Universidade do Minho
Escola de Economia e Gestão

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Optical Fiber: exploring costs and benefits

October 2021

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UMinho|2021

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Master´s Dissertation
Master in Economics

Work developed under supervision of
Professor Doctor Rita Sousa
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October 2021

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Resumo: “Fibra ótica: explorando os custos e os benefícios”

Vivemos numa fase de transformação digital e a importância das Tecnologias de Informação e Comunicação nas sociedades atuais é cada vez maior. O acesso e o uso destas tecnologias têm impactos socioeconómicos e os benefícios são transversais a vários setores.

A União Europeia tem criado iniciativas no sentido de aumentar e melhorar a conectividade a redes de comunicação mais rápidas e a preços acessíveis. Desta forma, a fibra ótica desempenha um papel fundamental, devido às suas vantagens, como maior velocidade, melhor conectividade, maior estabilidade do sinal e maior durabilidade das infraestruturas. Contudo, é visível a diferença de acesso, entre as cidades e as zonas menos habitadas, a este tipo de tecnologia, sendo necessário aumentar o investimento nos locais mais rurais. Portugal, neste contexto, apoiou este investimento através de concursos públicos e, em parceria com algumas empresas portuguesas, o acesso a fibra ótica tem vindo a aumentar nas zonas rurais.

Este trabalho propõe uma forma de mensurar os custos e os benefícios da implementação da fibra ótica em municípios portugueses, com menor densidade populacional. Apesar do investimento nestes locais não ser tão atrativo como nas cidades, o objetivo é perceber se os benefícios superam os custos. A metodologia usada foi uma análise de custo benefício, em linha com o estado da arte da área, e que a Comissão Europeia subscreve para este tipo de investimentos. Foi ainda estruturado e distribuído um questionário online junto dos Municípios em análise, com o intuito de perceber o nível de conhecimento e opiniões relativamente à fibra ótica.

Nos 63 municípios analisados, verificam-se benefícios superiores aos custos. Em média, por cada euro investido calcula-se um retorno de 3.49€ (no caso da instalação de fibra ótica) ou 1.74€ (no caso de ter existido um upgrade de banda larga básica para fibra ótica). Dentro dos pressupostos assumidos conclui-se que o investimento nestas zonas rurais é benéfico.

Palavras-chave: análise de custo-benefício; banda larga; fibra ótica

Abstract: "Optical Fiber: exploring costs and benefits"

We live in an era of digital transformation and, the importance of Technologies of Information and Communication in today's societies is increasing. The access and use of these technologies have socioeconomic impacts and, the benefits cover several sectors.

The European Union has created different initiatives to improve and increase connectivity to faster communication networks and, at affordable prices. In this way, optical fiber plays a fundamental role due to its advantages, such as higher speed, better connectivity, more signal stability, and greater infrastructure durability. However, there is a visible difference in access between cities and less populated areas to this type of technology, making it necessary to increase investment in more rural areas. In this context, Portugal created public tenders and, in a partnership with private companies, the access to fiber in rural areas has been increasing.

This work aims to measure the costs and benefits of optical fiber installation in Portuguese municipalities with lower population density. Although investment in these places is not as attractive as in cities, the objective is to prove that the benefits outweigh the costs.

The methodology used was a cost-benefit analysis, in line with the state of the art in the area and that the European Commission subscribes for this type of project. In addition, an online questionnaire was structured and distributed to the municipalities under analysis, to understand the general opinion regarding fiber optics.

In the 63 municipalities analyzed it was verified that the benefits outweighed the costs. On average, for each euro invested there, is calculated a return of 3.49€ (if there was a new fiber connection) or 1.74€ (if there was an upgrade from basic broadband to optical fiber). Thereby, under the assumptions assumed, it has been proved that investment in these rural areas is beneficial.

Keywords: broadband; cost-benefit analysis; optical fiber

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Acronyms

ADSL	Asymmetric digital subscriber line
ANACOM	Autoridade Nacional das Comunicações
CBA	Cost - Benefit Analysis
DESI	Digital Economy and Society Index
DSL	Digital Subscriber Line
FTTC	Fiber to the Curb
FTTH	Fiber to the home
FFTP	Fiber to the premises
GDP	Gross Domestic Product
GVA	Gross Value Added
ICT	Information and Communication Technology
IDATE	Institut De L'Audiovisuel Et Des Telecommunications En Europe
ITU	International Telecommunications Union
JASPERS	Joint Assistance to Support Projects in European Regions
MCA	Multi-Criteria Analysis
NGA	New Generation Access

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1 Introduction

In the globalized world we live in, communication between countries and people has become much easier with the use of internet. The demand for internet services has been increasing, and to face that demand, broadband has been developing. Broadband is the term used to define the internet connection above the speed of analogic devices. Broadband appeared back in the '90s in high-income countries and it is characterized by the high speed and permanent connectivity to the internet.

Broadband can now be transmitted by optical fiber, characterized as an even better and faster internet connection. Optical fiber has advantages for households and companies due to the faster speed and a more stable signal. However, it requires a considerable initial investment that usually is done in collaboration between private investors and the government. The main question is if the benefits are more significant than costs, meaning, if the implementation of optical fiber is socioeconomically justifiable. This work arises as a way to analyze the costs and benefits of providing better internet services to less populated areas in Portugal.

The World Bank´s World Development Report of 2016 highlighted the impact of digital technologies on economic growth and the labor market. These changes are accomplished through mechanisms, such as innovation and increased efficiency. For example, the rise of e-commerce platforms, only possible with high-speed internet access, creates a new group of micro-entrepreneurs who can access global markets in a way that was not possible before (Minges, 2016).

High-speed internet, such as optical fiber, has many advantages when compared to the previous internet connections. Optical fiber has almost unlimited bandwidth and allows faster downloads and uploads. Fiber also has a more stable signal and is more eco-friendly because the fiber infrastructures consume less energy and have a higher lifetime.

It is becoming clear that an increase in broadband connectivity delivers significant benefits across different economic sectors. Better broadband infrastructures allow consumers to access more services, permit businesses to expand their markets, be more productive and innovate more, and also let the governments simplify their services and communication.

The main question that the present work aims to answer is if implementing fiber in rural areas justifies the high costs needed. Therefore, to answer this, it is conducted a cost-benefit analysis (CBA). Making a CBA allows us to estimate the total benefits and costs from the implementation of fiber.

This work initially provides a European and Portuguese contextualization of the broadband market, presenting the market evolution in the last decade, especially in rural areas. Then it reviews the literature, summarizing the main effects of broadband on the economy, as well as a brief reflection about the possible impact of the covid-19 pandemic in the optical fiber market.

The following sections present the data, methodology, and results. Two different methodologies are applied: an online survey and a CBA. The survey was based on an online questionnaire to understand what people (that lived in rural counties) perceive as the main advantages of fiber. The majority of the answers were positive as the habitants agreed that optical fiber is faster, more stable, and has better connectivity. The CBA followed the formulas and rules of the European Commission Guide (2014), and after all the data was collected and analyzed, it was possible to conclude that the installation and improvement of fiber infrastructures in rural counties were worth it because the benefits were higher than the costs.

2 Broadband and economic growth

2.1 Definition of broadband

In the telecommunications sector, broadband is characterized as a wide bandwidth data transmission. In other words, a broadband connection is defined as the channel over which digital data services are delivered and it can be classified as, depending on the speed of data transmission:

- Dial-up connections: this connection was introduced in the 1990s and is provided by phone lines, therefore it has a very limited speed of 0.1Mb/s.
- First Generation always-on broadband connection: these types of connections, are mainly ADSL and can be achieved by telephone lines, coax cables, satellite or wireless connections, but the upload speed is below 1Mb/s.
- Next-Generation Network broadband connections: are becoming the most common in Europe and, the speed is between 30Mb/s and 100 Mb/s.
- High-Speed Next Generation Network broadband connections: include optical fiber and are the connections with the highest speed, above 100 Mb/s.

In this work, we will focus on the high-speed next generation network broadband connections, such as fiber, because this is the technology that is been introducing broadly over the last decade in the majority of the European countries, including Portugal.

2.2 The European Framework

Digital technologies present numerous new ways of interaction between countries, governments, people, new ways of doing business and access information. Digital technologies also have the power to change the world economy. The European Union (EU) considers the digital economy as an important booster of competitiveness and innovation (European Commission, 2020).

In 2010, the European Commission (EC) defined some targets for 2020, including that every European citizen would have access to a faster internet connection and, at least 50% of the European population should have an internet connection above 100 Mbit/s (European Commission, 2014).

The European Union Strategy for 2020 focuses on the concept of smart growth, which is a growth based on knowledge. Therefore, the provision of fixed broadband infrastructure and the reduction of the digital gap between rural areas and cities has a crucial role in this concept (European Commission, 2014).

To achieve the targets of the Digital Agenda is necessary to change the existing network infrastructure. Therefore, the initial investment is highly costly. However, the investment in better broadband facilities has economic and social benefits because it improves the GDP per capita (Madden and Savage, 1998). Broadband also tends to attract companies, which can positively influence local employment and productivity (Kolko, 2012).

The EU justifies broadband investments because an optical fiber system can:

1. Improve the telecommunications systems and reduce the information gap between markets (Carey, 2008).
2. Improve the access to internet for households.
3. Homogenize the cultural patterns (Breur et al., 2014).
4. Attract better resources into isolated areas and reduce the digital gap (Ding et al., 2008).
5. Improve the local economy and increase the productivity for business through the use of ICT (Tranos, 2012; Kolko, 2012).
6. Attract more companies and startups.

7. Drive innovation.
8. Facilitate the provision of reliable e-health, e-education, e-commerce...
9. Facilitate data share and information worldwide.

In 2016, the Eurasian Economic Union (EAEU) and the World Bank conducted a study and implemented a Digital Agenda, clarifying some priorities to form and legislate a communal digital space. Those priorities had the purpose to increase trade volumes, using e-commerce tools and, improve the efficiency of cross-border interaction between governments and citizens (Navas and Petrov, 2018).

To create the EAEU Digital Space it is necessary to promote better digital solutions and practices to create a common digital infrastructure and digital platforms, and also all the parts interested may need to work together (public-private partnerships).

The EAEU Digital Agenda for 2025 has some main objectives such as: increasing the share of the digital economy in the EAEU annual GDP growth; increase the productivity of the main sectors of the economy; increase the number of employees in the high-tech sectors; increase the exports of digital goods and services (Navas and Petrov, 2018).

The digital economy creates an economic dynamism that is not only focused on new technology firms and businesses. The value-added created in traditional industries by these digital technologies is approximately 75% (Navas and Petrov, 2018). The EAEU assuming a 30% average fixed broadband penetration, predicts that 2 to 4 million new jobs can be created by 2025 (Navas and Petrov, 2018). According to World Bank estimations, eliminating the legal and regulatory barriers in the EAEU space is expected a 2.6% GDP growth up to 2025.

By creating this communal space, it is believed that will exist a multiplier effect that will lead to an acceleration of economic growth as well as an increase in the number of new jobs, creating a solid foundation for further development of common markets for goods and services.

However, not everyone will benefit from the internet because there can be an increase in inequality on access. Therefore, governments must invest and create the right conditions to provide equal access to these digital technologies.

As was said before, to implement an optical fiber system that can provide all the digital technologies needed to achieve the goals previously presented, it is necessary a significant initial investment. Also, is important to decide whether it is better a private capital driven by market competition or a public and private partnership. In this perspective, counties can have a crucial role by providing the right incentives to attract private investors or by creating a good partnership.

This partnership between the counties/state and private companies, can be done in many ways, such as the private company can only build the infrastructure and let the market operators use it; the private company can build and also provide the broadband service; the state can build the infrastructure and let the operators use it. For example, Sweden and the USA use a direct investment from municipalities to the companies that will install the fiber system. Therefore, the investment is financed with internal capital, even if that implicates an increase in public debt. On the opposite side, the United Kingdom uses indirect investment like incentives to expand the fiber offer and competition between the potential suppliers. In the UK, investment is fully private (Molleyrd, 2015).

Fiber implementation has been done mainly by a partnership between the State and private investors. However, it is necessary to guarantee that, after the installation of this infrastructure, the operators can enter the market because more companies are usually associated with lower prices, allowing more citizens to access the internet.

The European Union makes several studies and researches about this topic and, the Digital Economy and Society Index is one of the most important to understand the digital situation in each member state.

2.3 Digital Economy and Society Index (DESI)

The Digital Economy and Society Index (DESI) evaluates the digital performance of each member state through 5 dimensions, which are (European Commission, 2020):

- *Connectivity*, using an indicator such as fixed broadband coverage, broadband prices, mobile broadband, and fixed broadband take-up.
- *Human Capital*, which measures the internet user skills.
- The citizens' *use of the internet* in online services and transactions
- *Integration of Digital Technology* in business digitalization and e-commerce.
- *Digital Public Services*, such as e-government.

The DESI 2020 considered 37 indicators and presented data from 2019, considering the previous 5 dimensions.

Broadband connectivity measures the availability, the level of access, and the level of preparation of the digital infrastructure in the countries of analysis. A modern digital infrastructure provides better coverage that can face the increase of demand, a consequence of the pandemic. In 2019, the Next Generation Access (NGA) coverage of households was 86%, while in 2018 was 83%, which reflects an improvement. 4G networks cover almost the entire European population, but the 5G is still progressing slowly.

The Human Capital dimension measures the digital skills of the population. The coronavirus crisis has encouraged the citizens to improve their digital skills. In 2019, the percentage of people that have at least basic digital skills was 58% (in 2015 was 55%). Yet, a large part of the EU population still lacks these skills.

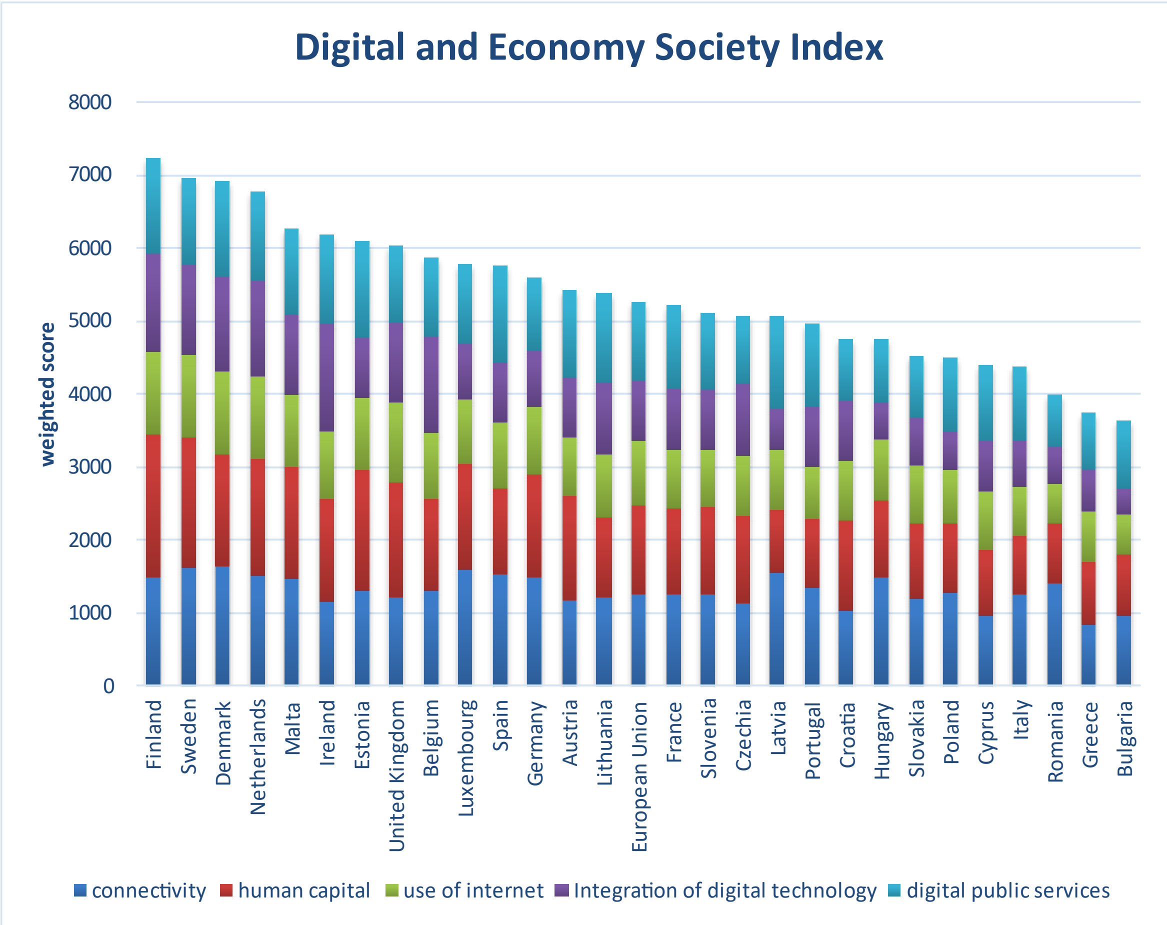
The internet use by citizens is a dimension that tries to measure the degree of utilization by the population of the different member states. The use of the internet has increased a lot during the pandemic, but even before, the use of video calls has increased from 49% of internet users in 2018 to 60% in 2019. Also, internet banking and online shopping have increased from 66% in 2018 to 71% in 2019.

The integration of digital technology by businesses measures the adoption and use of digital technologies by European companies. Even before the pandemic, enterprises were becoming aware of the importance of digitalized world. In 2019, 38.5% of large companies relied on advanced cloud services and, 32.7% were using big data technologies.

Lastly, digital public services measure the adoption of digital technologies by public administrations. In 2019, both the quality and usage of digital public services, such as e-government, have increased.

The DESI report 2020 analyzed the member states' progress between 2015 and 2020 and, Ireland stands out with the most significant progress in this index, followed by the Netherlands, Malta, and Spain.

Finland, Sweden, and Denmark lead the overall performance in digital, but Ireland was the country that had better progress in the past five years, occupying 6th place in this ranking (graph 1). Bulgaria, Greece, Romania, and Italy are the countries with the lowest scores in the index. Portugal was below the European Union average in the overall performance, being the 19th country (out of 28) in the ranking (European Commission, 2020).



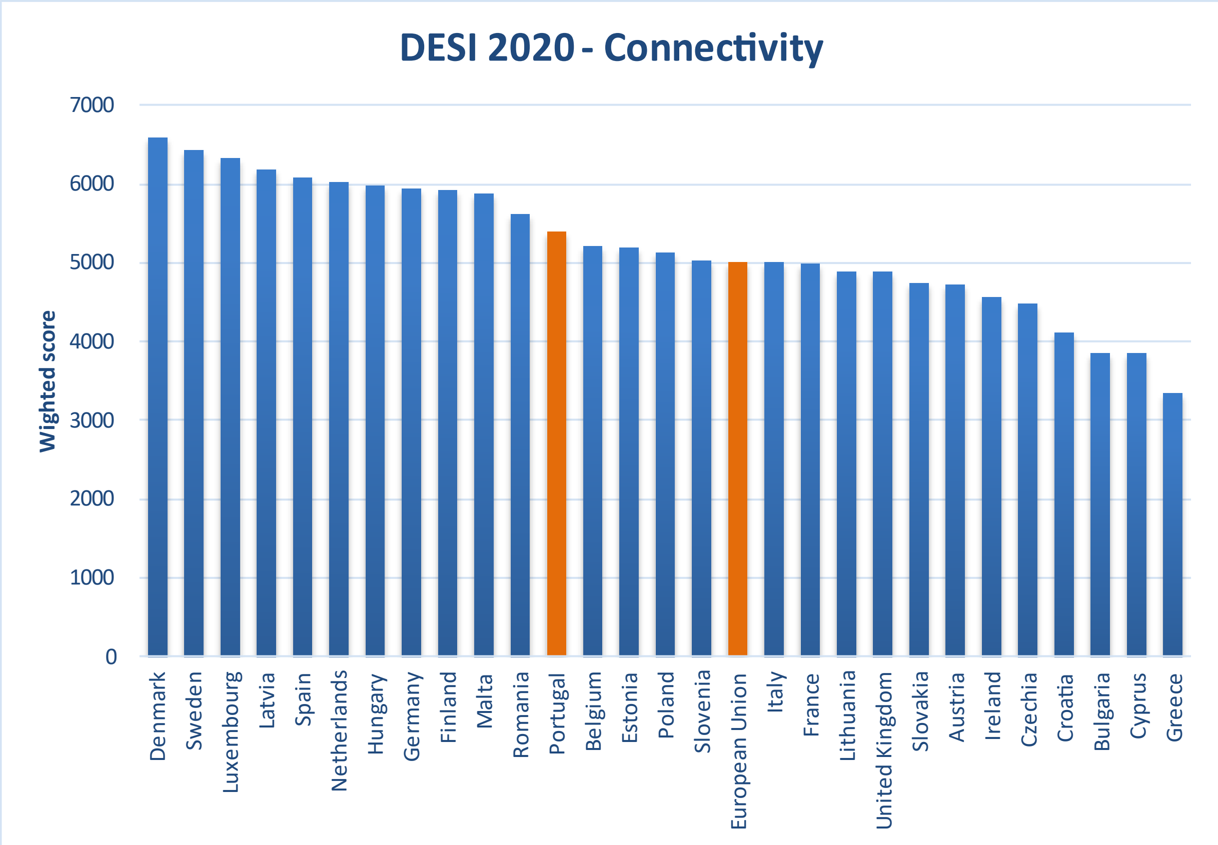
Graph 1: Digital and Economy Society Index 2020

(Source: European Commission, Digital Scoreband)

In terms of connectivity (graph 2), the country that has the highest score is Denmark, followed by Sweden and Luxembourg, while Bulgaria has once again one of the worst performances, as well as Cyprus and Greece.

Portugal, in the Connectivity and Digital Public Services dimensions, is above the EU average, occupying 12th place on the connectivity dimension and 13th on the Digital Public Services. The percentage of people in Portugal that do not have basic digital skills has been decreasing. But on the other hand, the percentage of Portuguese who never used the internet is double the EU average (DESI 2020, European Commission).

In 2019, the percentage of households that had access to fast broadband coverage was 86%. (DESI2020, European Commission)



Graph 2: Digital and Economy Society Index 2020, connectivity ranking

(Source: European Commission, Digital Scoreband)

Broadband coverage of rural areas is still one of the main issues in the EU. According to the DESI 2020 report, 10% of households in rural areas are not covered by any fixed network and, 41% of the households do not have access to NGA technologies, such as optical fiber (DESI 2020, European Commission).

Even though there have been done some efforts to increase the supply of NGA technologies in rural areas it remains a significant gap between cities and rural broadband coverage, which emphasizes the regional disparities in digital opportunities. This gap is reflected by the broadband penetration rates. In some countries, such as the Netherlands, the UK, Luxembourg, Germany, Denmark, Sweden, and Belgium, the penetration rate in cities and rural areas is similar. However, in a large group of member states, that includes Portugal, there are significant gaps of 12-30 percentage points between urban and rural broadband penetration rates (DESI 2020, European Commission).

Having access to high-speed networks is not enough. People must have the budget to subscribe to these services and fully benefit from them. In 2019, 26% of European households subscribed to ultrafast broadband (at least 100 Mbps), and Sweden and Portugal were the country's leading this ranking, with over 50% of households subscribing to at least 100 Mbps.

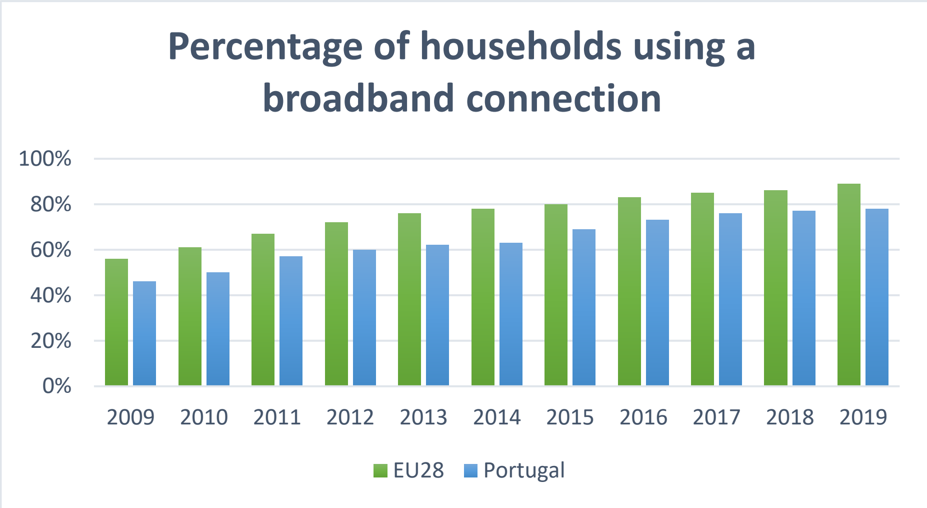
The DESI report, by showing how each country is behaving in those digital dimensions, can help the local governments to take action and improve their digital performance.

2.4 Portuguese broadband market

Portugal has a regulatory authority called "*Autoridade Nacional das Comunicações*" (ANACOM), which aims to control electronic communications. According to ANACOM in 2006, 88.4% of the consumers in Portugal had access to the internet by broadband. However, only 40% of the families had access to the internet in their homes. Since then, this number has been increasing (ANACOM, 2006).

The connection to broadband in Portuguese households is still below the European Union average. The following Graph 3 shows the percentage of households connected to the internet using a broadband connection, presenting data for the EU average (still including data for the United Kingdom) and the specific case of Portugal.

Between 2009 and 2019 it is observable an increase in the percentage of households with access to the internet. In 2010, only 50% of the Portuguese households had access to the internet, which was below the EU average (60%). In 2019, the EU average of households connected to the internet was around 90%, while for the case of Portugal, less than 80% of the households had a connection to the internet.



Graph 3: Percentage of households using a broadband connection

(Source: EUROSTAT)

Nowadays, fixed broadband can be supplied by optical fiber. In 2019, according to ANACOM data, more than half of the internet accesses were done by fiber, reaching 2 million accesses.

The telecommunication market in Portugal, in 2019, was compounded by four operators: MEO (with 40,3% of the market power); NOS (35,7%); VODAFONE (20%) e NOWO (3,7%) (ANACOM, 2019). This market is very concentrated, but Portugal is in the same situation as the majority of the European countries, where the average is between 3 and 4 operators.

The optical fiber substituted, for example, the ADSL (Asymmetric digital subscriber line) which, is also a technology that allows the transmission of data. The higher speed in transmission of information, the stronger signal, the less energy consumption and, the fact that fiber is lighter and more flexible explains the increase in fiber implementation and utilization. Nevertheless, the biggest disadvantage is related to the high costs of installation and maintenance.

Besides the increase in the use of fiber, the rural zones are less attractive to this type of investment, due to the small number of users. In that perspective normally the government stimulates the deployment of the technology in those areas. The Portuguese state under the National Strategy for Broadband, already in 2008, promoted the investment in the new generation of broadband. In that strategy, the government promised to adopt political measures that could incentive investment in optical fiber, mainly in rural areas, because the non-existence of broadband in the rural part of the country affects their economic and social development (ANACOM, 2009).

The state created five public tenders for the installation, management, exploration, and maintenance of this new generation of broadband in the rural areas, where the private operators would not usually invest. The main goal was to maximize the availability of broadband in all counties (presented on *Resolução do Conselho de Ministros nº120/2008*, July 30).

Before choosing the areas that would be selected for these projects, the competent authorities made a study to choose the counties where the perspective of private investment was lower, which includes the most isolated and less populated areas, where there are no alternative broadband infrastructures. After publicly presenting the areas chosen (around 139 counties), the companies interested made their offers. The process was closely accompanied by ANACOM and, the most economically advantageous projects won (presented on *Resolução do Conselho de Ministros nº120/2008*, July 30).

The state invested 106,2 million euros, but 103,2 million came from European funds and the other 3 million from the national budget. The direct beneficiaries of this project are the electronic communication operators that provide broadband services, but also the private users such as companies and families. The prices practiced were based on the average prices in the EU (European Commission, 2009).

In particular, the adjudication of the project took into account the following criteria (European Commission, 2009):

a) Amount of public funding required and percentage of investment made by the competitor using equity or other capital, with a coefficient of a weighting of 60%.

b) Technical quality of the proposal, with a 15% weight.

c) Quality of the Economic-Financial Plan, with a weighting coefficient of 15%.

d) Quality of the wholesale offer of access to networks, with a weighting coefficient of 10%.

DSTelecom was one of the companies that won one of the public tenders and, therefore they installed, manage, explore and maintain optical fiber in counties from North, Alentejo and Algarve. DSTelecom is a company that belongs to the DST group and has the purpose of building an ultramodern fiber-optic network in less populated areas, allowing the telecommunication operators to offer the best service available on the market.

The DSTelecom strategy pretends to “free people from the geographic barriers and builds a digital world” focusing on:

- Development of commercial and business actions that guarantee the greatest possible adhesion of operators to their infrastructures.
- Ensure operational efficiency.
- Consolidate the offer of innovative, safe, differentiated, and high-speed services.
- Search for new opportunities to expand the network.
- Monitor and develop opportunities to consolidate relevant networks, assets, and companies for the DSTelecom group.
- Attract and develop multipurpose talents.

In the present work, the Portuguese municipalities that were analyzed are the ones where DSTelecom operated and provided fiber. Therefore, in sections 5 and 6 the data presented is related to a sample of counties from north, Alentejo, and Algarve, intervened by DSTelecom, in the scope of the Portuguese National Broadband Strategy.

2.5 Fiber to the Home Technology

Fiber to the home (FTTH) or fiber to the premises (FTTP) is a technology that allows the transmission of signals over optical fiber directly from the operator's central point to our houses and businesses. This technology has been used since the 1980s, substituting the previous infrastructures, such as coaxial cable or telephone wires, to accommodate the increasing network demands of modern society.

FTTH is characterized by a connection speed of up to 100 megabits per second, which is much faster than cable modem or DSL (Digital Subscriber Line) connections. FTTH increases network performance due to the higher speeds over a long distance and higher bandwidth.

FTTH improves the performance for high-definition video streaming and allows multiple upgrades. FTTH provides the consumers with more daily applications, for example, teleworking, e-health, video-on-demand, and video communication with family, friends, or coworkers. FTTH technology has environmental advantages because it reduces energy consumption and, fiber makes it possible for people to work from home, which can lower the carbon footprint.

The installation of this technology can be costly, and in the alternative, some countries use Fiber to the Curb (FTTC), which corresponds to the connection of optical fiber cable to the curbs near to homes and businesses and then transfers the signal to the residences of the end-users.

The FTTH Council Europe is an organization that aims to create a Digital Society by providing larger fiber connectivity. The Council believes that this technology can enhance the quality of human life while improving the environment as well as increasing economic competitiveness and growth. The annual FTTH Council Europe Report published in April 2020 has come to some important conclusions. In 2019, more European governments implemented subsidy programs to incentive the installation and use of the FTTH, mainly in rural areas. However, FTTH investments have been delayed due to alternative technologies such as FTTC.

The Digital Agenda for Europe has clear goals for providing fiber in isolated areas. By 2025 the main objectives include (European Commission, 2020):

1. Provide a 1 Gbps connection to all socio-economic institutions, such as schools and transports.
2. Provide an internet connection of at least 100 Mbps to all European households.
3. Guarantee uninterrupted 5G coverage in all urban areas and on the main roads and railways.

According to an annual study made by IDATE for the FTTH Council Europe, in 2019 Portugal was the country with the highest rural FTTP coverage, leading this ranking with a 53% coverage, followed by Spain (42%) and Sweden (38%). In this indicator, Portugal is much better than the EU28 average (18%) (IDATE, 2020).

DSTelecom is one of the companies that has been contributing to these good results. DSTelecom is responsible for providing optical fiber to one-third of the Portuguese counties. DSTelecom takes fiber to 400 thousand houses located in 95 rural counties, with a network open to all the telecommunication operators.

3 Literature review

The literature agrees that high-speed broadband, such as optical fiber, has a positive impact on the overall economy. The diffusion of broadband infrastructures is a great driver of economic growth and provides direct and indirect benefits for consumers and businesses. Forzati and Mattson (2011) investigated the social and economic effects of FTTH in Sweden, using a multivariate regression analysis, and made a distinction between the direct and indirect effects. The direct effects are the ones that result directly from the FTTH installation, such as higher access capacity, new infrastructures, and direct economic values generated by networking. The indirect effects can include better service quality, which may lead to the development of new services (e-learning, teleworking, e-government, e-health) and the creation of new businesses.

Mason (2012) used two complementary methodologies, an input – output analysis and a consumer surplus estimation, and identified nine categories of socioeconomic effects of high-speed broadband, which are: employment and economics; environment; community; equality; education; health care; well-being; crime, security, and access to online authorities. The effects of a better broadband connection can take some time to be noticed because having optical fiber is not enough. It is necessary to change and adapt activities, processes, and organizations as well as education and training to see the effects. (Whalley & Sadowski, 2015).

The literature suggests that a higher broadband penetration benefits economic growth (Czernich et al., 2011) because it decreases the production costs of a firm and increases labor productivity (Akerman et al., 2015), both in public and private sectors (Qiand, 2009). Therefore, the existence of broadband is an indicator of the local economic activity because a higher broadband penetration is associated with higher productivity (Kolko, 2012; Mack and Faggian, 2013).

Czernich et al. (2011) also found a correlation between broadband penetration and GDP per capita, using data from 25 OECD countries, during a 1996 to 2007 period. Czernich used an instrumental variable model which derived its non-linear first stage from a logistic diffusion model where pre-existing cable TV networks predicted maximum broadband penetration. He concluded that when the broadband penetration increases by 10 percentage points, the annual GDP per capita tends to increase by 0.9 to 1.5 percentage points. A 10-percentage point increase in broadband penetration will increase by 1,21% of the GDP growth in developed countries and by 1,38% in developing countries. Overall, with more broadband availability the impact on GDP per capita is between 2,7% and 3,9% (Minges, 2016).

According to USA data, broadband positively influences the productivity of a region, but only if the population is highly educated (Mack and Faggian, 2013). Also, an improvement in the telecommunications supply can have a positive impact on revenues in sectors such as finance, insurance, and real estate (FIRE). Duplicating the kilometers of optical fiber will increase the FIRE revenues by 10 – 45% (Greenstein and Spiller, 1995). There is empirical evidence that shows a connection between broadband and productivity, but it depends on the level of broadband penetration. Waverman (2009), found that in OECD countries with medium or high broadband penetration there is a 0.13% increase in productivity for each percentage point of broadband penetration. However, the same does not happen for low-penetration countries (Katz, 2012).

A better broadband system has an impact on the number of companies because it attracts new business ideas. Companies have a higher probability (55%-98%) of installing their infrastructures in places where broadband is available. The non-existence of broadband in a rural area decreases the number of firms in that county (Whitacre et al., 2014). An increase of 10% on the optical fiber availability increases by 0,08% de number of firms per 1000 inhabitants, per year (Molleyrd, 2015).

Dutz et al. (2009) suggested that broadband can have a positive effect on business innovation and business operations. When a company uses a broadband system, all the costs related to the information and communication technologies decrease. For example, online sales are facilitated which can affect negatively the local market (Bresnahan and Hitt, 2002) but will benefit the firm's profits. Companies that have access to optical fiber can easily attract consumers and suppliers that are distant in geographic terms (Stenberg, 2009) and also creates new job opportunities, such as telework (Crandal and Jackson, 2001). However, these changes may not be seen immediately. Colombo et al. (2013)

highlighted that having access to high-speed broadband is not enough to obtain productivity gains, companies must make structural or strategic changes.

Literature also argues that broadband and consequently the use of ICT stimulates innovation. Katz (2012) says that the innovation effects of broadband can be of numerous forms, such as new applications or services, for example, e-commerce, e-learning, telemedicine, and social networks. Atkinson et al. (2009) also enumerate new forms of trade, optimization of distribution chains, and massive customer customization of goods. Still related to innovation, Kim and Orazem (2012) showed that a 10% increase in access to broadband in rural areas leads to a 1.6% increase in the number of start-ups.

Many studies find a correlation between employment and broadband. Fabritz (2013) showed that the impact of broadband on employment varies between sectors. Also, Fabritz clarifies that broadband has positive effects on employment but not necessarily on the employment rate. Still, he found that the impact on employment rates is greater in rural areas than in cities. The increase of broadband tends to diminish the unemployment rate of a region however, the impact is higher in rural areas. In cities, an increase in broadband availability does not affect the employment rate (Whitacre et al., 2014). Kolko (2012) concluded that broadband may increase local employment by 6.4%. Forzati and Mattsson (2011) used Swedish municipality data and, concluded that a 10% increase in the proportion of the population with access to FFTH reflected a 0.2% increase in the employment rate, at the municipality level, after 2.5 years of the installation of the optical fiber. Kandilov and Renkow (2010) found positive effects on employment in urban areas but non-existent or negative in rural areas. Additionally, Stefano et al. (2014) found no relation between broadband and employment per workplace. Whitacre et al. (2014a) reinforce that the positive impact on employment happens if there is a high broadband use.

Some studies prove that the use of broadband increases consumer surplus. Dutz et al. (2009) estimated that in the USA, the consumer surplus from using broadband at home is 32 billion dollars each year. The increase in the consumer surplus is related to the change in the attitude towards broadband because previously it was considered a luxury and now is a necessity.

Ahlfeldt et al. (2017) analyzed the impact of broadband speed on house prices in the United Kingdom. They used data from 1995 to 2010 and concluded that a high-speed connection, such as optical fiber, can add up to 5% to a house price. A United Kingdom survey from 2013 concluded that 1 in 10 potential buyers reject a new home if that house has a poor broadband connection. Also, 54% of the potential buyers consider the broadband speed before moving in and, only 37%, take into account the local crime rate, which shows the increasing importance that the citizens give to a better broadband connection (Ahlfeldt et al., 2017).

The majority of the literature does not find an impact of broadband on wages (Gillet et al., 2006) unless we have a highly educated population (Greenstein, 2012). Also, broadband has higher benefits for rural areas rather than cities (Kim and Orazem, 2016) and has better effects on developing countries (Minges, 2016).

Katz et al. (2010) used German data and calculated the broadband impact on employment and production. Using an input-output method, Katz et al. (2010) argued that optical fiber can have a positive impact on GDP and job creation. However, in another study using data from the USA, Lehr et al. (2005) did not find any positive impact of broadband on employment and wages. The same research noted that the share of small firms decreased in municipalities with broadband, relatively to non-broadband counties.

Even though broadband can have numerous advantages, it can also lead to some negative effects such as less privacy and, the ease with which information circulates online and can be used negatively or illegally.

To come to these conclusions, the majority of the literature uses panel data and a difference in differences strategy. Some use data from firms during a specific period, analyzing sales, profits, and annual balance sheets. The intention is to compare these variables before and after the installation of optical fiber. There appears to be a positive correlation between these variables and the existence of fiber (Schuller, 2015).

Other studies investigate the spatial/regional effects of fiber and, therefore, they compare municipalities also using diff in diff method. They create two groups: a control group with municipalities with no optical fiber and a treatment group with municipalities where fiber exists. This approach can also be done with firms that use optical fiber and firms that do not have access to it. When considering what firms to include in these studies, usually the nonprofit organizations, government agencies, and establishments with public services, such as museums are excluded, because they do not have the purpose of profit maximization (Kim and Orazem, 2016).

One study from the USA divided counties, taking into account the number of citizens, and a county with less than 20000 people was considered a rural area. After doing this distinction, they used a diff in diff strategy for rural and non-rural areas to see what differences exist in terms of economic growth and social development. Other studies prefer to use labor productivity as the dependent variable and compare two periods, one before the implementation of fiber and one after. The main goal is to analyze the impact of fiber on a firm's productivity, which tends to be positive.

In general, the econometric models are divided into three categories: cross-sectional, panel, and time series. The cross-sectional studies are used to measure the impact across a certain group of countries, regions, or firms during a specific period (panel and time series).

The main variables used were: initial investment cost; demand for services; revenues from data transmission services; business benefits; consumer surplus; e-government savings; e-health savings. Normally the costs include all the construction and planning costs of the infrastructure, while the benefits are the advantages for the consumers (families, companies and government). Following the literature, in our investigation, we used the initial investment cost and calculated the business benefits and household consumer surplus, as can be found in sections 5 and 6.

The present work opted for a Cost and Benefit methodology because it is a common tool used to analyze the socio-economic impacts of major investments, suggested by the European Commission. A Cost and Benefit analysis estimates and attributes a monetary value to the total benefits and total costs of a project to conclude if they are worthwhile or not.

A CBA is a complete instrument because it gathers all the costs and benefits related to investment and allows the policymakers to make more conscious decisions, and facilitates an efficient allocation of resources. Other methodologies focus on analyzing a specific economic indicator, while with a CBA, it is possible to measure multiple effects. For example, Katz et al. (2010) used the input-output method to realize the broadband impact on employment. This method is normally used to investigate the relationship between economic sectors, but it has the disadvantage of being robust in estimating the indirect benefits. Fabritz (2013) found a correlation between employment and broadband using regression analysis. The regression analysis method can be used to estimate the relationship between a dependent variable (normally the employment or GDP) and other independent variables. The downside of this method is the necessity to have enough data available, which sometimes is hard.

With a CBA, it is possible to calculate all the economic and social benefits from a project. The rationale behind a CBA is that sometimes the decision-makers only focus on the profit motivations and price mechanisms, which can result in socially undesirable outcomes. Therefore, with a CBA technique, social welfare is considered and, the external effects of investment are valued, at their social opportunity cost. Therefore, the present paper opted to analyze the costs and benefits of the broadband implementation in rural areas, based on the European Commission report (EC, 2014), released within the scope of the European Digital Agenda 2020.

4 Optical fiber and Covid-19

The COVID-19 pandemic has impacted socially and economically the world, leading to problems such as the reduction of GDP and job losses. Beyond the dramatic consequences on people's health, there were also negative effects on the economy.

The pandemic and its associated restrictions are impacting the EU economy and clarifying how important connectivity, digital skills, and digital technologies and services have become for the resilience of economic activity and, possibly, economic growth. Modern societies were obligated to change in a short amount of time, which accelerated the digital transition. Before COVID-19, internet access was not a priority for some people, but now it is crucial.

The adjustment of society to this unprecedented event has resulted in an increase in research and innovation, not only in the healthcare system. To protect public health, the governmental policies forced companies, schools, universities, and businesses to close, which accelerated the implementation and use of digital technologies.

Online technologies became crucial in society, from telemedicine, teleworking, online shopping, online learning, and more. Therefore, digital technologies became the base to maintain active all social interactions, allowing many digital inequalities to be known. Digital inequalities are not just related to the differences in access to technology but also differences in digital literacy (Latzer, 2018). Digital literacy evaluates whether or not the individuals have the knowledge and competence to access, engage and understand the information obtained from the digital technologies.

The pandemic has demonstrated some of the factors that can explain the existing digital inequalities, which can be related to the technical means and the autonomy of use (Fernandes, 2020). Low-income households presumably have less technical means, for example, fewer technological devices or outdated equipment. (Fernandes, 2020; Parolin, 2020; Wang and Tang, 2020). Poorer families may not be able to invest in better equipment but also, they may be unable to work from home because they do not have the tools for it. In terms of household connection to the internet, there are also differences. Access to high-speed broadband that facilitates online communication is not available for everyone. Rural areas still have a lack of access to a broadband connection.

Another factor for the digital inequalities is the autonomy of use. With the closure of many workplaces and public facilities, such as libraries, people who only had access to the internet through these places stop having access to the online world. Even the families that had access to the internet in their homes started to have some problems with some of their online activities because there were more people at the same time using the internet, which can delay the processes (Fernandes, 2020).

The pandemic also made it possible for students to have classes from home, which reflected not only the economic differences between children but also the different access to the internet. Once again, the rural areas were at a disadvantage due to the lack of better broadband infrastructures, making it difficult for the students to attend their classes.

Being aware of these differences, the EU has created a budget of 1074.3 billion euros to invest between 2021-2027 in the digital transition process. This investment is a great opportunity for the EU members to accelerate the digitalization process and converge the long-term objectives set by the Europe Digital Agenda.

On the other side, the pandemic and the rise of teleworking has proved that some jobs can be decentralized, allowing the workers to live in rural areas (where the cost of living is lower and the quality of life is better) while working for companies located in big metropolitan areas. This situation could help to decrease the housing prices in big cities as well as increasing the population in rural areas, fighting against the desertification of these counties.

Covid-19 pandemic has reinforced the reliance on digital tools which, consequently, increased the pressure on improving the broadband infrastructures, especially in rural areas. Therefore, the current situation is clarifying, even more, the relevancy of optical fiber implementation in as many areas as possible, providing the right tools for people to fully benefit from this digital transition.

5 Methodology and data

5.1 Initial data

As explained in the previous section 2.3, the data used in this work is related to a diverse sample composed of 63 Portuguese rural counties from North, Alentejo, and Algarve. DSTelecom was the company that provided optical fiber in these counties, in the scope of the Portuguese National Broadband Strategy, co-financed by the government and the EU.

According to *Associação Nacional dos Municípios Portugueses* (2014), a county is considered as rural when the population density is below 150 inhabitants/ Km². Therefore, the municipalities presented are all rural since all of them have less than 90 inhabitants per Km².

In this section, indicators from six of those 63 counties will be analyzed, providing a general characterization of the municipalities: territory; resident population; population density; total number of houses; number of houses connected to fiber; municipal GVA. The year of reference is 2019 and the counties are: Arcos de Valdevez, Arouca, Arronches, Salvaterra de Magos, Serpa and, Torre de Moncorvo. The full data can be found in the Appendix.

In 2019, the resident population was less than 21 000 inhabitants and, the number of houses was less than 18 000, in the selected six municipalities as supported in the following table 1. Salvaterra de Magos had a higher resident population, but the smallest territory in Km².

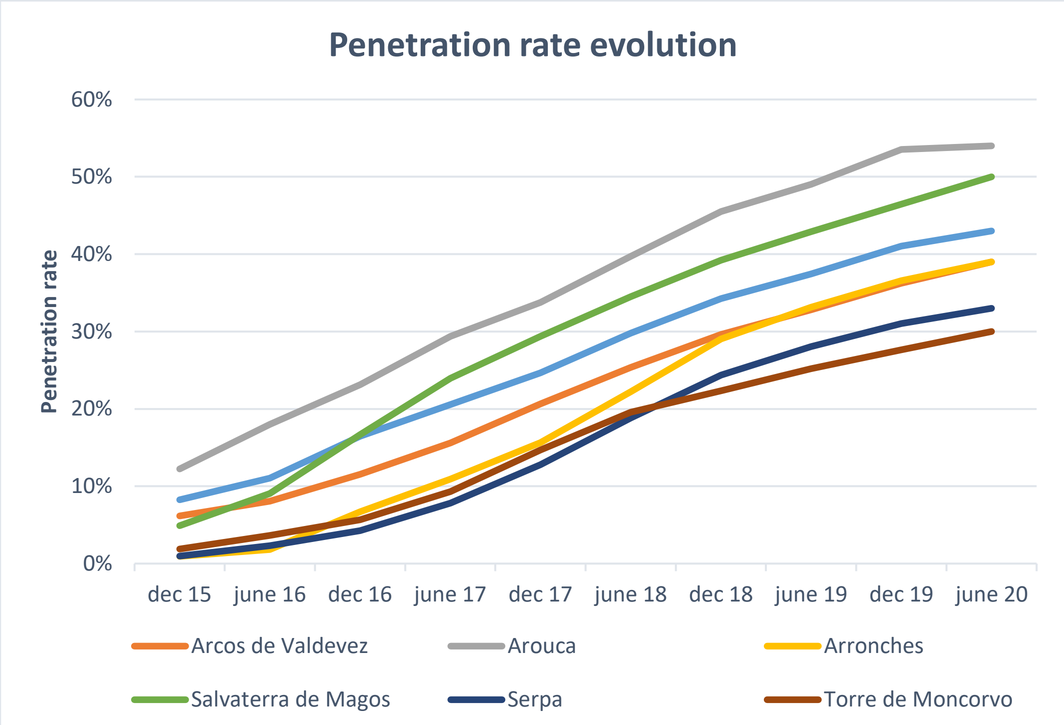
The municipal gross value added for the non-financial companies' is one of the indicators presented on the table 1. The Gross Value Added (GVA) is an economic productivity metric that measures the contribution of a company or a municipality to an economy, producer, sector, or region. The GVA is the value that the economic activities add to the goods and services consumed in its production process. In other words, it is the contribution to the Gross Domestic Product (GDP), obtained by the difference between the production value and the intermediate consumption absorbed by these activities. In the selected counties, in 2019, Arouca and Arcos de Valdevez had higher GVA, while Arronches had the smallest GVA. Arronches is also the county with a lowest resident population and population density.

Table 1: Municipalities socioeconomic and fiber connections characterization:

County	Territory	Resident Population	Population density	Houses	Houses connected to fiber	Municipal GVA
	Km²	N.	Persons/km2	N.	N.	M€
Arcos de Valdevez	448	20948	46.8	17670	9010	110744
Arouca	329	20791	61.9	11070	6336	151624
Arronches	315	2840	9.0	2565	1404	7023
Salvaterra de Magos	244	21282	87.2	11999	10287	85742
Serpa	1106	14339	13.0	10385	6067	45332
Torre de Moncorvo	532	7706	14.5	7365	4250	16505
Source:	PORDATA	PORDATA	INE	INE, estimations based on 2011 Censos	DSTelecom	PORDATA

Houses connected to fiber are considered to be all of those who have the possibility of subscribing to optical fiber, through the services of the telecommunications operators on the market. Thus, the estimated percentage of houses connected to optical fiber in 2019, was between 50% and 60%, except for Salvaterra de Magos that already has 85,7% of houses with access to high-speed broadband.

The percentage of houses connected to fiber has been increasing over the last decade, as well as the penetration rate in rural areas. As presented in Graph 4, below, in all the counties it is observed a gradual increase in the broadband penetration rate between 2015 and 2020. In December 2015 the lowest penetration rate was 1% in Serpa and Arronches, while in June 2020 this rate increased to 33% and 39% respectively. The highest penetration rate in these counties was only 12% in Arouca (December 2015), keeping this place up to 2020, with 54%.

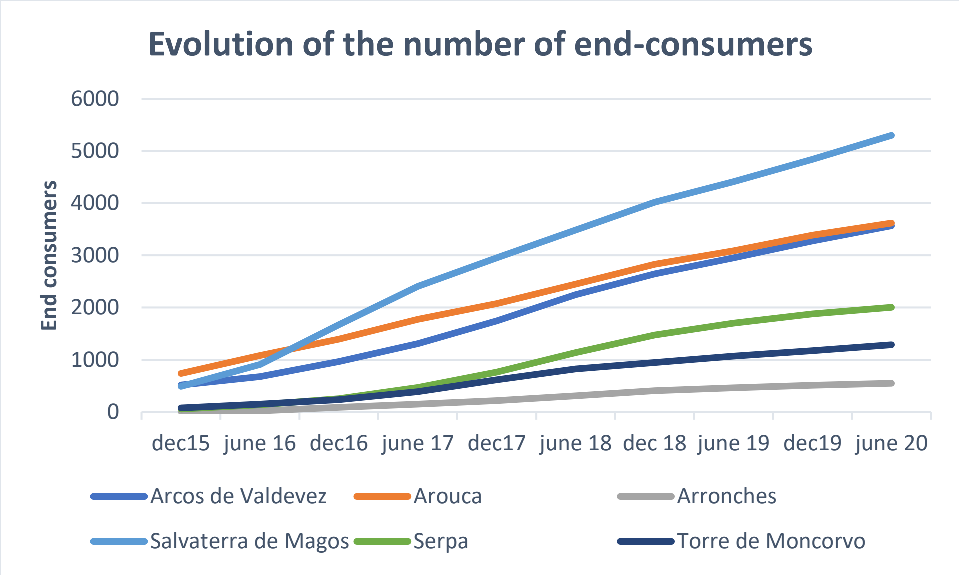


Graph 4: Penetration rate evolution

(Source: DSTelecom)

According to DSTelecom data, in 2015, all of the 6 counties had only one telecommunications operator, but after the implementation of optical fiber, the number of suppliers of internet services has been increasing. In 2016 the second operator entered the market and, the third entered only two years later.

Between 2015 and 2020, with a better penetration rate, the number of end consumers has increased in all the municipalities presented. Arcos de Valdevez, Arouca, and Salvaterra de Magos had the best increase in the number of end-consumers. This situation can indicate that the improvement in broadband facilities has contributed to an increase in consumers, which means that more people are using internet services in that area.



Graph 5: End-consumers evolution

(Source: DSTelecom)

Since 2015, the improvement in the penetration rate and on the end-consumers indicators is evident in all the counties under analysis, as can be observed by graph 4 and 5. This progress is a consequence of the installation and supply of optical fiber in these counties. As already said, DSTelecom was the company that won the public tender and was responsible for the construction of fiber infrastructure in these areas. DSTelecom gave some data for the initial investment made and the initial number of houses that were covered by the project. For a total of 89 counties from the North, Alentejo, and Algarve regions, the initial investment was more than 83 million euros, covering more than 240 thousand houses.

Table 2: Initial investment and initial houses covered.

Region	Initial Investment	Initial houses covered
North	49 925 224€	145 070
Alentejo and Algarve	33 512 460€	96 619
Total	**83 437 684€**	**241 689**

Source: DSTelecom

5.2 Survey

The methodology for this work is divided into two sections. The first section is a survey that was sent to selected rural city councils. According to Aaker et al. (2001), the construction of a questionnaire is considered an “imperfect art” because there are no exact procedures to guarantee that our main objectives will be achieved.

However, some stages need to be considered while writing a questionnaire. First, it is crucial to plan what we want to achieve with the survey, which in this case is to understand the benefits of optical fiber in rural areas. Secondly, the questionnaire needs to be structured. The questions need to be clear and precise and must be grouped according to some subtopics. Lastly, before the distribution of the survey, it must be reviewed and corrected to ensure that it faces the purposes.

Our inquire had 17 questions, mainly multiple-choice and scale questions. Multiple choices questions are easier and faster to answer, have less chance of errors, and are also easier to analyze. The scale questions are based on the Likert scale, which presents five propositions (strongly disagree, disagree, agree, strongly agree, and does not know), from which inquires must choose.

The inquire was sent via e-mail to presidents or vice presidents of a sample of 89 counties from North, Alentejo, and Algarve, in the areas where DSTelecom has installed optical fiber. The response rate was 70.8%, and the main conclusions are presented in section 6.1 Digital features of the municipalities - Survey results.

5.3 Cost-Benefit Analysis Methodology

5.3.1 The CBA theory

A Cost-Benefit Analysis (CBA) is a technique that is currently used in governments and international organizations, like the OECD and the World Bank. A CBA is a study that presents the cost and benefits of a project, which are the advantages (benefits) and disadvantages (costs) of an investment, calculated at a point in time, normally the present time (Ward, 1991).

A CBA is a tool commonly used in major investments to decide whether these projects should be co-financed with public funds or not. A CBA is strategic planning that clarifies the decision criteria and allows the decision process to be less arbitrary and less ambiguous (Ward, 1991). Also, a CBA is a microeconomic approach that allows the assessment of the project's value through the calculation of economic performance indicators and, can have an incremental approach, comparing a scenario with the project implemented and another without the project. In other words, a CBA can enable efficient use of limited resources, making sure the project with the best value is chosen (EC, 2014).

A Cost and Benefit method is inspired by the Pareto concept, meaning the social value of output being so increased that everyone can be better off by the change in question, which is after the project implementation. With a CBA, the goal is to improve the welfare of the population, and if the total benefits exceed the costs, a potential Pareto improvement is realized (Mishan, 2007).

The CBA framework contains some concepts, such as: numeraire, which is the unit of account of benefits and costs; opportunity cost, which is the potential gain from the best alternative forgone when a choice needs to be made between several mutually exclusive alternatives; long-term perspective, the CBA has to forecast future costs and benefits, attributing a monetary value to all the positive (benefits or revenues) and negative (costs or expanses) welfare effects of the intervention (Ward, 1991). Also, the discount rate is an important concept. The discount rate is the expected rate of return for an investment. The real discount rate in economic analysis is considered to be 5% (EC, 2014), which was the value assumed by us to calculate the annualized costs.

When creating a CBA, it is important to identify some of the effects of the project and their expected relevance, and detail some variables, such as the investment cost; the expected lifetime of the infrastructure; the expected demand services; the anticipated market share; the government savings; the expected revenues. The initial investment cost includes the capital cost of the fixed assets, such as planning, land, construction, equipment. The expected lifetime of the infrastructure, for the case of broadband infrastructure is between 15-20 years, but it may be longer (EC, 2014).

In the following section it will be explained in more detail the how a CBA should be done, int the case of a broadband project.

5.3.2 The case for broadband CBA

As previously defined, according to the "Guide to Cost-Benefit Analysis of Investment Projects" of the European Commission (2014), broadband investment has to analyze some elements, like the socio-economic issues that might affect the demand, the technical conditions (areas already with broadband infrastructures, population density…) and the market conditions. The European Union created the Digital Agenda in 2010 with some main goals (to be achieved until 2020) such as, all Europeans should have access to much higher internet speeds of above 30Mbps and at least 50% of European households should have an internet connection above 100 Mbps. This investment was expected to have an 89% return on its costs by the end of 2020.

The EU digital agenda built a forecasting framework with some key assumptions that reflect a cautionary approach, as both the total cost could be reduced with similar performance levels and the financing could be stretched over a longer period. The EU model has three variables: the fixed capital investment, labor participation and, the net additional broadband subscribers until the targets of the Digital Agenda are reached. The model is used to estimate the impact of broadband infrastructure and its outputs.

Broadband investments have economic effects that can only be realized after they have been deployed because, the investment made today, might only be reflected after some years or decades. This EU project is expected to have a net benefit of more than 222 billion euros. The payback period is considerably shorter than the useful economic life of the infrastructure, which may suggest that the direct macroeconomic advantage is significantly higher than its cost. The lifetime of fiber infrastructures can be affected by many factors, for example, environmental factors and also the maintenance, but the expected lifetime is considered to be 15-20 years (EC, 2014).

This broadband project is expected to have many socio-economic benefits such as less time spending on internet browsing; the possibility of having more people online; making the best use of network capacity; the improvement of micropayment mechanisms; extending the reach of smart solutions; reducing the opportunity cost of providing goods and services through the internet; equity in access; increase on the cost savings in the public sector; more operational efficiency gains (EC, 2014). Broadband investments are expected to have an environmental benefit, by having a neutral or positive effect on CO_2 emissions.

According to the European Commission (2014), the costs of implementing optical fiber may include:

- Planning and design fees.
- Land purchase value for the broadband infrastructure.
- Building and construction costs.
- Plant and machinery that was bought.
- Possible contingencies.
- Price adjustment (if applicable).
- Technical assistance.
- Project publicity.
- Supervision costs during construction implementation.

The benefits are harder to predict because there is uncertainty with the revenues and advantages that come from the fiber infrastructure. The socioeconomic benefits are usually calculated by applying proxies for the consumers' willingness to pay. The economic benefits are the direct advantages of the broadband implementation, for example:

- Business benefit per employee: expressed as a percentage increase of local gross value added, per employee in the private sector.
- Household consumer surplus: Estimation of consumer surplus from NGA-types adjusted for differences in income levels and differences in the costs of living.
- E-government savings: estimation of savings from the e-government activities annually.
- Tele-health-care benefits: estimation of the annual savings from the tele-health-care activities, normally presented as a percentage of the local health budget.
- Demand for services: the expected demand for broadband services, normally expressed as the number of consumers.
- Revenues from data transmission services.
- Revenues from the leasing of infrastructure: Revenues from leasing/renting the broadband infrastructure to the telecommunication operators.

The two areas that were identified to have a higher probability to benefit more from the development of fiber are the consumer benefits (measured as consumer surplus per month per household, from online savings, communication and entertainment) and the business benefits (calculated as productivity improvement, reflecting the improved efficiency and innovation). The other areas (e-government, e-health, e-education, environment...) are harder to calculate because the evidence is insufficient to quantify the value from these benefits.

The assumptions made by European Commission in the calculations of the previous benefits can be adapted because the model allows for flexibility. Therefore, our calculations, for the Business benefit per employee and the Household consumer surplus, were based on the European Commission guide but some changes were made and will be explained hereafter.

Formula 1, below, is used by the European Commission to calculate the business benefit per employee:

$$BBpe_i = GVA_i \cdot Ne_i \cdot \Delta\%GVA_i \tag{1}$$

i: region

$BBpe$: business benefit per employee

GVA: Gross Value Added

Ne: number of employees connected to basic NGA broadband as a result of the project

The percentage rise in the Gross Value Added per employee has estimated values of 4.5% if there is a new connection to basic broadband; a 6% rise if there is a new connection to high-speed broadband, such as fiber; or a 1.5% rise if there is an upgrade from basic broadband to high-speed broadband such as fiber. European Commission defines basic broadband as ADSL, cable and satellite networks (EC, 2014)

These values are proposed by the European Commission as a result of an analysis of productivity resulting from broadband take-up, combined with a study made by the International Telecommunications Union (ITU). The European Commission report (2014) suggests that an average potential rise in GVA per employee is between 6% and 11% in the EU member states. The ITU also studied the impact of broadband on GVA rise and, they assumed that doubling the broadband speed results in a 0.3% rise in GVA.

Therefore, the values presented above were calculated by combining both studies. The GVA rise due to basic broadband is suggested to be 4.5% because 6% minus 5*0.3% equals 4.5%. The 0.3% is multiplied by five because it is assumed that basic broadband speed needs to be double, approximately five times to reach the NGA broadband speeds. The GVA rise resulting from an upgrade from basic broadband to high-speed broadband is calculated as the differential between the NGA broadband (6%) and the basic broadband (4.5%).

In the present work, it was calculated the business benefit per employee for the counties that had answered our survey (63 counties). In the calculations, it was assumed two scenarios, one where there was a new connection to the optical fiber (6% rise of GVA) and the other considering an upgrade from basic broadband to fiber (1.5% rise in GVA).

Adapting the European Commission formula (1), the business benefit was calculating as:

$$BBpe_i = MGVA_i \cdot Ne_i \cdot \Delta\%GVA_i \tag{2}$$

i: region

$BBpe$: business benefit per employee

$MGVA$: Municipal Gross Value Added

The variable for the number of employees connected to optical fiber in their workplace was eliminated from the formula, because according to the European Commission, the majority of the companies are micro, small and medium companies and, therefore it can be considered that the average of employees using modern ICT in their daily work is 1.

The percentage rise in the GVA assumes the value of 6% if there is a new connection to optical fiber (scenario 1) and 1.5% if there is an update from basic broadband to fiber (scenario 2). The business benefit is measured as euros per year.

Formula 3, below, is used by the European Commission to calculate the Household Consumer Surplus:

$$HCSpe_i = CS_i \cdot Ne_i \cdot BC * 12 \tag{3}$$

i: region

$HCSpe$: Household consumer surplus

CS: Level of Consumer Surplus

Ne: number of households connected to basic NGA broadband as a result of the project

BC: Benefit Cost Ratio

12: number of months per year

The level of consumer surplus is calculated as the willingness to pay minus the subscription fee and it is assumed to be 12€ per month and household if there is a new connection to basic broadband; 8€ per month and household if there is a new connection to high-speed broadband, such as fiber; and 4€ per month and household if there is an upgrade from basic broadband to high-speed broadband such as fiber.

To calculate the level of consumer surplus, the EU applied the benefit transfer method, estimating the consumer surplus from NGA services derived from the industry study and adjusted for differences in income levels and the costs of living, using Eurostat data on GDP per capita in purchasing power standards.

Once again, to calculate the household consumer surplus was assumed two scenarios, one considering a new connection to fiber (8€ per month per household- scenario 1) and the other supposing a 4€ per month per household (upgrade from basic broadband to fiber - scenario 2).

Adapting the EC formula (3), the Household Consumer Surplus was calculated as:

$$HCSpe_i = CS_i \cdot Ne_i * 12 \quad (4)$$

i: region

$HCSpe$: Household consumer surplus

CS: Level of Consumer Surplus

Ne: number of households connected to basic NGA broadband as a result of the project

12: number of months per year

The Benefit Ratio was not considered, because it can create a circular problem. The number of houses connected to fiber were estimated based on DSTelecom information. Once again, the year in analysis is 2019. The household consumer surplus is measured as euros per year.

6 Results

6.1 Digital features of the municipalities

As previously said, installing and providing better broadband facilities may not create real benefits, if the population and the companies do not have the digital skills to fully benefit from this network, or if they do not have access to it, at affordable prices. Therefore, in order to have a better characterization of the municipality's context, it was created an online inquire with 17 questions, with the main purpose of qualitatively framing the fiber benefits. The response rate was 70.8%, as 63 of the 89 municipalities responded to the survey.

The inquire was sent to presidents and vice presidents, so we could have an opinion of someone who is close to the people and the local businesses and could give a general view on the topic. Some of the questions on the survey were focused on the Council access and utilization of the fiber networks. Since, it will be calculated in the next sections the business benefits and the household consumer surplus, it was lacking the benefits that the public sector also has. So, with this survey it may be possible to have an idea of what an optical fiber connection can improve in a Municipal Councils and the e-government services associated.

96.83% of the respondents are connected to optical fiber, from their Municipal Councils and of those, 87% already had fiber before 2020. The average number of people working in the different Municipal Councils who had access to computers and, consequently, to the optical fiber network through these devices has been increasing. In 2019, on average 119 public had access to fiber, while, in 2020, it was 128 and a standard deviation of approximately 85.

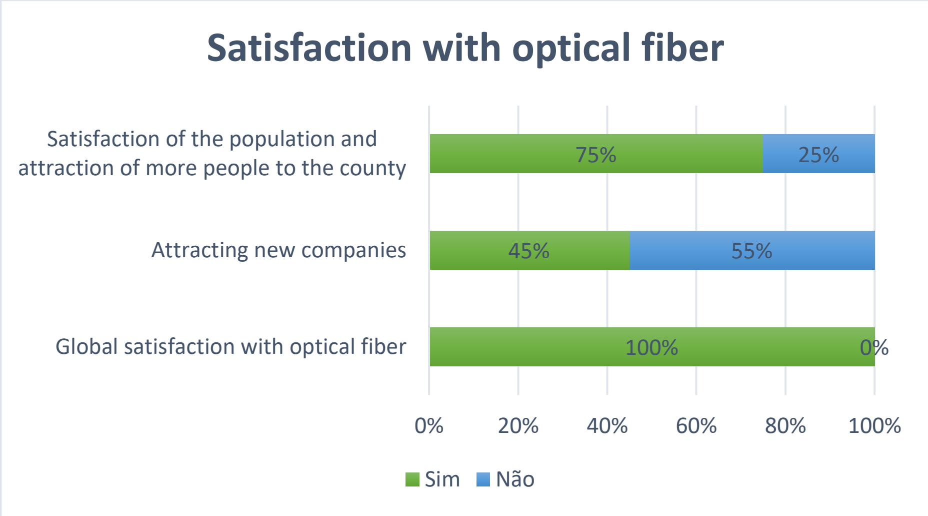
Regarding activities or areas of work that are computerized at the City Councils, 100% of respondents have computerized the management of financial, administrative, and human resources activities. 98,41% of respondents have computerized document management and the internal exchange of files. The registration, organization and, processing of information is computerized in 96,83% of the surveyed city councils. Internal communication is also computerized in 95,24% of Municipal Councils.

All the City Councils surveyed have a website and in terms of the e-services available on their websites: on all of them, the downloading and printing of forms is allowed; however, the online filling and submission of these forms are only possible in 73.3% of the City Councils' websites. On 91.8% of the websites, it is possible to consult public processes. Online service is only possible on 39% of the sites however, user support is possible on 63.90% of them. Regarding online ticketing only in 6.80% of the sites, this feature is active.

Regarding teleworking, 96.86% of the respondents consider it as a possibility in the City Council and some insights were collected about the benefits of teleworking. The opinions collected were as follows:

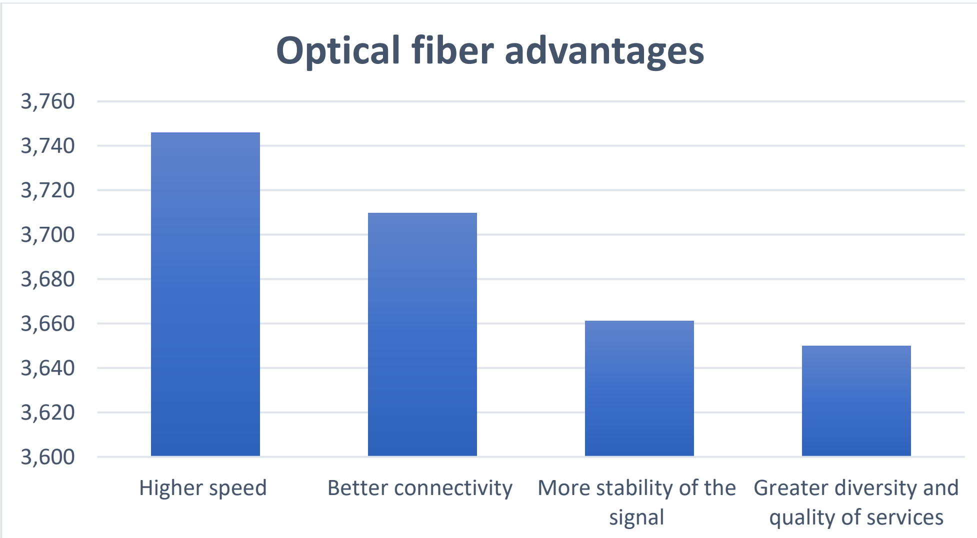
- Direct articulation between professional and personal life.
- The possibility of keeping employees closer and with more time for the family.
- More safety because of the pandemic, avoiding concentration of people.
- Being able to work from anywhere.
- Greater mobility and time flexibility.
- Decrease travel.
- Greater freedom and autonomy, which can help the worker's productivity and time management, as well as being more cost-effective for the worker.
- Decentralization of services.

Through the feedback of the Council’s representatives, the survey also tried to understand people's and companies' satisfaction with optical fiber. Globally, 100% of the respondents are satisfied with fiber. 75% of respondents considered that people were more satisfied and more willing to settle in the municipality, after the installation of fiber. Regarding the number of companies in the municipality, 45% of respondents believe that there has been an increase in the number of companies after the installation of optical fiber (see graph 6). It should be noted that other factors can contribute to this situation. Furthermore, this may not yet be the actual impact of optical fiber, as it takes a few years after fiber installation before all the benefits can be noticed.



Graph 6: Satisfaction with optical fiber

The optical advantages are known and one of the main reasons why EU invests and incentive the implementation and improving of the fiber infrastructures. Our survey had a question related to the advantages of optical fiber, hopping to know if people agree or not with the advantages of fiber. The answer options were: strongly disagree, disagree, agree, and completely agree. A weighted average was calculated, attributing a scale from 1 to 4, being 1-completely disagree and 4-completely agree and the conclusion is that, on average, respondents agree that optical fiber has higher speed, better connectivity, more stability of the signal and offers greater diversity and quality of services. "Higher speed" is the advantage that respondents most agree with (see graph 7).



Graph 7: Optical Fiber advantages

Our survey helped characterize the digital features in the municipalities under analysis, allowing us to understand the overall satisfaction with access to fiber. It is important to clarify that, in the majority of these municipalities, fiber is only available since 2015, which means that some of the social and economic benefits may not be fully noticed yet.

6.2 CBA Results

In this section we calculate the costs and the benefits of the fiber infrastructure. The year of analysis was 2019.

Costs

Our costs mostly include the initial investment and operational costs. The initial investment made by DSTelecom and the Portuguese state was 344€ per house (in northern counties) and 347€ per house (in Alentejo and Algarve), as it will be detailed in the next section 6.2.3. Additionally, the expected lifetime of a fiber infrastructure is 20 years (EC, 2014) and the discount rate of these types of projects is 5% (EC, 2014; JASPER, 2020).

Benefits

As explained before, the two areas with higher probability to benefit more from the implementation and use of fiber are the business benefits and the household consumer surplus. Therefore, these were the benefits that were calculated, in the next sections 6.2.1 and 6.2.2.

6.2.1 Business benefits

The business benefits were calculated according to formula 2, assuming two different scenarios:

- Scenario 1: considering there was no broadband and it is installed a new connection to optical fiber.
- Scenario 2: assuming it happened an upgrade from basic broadband (ADSL, cable or satellite) to fiber.

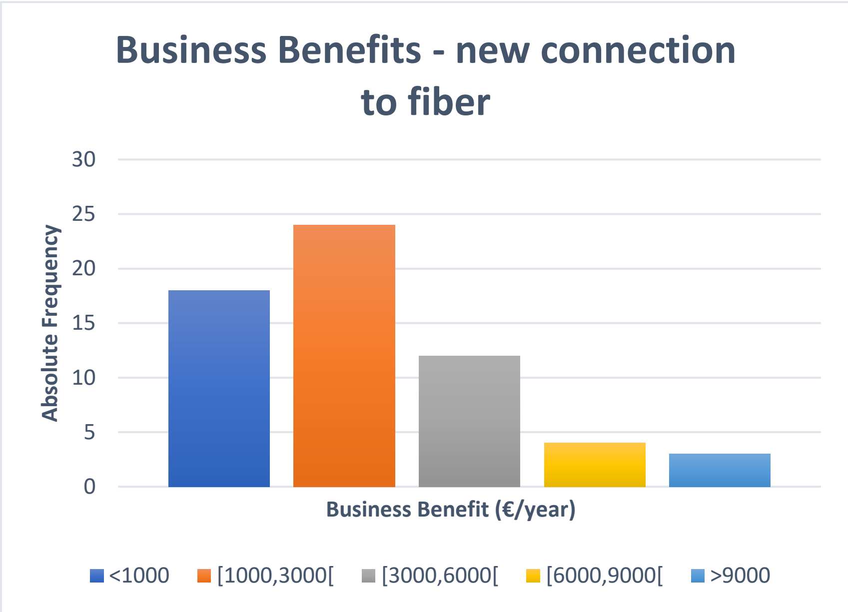
On the following Table 3 is presented the results for some of the counties analyzed, but the full data is on Appendix.

Table 3: Business Benefits - Results

	Business Benefits - Results	
	Scenario 1: New connection to fiber	Scenario 2: Upgrade from basic broadband to fiber
	€/year	€/year
Alcoutim	396	99
Alter do Chão	297	74
Arcos de Valdevez	6645	1661
Arouca	9907	2274
Arronches	421	105
Barrancos	164	41
Castelo de Vide	296	74
Mourão	262	65
Odemira	13571	3393
Ponte de Lima	14680	3670
Salvaterra de Magos	5145	1286
Serpa	2720	680
Sousel	1116	279
Torre de Moncorvo	990	248

On average, in 2019 the business benefit for the 63 counties in the analysis was 2785€ per year, considering a scenario where there is no access to any broadband services and it is installed optical fiber (Scenario 1 – Table 3). Ponte de Lima (14680€/year), Odemira

(13571€/year), and Arouca (9907€/year) were the counties that had a higher business benefit in 2019. While, Barrancos (164€/year), Mourão (262€/year), Castelo de Vide (296€/year) and Alter do Chão (297€/year) had the lowest business benefits, but still positive. In general, the counties from Alentejo and Algarve were the ones with lower business benefits.



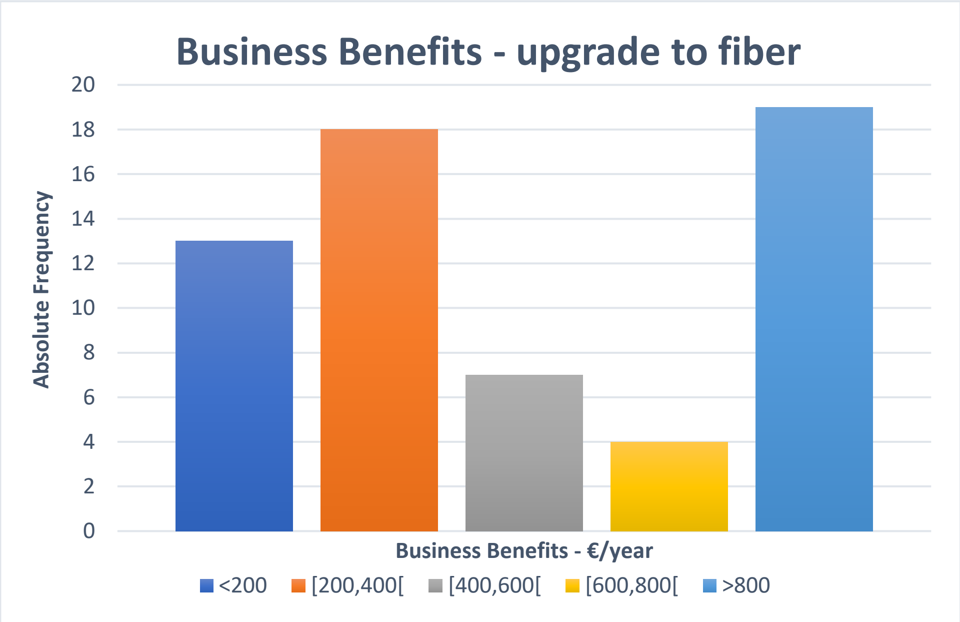
Graph 8: Business Benefits – new connection to fiber

In a scenario, with a new connection to fiber the business benefits per year are always positive (see graph 8). In 24 of the municipalities, the business benefit per year was between 1000€ and 3000€. In 18 of the municipalities under analysis, the business benefit was less than 1000€ per year, and the majority of those counties are from the Alentejo and Algarve. Normally, the counties from the North have higher business benefits. According to our estimations, there are 7 counties with a business benefit superior of 6000€ per year. Of those 7 counties, only one is from Alentejo, which is Odemira.

For a scenario where there is an upgrade from basic broadband to optical fiber (scenario 2 – Table 3), the business benefits were smaller but positive in all the counties in the analysis. On average, the business benefit was 696€/year. The counties from Alentejo and Algarve had lower business benefits, especially Barrancos (41€/year), Mourão (65€/year), Castelo de Vide (74€/year), and Alter do Chão (74€/year). Above the average were again Ponte de Lima (3670€/year), Odemira (3393€/year), and Arouca (2274€/year).

In the northern counties the municipal GVA is higher and therefore the business benefit is also bigger.

According to the results obtained, 19 counties had a business benefit superior to 800€/year (see graph 9). Once again, the majority of those are northern municipalities. The counties with a business benefit inferior to 200€ per year, when there is an upgrade from basic broadband to optical fiber, are mainly from Alentejo and Algarve.



Graph 9: Business Benefits – Upgrade to fiber

The results obtained were four times bigger when there is a new connection to fiber, rather than just an upgrade from basic broadband to fiber. These results make sense because the benefits are clearer when we transit from a situation where there is no access to any broadband service, including fiber, rather than just having an upgrade to fiber.

It is expected that these benefits keep increasing. As said before, having access to a better broadband infrastructure may not be enough, if the businesses choose to not adapt their processes in order to fully benefit from better connectivity. Some of the counties where the business benefits are lower are also the most rural, with extremely low population density (less than 10 individuals per km2).

6.2.2 Household benefits

The Household benefits were calculated according to formula 4, assuming two different scenarios, as before:

- Scenario 1: considering there was no broadband and it is installed a new connection to optical fiber.
- Scenario 2: assuming it happened an upgrade from basic broadband (ADSL, cable or satellite) to fiber.

The table 4 shows the results for some counties, but the full data is on Appendix.

Table 4: Household Consumer Surplus – Results

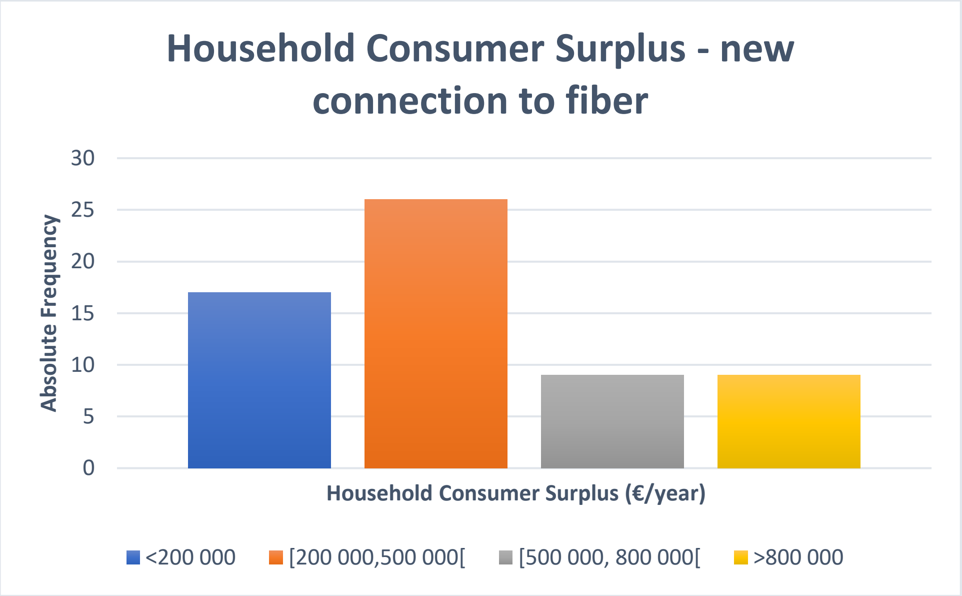
	Household Consumer Surplus - Results	
	Scenario 1: New connection to fiber	Scenario 2: Upgrade from basic broadband to fiber
	€/year	€/year
Alcoutim	89088	44544
Alter do Chão	132288	66144
Arcos de Valdevez	864960	432480
Arouca	608256	304128
Arronches	134784	67392
Barrancos	64224	32112
Castelo de Vide	608256	60768
Mourão	422016	50112
Odemira	1082400	541200
Ponte de Lima	1822368	911184
Salvaterra de Magos	987552	493776
Serpa	582432	291216
Sousel	864996	43248
Torre de Moncorvo	408000	204000

On average the number of houses connected to optical fiber in 2019 for the 63 counties in the analysis is 4232.

The household consumer surplus, when there is a situation of a new fiber connection (scenario 1 – Table 4) can bring a benefit of on average 406269€/year. The counties with a superior number of houses connected to fiber in 2019 had higher benefits.

Ponte de Lima (1822368€/year), Odemira (1082400€/year), Salvaterra de Magos (987552€/year) and Arcos de Valdevez (864960€/year) performed better in this indicator. Barrancos (64224€/year), Sousel (86496€/year) and Alcoutim (89088€/year) were below the average.

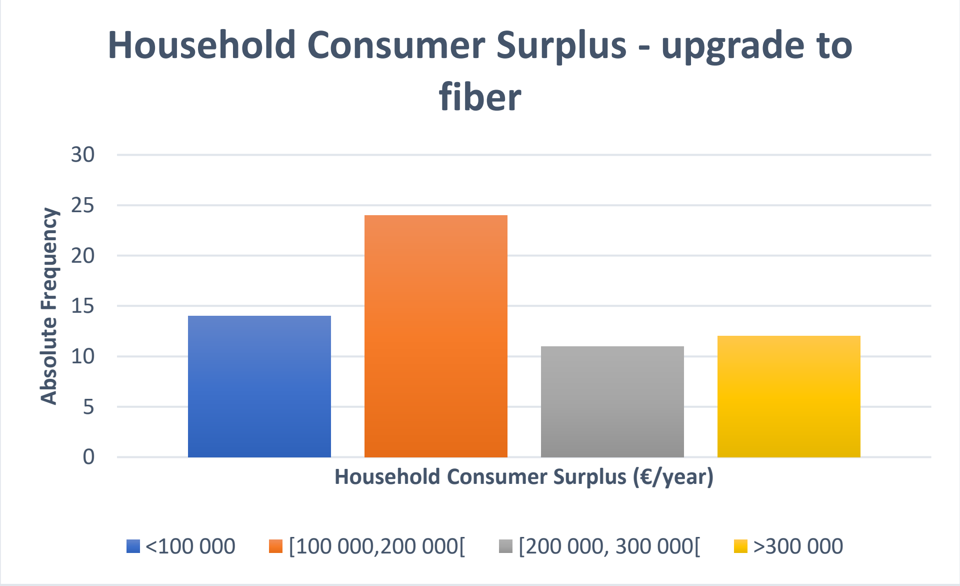
The household consumer surplus assumes significant values for all the counties. In the scenario where there is a new connection to optical fiber, 26 municipalities have a consumer surplus between 200 000€ and 500 000€ per household and per year (see graph 10). Also, 18 counties have an estimated household consumer surplus is over 500 000€ per year, which represents more than 41 thousand euros per month.



Graph 10 – Household Consumer Surplus – new connection to fiber

Considering again a situation of an upgrade from basic broadband to optical fiber (scenario 2 – Table 4) and therefore a level of consumer surplus of 4€/month/household the consumer benefits are less than the previous scenario, but still significant and positive. Ponte de Lima (911184€/year), Odemira (541200€/year) and Salvaterra de Magos (493776€/year) are again the counties with higher benefits, while Barrancos (32112€/year), Sousel (43248€/year) and Alcoutim (44544€/year) are the ones with lower.

As happened with business benefits, when it is considered a scenario with an upgrade from basic broadband to optical fiber, the impact is positive but not so big. The household consumer surplus in 24 municipalities is between 100 – 200 thousand euros per year and for 23 municipalities the consumer surplus is superior to 200 thousand euros per year and per household (see graph 11). The majority of the counties with a household consumer surplus inferior to 100 thousand euros per year are from Alentejo and Algarve. On the opposite side, the municipalities with a household consumer surplus higher than 300 thousand per year are mostly from the north of Portugal, except for Coruche, Ponte de Sor, Salvaterra de Magos and Odemira.



Graph 11 – Household Consumer Surplus – upgrade to fiber

As expected, the Household Consumer Surplus is two times bigger when there is a new connection to fiber, rather than with an upgrade from basic broadband to optical fiber.

6.2.3 Costs

The initial investment made by DSTelecom, and financed by the Portuguese state, in 2014 and 2015, was more than 83 million euros, with initial coverage of more than 240 thousand houses from 89 Portuguese rural municipalities.

In the specific counties from north Portugal, the initial investment was more than 49 million euros, comprehending a total of 145 thousand houses. In counties from Alentejo and Algarve, the initial investment was around 33 million euros, reaching 96 thousand houses. Therefore, it was calculated the initial investment per house in both regions, by diving the initial investment by the initial houses covered by fiber. In the northern counties the investment was 344€ per house, while, in Alentejo and Algarve was 347€ (Table 5).

Table 5: Investment and Costs calculations

Region	Initial Investment	Initial houses covered	Initial Investment per house	Annual Cost per house
			$\frac{Inital\ investment}{Initial\ houses\ covered}$	See formula (5)
North	49 925 224€	145 070	344€	27.6€
Alentejo and Algarve	33 512 460€	96 619	347€	27.8€
Total	83 437 684€	241 689		

Then, it was calculated the annual cost of providing fiber per house, making the distinction between the northern region and the Alentejo and Algarve.

The formula used was as follows:

$$ACi = \frac{r \times II}{1 - (1 + r)^{-n}} \quad (5)$$

i: region
ACi: Annual Cost per house
r: Discount rate
II: Initial Investment per house
n: Lifetime of the infrastructure

The discount rate used was 5% and the lifetime of the infrastructure was considered to be 20 years.

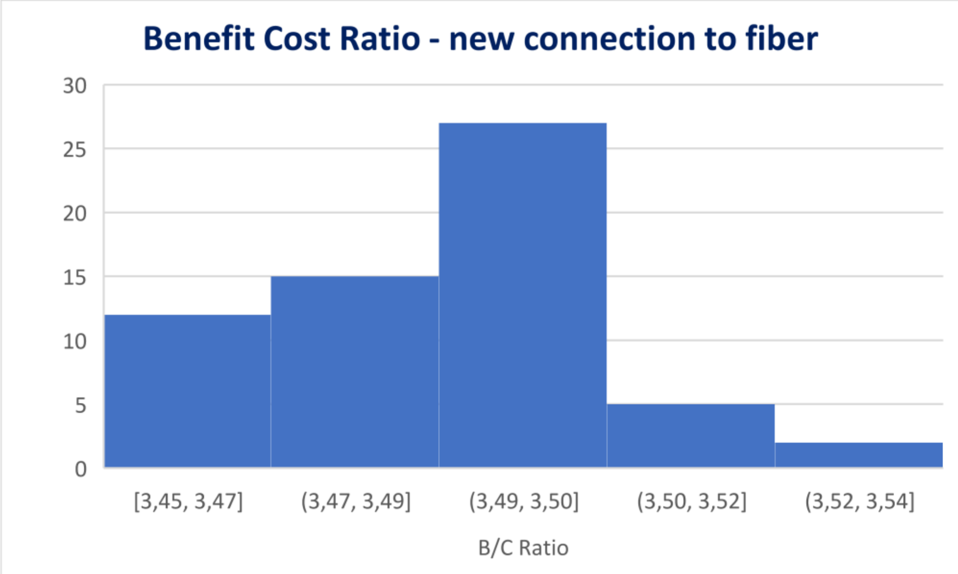
After calculating the Annual Cost of installation per house, the value achieved for the north counties was 27,6€ per house, while for the regions of Alentejo and Algarve was 27,8€. The costs per house were very similar, for both regions.

Lastly, it was calculated the total annualized costs per county, simply by multiplying the number of houses with access to fiber by the annual cost of installation per house.

6.2.4 Analysis

After all the benefits and costs have been quantified in monetary values, we now analyze the economic performance of the broadband implementation, by calculating the Benefit-Cost ratio, for the two scenarios we previously assumed. This ratio will allow to find out if the implementation of optical fiber in these specific counties was worth it, or not, which means if the relative benefits overcome the relative costs. The Benefit – Cost Ratio is the present value of the project benefits divided by the present value of the project costs. If the ratio is greater than 1, the project is suitable because it is expected a positive net value to the firms and the consumers in the counties under analysis.

Since it was considered two different scenarios, it was also estimated two benefit/cost ratios, according to those scenarios. For the first scenario with a new connection to an optical fiber, on average, the ratio was equal to 3.49 (see graph 12). If we analyze this number in monetary value, it means that for each euro spend implementing the optical fiber, is expected a return of approximately 3.49€. In 27 counties the benefit-cost ratio was between 3.45€ and 3.49€. 7 counties had a benefit-cost ratio above the average (between 3.50€ and 3.54€). Arouca (3.52€) and Vila Nova de Cerveira (3.54€) had the highest ratio, in other words, they were the two counties that had higher economic benefits. Nevertheless, for all the counties in our sample, the investment was worth it, and the resident population benefit from it.



Graph 12 – Benefit Cost Ratio – new connection to fiber

In the second situation where there is just an upgrade from basic broadband to optical fiber, the benefit-cost ratio is smaller but still bigger than 1. On average, the benefit-cost ratio was 1.74, assuming a minimum of 1.73 and a maximum of 1.75. This means that for each euro spent on improving the broadband infrastructures, it is expected a return of approximately 1.74€. Arouca, Mesão Frio, Ponte de Lima, Ribeira de Pena, Valença, Vila Pouca de Aguiar and Vila Nova de Cerveira had a return above the average, with a benefit-cost ratio equal to 1.75.

In both scenarios assumed, the benefit-ratio cost was bigger than 1, which means that the project economic performance is positive. Therefore, since the return is positive, we may believe that the investment was worth it and a Pareto improvement is verifiable in the areas analyzed.

7 Final remarks

The use of broadband and, in particular, of optical fiber, facilitates the way society interacts and communicates. Broadband investments generally aim to create and provide social and economic benefits while helping to eliminate the digital gap between cities and rural areas.

Providing high-speed broadband in less populated areas is not attractive for private investors, and it involves major investments but is essential to diminish the digital gap. Therefore, usually the governments incentive and co-finance these types of projects, creating a public and private partnership, as was presented in this work. A broadband investment benefits households by improving the access to e-services (e-commerce, e-banking, teleworking), but it also benefits businesses by increasing productivity (through the use of ICT), driving innovation, and allowing the development of new business ideas. Finally, the government also benefits from access to fiber by facilitating the provision of reliable e-services, such as e-education and e-health.

The main question of this work was to clarify if the implementation and improvement of optical fiber in the counties under analysis were worth it. After analyzing data from 63 rural Portuguese counties and estimating the costs and benefits for fiber installation in those areas, we may believe that the benefits are better than the costs. According to our calculations for the Benefit-Cost Ratio, the benefits are higher than the costs in all the counties analyzed. On average, for each euro invested there was a positive return in both of the scenarios assumed. Considering a scenario after the installation of optical fiber, where there was no access to broadband before, the return is on average 3.49€. In a situation where there is an upgrade from basic broadband to optical fiber, the return is, on average, 1.74€.

Also, with our online survey, it was possible to conclude that there is an overall satisfaction with fiber. Thereby, under the assumptions assumed, it was proved that investment in these rural areas is beneficial for the population.

The main difficulties throughout this work were the process of gathering data to calculate the costs and benefits accordingly to the European Commission 2014 Guide.

Future investigations may include the extension of these study to the e-government activities, such as the e-health and e-education sectors.

In conclusion, this work was able to answer our main question, proving that it is social and economically worth it to invest in rural counties, and therefore is important that the state continues to incentive these partnerships with private investors.

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9 Appendix

Appendix A: Data

Table 1: General Data

Counties	Territory	Resident Population	Population Density	Total houses	Nº of houses connected to fiber	% of houses connected to fiber
	Km² (Source: PORDATA)	Source: PORDATA	**average number of individuals per Km²** (Source: PORDATA)	Source: PORDATA	Source: DSTelecom	
Alandroal	543	5028	9,3	4532	2230	49,2%
Alcácer do Sal	1500	11686	7,8	8919	5296	59,4%
Alcoutim	575	2202	3,8	3528	928	26,3%
Alfândega da Fé	322	4559	14,2	3915	2014	51,4%
Alijó	298	10664	35,8	8616	4825	56,0%
Aljezur	324	5597	17,3	6002	2492	41,5%
Alter do Chão	362	3178	8,8	3056	1378	45,1%
Arcos de Valdevez	448	20 948	46,8	17670	9010	51,0%

Armamar	117	5781	49,3	5037	2576	51,1%
Arouca	329	20 791	63,2	11070	6336	57,2%
Arronches	315	2 840	9,0	2565	1404	54,7%
Baião	175	18820	107,8	11806	8581	72,7%
Barrancos	168	1640	9,7	1297	669	51,6%
Borba	145	6763	46,6	4225	3029	71,7%
Boticas	322	5029	15,6	4670	2230	44,9%
Carrazeda de Ansiães	279	5675	20,3	5363	2528	47,1%
Castelo de Vide	265	2935	11,1	2899	1266	43,7%
Castro Marim	301	6256	20,8	8500	2795	32,9%
Chamusca	746	9225	12,4	6251	4162	66,6%
Cinfães	239	18357	76,7	11786	8368	71,0%
Coruche	1116	17550	15,7	12730	7996	62,8%
Crato	398	3157	7,9	3271	1368	41,8%
Cuba	172	4597	26,7	3068	2031	66,2%

Freixo de Espada à Cinta	244	3305	13,5	3172	1436	45,3%
Gavião	295	3305	11,2	3619	3116	86,1%
Golegã	84	5357	63,5	3145	2381	75,7%
Macedo de Cavaleiros	699	14533	20,8	11881	6607	55,6%
Mértola	1293	6172	4,8	8616	2756	32,0%
Mesão Frio	27	3980	149,3	2409	1747	72,5%
Moimenta da Beira	220	9733	44,2	8064	4396	54,5%
Monção	211	17886	84,6	13645	8151	59,7%
Monchique	395	5130	13	4607	2277	49,4%
Mondim de Basto	172	6966	40,5	4634	3122	67,4%
Monforte	420	2982	7,1	2347	1287	54,8%
Montalegre	805	9044	11,2	10644	4079	38,3%
Moura	958	13734	14,3	10634	6239	58,7%
Mourão	279	2453	8,8	1935	1044	54,0%
Odemira	1721	24669	14,3	21086	11275	53,5%

Ourique	663	4630	7	4221	2046	48,5%
Paredes de Coura	138	8 548	61,9	6212	3311	53,3%
Ponte da Barca	182	11195	61,5	8218	5070	61,7%
Ponte de Lima	320	41407	129,3	22772	18983	83,4%
Ponte de Sor	840	15043	17,9	10422	6842	65,6%
Póvoa de Lanhoso	135	21473	159,5	11978	9803	81,8%
Reguengos de Monsaraz	464	10026	21,6	6486	4531	70,0%
Resende	123	10189	82,6	7552	4606	61,0%
Ribeira de Pena	217	6024	27,7	4991	2688	53,9%
Sabrosa	157	5918	37,7	4698	2639	56,2%
Salvaterra de Magos	244	21 282	87,2	11999	10287	85,7%
Sernancelhe	229	5390	23,6	4552	2396	52,6%
Serpa	1 106	14 339	13,0	10385	6067	58,4%
Sousel	279	4433	15,9	3774	901	23,9%
Tabuaço	134	6025	45	4463	2689	60,3%

Tarouca	100	7783	77,8	7077	3498	49,4%
Torre de Moncorvo	532	7 706	14,5	7365	4250	57,7%
Valença	117	13287	113,4	8327	6033	72,5%
Vila do Bispo	179	5154	28,8	6131	2288	37,3%
Vila Flor	266	6059	22,8	5305	2704	51,0%
Vila Nova de Cerveira	108	8894	82	6305	4010	63,6%
Vila Pouca de Aguiar	437	11985	27,4	10171	5434	54,4%
Vila Viçosa	195	7688	39,5	4806	3455	71,9%
Vinhais	695	7797	11,2	7074	3505	49,5%

Table 2: Investment

Counties	Region	Nº of houses connected to fiber	Total Municipal Investment (annualized)
	(North/AA)	2019	euros
Alandroal	AA	2230	62066
Alcácer do Sal	AA	5296	147400
Alcoutim	AA	928	25828
Alfândega da Fé	North	2014	55617
Alijó	North	4825	133243
Aljezur	AA	2492	69358
Alter do Chão	AA	1378	38353
Arcos de Valdevez	North	9010	248812
Armamar	North	2576	71137
Arouca	North	6336	174970
Arronches	AA	1404	39077
Baião	North	8581	236966
Barrancos	AA	669	18620
Borba	North	3029	83646
Boticas	North	2230	61582
Carrazeda de Ansiães	North	2528	69811
Castelo de Vide	AA	1266	35236
Castro Marim	AA	2795	77791
Chamusca	AA	4162	115838
Cinfães	North	8368	231084
Coruche	AA	7996	222547
Crato	AA	1368	38075
Cuba	AA	2031	56527
Freixo de Espada à Cinta	North	1436	39655
Gavião	AA	3116	86725

Golegã	AA	2381	66269
Macedo de Cavaleiros	North	6607	182453
Mértola	AA	2756	76706
Mesão Frio	North	1747	48244
Moimenta da Beira	North	4396	121396
Monção	North	8151	225091
Monchique	AA	2277	63374
Mondim de Basto	North	3122	86214
Monforte	AA	1287	35820
Montalegre	North	4079	112642
Moura	AA	6239	173646
Mourão	AA	1044	29057
Odemira	AA	11275	313809
Ourique	AA	2046	56945
Paredes de Coura	North	3311	91434
Ponte da Barca	North	5070	140009
Ponte de Lima	North	18983	524218
Ponte de Sor	AA	6842	190428
Póvoa de Lanhoso	North	9803	270711
Reguengos de Monsaraz	AA	4531	126108
Resende	North	4606	127195
Ribeira de Pena	North	2688	74230
Sabrosa	North	2639	72876
Salvaterra de Magos	AA	10287	286311
Sernancelhe	North	2396	66166
Serpa	AA	6067	168858
Sousel	AA	901	25077
Tabuaço	North	2689	74257
Tarouca	North	3498	96598
Torre de Moncorvo	North	4250	117364

Valença	North	6033	166602
Vila do Bispo	AA	2288	63680
Vila Flor	North	2704	74671
Vila Nova de Cerveira	North	4010	110737
Vila Pouca de Aguiar	North	5434	150061
Vila Viçosa	AA	3455	96161
Vinhais	North	3505	96791

Table 3: Benefits with a new connection to optical fiber

Counties	Business Benefit			Household Consumer Surplus			
	Municipal GVA 2019	% rise in GVA	**Result**	Level of consumer surplus	Nº of houses connected to fiber	Nº of months per year	**Result**
	M€	var%	**€/year**	€/fam/month	Nº	Nº	**€/year**
Alandroal	10367	6%	622	8	2230	12	214080
Alcácer do Sal	62373	6%	3742	8	5296	12	508416
Alcoutim	6593	6%	396	8	928	12	89088
Alfândega da Fé	11120	6%	667	8	2014	12	193344
Alijó	48124	6%	2887	8	4825	12	463200
Aljezur	29511	6%	1771	8	2492	12	239232
Alter do Chão	4943	6%	297	8	1378	12	132288
Arcos de Valdevez	110744	6%	6645	8	9010	12	864960
Armamar	22289	6%	1337	8	2576	12	247296
Arouca	151624	6%	9097	8	6336	12	608256
Arronches	7023	6%	421	8	1404	12	134784
Baião	63557	6%	3813	8	8581	12	823776
Barrancos	2729	6%	164	8	669	12	64224
Borba	23246	6%	1395	8	3029	12	290784

Boticas	19392	6%	1164	8	2230	12	214080
Carrazeda de Ansiães	16614	6%	997	8	2528	12	242688
Castelo de Vide	4926	6%	296	8	1266	12	121536
Castro Marim	25090	6%	1505	8	2795	12	268320
Chamusca	54613	6%	3277	8	4162	12	399552
Cinfães	81438	6%	4886	8	8368	12	803328
Coruche	85446	6%	5127	8	7996	12	767616
Crato	7845	6%	471	8	1368	12	131328
Cuba	9558	6%	573	8	2031	12	194976
Freixo de Espada à Cinta	14106	6%	846	8	1436	12	137856
Gavião	7372	6%	442	8	3116	12	299136
Golegã	29404	6%	1764	8	2381	12	228576
Macedo de Cavaleiros	60177	6%	3611	8	6607	12	634272
Mértola	14854	6%	891	8	2756	12	264576
Mesão Frio	36088	6%	2165	8	1747	12	167712
Moimenta da Beira	32613	6%	1957	8	4396	12	422016
Monção	72115	6%	4327	8	8151	12	782496
Monchique	23884	6%	1433	8	2277	12	218592

Mondim de Basto	18484	6%	1109	8	3122	12	299712
Monforte	8834	6%	530	8	1287	12	123552
Montalegre	24633	6%	1478	8	4079	12	391584
Moura	80095	6%	4806	8	6239	12	598944
Mourão	4360	6%	262	8	1044	12	100224
Odemira	226182	6%	13571	8	11275	12	1082400
Ourique	19383	6%	1163	8	2046	12	196416
Ponte da Barca	29145	6%	1749	8	5070	12	486720
Ponte de Lima	244667	6%	14680	8	18983	12	1822368
Ponte de Sor	74374	6%	4462	8	6842	12	656832
Póvoa de Lanhoso	112010	6%	6721	8	9803	12	941088
Reguengos de Monsaraz	49474	6%	2968	8	4531	12	434976
Resende	33318	6%	1999	8	4606	12	442176
Ribeira de Pena	36474	6%	2188	8	2688	12	258048
Sabrosa	25910	6%	1555	8	2639	12	253344
Salvaterra de Magos	85742	6%	5145	8	10287	12	987552
Sernancelhe	23480	6%	1409	8	2396	12	230016
Serpa	45332	6%	2720	8	6067	12	582432

Sousel	18601	6%	1116	8	901	12	86496
Tabuaço	11396	6%	684	8	2689	12	258144
Tarouca	26400	6%	1584	8	3498	12	335808
Torre de Moncorvo	16505	6%	990	8	4250	12	408000
Valença	87195	6%	5232	8	6033	12	579168
Vila do Bispo	66190	6%	3971	8	2288	12	219648
Vila Flor	25046	6%	1503	8	2704	12	259584
Vila Nova de Cerveira	124128	6%	7448	8	4010	12	384960
Vila Pouca de Aguiar	108072	6%	6484	8	5434	12	521664
Vila Viçosa	40542	6%	2433	8	3455	12	331680
Vinhais	15742	6%	945	8	3505	12	336480

Table 4: Benefit/Cost Ratio with a new connection to optical fiber

Counties	**Benefits 2019**		**Total Benefits**	**Total Costs**	**Benefit/Costs Ratio**
	Business Benefit	Household Consumer Surplus			
	€/year	€/year	€/year	€/year	**B/C**
Alandroal	622	214080	214702	62066	**3,46**
Alcácer do Sal	3742	508416	512158	147400	**3,47**
Alcoutim	396	89088	89484	25828	**3,46**
Alfândega da Fé	667	193344	194011	55617	**3,49**
Alijó	2887	463200	466087	133243	**3,50**
Aljezur	1771	239232	241003	69358	**3,47**
Alter do Chão	297	132288	132585	38353	**3,46**
Arcos de Valdevez	6645	864960	871605	248812	**3,50**
Armamar	1337	247296	248633	71137	**3,50**
Arouca	9097	608256	617353	174970	**3,53**
Arronches	421	134784	135205	39077	**3,46**
Baião	3813	823776	827589	236966	**3,49**
Barrancos	164	64224	64388	18620	**3,46**
Borba	1395	290784	292179	83646	**3,49**
Boticas	1164	214080	215244	61582	**3,50**

Carrazeda de Ansiães	997	242688	243685	69811	**3,49**
Castelo de Vide	296	121536	121832	35236	**3,46**
Castro Marim	1505	268320	269825	77791	**3,47**
Chamusca	3277	399552	402829	115838	**3,48**
Cinfães	4886	803328	808214	231084	**3,50**
Coruche	5127	767616	772743	222547	**3,47**
Crato	471	131328	131799	38075	**3,46**
Cuba	573	194976	195549	56527	**3,46**
Freixo de Espada à Cinta	846	137856	138702	39655	**3,50**
Gavião	442	299136	299578	86725	**3,45**
Golegã	1764	228576	230340	66269	**3,48**
Macedo de Cavaleiros	3611	634272	637883	182453	**3,50**
Mértola	891	264576	265467	76706	**3,46**
Mesão Frio	2165	167712	169877	48244	**3,52**
Moimenta da Beira	1957	422016	423973	121396	**3,49**
Monção	4327	782496	786823	225091	**3,50**
Monchique	1433	218592	220025	63374	**3,47**
Mondim de Basto	1109	299712	300821	86214	**3,49**

Monforte	530	123552	124082	35820	**3,46**
Montalegre	1478	391584	393062	112642	**3,49**
Moura	4806	598944	603750	173646	**3,48**
Mourão	262	100224	100486	29057	**3,46**
Odemira	13571	1082400	1095971	313809	**3,49**
Ourique	1163	196416	197579	56945	**3,47**
Ponte da Barca	1749	486720	488469	140009	**3,49**
Ponte de Lima	14680	1822368	1837048	524218	**3,50**
Ponte de Sor	4462	656832	661294	190428	**3,47**
Póvoa de Lanhoso	6721	941088	947809	270711	**3,50**
Reguengos de Monsaraz	2968	434976	437944	126108	**3,47**
Resende	1999	442176	444175	127195	**3,49**
Ribeira de Pena	2188	258048	260236	74230	**3,51**
Sabrosa	1555	253344	254899	72876	**3,50**
Salvaterra de Magos	5145	987552	992697	286311	**3,47**
Sernancelhe	1409	230016	231425	66166	**3,50**
Serpa	2720	582432	585152	168858	**3,47**
Sousel	1116	86496	87612	25077	**3,49**

Tabuaço	684	258144	258828	74257	**3,49**
Tarouca	1584	335808	337392	96598	**3,49**
Torre de Moncorvo	990	408000	408990	117364	**3,48**
Valença	5232	579168	584400	166602	**3,51**
Vila do Bispo	3971	219648	223619	63680	**3,51**
Vila Flor	1503	259584	261087	74671	**3,50**
Vila Nova de Cerveira	7448	384960	392408	110737	**3,54**
Vila Pouca de Aguiar	6484	521664	528148	150061	**3,52**
Vila Viçosa	2433	331680	334113	96161	**3,47**
Vinhais	945	336480	337425	96791	**3,49**

Table 5: Benefits with an upgrade from basic broadband to optical fiber

Counties	Business Benefit			Household consumer surplus			
	Municipal GVA 2019	% rise in GVA	**Result**	Level of consumer surplus	Nº of houses with fiber connection	Nº of months per year	**Result**
	M€	var%	**€/year**	€/fam/month	Nº	Nº	**€/year**
Alandroal	10367	1,5%	156	4	2230	12	107040
Alcácer do Sal	62373	1,5%	936	4	5296	12	254208
Alcoutim	6593	1,5%	99	4	928	12	44544
Alfândega da Fé	11120	1,5%	167	4	2014	12	96672
Alijó	48124	1,5%	722	4	4825	12	231600
Aljezur	29511	1,5%	443	4	2492	12	119616
Alter do Chão	4943	1,5%	74	4	1378	12	66144
Arcos de Valdevez	110744	1,5%	1661	4	9010	12	432480
Armamar	22289	1,5%	334	4	2576	12	123648
Arouca	151624	1,5%	2274	4	6336	12	304128
Arronches	7023	1,5%	105	4	1404	12	67392
Baião	63557	1,5%	953	4	8581	12	411888
Barrancos	2729	1,5%	41	4	669	12	32112
Borba	23246	1,5%	349	4	3029	12	145392

Boticas	19392	1,5%	291	4	2230	12	107040
Carrazeda de Ansiães	16614	1,5%	249	4	2528	12	121344
Castelo de Vide	4926	1,5%	74	4	1266	12	60768
Castro Marim	25090	1,5%	376	4	2795	12	134160
Chamusca	54613	1,5%	819	4	4162	12	199776
Cinfães	81438	1,5%	1222	4	8368	12	401664
Coruche	85446	1,5%	1282	4	7996	12	383808
Crato	7845	1,5%	118	4	1368	12	65664
Cuba	9558	1,5%	143	4	2031	12	97488
Freixo de Espada à Cinta	14106	1,5%	212	4	1436	12	68928
Gavião	7372	1,5%	111	4	3116	12	149568
Golegã	29404	1,5%	441	4	2381	12	114288
Macedo de Cavaleiros	60177	1,5%	903	4	6607	12	317136
Mértola	14854	1,5%	223	4	2756	12	132288
Mesão Frio	36088	1,5%	541	4	1747	12	83856
Moimenta da Beira	32613	1,5%	489	4	4396	12	211008
Monção	72115	1,5%	1082	4	8151	12	391248
Monchique	23884	1,5%	358	4	2277	12	109296

Mondim de Basto	18484	1,5%	277	4	3122	12	149856
Monforte	8834	1,5%	133	4	1287	12	61776
Montalegre	24633	1,5%	369	4	4079	12	195792
Moura	80095	1,5%	1201	4	6239	12	299472
Mourão	4360	1,5%	65	4	1044	12	50112
Odemira	226182	1,5%	3393	4	11275	12	541200
Ourique	19383	1,5%	291	4	2046	12	98208
Ponte da Barca	29145	1,5%	437	4	5070	12	243360
Ponte de Lima	244667	1,5%	3670	4	18983	12	911184
Ponte de Sor	74374	1,5%	1116	4	6842	12	328416
Póvoa de Lanhoso	112010	1,5%	1680	4	9803	12	470544
Reguengos de Monsaraz	49474	1,5%	742	4	4531	12	217488
Resende	33318	1,5%	500	4	4606	12	221088
Ribeira de Pena	36474	1,5%	547	4	2688	12	129024
Sabrosa	25910	1,5%	389	4	2639	12	126672
Salvaterra de Magos	85742	1,5%	1286	4	10287	12	493776
Sernancelhe	23480	1,5%	352	4	2396	12	115008
Serpa	45332	1,5%	680	4	6067	12	291216

Sousel	18601	1,5%	279	4	901	12	43248
Tabuaço	11396	1,5%	171	4	2689	12	129072
Tarouca	26400	1,5%	396	4	3498	12	167904
Torre de Moncorvo	16505	1,5%	248	4	4250	12	204000
Valença	87195	1,5%	1308	4	6033	12	289584
Vila do Bispo	66190	1,5%	993	4	2288	12	109824
Vila Flor	25046	1,5%	376	4	2704	12	129792
Vila Nova de Cerveira	124128	1,5%	1862	4	4010	12	192480
Vila Pouca de Aguiar	108072	1,5%	1621	4	5434	12	260832
Vila Viçosa	40542	1,5%	608	4	3455	12	165840
Vinhais	15742	1,5%	236	4	3505	12	168240

Table 6: Benefit/Cost Ratio with an upgrade from basic broadband to optical fiber

Counties	Benefit 2019		Total Benefits	Total Costs	Benefits/Costs Ratio
	Business Benefit	Household consumer surplus			
	€/year	€/year	€/year	€/year	**B/C**
Alandroal	156	107040	107196	62066	**1,73**
Alcácer do Sal	936	254208	255144	147400	**1,73**
Alcoutim	99	44544	44643	25828	**1,73**
Alfândega da Fé	167	96672	96839	55617	**1,74**
Alijó	722	231600	232322	133243	**1,74**
Aljezur	443	119616	120059	69358	**1,73**
Alter do Chão	74	66144	66218	38353	**1,73**
Arcos de Valdevez	1661	432480	434141	248812	**1,74**
Armamar	334	123648	123982	71137	**1,74**
Arouca	2274	304128	306402	174970	**1,75**
Arronches	105	67392	67497	39077	**1,73**
Baião	953	411888	412841	236966	**1,74**
Barrancos	41	32112	32153	18620	**1,73**
Borba	349	145392	145741	83646	**1,74**

Boticas	291	107040	107331	61582	**1,74**
Carrazeda de Ansiães	249	121344	121593	69811	**1,74**
Castelo de Vide	74	60768	60842	35236	**1,73**
Castro Marim	376	134160	134536	77791	**1,73**
Chamusca	819	199776	200595	115838	**1,73**
Cinfães	1222	401664	402886	231084	**1,74**
Coruche	1282	383808	385090	222547	**1,73**
Crato	118	65664	65782	38075	**1,73**
Cuba	143	97488	97631	56527	**1,73**
Freixo de Espada à Cinta	212	68928	69140	39655	**1,74**
Gavião	111	149568	149679	86725	**1,73**
Golegã	441	114288	114729	66269	**1,73**
Macedo de Cavaleiros	903	317136	318039	182453	**1,74**
Mértola	223	132288	132511	76706	**1,73**
Mesão Frio	541	83856	84397	48244	**1,75**
Moimenta da Beira	489	211008	211497	121396	**1,74**
Monção	1082	391248	392330	225091	**1,74**
Monchique	358	109296	109654	63374	**1,73**

Mondim de Basto	277	149856	150133	86214	**1,74**
Monforte	133	61776	61909	35820	**1,73**
Montalegre	369	195792	196161	112642	**1,74**
Moura	1201	299472	300673	173646	**1,73**
Mourão	65	50112	50177	29057	**1,73**
Odemira	3393	541200	544593	313809	**1,74**
Ourique	291	98208	98499	56945	**1,73**
Ponte da Barca	437	243360	243797	140009	**1,74**
Ponte de Lima	3670	911184	914854	524218	**1,75**
Ponte de Sor	1116	328416	329532	190428	**1,73**
Póvoa de Lanhoso	1680	470544	472224	270711	**1,74**
Reguengos de Monsaraz	742	217488	218230	126108	**1,73**
Resende	500	221088	221588	127195	**1,74**
Ribeira de Pena	547	129024	129571	74230	**1,75**
Sabrosa	389	126672	127061	72876	**1,74**
Salvaterra de Magos	1286	493776	495062	286311	**1,73**
Sernancelhe	352	115008	115360	66166	**1,74**
Serpa	680	291216	291896	168858	**1,73**

Sousel	279	43248	43527	25077	**1,74**
Tabuaço	171	129072	129243	74257	**1,74**
Tarouca	396	167904	168300	96598	**1,74**
Torre de Moncorvo	248	204000	204248	117364	**1,74**
Valença	1308	289584	290892	166602	**1,75**
Vila do Bispo	993	109824	110817	63680	**1,74**
Vila Flor	376	129792	130168	74671	**1,74**
Vila Nova de Cerveira	1862	192480	194342	110737	**1,75**
Vila Pouca de Aguiar	1621	260832	262453	150061	**1,75**
Vila Viçosa	608	165840	166448	96161	**1,73**
Vinhais	236	168240	168476	96791	**1,74**

Appendix B: Questionnaire example

1. **Em qual dos seguintes municípios se insere a Câmara Municipal que representa?**

2. **A ligação à internet na sua Câmara Municipal é feita por:**

- Fibra ótica
- ADSL
- Satélite
- Ligação coaxial
- Não sabe

3. **Se respondeu a primeira opção, desde quando têm fibra ótica?**

- Há menos de 1 mês
- Há menos de 6 meses
- Entre 6 meses e 1 ano
- Há mais de 1 ano
- Anterior a 2020

4. **Por favor indique quais considera serem as principais vantagens da Fibra ótica?**

	Discordo Completamente	Discordo	Concordo	Concordo completamente	Não sabe / Não responde
Maior velocidade					
Mais conectividade					
Melhor estabilidade do sinal					
Maior diversidade e qualidade de serviços					

5. **Na Câmara Municipal que representa, existem computadores com acesso à Internet?**

· Sim

· Não

6. **Em 2019, qual o número médio de pessoas ao serviço que utilizaram computadores para fins profissionais?**

7. **E em 2020?**

8. **Indique se as seguintes atividades/ áreas de trabalho se encontram informatizadas na sua Câmara Municipal?**

	Informatizada	Não informatizada	Não se aplica
Gestão financeira e administrativa			
Gestão de recursos humanos			
Gestão de stocks			
Gestão documental			
Comunicação interna			
Troca interna de ficheiros			
Registo, organização e processamento de informação			

9. **A sua Câmara Municipal tem website?**

- Sim
- Não

10. **Indique quais os serviços / funcionalidades são disponibilizadas no website da sua Câmara Municipal?**

	Sim	Não
Download e impressão de formulários		
Preenchimento e submissão online de formulários		
Processos de consulta pública		
Bilheteira eletrónica (ex: venda de bilhetes para espetáculos)		
Inquéritos aos cidadãos		

Apoio ao utilizador		
Atendimento online (Ex: Balcão de atendimento virtual		

11. Em que medida considera que:

	Menos do que em 2019	Sensivelmente o mesmo que em 2019	Mais do que em 2019
Em 2020, A Câmara Municipal encomendou mais bens e /ou serviços através da Internet.			
Em 2020, a Câmara Municipal efetuou pagamentos online pela encomenda de bens e /ou serviços através da Internet.			

12. A existência de teletrabalho é uma possibilidade na sua Câmara Municipal?

- Sim
- Não

13. Se não, porquê?

- A atividade da Câmara Municipal requer a presença física dos seus trabalhadores
- Os trabalhadores não têm acesso à Internet a partir de casa
- A Câmara Municipal não permite o trabalho à distância
- A Câmara Municipal alega que os custos do teletrabalho são elevados ou pioram a produtividade

14. Quais considera ser as principais vantagens do teletrabalho?

15. Considera que as empresas do município ficaram satisfeitas com a instalação da fibra?

- Sim
- Não

16. Considera que após a instalação da fibra ótica no município houve um aumento no número de empresas instaladas no concelho?

- Sim
- Não

17. Considera que as pessoas ficaram mais satisfeitas e com maior vontade de se fixarem no concelho, após a instalação da fibra ótica?

- Sim
- Não