat{\beta} - \beta| > \delta] = 0\ \forall \delta > 0$ (Lopes, A., 2009).

In this sense, having identified weaknesses in the OLS created, the following sections will discuss an econometric option that may counteract this problem, panel data.

Homoscedasticity is one of the most important assumptions of this method. This assumption is verified when the variance of the errors is constant (that is, it is the same throughout the population). When this situation is not verified, we are facing a heteroscedasticity situation. The homoscedasticity formula $Var\ (u|x,\ x_2,\ \ldots,\ x_k) = \sigma^2$. Otherwise, the variance of errors will be different for each conditional value of X_{ji}: $Var\ (u_i\ |X_{1,\,i}, X_{2,i}, \ldots, X_{k,i}) = \sigma^2$ and we will be facing a case of heteroscedasticity. In this regard, when homoscedasticity fails there are several consequences, including the variance and covariance matrix changes; the standard error estimates and the t-test and F-test statistics are no longer valid, even for large samples, because the variance estimate of the coefficient estimators will be biased; the estimators cease to be BLUE (linear, unbiased and have the least variance among the class of all linear and unbiased estimators); when errors are heteroscedastic, estimators continue to be unbiased and consistent, but cease to be efficient, because the minimum variance conjecture is abandoned (in which estimators give more importance to the residuals of observations with higher variance, since the sum of squares of the residuals associated with the terms of higher variance, tends to be higher than the one associated with the terms of lower variance). To verify, White's test was performed. Additionally, VIF (Variance Inflation Factor) was also calculated to understand how much the behaviour of an independent variable is influenced by multicollinearity – a high VIF value indicates that the independent variable is highly collinear with the other variables in the model. In this regard, the models did not present heteroscedasticity. However, OLS does not allow removing possible endogeneity due to municipalities characteristics and therefore it is more certain to use a panel study with FE or RE.

5.2. Panel data

A panel database was searched, which is, a database containing several sample units monitored over time, where there is information for the same unit but in different periods. Panel data combines time series and cross-section data, by having information on the same unit of analysis over time. In this case, it intends to follow the evolution of municipalities during time, 2013 until 2018. The advantages of using panel data over cross-sectional or time-series data are several, such as a greater capacity for capturing the complexity of human behaviour, simplifying computation and statistical inference and more accurate inference of model parameters (Hsiao, C., 2007). In this sense, it allows controlling for different sources of unobserved heterogeneity, improving the efficiency of estimators, and of allowing one to control for unobserved and invariant variables over time that may be correlated with the error term of the regression (Jeffrey Wooldridge, 2010).

In the present work, the determinants of GVA (Gross Value Added) per Resident Population were estimated also using the Fixed Effects method and the Random Effects method.

Additionally, the introduction of additional error components that account for unobserved heterogeneity is allowed due to repeated observations. It is possible to use mixed models and error components are treated as random effects when error components are uncorrelated with observed explanatory variables. On the other hand, fixed effects are needed to be considered when the error components are correlated with observed explanatory variables. There are several advantages of using panel data, such as Improved efficiency in estimators and gains in terms of identification, Control for unobserved time-invariant variables potentially correlated with the error term and flexibility in modelling unit behaviour. The Fixed Effects (FE) method is widely used in empirical research in economics, allowing research with panel data and dependent ordinal variables to control for unobserved heterogeneity and time invariants that are correlated with observed covariates. The Random Effects (RE) method is attractive when we think that the unobserved effect is not correlated with all explanatory variables. As three techniques were used to estimate the determinants, some variables were not chosen since they did not obey the characteristics that were required (constant variables over time).

The following model described can be considered a generic model:

$$y_{it} = x'_{it}\beta + z'_{i}\alpha + \varepsilon_{it} \qquad (2)$$

where i represent the municipality, t represents time, x_{it} is a dimension vector (t x k) with k regressors, excluding the constant; β is the column vector (k x 1), $z'_{i}\alpha$ includes the constant and other variables that assume a constant value within municipalities, and it includes unobserved heterogeneity, and this component may contain both observed and unobserved variables.

Subsequently, **Fixed Effects (FE) model** will be discussed. Here, items that are not observed in the data but are constant over time may be correlated with the variable.

The equation 3 is defined in matrix terms, where each element is a vector and α_i is unknown and it can be estimated:

$$Y_i = X_i\beta + i\alpha_i + \varepsilon_i \qquad (3)$$

where α_i corresponds to an unobserved component; ι represents a column of 1's with dimension (T x 1); and T corresponds to the number of observations per municipality i.

The differences between municipalities are captured as the differences in the constant term of the model, α_i. Considering the first differences it is possible to eliminate α_i e, in this case, the OLS estimator is unbiased:

$$y'_{it} - y_{it-1} = (x_{it} - x_{it-1})'\beta + (\varepsilon_{it} - \varepsilon_{it-1}) \qquad (4)$$

The consistency of the estimator depends on $E\{(x_{it} - x_{it-1})\,\varepsilon_{it}\} = 0$ and the variance-covariance matrix is:

$$\widehat{V(\widehat{\beta 1})} = s^2(X'M_DX)^{-1} \qquad (5)$$

where,

$$s^2 = \frac{(MdY - Md\beta)'(MdY - MdX\beta)}{nT - n - k}$$

where $M_d = I - D(D'D)^{-1}D'$ and $D = [d_1, d_2, \ldots d_n]$, matrix D with n columns, nT lines and d_i which corresponds to dummy variables.

To test for the presence of fixed effects, an F-test must be implemented to test if there are no differences between the units. In this regard, if the null hypothesis is rejected there is unobserved heterogeneity among municipalities and the fixed effect should be used.

$$F_{(n-1, nT-n-k)} = \frac{\frac{R^2lsdv - R^2ols}{n-1}}{\frac{1 - R^2lsdv}{nT-n-k}} \qquad (6)$$

H_0: $\alpha_2 = \alpha_3 = \ldots = 0$

H_1: H_0 is not true

In the **Random Effects model**, the random error represents all factors that influence the dependent variable (*logGVAptrab*) but are not included in the model as regressors.

According to equation 7, we have that:

$$y_{it} = \mu + x'_{it}\beta + \alpha_i + \varepsilon_{it} \quad (7)$$

where α_i is independent and identically distributed across individuals, which does not vary over time. Additionally, $\alpha_i + \varepsilon_{it}$ is the error term with two components and

$$\varepsilon_{it} \sim IID(0, \sigma^2\varepsilon); \alpha_i \sim IID(0, \sigma^2_\alpha) \quad (8)$$

The residual component of the error term is not serially correlated over time nor correlated with the regressors, and this is not correlated to the explanatory variables included in the model. The serial correlation is associated with α_i.

The OLS model produces consistent estimates of μ and β. However, the standard errors associated with OLS are not correct. In this regard, we can use a more efficient estimator exploring the structure of the variance-covariance matrix of the error term.

When T is large, the FE and RE estimators are identical:

$$\hat{\beta}_{GLS} = \Delta\hat{\beta}_B + (I_k - \Delta)\,\hat{\beta}_{FE} \quad (9)$$

where $\hat{\beta}_{GLS}$ is a weighted average of the between-groups and fixed effects estimators, where the weighting depends on the variance between the two estimators and Δ is a weighting matrix proportional to the inverse of the Variance-covariance matrix of $\hat{\beta}_B$ (between-groups estimator). This estimator is more efficient when compared to both estimators.

When the explanatory variables are independent of α_i and ε_{it}, the RE estimator is unbiased. In this regard, when:

$$y_{it} - \upsilon\bar{y}_i = \mu(1 - \upsilon) + (x_{it} - \upsilon\bar{x}_i)'\beta + u_i \quad (10)$$

The random effects estimator is more efficient than the fixed effects estimator (if $\psi > 0$; $\upsilon = 1 - \sqrt{\psi}$). Additionally, the efficiency gain results from the use of the between-groups variation $(\bar{x}_i. - \bar{x})$ and for the fixed effects model we can think that the results are only valid for the units included in the sample used in the estimation. If $\psi = 1$ we have GLS = OLS. In this case $\sigma^2_u = 0$. If $\psi = 0$ we have GLS = LSDV (Least Squares Dummy Variable). In this case $\upsilon = 1$.

Random Effects versus Fixed Effects

The Least Squares Dummy Variable implies a significant loss in the degrees of freedom and the RE model has the issue of inconsistency associated with possible correlation between regressors and the specific Effect. To understand which model, we should use, the Hausman test is appropriate. The statistic of the test is defined as:

$$w = [b - \hat{\beta}]'[\text{Var}(b) - \text{Var}\,\hat{\beta}]^{-1}[b - \hat{\beta}] \sim \chi^2_{(k)} \quad (11)$$

where k is the number of elements in b, and, under the null hypothesis, b is a consistent estimator and $\hat{\beta}$ is an efficient estimator.

To sum up, the model with FE is operationally simpler but may consume many degrees of freedom when there are many cross-sectional and time-series units. Thus, the model with RE would be especially attractive in situations where there is a substantially large characterization of cross-section variations and time-series.

6. Empirical Results and Discussion

6.1. Portugal

As mentioned before, the dependent variable is GVA per worker to evaluate productivity at each point in time over the defined period.

The first step was to calculate only the impact of accesses - total, residential, and non-residential - on the dependent variable. In this sense, three robust OLS models were created in which there was a distinction between the three types of accesses.

	OLS1	OLS2	OLS3
logAccesses_total_ptrab	-0.1352***		
	(0.0304)		
logAccesses_res_ptrab		-0.0774***	
		(0.0267)	
logAccesses_nres_ptrab			-0.4699***
			(0.0488)
2013	-0.0021	-0.0060	0.0425
	(0.0368)	(0.0368)	(0.0354)
2014	0.0344	0.0224	0.1188***
	(0.0365)	(0.0365)	(0.0359)
2015	0.0919**	0.0750**	0.1898***
	(0.0372)	(0.0370)	(0.0377)
2016	0.1377***	0.1169***	0.2550***
	(0.0371)	(0.0368)	(0.0388)
2017	0.1966***	0.1725***	0.3476***
	(0.0372)	(0.0368)	(0.0400)
2018	0.2351***	0.2084***	0.4069***
	(0.0370)	(0.0365)	(0.0409)
Constant	2.5610***	2.5736***	1.5729***
	(0.0283)	(0.0303)	(0.1130)
R^2	0.03	0.03	0.10
RMSE	0.42	0.42	0.41
N	1,934	1,934	1,934

Table 6: Results of OLS #A [2]

According to the table above, the coefficient associated with the logarithm of the accesses, whether total, residential, or non-residential, has a negative and statistically significant influence on productivity, with the smallest impact on residential accesses. In the OLS1 model, which considers

[2] Table 6: Estimation of the OLS #A, where three models are considered differentiating the type of internet access used, that is, what is the impact of each type of access on productivity; Significance level: *** p<0.01, **p<0.05 e * p<0.1. Between parentheses are reported the standard errors of the models considered.

total accesses, a 1% increase in the independent variable leads, on average, to a decrease of around 0.14% in the logarithm of productivity, with everything else remaining constant. It should be noted that all models include the same dependent variable and the same independent variables to enable the comparison of results.

	OLS4	OLS5	OLS6
logAccesses_total_ptrab	-0.2074***		
	(0.0253)		
logAccesses_res_ptrab		-0.1732***	
		(0.0219)	
logAccesses_nres_ptrab			-0.3386***
			(0.0428)
logCons_Eletpc	0.0099	0.0088	0.0300*
	(0.0163)	(0.0163)	(0.0160)
high_schoolpc	4.2552***	4.2416***	4.2039***
	(0.4856)	(0.4818)	(0.4927)
Collegepc	3.1459***	3.1906***	2.8048***
	(0.4177)	(0.4162)	(0.4205)
Age2	0.0151***	0.0161***	0.0080**
	(0.0031)	(0.0030)	(0.0032)
2013	-0.0136	-0.0173	0.0110
	(0.0311)	(0.0312)	(0.0311)
2014	0.0162	0.0084	0.0566*
	(0.0299)	(0.0299)	(0.0306)
2015	0.0487	0.0395	0.0888***
	(0.0308)	(0.0307)	(0.0328)
2016	0.0720**	0.0609**	0.1188***
	(0.0310)	(0.0306)	(0.0340)
2017	0.1087***	0.0944***	0.1759***
	(0.0310)	(0.0307)	(0.0350)
2018	0.1252***	0.1092***	0.2033***
	(0.0312)	(0.0308)	(0.0363)
Constant	0.8811***	0.7946***	0.7926***
	(0.1700)	(0.1684)	(0.1787)
R^2	0.37	0.37	0.38
RMSE	0.34	0.34	0.34
N	1,934	1,934	1,934

Table 7: Results of OLS #B [3]

[3] Table 7: Estimation of the OLS #B, where three models are considered differentiating the type of internet access used, that is, what is the impact of each type of access on productivity, where other independent variables were added to the different models; Significance level: *** p<0.01, **p<0.05 e * p<0.1. Between parentheses are reported the standard errors of the models considered.

Regarding the OLSB model, more independent variables were added, which allow capital and human quality to be considered.

According to the table above, the coefficient associated with the logarithm of the accesses, whether total, residential, or non-residential, has a negative and statistically significant influence on productivity, with the smallest impact also on residential accesses. In the OLS4 model, which considers total accesses, a 1% increase in the independent variable leads, on average, to a decrease of around 0.21% in the logarithm of productivity, with everything else remaining constant.

In this table, we can observe that the variable of high and medium voltage electricity consumption (No.), *logCons_Eletpc*, presents a positive coefficient in the three models created, as well as the variable that represents employees with high school and university degree education, *high_schoolpc* and *collegepc* and the variable of the resident population between the ages of 14 and 65, *Age2*.

As can be seen in the table, not all values are statistically significant. It should be noted that all models include the same dependent variable and the same independent variables to enable the comparison of results. Additionally, with the addition of new variables, the R^2 value also increased. Also, about OLS1, the R^2 is 0.34, which means that the model explains around 34% of the variations occurring in the dependent variable.

Then, the models were built based on the Fixed Effects.

	FE1	FE2	FE3
logAccesses_total_ptrab	0.0319		
	(0.0349)		
logAccesses_res_ptrab		0.0065	
		(0.0335)	
logAccesses_nres_ptrab			0.0991***
			(0.0284)
logCons_Eletpc	0.1844***	0.1943***	0.1543**
	(0.0691)	(0.0689)	(0.0699)
high_schoolpc	0.8140*	0.8311*	0.7298*
	(0.4364)	(0.4391)	(0.4263)
Collegepc	0.2361	0.2200	0.2457
	(0.3726)	(0.3702)	(0.3727)
Age2	-0.0123	-0.0109	-0.0125*
	(0.0077)	(0.0077)	(0.0071)
2013	-0.0321***	-0.0317***	-0.0381***
	(0.0122)	(0.0121)	(0.0124)
2014	0.0034	0.0091	-0.0148
	(0.0135)	(0.0130)	(0.0147)
2015	0.0396**	0.0479***	0.0191
	(0.0175)	(0.0171)	(0.0182)
2016	0.0703***	0.0805***	0.0460**
	(0.0208)	(0.0203)	(0.0214)
2017	0.1218***	0.1337***	0.0900***
	(0.0232)	(0.0222)	(0.0247)
2018	0.1520***	0.1653***	0.1157***
	(0.0269)	(0.0259)	(0.0287)
Constant	4.1268***	4.0672***	4.2186***
	(0.6104)	(0.6209)	(0.5784)
R^2	0.32	0.32	0.33
RMSE	0.10	0.10	0.10
N	1,934	1,934	1,934

Table 8: Results of FE[4]

In Table 8, not all values are statistically significant. Also in this sense, contrary to what happens in the OLS models, it is possible to verify that the variable that informs us about Internet accesses - total, residential, and non-residential - shows a positive impact on the coefficient of the dependent variable, productivity. In the FE1 model, which considers total accesses, a 1% increase

[4] Table 8: Estimation of the FE, Fixed Effects, where three models are considered differentiating the type of internet access used, that is, what is the impact of each type of access on productivity, where other independent variables were added to the different models; Significance level: *** p<0.01, **p<0.05 e * p<0.1. Between parentheses are reported the standard errors of the models considered.

in the independent variable leads, on average, to an increase of approximately 0.18% in the logarithm of productivity, *ceteris paribus*.

Additionally, two variables present positive impacts, namely *logCons_Eletpc* and *high_schoolpc*, on GVA per worker. In this case, for *collegepc*, for the first model, when employees with secondary education varies by 1 unit, the logarithm of productivity varies by 0.2361 percentage points. A similar reading happens with the variable *high_schoolpc.* On the contrary, the variable *Age2* present negative impacts.

Subsequently, the models were built, based on Random Effects.

	RE1	RE2	RE3
logAccesses_total_ptrab	0.0002		
	(0.0248)		
logAccesses_res_ptrab		-0.0149	
		(0.0228)	
logAccesses_nres_ptrab			0.0580**
			(0.0285)
logCons_Eletpc	0.0233	0.0271	0.0057
	(0.0256)	(0.0255)	(0.0403)
high_schoolpc	1.3871***	1.3968***	1.3285***
	(0.1884)	(0.1880)	(0.4863)
collegepc	1.0740***	1.0664***	1.0938***
	(0.2549)	(0.2549)	(0.3537)
Age2	0.0059	0.0065*	0.0056
	(0.0037)	(0.0037)	(0.0057)
2013	-0.0163	-0.0161	-0.0208*
	(0.0100)	(0.0100)	(0.0115)
2014	-0.0025	0.0007	-0.0169
	(0.0112)	(0.0109)	(0.0142)
2015	0.0303**	0.0352***	0.0128
	(0.0127)	(0.0124)	(0.0171)
2016	0.0576***	0.0636***	0.0366*
	(0.0142)	(0.0138)	(0.0197)
2017	0.1024***	0.1092***	0.0761***
	(0.0155)	(0.0150)	(0.0225)
2018	0.1277***	0.1352***	0.0980***
	(0.0168)	(0.0161)	(0.0261)
Constant	2.1194***	2.0840***	2.1947***
	(0.2365)	(0.2393)	(0.3682)
R^2	0.30	0.30	0.31
RMSE	0.11	0.11	0.11
N	1,934	1,934	1,934

Table 9: Results of RE[5]

In Table 9, similarly to Table 8, not all values are statistically significant. Contrary to what happens in the OLS and FE models, it is possible to verify that the variable that informs us about Internet accesses - total, residential, and non-residential - demonstrate different impacts on the coefficient of the dependent variable, GVA per employee – including a negative impact in RE2 model. In the RE3 model, which considers non-residential accesses, a 1% increase in the

[5] Table 9: Estimation of the RE, Random Effects, where three models are considered differentiating the type of internet access used where other independent variables were added to the different models; Significance level: *** p<0.01, **p<0.05 e * p<0.1. Between parentheses are reported the standard errors of the models considered.

independent variable leads, on average, to a decrease of approximately 0.058% in the logarithm of productivity, with everything else remaining constant.

Additionally, the variables, *logCons_Eletpc, high_schoolpc*, *collegepc and Age2* have positive impacts on GVA per worker.

Subsequently, the Hausman test was applied to find out which model was preferable. In this case, the Fixed Effects model was found to be preferable.

6.2. Low-density regions

Following the models carried out for mainland Portugal, it was decided to carry out a more detailed analysis for low-density regions since the issue is more relevant for these municipalities as there is a greater lack of Internet access. According to the National Association of Portuguese Municipalities, it was found that local units are identified as low-density areas if their population density is below 150 inhabitants/km2 and, in this sense, this was the criterion followed to decide which municipalities to check. This more detailed analysis was only done considering total and non-residential accesses. Additionally, an interaction variable was created, which allows observing the interaction between total Internet accesses and low-density zones. According to table 10, we can see that there is a positive impact on the dependent variable.

	FE4	FE5
c.logAccesses_nres_ptrab##i.baixa_dens	0.1140***	
	(0.0374)	
c.logAccesses_nres_ptrab##c.Pop_Dens		0.0796*
		(0.0408)
logCons_Eletpc	0.1525**	0.1651**
	(0.0697)	(0.0782)
high_schoolpc	0.7288*	0.6237
	(0.4258)	(0.4455)
Collegepc	0.2395	0.2662
	(0.3692)	(0.4037)
Age2	-0.0112	-0.0201*
	(0.0075)	(0.0107)
2013	-0.0386***	-0.0469***
	(0.0125)	(0.0152)
2014	-0.0157	-0.0259
	(0.0147)	(0.0202)
2015	0.0174	0.0129
	(0.0184)	(0.0248)
2016	0.0441**	0.0466
	(0.0215)	(0.0292)
2017	0.0884***	0.0886***
	(0.0246)	(0.0336)
2018	0.1136***	0.1108***
	(0.0282)	(0.0384)
Constant	4.0879***	4.5672***
	(0.6046)	(0.8301)
R^2	0.33	0.29
RMSE	0.10	0.11
N	1,934	1,377

Table 10: Results of FE (low-density areas)[6]

Therefore, according to Table 10, we can observe that two strategies were used, that is, in one model only the low-density municipalities were taken and in the other an interaction (dummy) was created. Not all values are statistically significant. We can observe that the interaction created has a positive impact on the productivity coefficient, that is, for lower density municipalities internet access boosts productivity.

[6] Table 10: Estimation of the Fixed Effects, to conclude what is the impact of each type of access on productivity, where other independent variables were added to the different models and adding interaction variables; Significance level: *** p<0.01, **p<0.05 e * p<0.1. Between parentheses are reported the standard errors of the models considered.

6.3. Discussion of Results

At this stage of the study, it is intended to compare the results obtained for the various models created with each other, to establish a bridge with the initial literature. In this sense, essentially the results of the FE models will be discussed, since, as previously concluded, this is the most appropriate model to use.

Therefore, for the models in question, we conclude that GVA per worker, productivity, is positively related to Internet access, which is in line with the literature studied, and a 1% increase in total Internet accesses leads to an average 0.0319% increase in productivity. Additionally, a 1% increase in residential Internet accesses leads to an increase, on average, of 0.0065% and, in relation to non-residential accesses, a 1% increase in this variable leads to an average increase of 0.0991%. These values are statistically significant.

In relation to the remaining variables, *logCons_Eletpc, high_shcoolpc*, these present positive coefficients in the models elaborated, presenting, in this sense, a positive impact on productivity. Shiyi Chen, Wanlin Liu and Hong Song (2020) found that high-speed internet significantly increases firm productivity and worker wages, and the estimate is higher for firms in skill-intensive industries and more educated workers.

Additionally, the variable *Age2*, presents a negative coefficient, suggesting that they have a negative impact on productivity. For the models that contain total and residential accesses, respectively, and for the *Age2* variable, the values are not always statistically significant.

For the variable *collegepc*, which represents employees who have higher education, it goes according to the literature reviewed. According to Martin Falk a, Eva Hagsten (2012) notes that there is an indirect relationship between access to high-speed broadband and the presence of university-educated employees and researchers. Additionally, Robert LaRose, Jennifer L. Gregg, Sharon Strover, Joseph Straubhaar, Serena Carpenter (2007), note that age and income, have direct impacts. Efforts that promote the personal benefits of broadband and advanced ICT literacy skills among Internet users are recommended. Age was significantly related to Internet experience, but in the opposite direction to this hypothesis.

Regarding the analysis of low-density municipalities, we conclude that all variables, except for *Age2*, have a positive impact on productivity, however, not all values found are statistically significant. We can thus conclude that, for low-density municipalities, Internet access fosters productivity, keeping everything else constant.

7. Conclusion

Not only in Portugal, but all over the world, the debate on productivity has been constant, even more so given the recent pandemic.

In Portugal, during COVID-19, only certain services were open during the state of emergency. However, if people did not have access to the internet, the damage would be even higher because we would not be able to work and learning from home. By having access to the internet, workers that lived in rural areas could work from home. This phenomenon could fight against centralization in big metropolitan cities.

Nevertheless, around the world, only 54% is connected today. Governments should create and implement policies to provide access to the internet, for example, by removing the consumer-facing taxes on data and internet services, protect broadband infrastructures from vandalism. Besides, if possible, public-private partnerships could join and expand connectivity.

Through the econometric methods used, it is possible to conclude that the variables studied during the work influence GVA per Resident Population in different ways.

It is increasingly important to understand the influence that internet access has on certain variables. In this case, we analyse the impact of Internet access on GVA, adding other variables to the models. Therefore, the relevance of the topic is always great, and the studies carried out around it produce additional knowledge that enable a greater understanding of it.

Considering the particularity of the Portuguese geography and the population dimension of each area, it is necessary to direct the studies to our reality. In this sense, the work developed was focused on analysing the GVA per Resident Population, to better understand the logistics of each municipality.

As mentioned above, we intend to answer the following question: What is the effect of broadband on productivity? In this sense, a database was then built from the data made available by the National Institute of Statistics from 2013 to 2018.

The database therefore contains information on internet accesses, high and medium voltage electricity consumption, the educational qualifications of employees and the resident population aged between 14 and 65, which will be used to assess and measure the impact they have on the logarithm of productivity (GVA per worker).

Thus, we conclude that the main effect on productivity for Portugal comes from non-residential accesses, that is, at the business level. For low-density municipalities, the issue of Internet access is much more relevant, as this is where there is a greater need, and it is observed that Internet access boosts productivity.

Regarding the limitations of the study, considering the international studies on the topic, it is perceived that, for Portugal, there is very little literature regarding the topic in question, decreasing, even more, when the analysis is made at a municipal level and focusing on low-density areas. Additionally, the main limitation is the little data available at a municipal level.

As a natural consequence of the present work, it would be interesting to follow a line of research that would allow us to analyse what influence Internet access had during the pandemic. In another perspective, to study how broadband infrastructures can affect not only economic activity, but also the labour market in dimensions other than the employment rate.

In a future perspective, and as a complement to the study carried out, it would be interesting to expand the analysis by introducing new variables such as GDP, area, and municipal surcharges, for example.

Additionally, it is relevant to rethink the introduction of new variables that allow a better analysis of the models.

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9. Attachments

1. Literature Review Table

Does state aid for broadband deployment in rural areas close the digital and economic divide?	Diff-in-diff (German)	Wolfgang Briglauer, Niklas S. Durr, Oliver Falck, Kai Huschelrath	Centre for European Research 2019	Share of household broadband coverage in municipality i in year t at various levels of brandwidth quality; Relevant employment outcome in municipality I in period t.	Variables that indicate if the municipality received treatment (broadband adoption) or not; Impact of broadband coverage on employment outcome variables;	The effect of state aid is more pronounced for medium bandwidth levels and that gains strength over the years after treatment. Positive effects with respect to the size of the residential population that is employed; More people decided to move into (or stayed in) treated municipalities than left these rural areas, indicating that improved broadband coverage makes these municipalities more liveable places; Creates new jobs in these municipalities;
Measuring development levels of NUTS-2 regions in Turkey based on capabilities approach and multi-criteria decision-making	Pythagorean Fuzzy Analytic Hierarchy Process	Yasal Ozdemir, Muhammet Gul	Computers & Industrial Engineering 2018			There is a significant lack of awareness of the link between the capabilities and the development; Unmeasurable factors which prone to be neglected, might affect a society's future more than the others;
Broadband access in the EU: Na assessment of future economic benefits	Simultaneous equations model	H. Gruber, J. Hatonen, P. Koutroumpis	24th European Regional Conference of the International Telecommunication Society 2014	GDPit in a country i at time t to a set of production facts; Broadband penetration; Stylized representation of the supply side; Annual change in broadband penetration; Function of revenues	Stock of capital, labour, and broadband and fixed telecommunications infrastructure; GDP per capita, the price of a standard service for the connection to the network and the market segmentation; competition across firms, technologies, urbanization, and the price of a standard service for the	In most cases the benefits are substantially well above the costs. Private sector is reluctant to invest, as investors in broadband infrastructure only can partially appropriate benefits. This would suggest a rationale for the public sector to subsidize built-out of high speed of broadband infrastructure.

					connection to the network; Broadband revenues	
Development of High-Speed Networks and the Role of Municipal Networks	IV Estimation/Passive-Layer Open Model/Active-Layer Open Model	Bengt G. Mölleryd	OECD Science, Technology and Industry Policy Papers, No. 26 2015			Facilitates opportunities for economic development as well as being more attractive places to live and work; Improve public and social services for citizens and improve the availability of information and communication; development of new jobs and strengthen the competitiveness of businesses located in their towns and regions
Does rural broadband impact jobs and income? Evidence from spatial and first-differenced regressions	First-differenced regressions; Cross-section spatial models	Brian Whitacre, Roberto Gallardo, Sharon Strover	The Annals of Regional Science 2014	Cross-section spatial models: dependent variables (% Nonfarm proprietors; Median household income; No. Estab. w/paid employees; Total Employed); First-differenced regression: ΔYi is the change to a specific economic measure such as median household income for county i	Control variables. County-level characteristics such as population, education, and ae groupings; changes in broadband provider/adoption category	Increases in broadband availability (not adoption) over time has no statistical impact in either jobs or income. Non-metropolitan areas with high levels of broadband availability are associated with lower total employment; Higher number of businesses and jobs; Increases in broadband adoption (but not availability) are associated with increases in median household income and the percentage of nonfarm proprietors.
Does broadband matter for rural entrepreneurs or "creative class" employees?	Cross-sectional Spatial Models; First-differenced regressions	Kelsey Conley	2013	Cross-section spatial models: percent of non-farm proprietors; percent employed in creative class; First-differenced regression: change in the percent employed in creative class jobs in county	Overall broadband adoption dummy variable; is the non-metro broadband adoption interaction term; include various other socio-economic controls; Vector of changes to the other county-level characteristics such as population, education, and age groupings; right-hand side variable of interest denoting changes in broadband availability category	Policies might be a step in the right direction. Adoption was found to be negatively associated across all models, where availability was found to be positive in most cases; Entrepreneurs in rural areas may not even be involved in industries where "high" broadband access/ adoption prove to be beneficial; Broadband adoption seem to be negatively associated with creative class employees in rural America; Increasing broadband infrastructure may be an important step for rural communities to attract their "creative" presence.

					between 2000 and 2011.	
Internet infrastructure and regional convergence: Evidence from Turkey	Spatial Autoregressive Model	Mehmet Guney Celbis, Denis de Crombrugghe	Papers in Regional Science, Volume 97 Number 2 2016	Average per capita income growth rate of economy i.	Wij é o elemento da matriz de peso W de inversa entre regiões com zeros na diagonal; número de unidades espaciais;	Internet infrastructures may provide potential benefits to the regional economy; Air transport capacity can also contribute significantly to the regional economy as human capital
The impact of Broadband on Economic Activity in Rural Areas: Evidence from German Municipalities	Fixed effects regressions	Nadine Fabritz	Ifo Working Paper, No. 166, Ifo Institute Leibniz Institute for Economic Research at the University of Munich 2013	Causal effect of broadband infrastructure on local employment	Local business tax rates; industrial area as proxies for local government involvement; population density	Less densely populated areas benefit most from broadband infrastructure; Broadband may affect economic activity and the labour market in dimensions other than employment rate; Local infrastructure might also have longer-term effects.
Broadband Diffusion and Firm Performance in Rural Areas: Quasi-Experimental Evidence	Diff-in-diff	Giulia Canzian, Samuele Poy and Simone Schuller	ZA Discussion Papers, No. 9429, Institute for the Study of Labor (IZA) 2015	Measure of annual performance of firm i in municipality m in year t	Treatment status of firms located in municipality m by the end of year t; in case of continuous treatment intensity measure, they also ass a specification including a squared term	Significant increase in annual sales turnover and an increase in value added; Positive effect is found to be rather stable for different lengths of treatment exposure and across industrial sectors;
Broadband Internet and New Firm Location Decisions in Rural Areas	Diff-in-Diff	Younjun Kim and Peter F. Orazem	Bureau of Business Research, University of Nebraska-Lincoln 2016	Firm profit	Broadband availability; Local demand shifters, county and state characteristics, common market price; location-specific fixed effects; local wages and rental rate on capital	Broadband availability has a positive and significant effect on location decisions of new firms in rural areas; The broadband effect is larger in more populated rural areas and those adjacent to a metropolitan area, suggesting that broadband effect increases with agglomeration economies.
The economic Impacts of Telecommunications Networks and	Structure overview of the quantitive literature	Irene Bertschek, Wolfgang Briglauer, Kai	Centre for European Economic Research 2016			Telecommunication networks exert positive effects on economic growth as well as national and sectoral productivity; Mobile wireline telecommunications networks

Broadband Internet: A survey		Huschelrath, Benedikt Kauf and Thomas Niebel				have a positive impact on developing countries; Positive impacts of broadband networks on economic outcomes.
Exploring the Relationship between broadband and Economic Growth	Cross-sectional and panel	Michael Minges	World Development Report 2016 2016	Average growth rate of real GDP per capita; real GDP per capita; GDP per capita; Gross Domestic Product per household	GDP in 1980, primary school enrolment rate, average fixed broadband penetration, Capital Formation, average number of years of schooling and n is the growth of the working age population, Economic Freedom Index, fixed and mobile broadband per household	Positive economic impact from fixed broadband; Inconclusive about whether fixed broadband has a bigger impact on the economy compared to other ICTs, access from a mobile phone would have different economic significance than from a computer or a machine.
The employment and wage impact of broadband deployment in Canada		Olena Ivus and Matthew Boland	Queen's School of Business, Queen's University, 2014	Employment	Change in broadband Coverage; regional controls for initial or permanent characteristics; log of population, population density per square kilometre, age distribution; educational attainment; firm/establishment size; degree of urbanization and an indicator variable for rural economic regions.	Authors found out that the deployment of broadband in 1997–2011 promoted rural employment and wage growth in service industries. Goods industries were not impacted. The findings suggest that broadband helps service industry businesses overcome geographical barriers that have traditionally hampered rural growth.
Broadband internet and firm entry: evidence from rural Iowa		Younjun Kim and Peter F. Orazem	Economics Working Papers, 2012	Production of firm	Broadband availability; location	Broadband availability in a rural ZIP code has a positive and significant effect on firm entry in the ZIP code but only in rural markets adjacent to a metropolitan area or with a

						larger urban population. Broadband access does not affect new firm entry in more remote rural markets.
Impact of high-speed broadband access on local establishment dynamics	Fixed Effects and Spatial Durbin model estimations	Martin Falk a, Eva Hagsten	Telecommunications Policy 45, 2021	Number of establishments and the broadband infrastructure variable	Establishments, higher education, public investments, and innovation.	When the proportion of establishments with high-speed broadband access is combined with the local presence of university educated employees and researchers, a stronger indirect relationship appears; Evidence that the broadband availability in neighbouring municipalities has a spill over effect. The relationship between contracting municipalities and in those with a low-skilled workforce is far weaker.
What is the impact of Broadband Bandwidth Variability on Quality of Life? - Lessons from Sweden		Moinul Zaber, Sven Lindmark, Erik Bohlin	Lessons from Swedem, 2017	Quality of life variables	Impact of high-speed broadband and reliable high-speed coverage	Positive connection between high-speed broadband access and number of firms and workplaces; positive relationship between broadband speed and mathematics, and negative with native language; Mobile download speed has enabled people to work from distance and we see a positive impact of download speed on the increase in people's propensity to drive
Broadband adoption and firm productivity: Evidence from Irish manufacturing firms	Two-stage least squares estimator	Stefanie A. Haller, Seán Lyons	Telecommunications Policy 39, 2015	Productivity or productivity growth	Sales, capital stock, material purchases, number of employees in firm	While more productive firms are on average more likely to be using DSL broadband, they found no statistically significant effect of broadband adoption on firms' productivity or productivity growth
Do digital information technologies help unemployment job seekers find a job? Evidence from the broadband internet expansion in Germany	Fixed effects and Instrumental variable approach	Nicole Gürtzgena, André Diegmann, Laura Pohland, Gerard J. van den Berge	European Economic Review – Elsevier (2021)	Level of households with DSL availability	Inflow unemployed, Population, Female population share, Population shares aged 18-65, Population share >65, Net migration rate, Unemployment rate, Average real daily wage, Low-skilled, Medium-skilled, High-skilled, foreign nationals, Number of establishments, Establishment size, Number of firm entries,	Internet access mainly changes male job seekers' search behaviour by increasing online search and the number of job applications; Broadband internet improves reemployment rates after the first months in unemployment for males.

					Number of firms exits, Sales	
Effects of advancing internet technology on Chinese employment: a spatial study of inter-industry spillovers.	Industrial spatial econometric model, Moran's I test; Spatial econometric model	Huijuan Wanga, Lin Dinga, Rong Guana, Yan Xia	Technological Forecasting & Social Change – Elsevier (2020)	Quantity of employment in industry	Advancing internet technology, employment, capital stock, gross output, value added in current and constant prices	Internet technology progress in one industry will significantly promote Internet technology progress in "adjacent" industries. Internet technology progress directly promote the employment within industry. Internet technology progress also exerts positive effects on employment in other industries and positively affects employment within industry again through various feedback loops between industries. Therefore, policy should promote Internet technology in various industries, especially those closely linked to other industries, to stabilize employment and growth.
Broadband upgrade and firm performance in rural areas: Quasi-experimental evidence	Diff-in-diff	Giulia Canzian, Samuele Poy, Simone Schüller	Regional Science and Urban Economics (2019)	ADSL2+ availability	Revenue, Value added, Personnel costs, Tangible fixed assets, Intermediate inputs, Manufacturing, Construction, Retail, Services, Population density, Population growth, Education, Employment rate, No. of firms, Employment growth rate, Employmnet share in primary sector, Employment share in manufacturing, Employment share in construction, Employment share in retail, Employment share in services, Municipality's altitude, Distance to nearet motorway	ADSL2+ availability is associated with increases in firms' revenue and total factor productivity, but not with significant changes in personnel cost or employment. Additional analysis of aggregate administrative data shows no significant impact on the total number of active firms or local employment.

Broadband internet, firm performance, and worker welfare: evidence and mechanism	Diff-in-diff	Shiyi Chen, Wanlin Liu and Hong Song	Western Economic Association International (2020)	Firm's productivity	Fixed-line tele-intensity, Infrastructure, Age, TFP, Foreign, Home, KLratio, Firm scale, Profit, Output, Sales, Capital growth, Managerial expense to sales ratio, Managerial expense per capita, Industry scale, State own capital share, Yearly wage, Income, Employment, Gender, Marital, Education, Hukou	High-speed internet significantly increases firm's productivity and worker's wage, and the estimate is larger for firms in industries with high skill intensity and for more educated workers. They provide suggestive evidence that the mechanism is likely from firm's increased use of skill-biased technology and the flattened management organization.
Patterns of Innovation among Urban and Rural Firms - The effects of Broadband	Logistic regression model	Malin Allgurin	Master Thesis (2017)	Firm innovation	Firm characteristics and Local characteristics	Firm characteristics are the main determinants of firm innovation. A firm that wants to increase their chances to be innovative should choose an urban location. The availability of broadband increases the probability of innovation. Firms with a good broadband connection can reach other types of knowledge and information. Organisations should therefore strive to have a good broadband connection with a high-speed internet to access external knowledge and increase the innovative activity.
Broadband Internet availability and establishments' employment growth in Germany: evidence from instrumental variables estimations	Instrumental variable approach	Bistian Stockinger	Journal for labour Market Research (2019)	Establishments' employment growth	DSL availability, Full-time employment, Full-time wage, young establishment, mid-establishment, share high-skilled, Year, Industry, District	Negative employment growth effect of broadband availability for Western German manufacturers, and a robustly positive effect for Western German service establishments, including most knowledge-intensive industries. For Eastern Germany, a similar identification strategy is potentially available, but turns out invalid in this setting. An alternative identification approach indicates positive employment growth effects in both sectors for Eastern Germany. Overall, the findings suggest that broadband expansion has helped create jobs in firms which use broadband intensely.
Closing the rural broadband gap: Promoting adoption		Robert LaRose, Jennifer L. Gregg, Sharon	Science Direct, Telecommunications		Broadband intentions, Internet experience, Enactive learning,	Prior experience with the Internet, the expected outcomes of broadband usage, direct personal experience with broadband, and self-efficacy had direct effects on broadband intentions.

of the Internet in rural America		Strover, Joseph Straubhaar, Serena Carpenter	Policy 31 (2007) 359–373, Elsevier		Observational learning, Self-efficacy, Expected outcomes, Education, Income, Hispanic, Gender, Age	Age and income, but not education or ethnicity, also had direct impacts. Efforts that promote the personal benefits of broadband and advanced ICT literacy skills among Internet users are recommended. Age was significantly related to Internet experience but in the direction opposite that hypothesized