COMISIÓN NACIONAL DE LOS MERCADOS Y LA COMPETENCIA

QUANTITATIVE ANALYSIS OF PUBLIC AID FOR BROADBAND DEPLOYMENT IN SPAIN

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INDEX

1. INTRODUCTION

Most EU Member States, as a complement to the network deployment efforts of operators, are developing national strategies for broadband infrastructure deployment as a complement to [1] in order to achieve the connectivity objectives of the Digital Agenda[2] in their respective territories, including the elimination of the digital divide between rural and urban areas[3]. In this regard, Spanish Law 45/2007 for sustainable development in rural areas, defines a small rural municipality as a town with less than 5,000 inhabitants that is integrated into the rural environment.

Most of these strategies involve using public funds to expand broadband coverage in areas where commercial operators do not have incentives to invest and thus accelerate the rollout of high-speed and very high-speed new-generation access networks.[4] .

According to the European Commission's 2022 Digital Economy and Society Index (DESI), Spain is the third most digitally connected country in the EU. In the period 2014-2020, Spain ranks sixth in cumulative spending in the EU on aid for the deployment of broadband networks (approximately 700 million), according to the European Commission's 2022 State Aid Scoreboard.

Among the aid programmes recently implemented in Spain for broadband deployment after the end of Programa Avanza, the following stand out: the Broadband Extension Programme in its first version and the New Generation Broadband Extension Programme, as subsequently modified (hereinafter, PEBA or PEBA-NGA as per their acronyms in Spanish). The objective of these programmes was to promote the deployment of networks and services to ensure digital connectivity and transfer to society the economic, social and competitiveness benefits derived from ultra-fast broadband networks and the development of innovative digital services, thus boosting territorial cohesion by 2025. Since its launch in 2021, Spain is currently implementing the Universalisation of Digital Infrastructures for Cohesion Programme - Broadband

[1]In this sense, the CNMC has contributed to this dynamic through the design of the regulatory framework (ANME/DTSA/002/20 and ANME/DTSA/2154/14), especially highlighting the imposition of wholesale regulated access, at cost-oriented prices, to the civil infrastructure of Telefónica.

[2]The objectives set in the Digital Agenda for Europe were to have coverage of more than 30 Mbps for 100% of citizens and for at least 50% of households to have contracted speeds of more than 100 Mbps by 2020.

[3]In Spain, the programme " Digital Spain 2025" consists of nearly 50 measures that are articulated around ten strategic axes, one of which is to guarantee adequate digital connectivity for the entire population, promoting the elimination of the digital divide between rural and urban areas, with the objective that 100% of the population has 100 Mbps coverage by 2025.

[4]For a more detailed consultation on public aid for the deployment of broadband from the perspective of efficient economic regulation, consult Eiriz (2017).

(hereinafter, UNICO[5]), aimed at reinforcing and giving continuity to the PEBA programme. This programme is part of Componente 15, of the Recovery, Transformation and Resilience Plan for the Spanish economy, and is financed by the European Union with *Next Generation EU* funds. In addition to State aid programmes, some autonomous communities and local entities have also contributed to the aforementioned objective through their respective PEBAs.

The implementation of these aid programmes poses significant challenges, not only in terms of increasing broadband coverage throughout Spain but also in terms of achieving this without **distorting competition**. In this respect, the 2013 EU Guidelines for the application of State aid rules to the rapid deployment of broadband networks (hereinafter, EU Broadband Guidelines) stated that aid must be granted where **there is a market failure** and where such aid **can cause a competitive improvement**, all the while protecting competition and ensuring there are incentives for private investment. It should be noted that both issues were considered in the design of the aid programmes discussed here[6].

With these premises in mind, the CNMC, as the body responsible for preserving and promoting effective competition in all markets and productive sectors, has produced more than 25 reports on public aid projects for the deployment of new-generation networks, both on national, regional and local plans (available at the following link). These reports have been issued under the CNMC's advisory powers as set out in Law 3/2013 of 4 June creating the CNMC and Law 11/2022 of 28 June (the Spanish General Telecommunications Act), as well as its predecessor, Law 9/2014, and their implementing regulations[7].

The purpose of these reports is usually to regulate the terms and conditions or the calls for the granting of aid for the deployment of high-speed or very high-speed NGA (Next Generation Access) networks. In these reports, the CNMC has

[5]With the UNICO Programme, Spain begins the undertaking of one of the main actions of the Recovery Plan in the area of digital connectivity. The Plan foresees an investment of 4,000 million euros to extend connectivity, accelerate the deployment of 5G networks and promote a cybersecurity ecosystem. In 2021, more than 850 million euros were invested, and there is a total budget of 250 million euros for the 2022 round of aid.

[6]In December 2022, the European Commission has approved an updated review of the 2013 Broadband Guidelines, whose entry into force is scheduled for January 2023.

[7]Legislation Royal Decree 462/2015, of June 5, which regulates coordination instruments and procedures between different Public Administrations in the field of public aid aimed at promoting the promotion of the information society by promoting the supply and availability of broadband networks. The Ministry of Economic Affairs and Digital Transformation is the coordinator of the aid measures that the public administrations intend to carry out (article 3). This precept also establishes that the CNMC will establish the requirements related to the setting of prices and conditions of wholesale access to the infrastructures that are the object of said aid.

reiterated, along with other recommendations, **the advisability of including ex-post evaluations of the impact of such aid**[8].

Every year, the CNMC produces an annual report on public aid in Spain pursuant to Article 11 of Law 15/2007 of 3 July on the Defence of Competition (Spanish Competition Act; LDC). Therefore, this study, drawn up within the framework of the CNMC's competition advocacy functions (specifically, those provided for in Article 5.1.h of Law 3/2013 of 4 June), supplements the aforementioned annual report on public aid for 2022.

In this context, the purpose of this document is to analyse the main aid granted since 2013 and completed by the end of 2020 for broadband rollout in Spain. Thus, chapters 2 and 3 describe the state of the retail broadband access market (hereinafter, broadband market) and the existing aid in Spain. Chapter 4 analyses the impact of aid for the deployment of optical fibre (FTTH) from two perspectives: **connectivity** (in terms of the retail use of the new infrastructure) and **competition** (in terms of the degree of concentration of the main operators). Chapter 5 presents the conclusions and Chapter 6 the references used. Finally, the annexes include a descriptive analysis of the number of operators and address methodological issues of the quantitative analysis.

[8] Among the recommendations made by the CNMC, the need to guarantee wholesale access to third parties, the justification and objective evaluation of the award criteria and the setting of sufficient deadlines for the presentation of the projects stand out.

2. MARKET DESCRIPTION

By way of context, below is a brief review of the Spanish broadband market, with special attention to fibre optic networks (FTTH), and the changes that occurred between 2013 (when the first calls for aid under the PEBA programme took place) and 2020 (the last year with available data)[9]. To this end, this report uses the data and information contained in the Geographical Analysis of Broadband Services and NGA Deployment in Spain, drawn up by the CNMC based on the information provided by the main operators[10].

The information presented throughout the report, especially as regards the empirical analysis, focuses on the take-up (active connections[11]) of the different broadband technologies at the retail level, not on their availability (coverage). In terms of coverage, data from the Ministry of Economic Affairs and Digital Transformation's Coverage Report and the European Commission's Digital Economy and Society Index (DESI) can be publicly consulted[12].

2.1. Broadband market

According to the Ministry of Economic Affairs and Digital Transformation, (MINECO in Spanish), broadband services are services that allow users, by means of a specific terminal (computer, mobile phone, television, etc.), to have a permanent data connection with a high transmission capacity.

These services may consist of both fixed network solutions (over physical carriers or radio systems) and mobile network solutions. This section focuses on showing the evolution of active connections in the retail market for **fixed wired broadband**, taking as reference the years 2013 and 2020 (the last year with published geographic data), which were the focus of the quantitative study described in Chapter 4. Both in 2013 and in 2020, different technologies can be distinguished: xDSL (copper pair), HFC (hybrid fibre coaxial) and fibre to the home (FTTH)[13].

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[9]Fibre optics to the home (FTTH) is the predominant technology in the aid programmes considered in this study (more than 90% of aid both in monetary terms and in territorial perspective).

[10]The geographic data of the CNMC includes the operators Telefónica, Orange, Más Móvil, Vodafone and Euskaltel.

[11]The active accesses at the retail level of a certain operator may correspond to the network deployed by the operator itself or to networks deployed by another operator by virtue of other agreements or obligations.

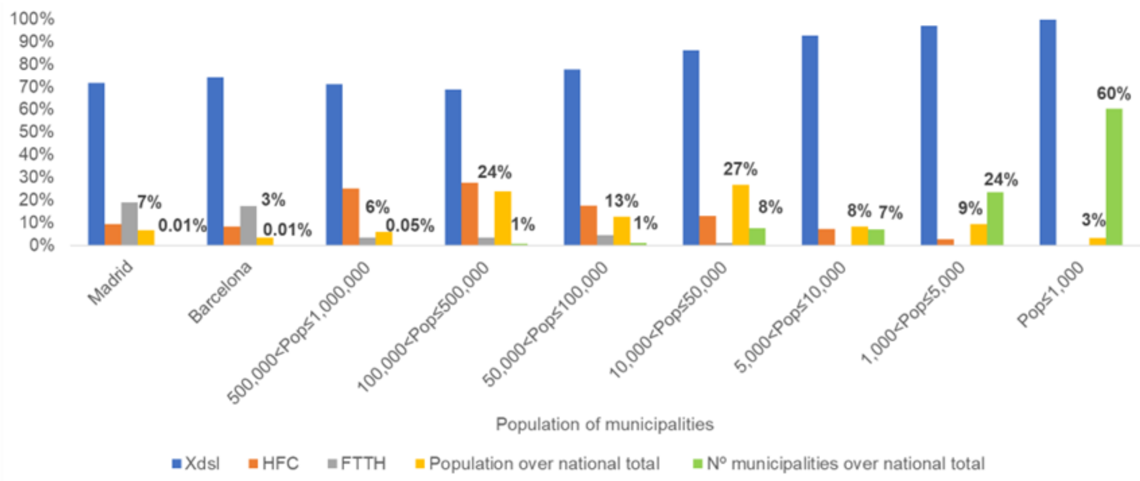
[12]Specifically, the most recent coverage studies are available at the following link: https://digital-strategy.ec.europa.eu/en/library/broadband-coverage-europe-2021 .

[13]The latest review of the wholesale broadband markets approved by the CNMC in October 2021 (Resolution ANME-DTSA-002-20) identifies the retail broadband access market as the market that includes the

2.1.1. Description of the market in 2013

In 2013, there were approximately 12 million active broadband connections in Spain at the retail level. Of these, **79% used xDSL technology**, compared to 16% using HFC technology and only 5% fibre-to-the-home (FTTH) connections. The territorial distribution at the municipal level (Figure 1) shows that the share of xDSL was higher in less populated municipalities.

Figure 1 Share of fixed broadband technologies by population group in 2013



Note: The share of the different broadband technologies is calculated as the percentage of active connections over the total number of connections for each population group. Source: CNMC based on own data (2013).

Regarding competition, the largest operator in terms of the total number of connections was Telefónica, with a market share of 49%, which reached 75% in municipalities with up to 50,000 inhabitants and 43% for municipalities with more than 50,000 inhabitants. Figure 2 breaks down the total number of retail connections according to technology and operator by population groups[14]. This graph shows how the presence of FTTH is relatively small, owned mainly by a single operator (Telefónica) and concentrated in Madrid and Barcelona, while xDSL technology has a greater presence in smaller municipalities. Moreover, Telefónica tends to hold a predominant position in municipalities with less than 50,000 inhabitants. Lastly, 15% of municipalities did not report any direct

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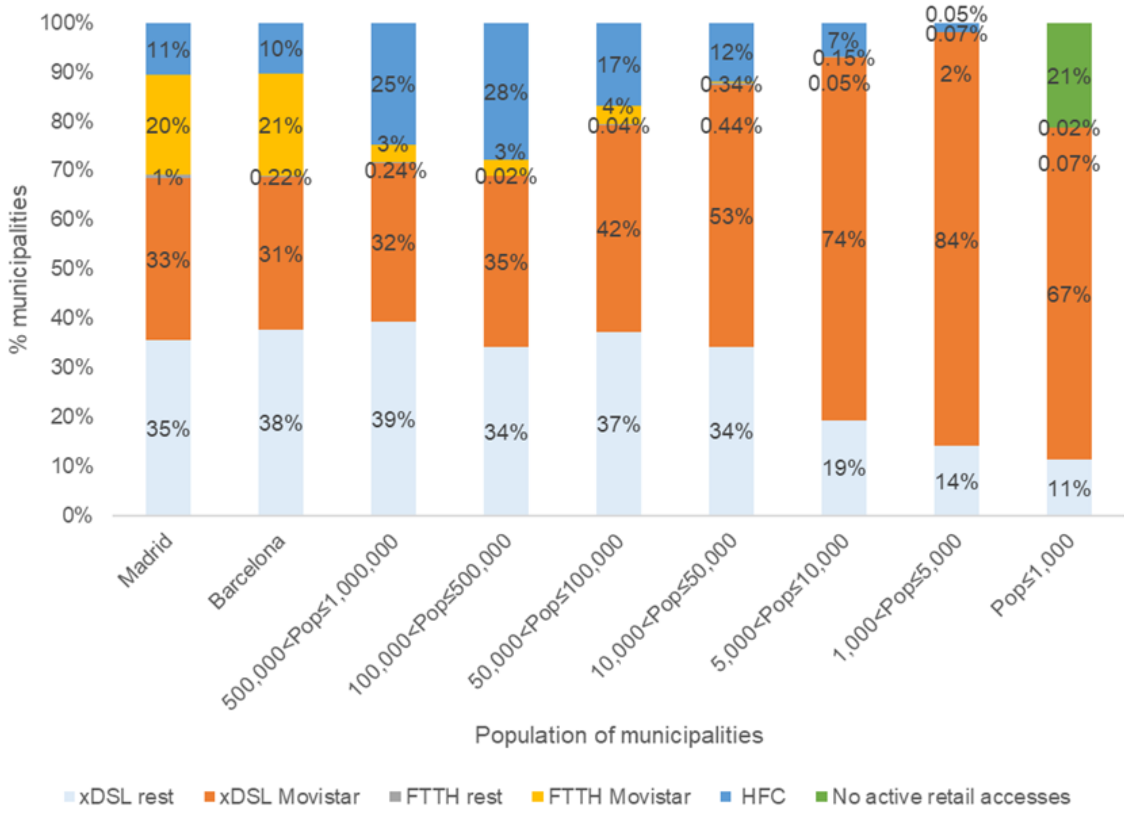
broadband services that operators provide to end users of the mass segment (standardised offers) on any fixed access technology; mostly copper (xDSL), fibre (FTTH) and cable (HFC). Therefore, mobile broadband services are excluded. The broadband market includes both standard broadband services and ultra-fast broadband (BAU) services.

[14]A distinction is made between Telefónica and other operators for xDSL and FTTH. Telefónica does not offer HFC technology among its broadband services, so everything corresponds to alternative operators.

connections at the retail level, with the majority (99%) being towns of less than 1,000 inhabitants.

Figure 2 Composition, by population group, of fixed broadband connections (%) according to technology and operator in 2013.



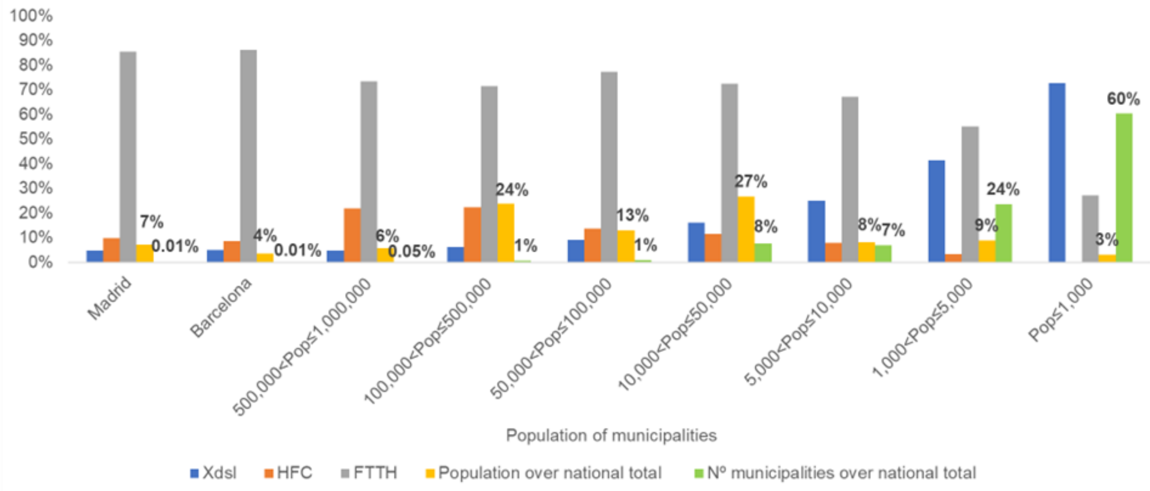
Source: CNMC based on own data (2013).

2.1.2. Description of the market in 2020

In 2020, the number of active retail connections amounted to 16 million, a majority of which corresponded to FTTH technology (more than 11.5 million direct connections). As seen in Figure 3, **fibre is clearly the leading technology** in all municipalities with more than 10,000 inhabitants, while in smaller municipalities there is still a significant presence of **xDSL**, which remains the predominant technology in municipalities with less than 1,000 inhabitants.

In general, in the 2013-2020 period, there has been a **decline in the share of other technologies,** especially xDSL technology**, in favour of fibre**. This trend has been more pronounced in larger municipalities (in proportion to their population).

Figure 3. Share of fixed broadband technologies by population group in 2020.

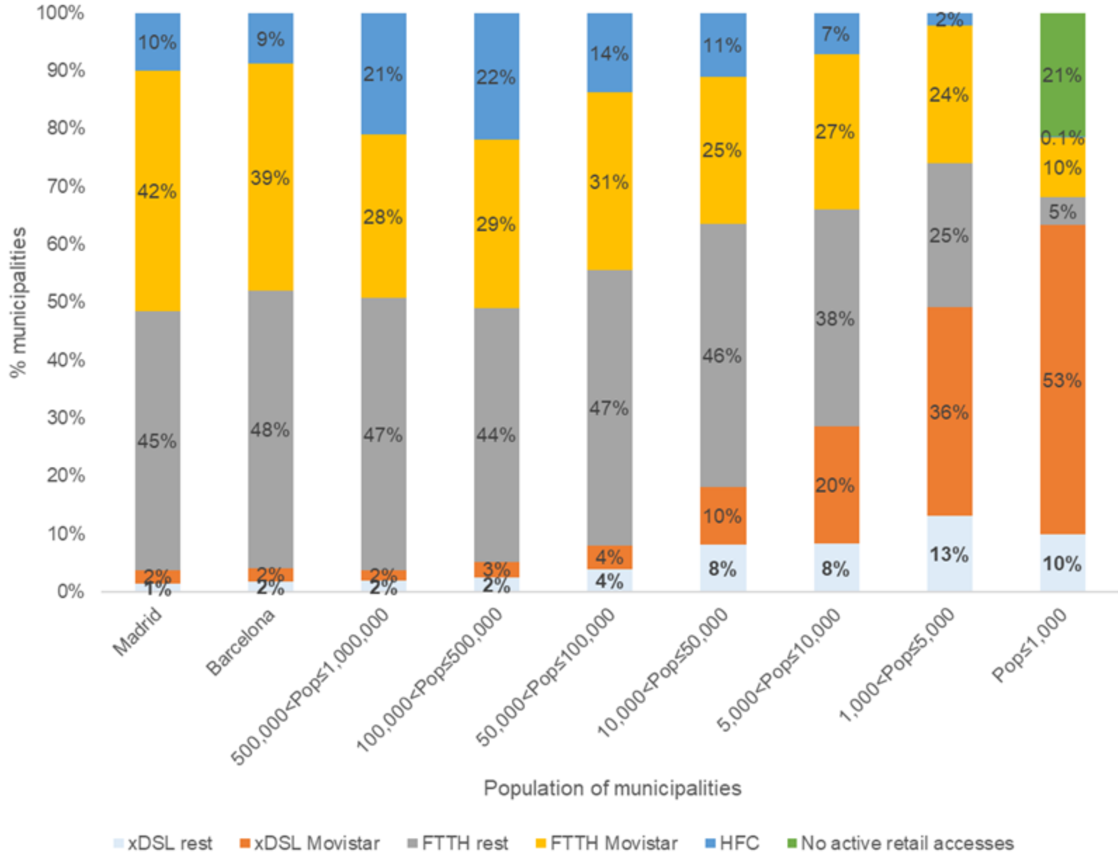


Source: CNMC based on own data (2020).
Note: The share of the different broadband technologies is calculated as the percentage of active connections over the total number of connections for each population group.

From a competition perspective, although Telefónica (Movistar) remains the largest operator (37% of active retail connections nationwide), its share has fallen twelve percentage points compared to 2013.

Figure 4 breaks down total retail connections by technology and operator in 2020. While in 2013 fibre was only present in a minority of municipalities and was concentrated in a single operator in the cities of Madrid and Barcelona, in 2020 it has become present in all population groups, to the detriment of xDSL technology. In terms of competition, the share of fibre connections of other operators is higher than that of Telefónica in all municipalities with more than 1,000 inhabitants. Finally, it is worth noting that in the range of municipalities with up to 1,000 inhabitants, although the percentage of municipalities that do not report active retail fixed broadband connections has remained quiet stable between 2013 and 2020, 99.5% of these municipalities did report retail mobile broadband connections in 2020. Thus, in 2020, 99.3% of all municipalities in Spain reported retail broadband connections (fixed or mobile), while the remaining 0.7% consisted mostly of municipalities with up to 1,000 inhabitants.

Figure 4. Composition, by population group, of fixed broadband connections (%) according to technology and operator in 2020.



Source: CNMC based on own data (2020).

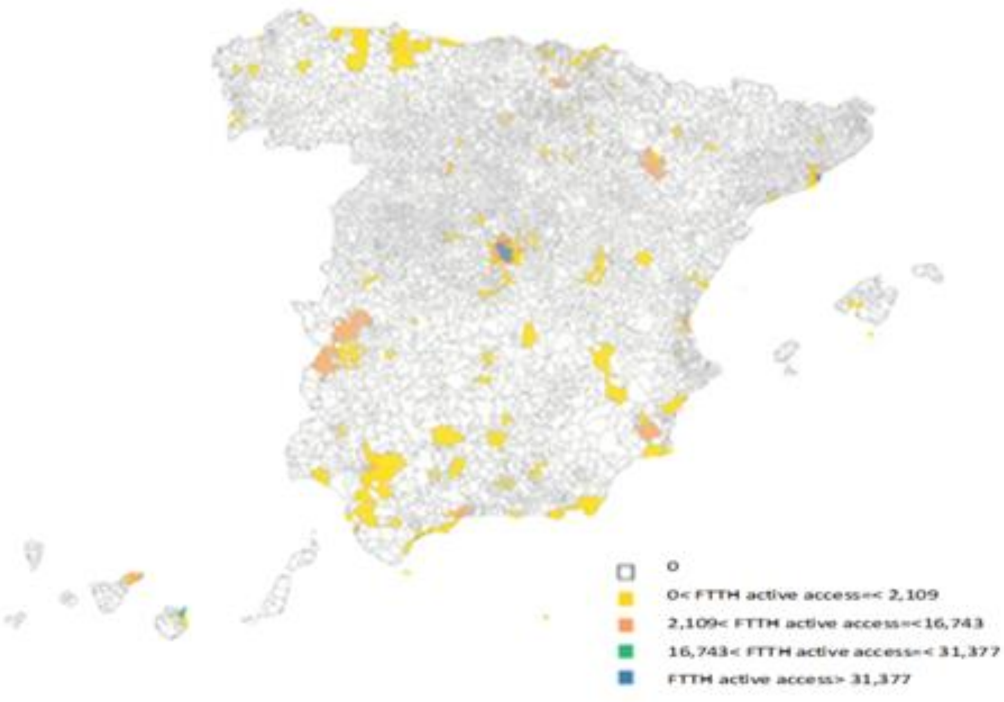
2.2. Fibre-to-the-home (FTTH) market

The previous section highlights the enormous progress of fibre from its minority position in 2013 to becoming the dominant technology in terms of connections in 2020. In addition, as will be discussed in Section 3, fibre has received most of the aid to subsidise part of the costly infrastructure for its deployment. Below is an overview of the main figures related to the take-up of fibre broadband.

2.2.1. Description of the fibre optic market in 2013

In 2013, there were 569,512 active fibre optic connections, spread across 270 municipalities (of the more than 8,000 municipalities in Spain), of which 99.9% were at the retail level. **97% of retail fibre connections belonged to Telefónica**. Of the 270 municipalities with active connections, there were only 36 (13%) where Telefónica's market share was not 100% (the metropolitan areas of Madrid and Barcelona and other provincial capitals and large towns). This situation is illustrated in Figure 5.

Figure 5. Geographic distribution of active FTTH connections in 2013

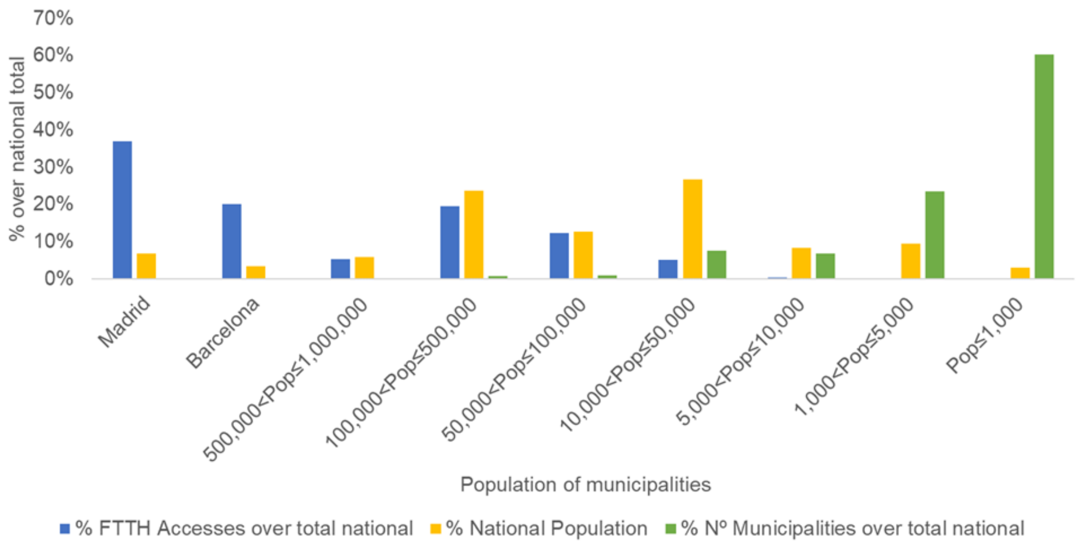


Source: CNMC Geographic Report (2013).

As regards the distribution of connections according to the size of the municipality, Figure 6 shows that **more than half of the active fibre optic**

connections in 2013 were concentrated in the municipalities of Madrid and Barcelona, while municipalities with populations of up to 50,000 inhabitants only accounted for 10% of them. These numbers contrast with the figures in terms of the population percentage and the number of municipalities (more than 97% of Spanish municipalities have less than 50,000 inhabitants). Therefore, **the FTTH market was characterised by a low penetration centred on large municipalities and a high concentration, with Telefónica as nearly the only operator.**

Figure 6. Share of FTTH by municipality and population groups in 2013

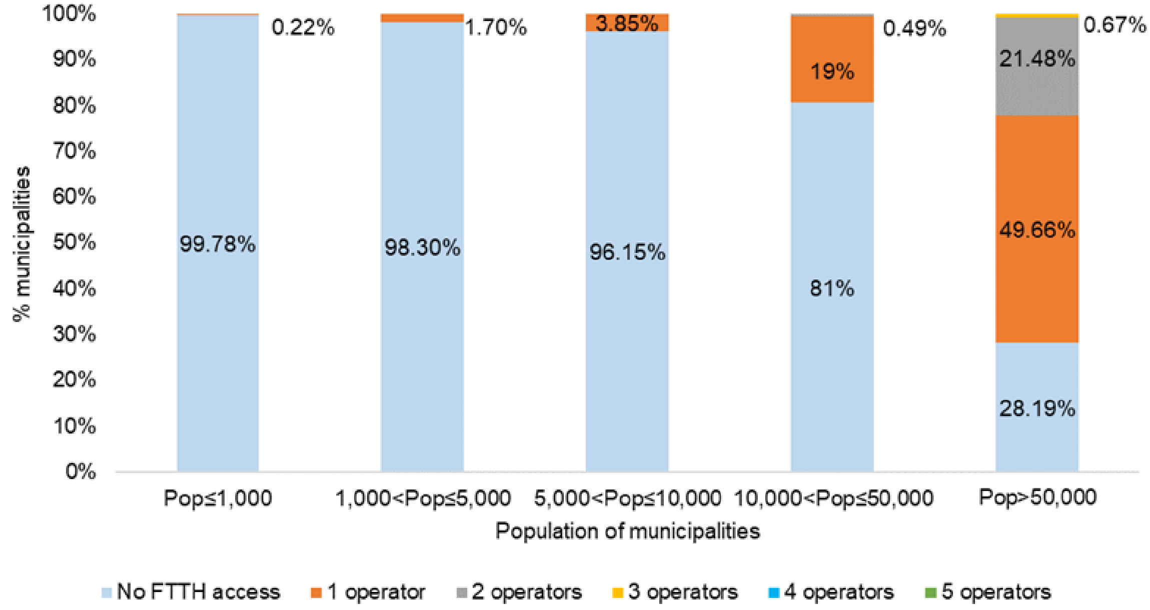


Note: the share of FTTH is calculated as the percentage of active connections over the national total. Source: CNMC based on own data (2013).

As for the **municipal distribution of the number of operators**[15] (in terms of active retail connections) according to population groups, Figure 7 illustrates how nearly all municipalities with up to 10,000 inhabitants were characterised by the absence of retail fibre connections. In the population group between 10,000 and 50,000 inhabitants, close to 20% of the municipalities had active fibre optic connections, mostly belonging to Telefónica. Finally, municipalities with more than 50,000 inhabitants were characterised by having access to fibre (more than 70% of these municipalities), although only 22% had more than one operator.

[15]Geographically, the CNMC data includes the operators Telefónica, Grupo Orange, Más Móvil, Vodafone and Grupo Euskaltel.

Figure 7. Municipal distribution (%) of the number of operators (active FTTH retail connections) by population group in 2013[16].



Source: CNMC based on own data (2013).

Regarding the connectivity rate (Table 1), calculated as the ratio between the number of active connections and the total of households and business premises in each municipality, the average rate for all municipalities with fibre connections in 2013 was 3.2%. The highest levels were in Madrid, Barcelona and in municipalities with a population of up to 1,000 inhabitants, where the mean value was 14%.

[16]According to the CNMC Geographical Report (2013), the total number of municipalities in each population group (values corresponding to each column) is as follows: 5,005 (≤1k), 1,826 (>1k and ≤5k), 545 (>5k and ≤10k), 610 (>10k and ≤50k) and 149 (>50k).

Table 1. Connectivity rate according to municipal population (2013)

Municipalities	Connectivity rate	No. Municipalities
Madrid	13.8%	1
Barcelona	14.3%	1
500,000<Pop≤1,000,000	2.4%	4
100,000<Pop≤500,000	2.8%	49
50,000<Pop≤100,000	5.0%	52
10,000<Pop≤50,000	2.0%	118
5,000<Pop≤10,000	2.9%	19
1,000<Pop≤5,000	4.2%	23
Pop≤1,000	14.3%	3
Average/ No. Municipalities	3.2%	270

Source:CNMC based on own data (2013).

Finally, regarding concentration[17] (Table 2), the average CR1 is 99.16% for the 270 municipalities that reported active fibre connections in 2013. This value reaches 100% for municipalities with up to 10,000 inhabitants and ranges between 90% and 99% above this threshold.

The average CR2 was 99.97% for the 36 municipalities with at least 2 operators (all have more than 10,000 inhabitants). There was only one municipality with three operators (CR3 equal to 100%).

Table 2. Concentration by municipal population groups in 2013

Municipalities	With fiber		At least 2 operators		At least 3 operators	
	CR1	No. Municipalities	CR2	No. Municipalities	CR3	No. Municipalities
Madrid	97%	1	99%	1	100%	1
Barcelona	99%	1	100%	1		
500,000<Pop≤1,000,000	90%	4	100%	4		
100,000<Pop≤500,000	99%	49	100%	22		
50,000<Pop≤100,000	98%	52	100%	5		
10,000<Pop≤50,000	100%	118	100%	3		
5,000<Pop≤10,000	100%	19				
1,000<Pop≤5,000	100%	23				
Pop≤1,000	100%	3				
Average/ No. Municipalities	99%	270	99.99%	36	100%	1

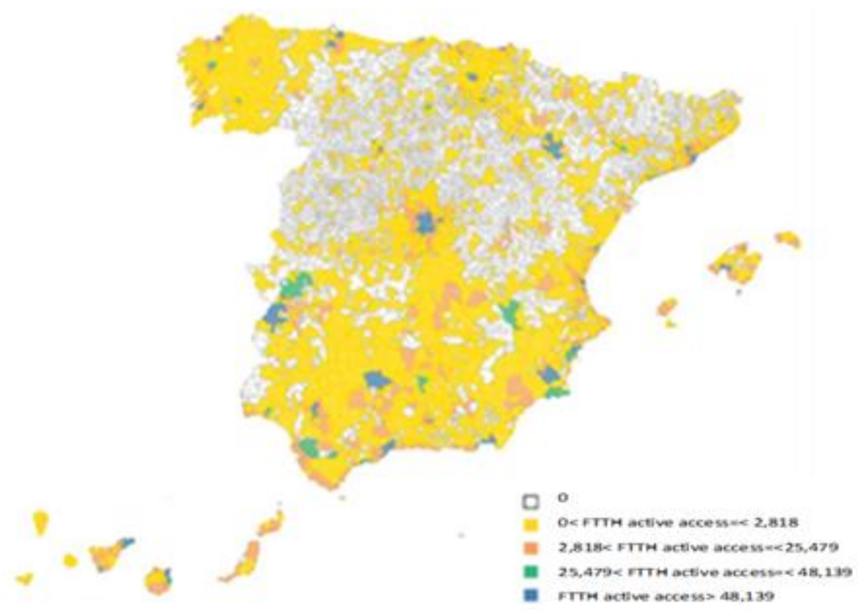
Source:CNMC based on own data (2013).

[17]For this analysis, the concentration ratio CRk is used, which is the sum of the market shares of the k operators with the most active accesses. Thus, CR1 is the concentration ratio of the majority operator, that is, its market share. The CR2 corresponds to the concentration ratio of the two majority operators, and so on.

2.2.2. Overview of the fibre optic market in 2020

In 2020, the number of FTTH retail connections was 11.2 million, **more than twenty times higher than in 2013**. In addition, **Telefónica's share fell to 40%** of total active connections[18], and the number of municipalities with active connections reached 3,964 (close to half of the total), accounting for 96% of the population, as illustrated in Figure 8.

Figure 8. Geographical distribution of active FTTH connections in 2020

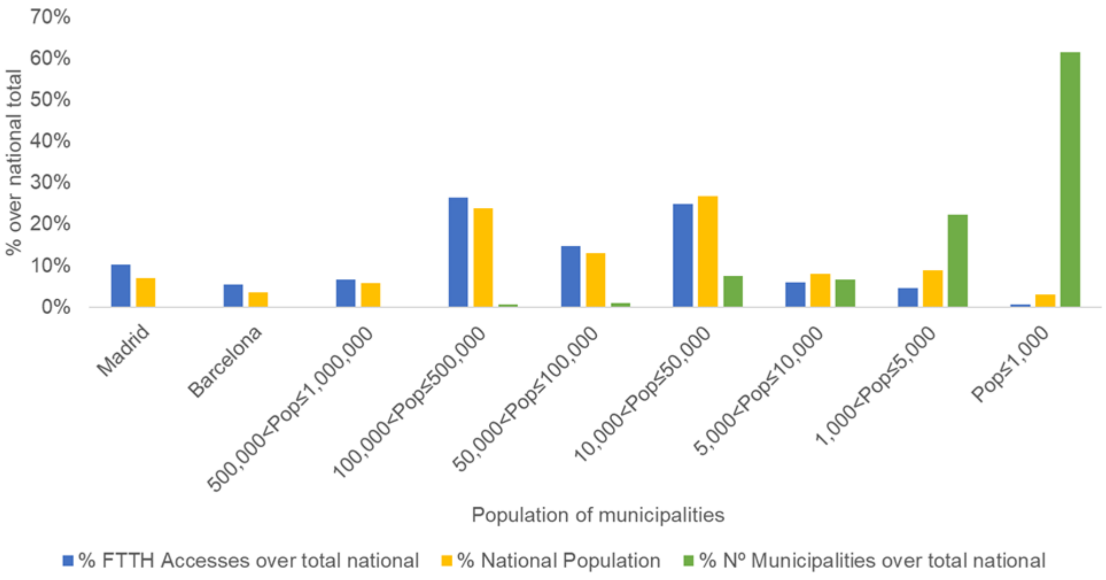


Source: CNMC Geographic Report (2020)

A significant change can be seen at the municipal level, as the **distribution of connections is more proportional to the population**, although there are still proportionally fewer connections in the smaller municipalities, most of which are in rural areas (Figure 9).

[18] Orange ranks as the second operator with 29% of assets and Grupo Mas Móvil is ahead of Vodafone, now having a share of active accesses of 15% (Table 1.1 of the 2020 Geographical Report).

Figure 9. Share of FTTH according to municipalities by population group in 2020



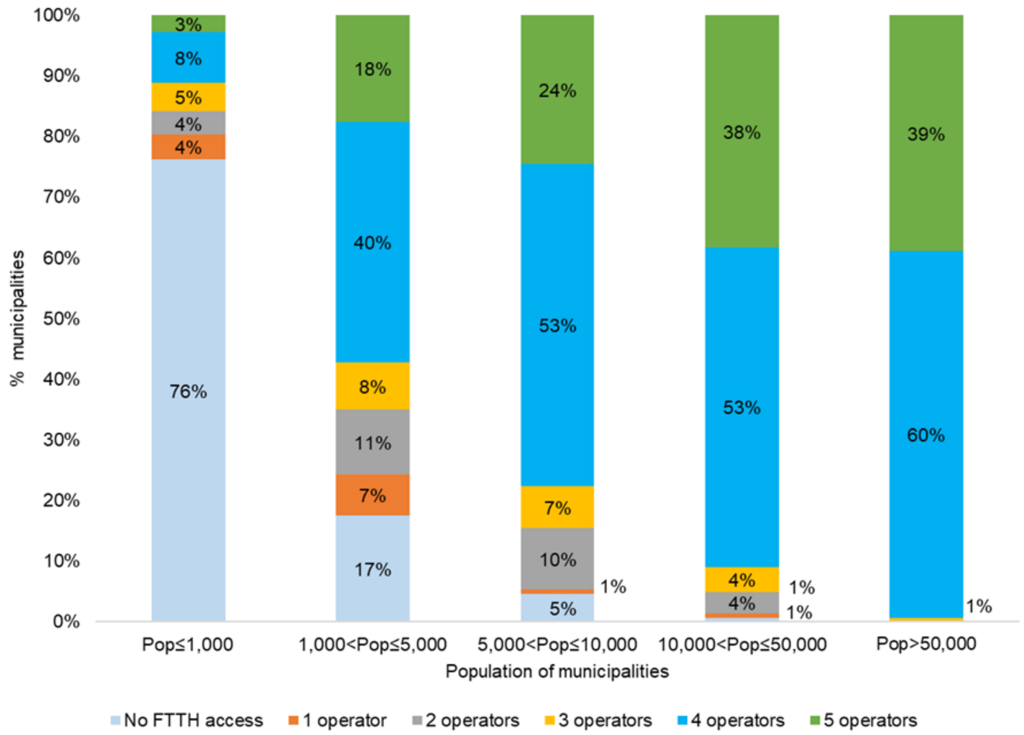
Source: CNMC based on own data (2020).
Note: the share of FTTH is calculated as the percentage of active connections over the national total.

On the other hand, with regard to the municipal distribution of **the number of operators** (in terms of active retail connections) **according to population groups**, Figure 10 shows that, in 2020, above the threshold of 1,000 inhabitants, most municipalities have more than one operator[19]. Moreover, the percentage of municipalities with 4 and 5 operators rises as the population increases.

Therefore, the situation in 2020, compared to the generalised lack of active connections and competition in 2013 (Figure 7), shows significant progress, both from the point of view of greater penetration of fibre optic broadband, extending to all population groups, and from the point of view of the competitive situation, with a majority of municipalities with more than 1,000 inhabitants having more than one operator (between 76% and 99%).

[19]Specifically, the range covers 76% in municipalities with between 1,000 and 5,000 inhabitants and 99% in municipalities with more than 50,000 inhabitants.

Figure 10. Municipal distribution (%) of the number of operators (active retail connections) by population groups in 2020[20].



Source: CNMC based on own data (2020),

As regards the connectivity rate (Table 3), the national average at the municipal level in 2020 was 35%, although there are large fluctuations depending on the population. Thus, values greater than 50% can be seen above 10,000 inhabitants, while the rate is less than 30% in municipalities with up to 5,000 inhabitants.

[20]The total number of municipalities present in the data of the geographic report of the CNMC (2020) according to size is the following: 5,005 (≤1k), 1,822 (>1k and ≤5k), 545 (>5k and ≤10k), 610 (>10k and ≤50k) and 149 (>50k). In terms of population over the national total, its distribution is as follows: 3% (≤1k), 9% (>1k and ≤5k), 8% (>5k and ≤10k), 27% (>10k and ≤50k) and 53% (>50k)

Table 3. Connectivity rate according to municipal population (2020)

Municipalities	Connectivity rate	No. Municipalities
Madrid	75.0%	1
Barcelona	77.7%	1
500,000<Pop≤1,000,000	59.7%	4
100,000<Pop≤500,000	60.3%	57
50,000<Pop≤100,000	64.4%	86
10,000<Pop≤50,000	50.9%	606
5,000<Pop≤10,000	43.1%	519
1,000<Pop≤5,000	29.7%	1,493
Pop≤1,000	25.8%	1,178
Average/ No. Municipalities	34.8%	3,945

Source:CNMC based on own data (2020).

Finally, in relation to concentration (Table 4), the average CR1 in 2020 for the 3,964 municipalities with fibre connections amounted to 61.63%; CR2 was 81%; CR3, 92%; and CR4, 99.6%.

Table 4. Concentration according to municipal population groups in 2020

Municipalities	With fiber		At least 2 operators		At least 3 operators		At least 4 operators	
	CR1	No. Municipalities	CR2	No. Municipalities	CR3	No. Municipalities	CR4	No. Municipalities
Madrid	48.3%	1	76.2%	1	88.1%	1	100.0%	1
Barcelona	45.0%	1	73.9%	1	87.7%	1	99.4%	1
500,000<Pop≤1,000,000	38.5%	4	71.0%	4	89.6%	4	100.0%	4
100,000<Pop≤500,000	42.1%	49	72.0%	57	90.4%	57	99.4%	57
50,000<Pop≤100,000	42.0%	52	70.4%	86	88.5%	86	99.8%	86
10,000<Pop≤50,000	45.5%	118	72.5%	602	88.7%	580	99.4%	560
5,000<Pop≤10,000	52.6%	19	78.3%	516	90.8%	461	99.4%	427
1,000<Pop≤5,000	63.5%	23	82.6%	1,380	92.9%	1,185	99.5%	1,055
Pop≤1,000	74.0%	3	88.4%	985	95.9%	794	99.9%	589
Average/ No. Municipalities	61.6%	270	81.4%	3,632	92.4%	3,169	99.6%	2,760

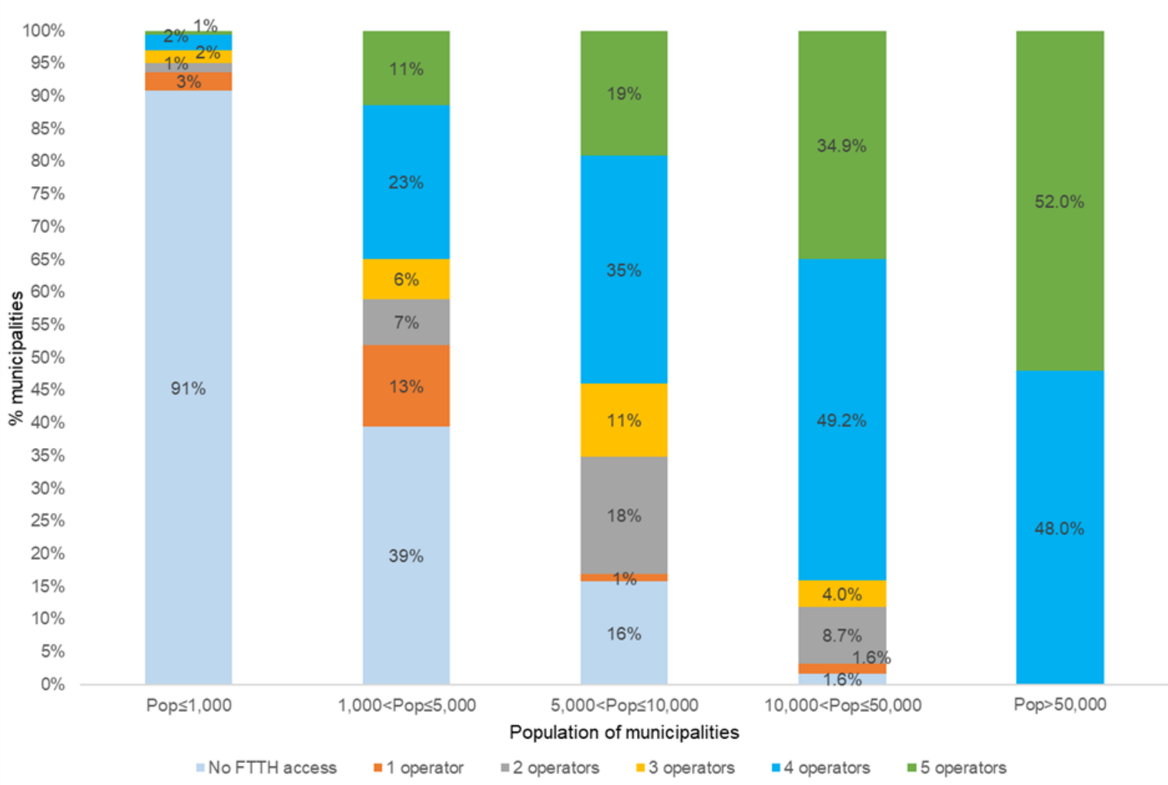
Source:CNMC based on own data (2020). Data on active retail connections

The table shows how, in general, the concentration is greater as the population size of the municipality decreases. In addition, it shows that concentration levels (especially CR1 and CR2) increase in municipalities with less than 50,000 inhabitants, a figure sometimes used as the maximum limit for subsidies.

In this respect, as a prelude to the following chapters, this section provides a breakdown of the distribution of the number of operators according to active fibre connections for municipalities with and without subsidies (aid for the fibre optic deployment completed by the end of 2020). The existence of more than one operator indicates the presence of competition, which is positive for consumers and users and encourages innovation and optimisation of the services offered.

Firstly, with respect to municipalities without aid, Figure 11 shows that municipalities with up to 1,000 inhabitants are characterised by an almost total absence of fibre. Concerning the existence of more than one operator, this can be seen in municipalities with more than 5,000 inhabitants (83% of municipalities with between 5,000 and 10,000 inhabitants and almost 100% of municipalities with more than 10,000 inhabitants). In fact, the most frequent category corresponds to the existence of four and five operators above 5,000 inhabitants.

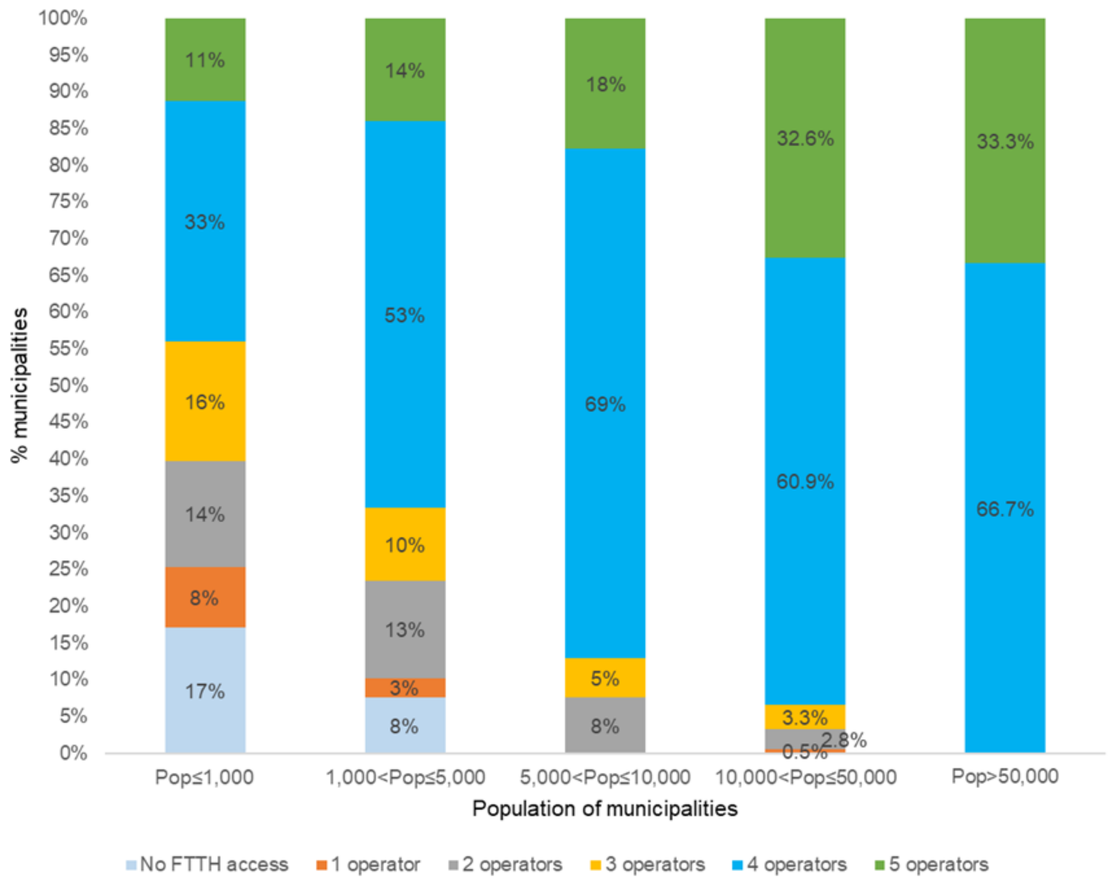
Figure 11. Distribution of the average number of operators in municipalities without aid in 2020, according to the size of the municipality.



Source: CNMC based on own data and data from MINECO and the autonomous communities.

On the other hand, in municipalities with aid (Figure 12), the existence of more than one operator is prevalent in all population groups, with the most common number of operators being four for all groups. Lastly, it should be noted that there are municipalities with concluded aid programmes but without active fibre connections. This situation is due to the fact that almost all of these subsidies ended on the closing date (December 2020), so there has not been sufficient time for retail contracting to take place.

Figure 12. Distribution of the average number of operators in municipalities with aid in 2020, according to the size of the municipality.



Source: CNMC based on own data and data from MINECO and the autonomous communities.

In short, the descriptive analysis shows that the proportion of municipalities without fibre (understood as contracted active connections) is much higher among municipalities that have not received aid (compared to municipalities with aid). In addition, among municipalities that have received aid, there is, on average, a greater presence of operators (with or without their own network) for all population groups. The aid imposed wholesale access conditions on the beneficiary of the subsidised infrastructure, as explained in Chapter 4.

2.2.3. Conclusions of the comparative analysis

A comparative and merely descriptive analysis in 2013 and 2020 of the distribution of the **FTTH** market by operators confirms that both connectivity and **the competitive situation have improved,** with the following data standing out:

- There is a considerable increase in the number of municipalities with fibre access, from 270 municipalities in 2013 to 3,964 in 2020. In 2020, almost all municipalities (more than 99%) with more than 10,000 inhabitants had fibre access.

- In 2020, of the total number of municipalities with fibre access, 9% had a single retail operator with active connections. The majority (98%) were municipalities with up to 5,000 inhabitants. This contrasts with the situation of 2013, when 87% of the municipalities with fibre access reported connections from a single operator.

- In 2013, only 36 municipalities (13% of all municipalities with fibre, all with populations above 10,000 inhabitants) reported active fibre connections from more than one operator. In 2020, the figure had risen to 3,632 municipalities (45% of all municipalities in Spain and 91% of all municipalities with fibre, accounting for 96% of the population).

- In terms of the concentration ratio[21] at the municipal level, while the average CR1 exceeded 99% in 2013, it dropped to 62% of total active connections in 2020. Telefónica was the main operator for both years. As for CR2[22], the average concentration also decreased from 99.9% in 2013 to 81% in 2020. The other ratios for 2013 are not shown, as only one municipality reported connections from more than two operators. In 2020, CR3 reached 92% in the more than 3,169 municipalities where active connections from at least 3 different operators were registered. As for CR4, it reached 99.5% for the 2,723 municipalities with at least 4 operators.

- Most municipalities without fibre access in 2013 had up to 5,000 inhabitants. This population group has seen significant progress, from 83% lacking active connections in 2013 to 61% in 2020. This trend in terms of connectivity has been especially relevant in municipalities with populations of between 1,000 and 5,000 inhabitants (in 2013, 98% of these

[21]For this analysis, the concentration ratio CRk is used, which is the sum of the market shares of the k operators with the most active accesses. Thus, CR1 is the concentration ratio of the majority operator, that is, its market share.

[22]Concentration ratio of the two operators with the highest market share.

municipalities did not report any fibre connections, while in 2020 this figure dropped to 17%). Finally, with regard to municipalities with up to 1,000 inhabitants, the percentage of municipalities without fibre access decreased from 99.7% in 2013 to 76% in 2020.

- As regards **rural areas**, data from the study Broadband Coverage in Europe 2020 used as a basis for the European Commission's Digital Economy and Society Index (DESI) shows significant progress in high-speed broadband coverage in rural areas between 2013 and 2020, although there is still a certain gap with respect to the whole territory[23].

The available data on active connections does not allow a distinction between populations in rural areas and the rest of the populations following the methodological criteria[24] of the European Commission's Broadband Coverage Study, so an analysis based on these categories is not possible.

Instead, the study is based on the provisions of Law 45/2007 of 13 December 2007 for the sustainable development of the rural environment, whose Article 3 defines a small-sized rural municipality as a "*municipality with a resident population below 5,000 inhabitants and integrated into the rural environment"*. The rural environment is defined as "*a geographic space formed by the aggregation of municipalities or smaller local entities defined by the competent administrations with a population below 30,000 inhabitants and a density below 100 inhabitants per km^2*".

Given that these geographic spaces formed by the aggregation of entities with a population below 30,000 inhabitants defined by the administrations are unknown, this study considers as rural those municipalities with populations of up to 5,000 inhabitants (which, in Spain, represent 84% of the number of municipalities and 12% of the population). A separate analysis of these municipalities is provided below.

In 2013, only 1% of municipalities with up to 5,000 inhabitants had fibre connections, representing 0.4% of connections nationwide, and these were

[23]https://digital-strategy.ec.europa.eu/en/library/broadband-coverage-europe-2020. The study shows that new generation broadband coverage in rural areas in Spain has experienced great growth, going from 64.9% of households in 2013 to 92.9% in 2020. Also, the evolution in the speed of Broadband networks in rural areas has been very notable, with high-speed networks (more than 30 Mbps) going from covering 23.1% of homes in 2013 to 70.1% in 2020. Regarding fibre and cable networks, there is only data from 2019 that confirms the gradual reduction of the gap between rural areas and the national total. In 2020, fibre and cable coverage rose to 64.1% of households in rural areas (71.5% in 2021), compared to 91.7% of households in the national total (93.8% in 2021).

[24]"*One of the key dimensions of the study is centred around gaining information on broadband coverage in rural areas. In order for the rural data collected in the period 2013-2020 to be comparable to the 2012 dataset, the research team uses a methodology first developed by Point Topic in 2012, which defines rural areas using the Corine land cover database and creates a database of population and land type in every square kilometre across Europe. Households in square kilometres with a population of less than one hundred are classified as rural. This granular approach based on population density identifies the truly rural areas likely to be unserved or underserved by broadband operators."*

mostly provided by a single operator. However, by 2020, 39% of rural municipalities had fibre connections, representing 6% of total connections, and most municipalities had 4 operators.

Despite the clear progress, it is important to note that municipalities with up to 5,000 inhabitants represent 12% of the total population, yet active connections in these municipalities only account for 6% of total active connections, which illustrates the persistent gap with respect to municipalities with larger populations.

In addition, the presence of more than one operator is higher in municipalities that receive aid compared to municipalities without aid, which suggests that public aid may have contributed to reducing the aforementioned digital divide. Section 4 will delve into the effects of aid on connectivity and competition.

In summary, the comparison between 2013 and 2020 shows a significant growth in active FTTH connections, which were initially concentrated in large municipalities and in the hands of a single operator. Despite the persistence of a decreasing digital divide between large and small municipalities, in the last available year (2020), all groups of municipalities show fibre penetration and, in general terms, less concentration.

The next chapter presents the aid programmes for broadband deployment in Spain, while Chapter 4 analyses the contribution of such aid to: i) **the improvement of the population's broadband connectivity** (FTTH) and ii) **a possible pro-competitive effect** on operators related to the deployed infrastructure.

3. AID PROGRAMMES FOR BROADBAND DEPLOYMENT

3.1. Introduction

Aid for broadband deployment, mainly co-financed with ERDF funds, is mostly provided by the national PEBA-NGA programme, currently managed by the Ministry of Economic Affairs and Digital Transformation (MINECO). In addition to the national PEBA programme, there are other aid programmes managed by Spain's autonomous communities. The following sections show the main magnitudes of aid for the broadband deployment granted between 2013 and 2021[25], with a special focus on aid programmes completed by the end of 2020, which is the reference date for the analysis of Chapter 4[26].

This analysis is based on data published by the MINECO, as well as on the information obtained in separate requests for information made by the CNMC to the MINECO (to obtain an updated list of State aid files), and to the autonomous communities (to collect the most relevant data on regional aid).

3.2. State aid programme (PEBA-NGA)

The following is a review of the main magnitudes of the State aid programme PEBA-NGA, which can be consulted in detail on the MINECO website.

It is important to highlight the dual dimension of aid programmes. On the one hand, aid is organised around files for which a monetary amount, a technology, and an awardee are assigned. This implies that the monetary amount allocated to each population entity in an aid file is unknown, making it impossible to carry out an analysis based on the amount of aid per territorial area. On the other hand, each file contains geographical information detailing the population centre that actually receives the aid, which in many cases corresponds to population entities (or parts thereof) smaller than a municipality (e. g., singular population entities, hereinafter ESP as per their acronym in Spanish).

3.2.1. Overview of State aid files

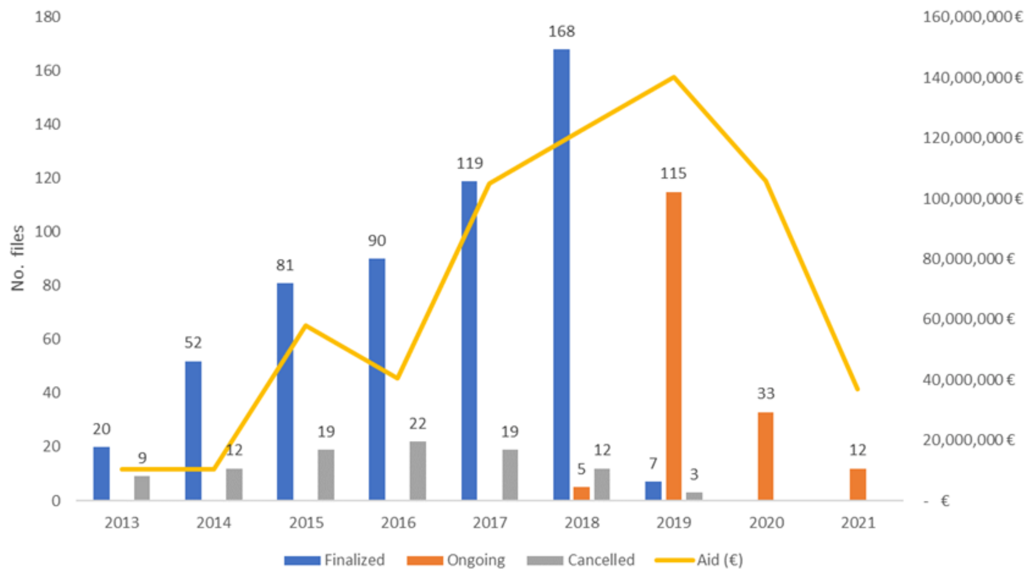
In all of Spain, between 2013 and 2021, the different calls for aid resulted in 798 aid files, with a heterogeneous territorial scope and composition depending on

[25]It includes all the aid rounds in the PEBA-NGA Programme. In the 2020 and 2021 calls, of which no project has been completed at the end of 2020, areas with deficient NGA coverage (understood as that provided or planned by a single operator -NGA grey areas- at lower speeds below 100Mbps) were also included.

[26]This reference date responds to the fact that, at the date of drafting the report, the latest available data on the broadband market correspond to the year 2020.

the characteristics of the population centres involved. These files have generated investments ("fundable budget" or total project budget) of more than 1.1 billion euros, of which more than half (620 million) corresponds to public aid. At the end of 2020, 537 files (67%) had been completed, 165 (21%) were scheduled to be completed in 2021 and 2022, and 96 files (12%) had been cancelled, as can be seen in Figure 13, which shows that most of the aid files and the largest amounts of aid are concentrated in the calls for aid granted between 2015 and 2019[27].

Figure 13. Status of State aid files and amount of aid for PEBA-NGA projects by year of call.



Source: CNMC based on MINECO data.
Note: each year on the x-axis shows the number of completed, ongoing or cancelled projects from that year's call, with data updated as of October 2021.

As regards the **cancellation of aid**, which means that the awardees must repay all the aid received so far, including late-payment interest, for use in future calls, the reasons for cancellation can be grouped into three categories:

- Cancellation due to **lack of guarantees** (when, once the award resolution has been issued, the beneficiary is unable to present the necessary guarantees for the aid to be recovered). This was the reason for 22% of cancellations in the analysed period.

[27]In this sense, the configuration of the aid files changed in the 2020 and 2021 calls, becoming (if part of the call) a single file per province. In previous years, there could be multiple files for each autonomous community, covering several provinces.

- Cancellation due to **non-compliance** (when it is found that more than half of the project objectives have not been achieved once the project is completed). This accounts for 34% of cancellations in the analysed period.

- Cancellation due to **renunciation** (when, once the aid has been awarded and received, the beneficiary renounces it). This is the most common cause of cancellation (44% of cases).

In the case of the national PEBA programme, the funds earmarked for the 96 cancelled files amounted to more than 20 million euros (3.2% of the total aid). In terms of technology, 61 of the cancelled files were for fibre (FTTH), 31 for wireless technologies, and 2 for other technologies. Regarding the beneficiaries, 25 corresponded to the five largest operators, while the rest of the cancellations, almost 74%, had smaller operators as beneficiaries.

Hereinafter, the analysis will focus on aid files **completed by the end of 2020**, as the aim is to understand the effects of the aid and, for this, the projects must be completed.

The **total budget** of the PEBA-NGA projects called since 2013 and completed by the end of 2020 amounted to more than 634 million euros, while the **aid**, mostly from subsidies and advances from European funds, **amounted to 317 million** euros. Therefore, the average aid ratio was 50% of the total budget, with slightly more than 40% of the total investments still to be completed[28].

In terms of the technologies used, the **fibre to the home (FTTH)** was clearly the most subsidised technology (95% of the aid files), gaining progressively more weight until it became **the only technology subsidised since 2017[29]**. The rest of the aid files have subsidized LTE [30] (1%) and WIMAX wireless technologies[31] (1%), HFC technology (0.2%), and other technologies (3%). In monetary terms, the predominance of fibre is even greater, having received more than 99% of the aid for completed projects.

Regarding the **operators benefitting from completed aid**, there were more than 100 different beneficiaries. Telefónica was the beneficiary of 42% of the

[28]Regarding the files in progress, the financeable budget amounted to 462 million euros, the aid was 291 million euros, with a financing intensity of the aid of 65% of the financeable budget.

[29]Likewise, all the files in execution have the purpose of deploying FTTH.

[30]LTE includes “LTE-FDD” and “LTE-TDD.”

[31]WIMAX includes “WIMAX-NGA” and “WIMAX.”

completed aid files, followed by Orange (7%) and the MásMóvil Group (7%)[32]. If we focus on the amount of aid received, Telefónica was also the main beneficiary, receiving 247 million euros (78% of the total), followed by Orange with 20 million euros (6%) and MásMóvil with 17 million euros (5%). The five main operators received 93% of the total completed aid (290 million euros)[33]. Telefónica's greater share in monetary terms is related both to the fact that it was the beneficiary of the largest number of subsidies (it was also the operator with the largest number of applications for these programmes and, consequently, the operator that invested the most in them) and to the fact that it was the beneficiary of most of the projects with the largest budgets (specifically, projects for the deployment of fibre, the most expensive technology, whose average budget is more than 10 times higher than the other subsidised technologies).

As regards the **distribution of aid for completed projects among the different regions**, Figure 14 shows that the per capita presence of aid has generally been higher in the autonomous communities with a more unfavourable starting situation in terms of active fibre connections[34], such as Galicia, Castilla-La Mancha, Castilla y León and the Canary Islands[35].

Lastly, the **aid ratio[36] for each autonomous community or city** tends to range between 40% and 60% of the total budget for completed projects, with higher values in regions with more dispersed and mountainous population centres (such as Galicia or Asturias) or with geographical particularities (such as Ceuta).

[32]Regarding the beneficiaries of the aid being delivered, according to the number of files, Telefónica stands out with 52% of the projects that are underway, followed by Adamo with 5% and Orange with 4%. The five largest operators have a cumulative share of 53%. Regarding the distribution of the amount of aid between operators, Telefónica is the recipient of 62% of the aid in execution, Adamo 29%, and Albacete System with 1%. The five largest operators have a share of 66%.

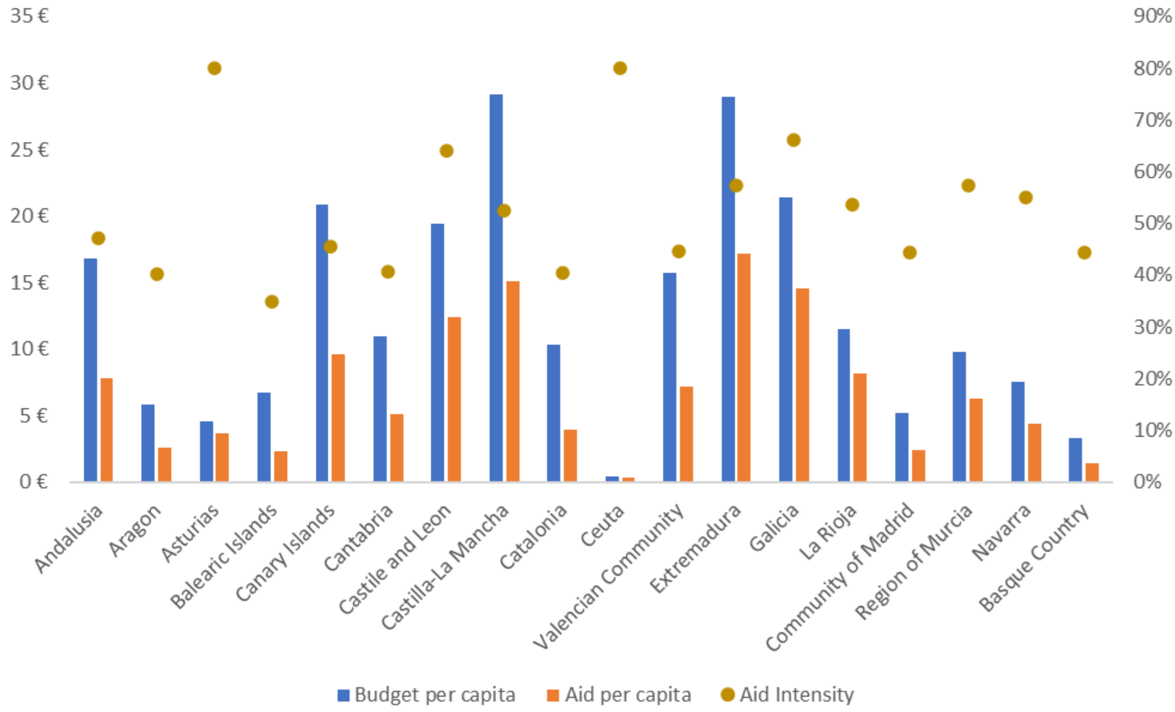
[33]It includes the operators Telefónica, Grupo Orange, Más Móvil, Vodafone and Grupo Euskaltel. It should be noted that ADAMO, even though it was not one of the most prominent operators in the market at the end of 2020 (it had 4% of the projects completed), in that same year it had another 25 ongoing files (all in FTTH).

[34]See figure 5.

[35]These Autonomous Communities have received 12%, 10%, 9% and 7% respectively of the total funds allocated to aid completed in 2020. In addition, with respect to the ongoing aid projects, the majority of the ongoing aid funds are focused on Galicia (22%), Andalusia (20%), Castilla y León (16%) and Castilla-La Mancha (10%), in line with the distribution of aid already completed.

[36]Ratio between the amount of aid granted and the total budget of a project (expressed as a percentage).

Figure 14. Distribution of budget, amount of aid and aid ratio by autonomous communities and cities



Source: MINECO data

Note: The right vertical axis indicates the aid ratio for each autonomous community and city.

3.2.2. Distribution of State aid at the local level

To carry out this analysis, reference is made to the census of the INE(the National Statistics Institute), which offers a distribution of population units at the national level using an 11-digit code as the identifier of a population unit, where the first 5 digits indicate the municipality, the first 9 digits the singular population entity (ESP) of the municipality and the 11 digits the centre or scattering of the singular entity of a given municipality (which depends on factors such as size or other administrative reasons).

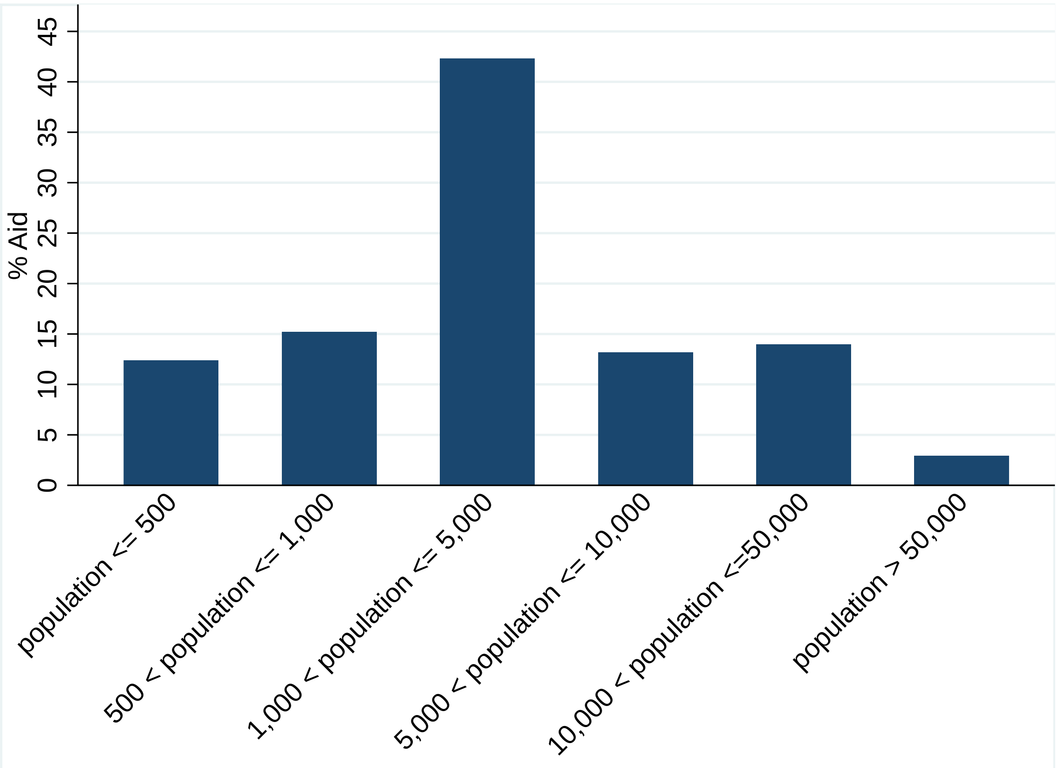
In this respect, it should be noted that the aid is allocated to population units with up to 11 digits of the abovementioned code. This means that in some cases aid is allocated to centres, scatterings, or parts thereof within a municipality, while in other cases aid is allocated to an entire municipality. These different population levels are relevant as they condition the different perspectives of analysis.

The distribution of completed aid under the national PEBA-NGA aid programme at the municipal level[37] is detailed below, given the greater availability of data on the other variables included in the next chapter.

The aid analysed (projects completed by the end of 2020) was deployed across **3,268 municipalities** (40% of all Spanish municipalities) in 7,263 singular population entities (11% of all ESPs). In terms of the population potentially affected by the aid, the population of the singular population entities with aid exceeds 21 million people (44% of the national population)[38].

From a municipal point of view, subsidies focused mainly on municipalities with fewer than 5,000 inhabitants (70% of the total), as can be seen in Figure 15. This distribution tends to be the same for most provinces[39].

Figure 15. Distribution of completed aid by the size of the municipality (%)



Source: MINECO data.

[37]It includes the first five digits of the INE identifier.

[38]It is important to note that this is an approximate figure that constitutes an upper limit, since it is common for the aid to affect only part of the territory of a municipality or singular population entity.

[39]The inclusion of aid in execution would raise the number of ESPs to 26,806 and the number of municipalities to 5,488. In addition, the aid in execution is focused mainly on municipalities with up to 500 inhabitants (40%), followed by the range between 1,000 and 5,000 inhabitants (28%) and the range between 500 and 1,000 inhabitants (13%).

3.3. Regional aid programmes

The aid data in this section comes from a request for information made by the CNMC to all autonomous communities and cities, which requested information on the aid for broadband deployment in their territory granted during the analysed period (2013- 2020). This section, following the same criteria as in the analysis of the national PEBA programme, provides a brief description of the information collected, structured as the information on the national programme, and its relative share with respect to the national programme.

As can be seen in Table 5, the autonomous communities with regional aid programmes completed by the end of 2020 are as follows: Andalusia, the Balearic Islands, the Canary Islands, Castilla-La Mancha, Castilla y León, Galicia, Navarra and the Basque Country. These programmes involved just over 27 million euros of aid (8.5% of the amount of the national programme) for projects and a total investment of 37 million[40].

These figures are lower than those described for completed State aid (see Section 3.2). The results show major contrasts between autonomous communities since, although their relative importance in some communities (Andalusia, the Canary Islands, Galicia, Castilla-La Mancha or Castilla y León) is very small, in the case of the Basque Country, the regional aid funds exceed by more than four times the amount of the State programme in that autonomous community. Moreover, it is also significant that the aid ratio is higher in all regional aid programmes.

[40]Regarding the amount of ongoing aid files at the end of 2020 (expected completion between 2021 and 2023), Aragón has aid corresponding to two for an amount of more than 22 million euros, Andalusia has aid relating to a file for 2 million euros, Galicia a file for 12 million and the Basque Country aid relating to six files amounting to 14.5 million euros. With regard to cancelled cases, Cantabria summoned a file for aid (more than 1 million euros) that was cancelled due to non-compliance.

Table 5. Ratio between completed regional and State aid.

Regions	Regional Programs			Statal Program			Relationship between regional and state program		
	Budget (€)	Aid(€)	Intensity	Budget (€)	Aid(€)	Intensity	Budget	Aid	Intensity
Andalusia	31,666	25,333	80%	142,418,561	65,666,668	47%	0.000222	0.0004	1.7
Aragon				7,734,249	3,385,347	40%			
Asturias				4,636,721	3,709,377	80%			
Balearic Islands	5,549,110	2,264,451	41%	7,813,508	2,647,142	35%	0.71	0.86	1.17
Canary Islands	3,223,668	2,712,347	84%	45,450,928	20,899,232	45%	0.07	0.13	1.85
Cantabria				6,364,816	2,958,828	41%			
Castilla-La Mancha	78,942	59,978	76%	59,525,592	30,831,984	52%	0.00	0.00	1.45
Castile and Leon	6,051,352	4,924,014	81%	46,574,553	29,634,379	64%	0.13	0.17	1.28
Catalonia				80,433,744	30,303,341	40%			
Ceuta				32,554	26,043	80%			
Valencian Community				79,278,561	36,092,818	45%			
Extremadura				30,804,952	18,292,333	57%			
Galicia	5,483,007	3,300,059	73%	57,860,204	39,311,947	66%	0.09	0.08	1.10
La Rioja				3,680,757	2,601,562	54%			
Community of Madrid				34,845,914	16,205,097	44%			
Region of Murcia				14,774,381	9,510,093	57%			
Navarra	2,202,025	1,294,073	59%	5,002,469	2,868,811	55%	0.44	0.45	1.07
Basque Country	14,719,352	12,768,677	87%	7,326,995	3,027,407	44%	2.01	4.22	1.97
National Total	37,339,121	27,348,932	73%	634,559,460	317,972,408	50%	0.06	0.09	1.47

Source: prepared by the CNMC based on the request for information made by the CNMC.

In terms of **technology**, the distribution of aid has followed similar parameters to that of the national PEBA programme, with a predominance of aid for fibre optics (80% of aid files and 93% of aid funds), although with a higher proportion of aid for wireless technologies (20%)[41].

With regard to the **beneficiary operators**, Telefónica implemented 63% of the completed aid files [42], followed by Ensinca Network SL (4%) and Grupo Euskaltel (2%). Together, the five main operators accounted for a cumulative share of 68%. Therefore, the concentration of regional aid is lower than at the national level, where the share of the five largest operators was 93% of the total amount of completed aid.

At the **territorial level**, regional aid has been deployed across 534 municipalities (in 1,162 ESPs)[43], which represents a smaller share than the 3,268 municipalities covered by the national PEBA programme. In terms of the population potentially affected by this aid, the population of the singular population entities with aid is approximately 1.5 million (14% of the population affected by the national programme), while that of the municipalities to which they belong exceeds 3.5 million. In addition, 203 municipalities have received both State and regional aid for broadband deployment, although the subsidies was generally granted for different technologies.

[41]As for the files in progress, all of them are aimed at the deployment of fibre optics (FTTH) except for a file in Aragon for VDSL dating from 2014 and scheduled for completion in 2021.

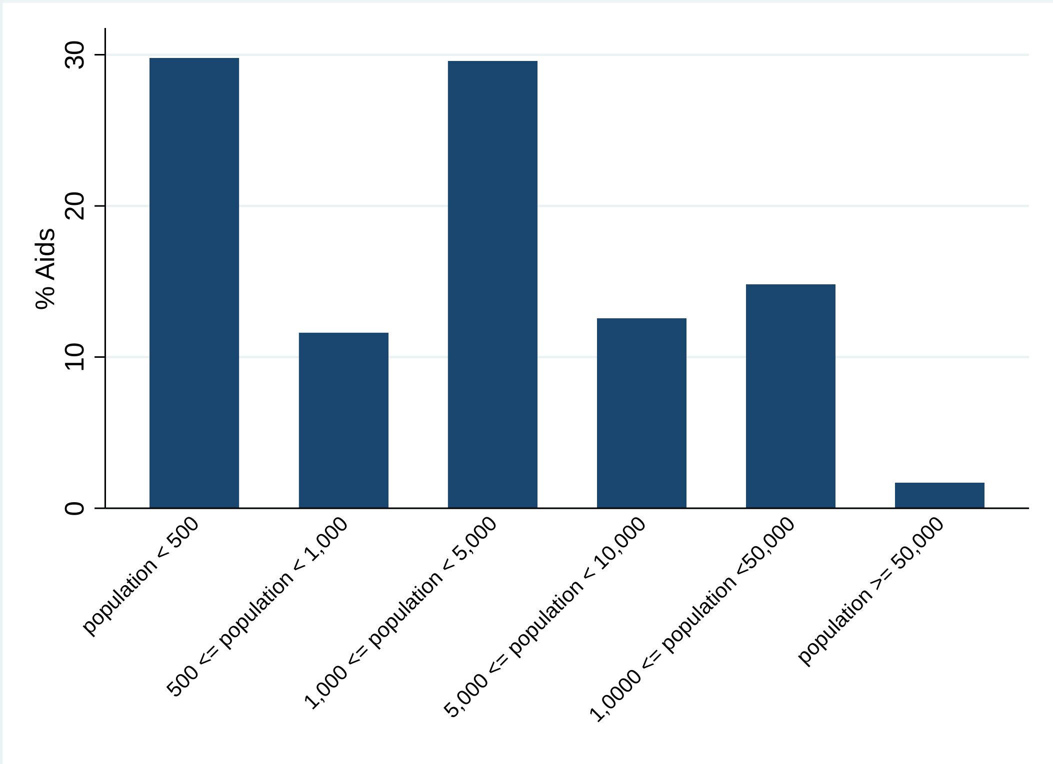
[42]The proportion is similar (69%) for aid in progress.

[43]The number rises to 1,086 municipalities and 2,565 ESP if we include the aid in progress.

As for the **distribution according to the population of the municipality** (Figure 16), regional aid has followed a similar pattern to that of the national programme, with more than 70% of subsidies going to municipalities with fewer than 5,000 inhabitants[44].

[44]If we include the data for aid in progress, the distribution remains similar, but with a greater weight of municipalities with less than 500 inhabitants (40%).

Figure 16. Distribution of regional aid according to the population of municipalities



Source: prepared by the CNMC based on the request for information made by the CNMC.

In summary, the aid programmes for broadband deployment in Spain amount to more than **345 million euros of completed aid** for a total investment of more than 670 million euros, with the State programme accounting for a clearly higher proportion (91% of completed aid) than regional aid.

In terms of **technology**, the completed aid focused on fibre optic deployment both in terms of the number of aid files (95% of State aid files and 80% of regional aid files) and the share of total aid funds (99% of the State aid and 93% of regional aid).

As for **beneficiary operators** (more than one hundred), the largest recipient of aid, both in terms of the number of completed aid files and the amount of aid (both at the State and regional level), is Telefónica[45]. The share of the five main operators is clearly higher in State aid (93%) than in regional aid (68%), although the presence of these five operators tends to be concentrated in the costliest projects (99% of aid), which are associated with fibre optic deployment.

[45]Regarding the files completed at the end of 2020, Telefónica has been a beneficiary in 42% of state projects and 63% of regional projects. Regarding the amount of aid finalised, Telefónica has benefitted from 78% of state funds and 87% of regional funds.

Finally, at **territorial level,** both programmes (state and regional aid) have focused on municipalities with less than 5,000 inhabitants (70% of the municipalities with aid), and it is noteworthy that many of the subsidies underway at the end of 2020 (around 40%) cover municipalities with less than 500 inhabitants.

4. AIDS AND COMPETITION. QUANTITATIVE ANALYSIS OF THE AID FOR BROADBAND DEPLOYMENT

The aid for the rollout of broadband aims to **facilitate investment in the costly infrastructure and civil engineering that comes with most technologies** (essentially cable and fibre optic conduits) in those areas that lack coverage and where it is foreseen that there will be little interest in building businesses by private enterprise, over the next three years (the so-called "*white zones*"[46]). In this sense, as established in the Treaty on the Functioning of the EU and as recommended by the EU Broadband Guidelines, the design of aid plans should **ensure that distortions to competition are avoided** in the market, and aid should be granted in places where operators would not normally have decided to invest[47] .

To avoid distortions of competition, and as established in the regulatory bases of the aid measures, once the infrastructure is built, the operator that is developing the network is obliged to offer access to the infrastructure to the rest of the interested operators. **enabling effective competition at the retail level**, guaranteeing the provision of competitive and accessible services to end users[48] .

In this way, the aid, in addition to offering coverage in places where there would not be any, **can operate as a facilitator of competition**, by increasing the business interest of the operators, who can proceed to attract customers without

[46]In accordance with section 66 of the EU Broadband Guidelines, white areas "are those where broadband infrastructure does not exist and is unlikely to be developed in the near future." The term "near future" shall be understood to mean a period of three years.

[47]The treaty itself The Functioning of the European Union (article 107.1) provides that " *Aid granted by States or through State funds, in any form, that distorts or threatens to distort competition, favouring certain companies or productions, will be incompatible with the internal market, to the extent that they affect trade between Member States.* ".

In addition, the sixth paragraph of the European Union Guidelines for the application of the rules on state aid to the rapid deployment of broadband networks highlights: " *The objective of state aid control in the field of broadband is to ensure that state aid will result in a higher degree of broadband coverage and penetration, or at a faster rate than it would without the aid, by supporting the higher quality and more affordable services, pro-competitive investment and ensuring that the positive effects of aid counteract distortions of competition* ".

[48]In accordance with article 52.7 of Regulation 651/2014 of the European Commission, "The operation of the subsidised network will offer the widest possible active and passive wholesale access, in accordance with article 2, point 139, under fair and non-discriminatory conditions, including physical disaggregation. A project may offer virtual unbundling instead of physical unbundling if the national regulatory authority declares the virtual access product as equivalent to physical unbundling. Active wholesale access will be granted for a minimum period of seven years and wholesale access to physical infrastructure, including ducts or poles, will be for an unlimited time. The same access conditions will apply to the entire subsidised network, including those parts of the network where existing infrastructures have been used. The access obligations will be executed regardless of any change in the ownership, management, or operation of the subsidised network. In the case of aid for the construction of pipes, these will be large enough to accommodate at least three networks and different network topologies."

having to bear the higher cost related to the deployment of the technology. In turn, consumers and users have a greater range of options, which will result in greater well-being.

On these premises, this chapter analyses, through econometric techniques (*matching*[49]), **to what extent the aid has contributed to a greater use of fibre optics** (FTTH) due to an increase in the number of active accesses, and how **they have affected competition**, measured in terms of business concentration.

This exercise is essentially based on evaluating the impact of public intervention by comparing it with a scenario that reflects what would have happened in the absence of intervention (counterfactual analysis). The methodology used is the ***Propensity Score Matching*** **(PSM)**, a method that builds a counterfactual scenario of the municipalities that have received aid ("treatment" group) against their "matching" with one or several municipalities that have not received aid ("control" group). The core of the PSM method lies precisely in the selection of the municipalities for the control group and their pairing with the municipalities in the "treatment" group according to certain determining characteristics.

In order to isolate the effect of the aid, the matching is carried out based on the similarity of the municipalities prior to the intervention and to to do this, **an index is built** (the “propensity score” or “*pscore*”), based on a series of relevant characteristics (covariates or control variables) shared by the municipalities of both groups. As will be set out later (See Annex A.2.2.), the pairing has been based on the following **observable characteristics** of the municipalities: population, area, average income per person and percentage of the population between 16 and 65 years of age[50] . In this way, the pairings will be made up of municipalities that are homogeneous in terms of these characteristics, with the exception that the municipalities in the treatment group have participated in an aid programme and those in the control group have not.

Once the matching process is done, the methodology works out the average impact of public aid based on the differences between the matched municipalities.

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[49]The literature on quasi-experimental techniques, including matching methodologies, has grown remarkably in the last decade. Thus, works such as those by Gertler et.al (2017) and Angrist et.al (2009) focus on the theoretical treatment of matching, while, for example, the article by Tchorzevska et.al (2022) offers a demonstration of its application to specific cases. In addition, regarding the application of the PSM on the evaluation of the effects of public aid, the work of Duso et.al (2021) deals with public aid in the broadband market in Germany and the work of Heim et al (2017) studies the impact of aid from the European Commission on the survival and financial viability of companies. Likewise, it is worth noting the latest edition (2022) of the *Spanish economy papers* (nº 172)., “Evaluation of public policies”, in which a review of the main evaluation techniques is carried out, among which is the PSM.

[50]In this sense, Lera-López et al. (2011) expose the relationship between people with more income, studies and young people and a greater use of broadband,

The PSM methodology enables an approximation to be made of the **causal relationship between public intervention** (having benefitted from an aid programme), **and a series of facts that you want to contrast** (in this case, greater use of fibre optics and improvement in the level of competition in the broadband market).

4.1. Empirical framework

4.1.1. Scope and criteria for the eligibility of municipalities for analysis

As a step prior to the exercise, it is essential to narrow down the main **dimensions** of the analysis and the **criteria** so that the municipalities for which information is available become part of the analysis.

Regarding **the time element**, this analysis includes the programmes convened between 2013 and 2020, which are completed by the end of 2020 (the last year available at the date of drafting this report).

With regard to **the territorial element**, this analysis addresses municipal level, incorporating information from both state and regional aid[51] . Although the aid is normally allocated to smaller population units (singular population entities, nuclei, disseminated, etc.), the availability of socioeconomic variables at these levels is practically non-existent, making any type of counterfactual analysis difficult. Accordingly, aid data has been aggregated at the municipal level, as detailed in Annex 2 (Section 1)[52] . In addition, those municipalities with more than 50,000 inhabitants in 2013 have been excluded, since the calls for aid are focused on municipalities with a population below that figure.[53] .

As far as **broadband technologies** are concerned, the empirical analysis focuses exclusively on active fibre optic access to the home (FTTH) at the retail level, given that the vast majority of aid, both in number of files (95% at the state level and 89% at the regional level) and in monetary terms (92% of the total amount of state aid and 93% at the regional level) in the period under study have been allocated to this technology. Furthermore, in order to avoid bias in the analysis, those municipalities that already had active fibre optic accesses at the retail level in 2013 and that therefore would not be eligible for the different aid

[51]The information contained covers, among others, the following fields: beneficiary territorial area, beneficiary operator, subsidised technology, date of completion or cancellation, eligible budget, or amount of aid.

[52]Includes the first five digits of the INE identifier (see section 3.2.2).

[53]The number of municipalities with a population of more than 50,000 inhabitants in 2013 represents less than 2% of the total number of municipalities.

programmes (since they are not white zones) would be excluded[54]), thus ensuring that the starting point is homogeneous in the municipalities under analysis.

4.1.2. Dependent or outcome variables

The two variables of interest (dependent variables) through which the relationship between state and regional aid and the evolution of the broadband sector in Spain are analysed have been the following:

- **Use of fibre optics.** It is measured by the connectivity rate, calculated as the quotient between the number of active accesses at retail level and the sum of the number of homes and premises**.**

  This variable picks up whether the aid **has contributed to the main objective of increasing connectivity (use)** of (fibre optic) broadband in Spanish municipalities.

  The data for its calculation are obtained from the statistical information compiled by the CNMC from the five main operators on a quarterly basis for all the municipalities in Spain (these operators are: Telefónica, Orange, Euskaltel Group, Vodafone, and Más Móvil). This information is further completed with the last census of households and premises in the municipality, carried out by INE (the Spanish National Statistics Institute in 2011).

- **Competition in the fibre optic market.** It is measured by the concentration ratio, calculated from the shares of active retail accesses of each operator with respect to the total contracted fibre optic accesses[55] . Specifically, two ratios have been used: CR1 or principal market share operator, and CR2 or sum of the quotas of the two main operators.

  This variable picks up whether the aid has favoured the **entry of new operators and a decrease in the degree of concentration of the main operators.**

  This information also comes from the statistical data of the CNMC.

[54]Only 4% of the total number of municipalities in Spain had active accesses at the retail level in Spain in 2013.

[55]There are also indirect accesses and unbundled loops, which have not been considered in the analysis as they are not part of the subsidised technologies. The proportion of this type of indirect fibre access to total access ranges from 1% in 2013 to 30% in 2020.

However, it is necessary to consider that the number of observations (municipalities) decreases the larger the population, reducing the possibilities of analysis. In the same way, as concentration ratios focus on a greater number of operators (for example, from CR1 to CR2), there are fewer observations available, and it is not possible to analyse the concentration ratio of the three largest operators (CR3) if there are not at least three operators.

4.1.3. Treatment and control groups

The criteria for creating the treatment and control groups are conditioned by the three circumstances mentioned above. First, the aforementioned **territorial variety** in this area means that the aid is awarded at a territorial level smaller than the municipality, grouping different recipient subjects. Second, there are no **socioeconomic variables** available that allow a characterisation of recipient subjects at the infra-municipal level. To overcome these difficulties, aid at municipal level has been added, applying homogeneous criteria to consider the possibility that within the same municipality there may be parts with aid and parts without aid, in addition to the existence of aid that may affect different technologies. Finally, it is necessary to consider the limitation of information about **the identity and diversity of operators benefitting from the aid**, given that the CNMC only has data from the five largest operators[56] .

With these premises, highlighting that, in the period analysed, most of the aid has been received by the five largest groups of operators for FTTH deployment[57] and that these have affected on average the majority (80%) of the population in the municipalities, a conservative view has been adopted where it is considered that a **municipality is part of the treatment group** if you meet the following requirements:

1. It has received state or regional aid for the deployment of fibre optics between 2013-2020 and the programme is completed by the end of 2020.
2. The aid it has received has affected at least 75% of the municipality's population.
3. The operators benefitting from the aid belong to one of the largest groups of operators in at least 75% of the aid in the municipality.

[56]Telefónica, Vodafone, Grupo Orange, Más móvil and Grupo Euskaltel. These are the operators whose data is available to the CNMC on the dates of this analysis.

[57]The FTTH represents 95% of the files at the state level and 80% at the regional level; In terms of aid (in euros), this technology received 99% of the total amount of state aid and 93% of regional aid.

4. 75% of the total amount of aid received by the municipality has been allocated to fibre optic projects.

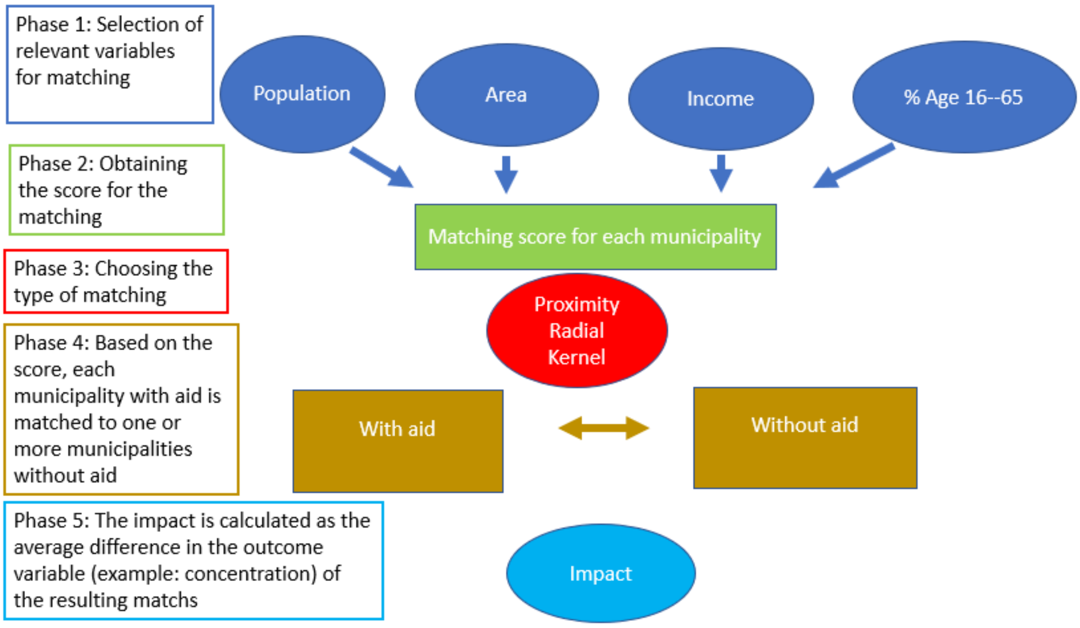
In addition, municipalities with aid that do not meet the requirements to be part of the treatment group are excluded from the analysis in order to narrow down the characteristics of the considered municipalities and thus be able to separate the effects of the aid.

The **control group** is made up of those eligible municipalities (that meet the criteria referred to in section 4.1.1) that have not received state or regional aid for the deployment of broadband in the period under consideration.

4.2. Methodology

This exercise is an **impact evaluation ex post** of the main aid programmes for the deployment of fibre optics (FTTH) by means of the propensity score matching methodology or *propensity score matching (PSM)*[58] , summarised in the following diagram (figure 17).

Figure 17. Summary of the PSM methodology



Source: own elaboration by CNMC

[58]Within the framework of impact evaluations, depending on whether the assignment of treatment (aid) has been carried out randomly or not, it is possible to speak of experimental techniques (e.g., randomised trials) or quasi-experimental (e.g., matching, discontinuity regression, differences in differences, instrumental variables), respectively.

Since the aid is not assigned randomly[59], but rather by following a series of criteria, such as the current and near future absence of coverage (a white zone) and other criteria of which we have full knowledge, this situation implies the potential for selection bias[60] , which is intended to be corrected using the PSM matching technique based on the observable data prior to the end of the initial aid period.

Taking into account that it is not possible to know the results of the same municipality under two different realities (with and without aid), matching methods such as the PSM seek to build a scenario that is as similar as possible.[61] (counterfactual) through the data observed prior to the intervention (in this case, the end of the aid).

In order to determine which municipalities are comparable (construction of the counterfactual) and to minimise the aforementioned selection bias, a series of relevant treatment-determining variables must be included in the PSM (the decision to invest in the deployment of fibre optics with the help of a public aid programme) and that summarise the main characteristics of all the municipalities before the existence of the aid programmes[62] . Taking into account the availability of data[63] and the potential factors that could determine the decision to invest in the deployment of fibre optics, the variables used (phase 1 of the diagram) in this study as covariates are the following: **population** (number of inhabitants per

[59]In the case of a random assignment, it is guaranteed that there is no selection bias because randomness allows the observable and unobservable control variables (covariates) to be balanced, and the treatment variable (existence of help) is independent of the outcome variable. However, when the assignment is not random, quasi-experimental methodologies seek to correct for selection bias using statistical and econometric techniques that focus on observable data, such as matching, or on both observable and unobservable data, as is the case of the difference-in-differences methodology or discontinuity regressions.

[60]Introduced by Heckman (2001), the concept of selection bias is based on the fact that the units participating in the evaluation may be different in measurable characteristics (e.g., population or economic power of the participants) and non-measurable (e.g., the motivation of the evaluators or of the participating units). Thus, while measurable characteristic differences can be controlled in statistical or econometric analyses (e.g., PSM), unmeasurable differences can be problematic if they are related to the outcome variable, potentially biasing impact estimates. This last situation is what is known as selection bias.

[61]Thus, it is especially important to justify that the control group is sufficiently similar to the treatment group, except that they are municipalities that have not received aid. In this sense, for the matching to reduce the potential selection bias, it is necessary to consider a set of relevant observed variables (also called covariates). In case of having a wide range of variables considered in the matching, the so-called problem of dimensionality may arise. That is, in a model with an explanatory variable (e.g., population) it is possible to choose for each treated unit one (or several) control units with a similar population; however, when we add other variables (e.g., income and median age), it is not as easy to determine which control unit is the closest since the number of combinations of the values of the different covariates increases.

[62]In this regard, it may be beneficial to include variables that are possibly related to outcome, even if not related to treatment, thereby reducing potential bias (Brookhart et al 2006; Austin 2011). Along the same lines, Rubin & Thomas (1996) emphasise that, when faced with variables in which there is reasonable doubt about their inclusion, it may be advisable to include them in the analysis.

[63]That they are present in the largest possible number of municipalities and not only in the largest, which are precisely the least subsidised.

municipality), **surface area** (expressed in square kilometres), **average income per person** (in euros) and **percentage of the population aged between 16 and 65 in each municipality**[64] .

Once the relevant variables for the matching have been determined and a series of conditions have been satisfied so that the results obtained through the PSM are valid[65], the PSM balances the distribution of the descriptive variables observed in the two groups, treatment and control, and seeks to find the probability of belonging to the treated group.

The prediction resulting from this model for each municipality is called the *propensity score* (*pscore*), where the properties of the explanatory variables are brought together in a single value (score), reducing the estimate to a single dimension (phase 2 of the diagram).

From this score, according to different **types of pairings** (phase 3 of the diagram) that use different criteria about the distribution and distance of the covariates used, an association can be made with each municipality of the treated group with one or more municipalities of the control group that presents the closest value of the *propensity score*. In the empirical exercise carried out, the following types of matching with replacement have been used[66] :

- **nearest neighbour**: For each municipality in the treatment group, a municipality from the control group that has the closest score is selected (i.e., municipalities are matched with the most similar *pscore*).

- **Radial**: For each municipality in the treatment group, a maximum allowable score distance is established, comparing each treatment municipality with the mean of the scores of the control municipalities that are within the defined radius.

- **Kernel:** is a variant of the radial methodology with the difference that each municipality in the control group is weighted based on its distance from each municipality in the treatment group, giving more weight to the closest municipalities.

[64]To learn more about the characteristics of the covariates and the results of their balance between the treatment and control groups in the different established scenarios, see Annex 2 (section 2).

[65]Annex 2 (section 3) provides a description of the necessary conditions of a PSM analysis. Publications such as Garrido et al. (2014) offer a guide on the verification of each of the mentioned conditions through the Stata software.

[66]For a description of the different PSM methods used in the empirical analysis together with a graphical illustration of each, see Annex 2 (section 4).

Finally (phase 4 of the diagram), **the impact of the aid programme is captured by the difference in the outcome variables** (in our case, the connectivity rate and the concentration ratio in the year 2020) between those municipalities that have received aid (municipalities in the treatment group) and those that have not received it (those in the control group) that have a close score[67]. This difference allows for an attribution to be made **to the aid programme for the changes in the degree of use of fibre optics and the degree of concentration in said markets.** Hence, the definition of which municipalities belong to the treatment group, and which belong to the control group, together with the choice of covariates, are of fundamental importance.

4.3. Results

Next, after offering the list of municipalities that are part of the quantitative analysis, the main results of the analysis are presented considering **both state and regional aid** (**global** scenario). In addition, the results of the aid are shown based on the size of the population of the municipalities (**population bands** scenarios). Finally, Annex 1 (section 5) offers a robustness analysis using the Mahalanobis distance matching method.

4.3.1. List of municipalities that are part of the quantitative analysis.

Table 6 below shows the breakdown of the municipalities that have been part of the quantitative analysis based on the variable analysed and the territorial perspective adopted.

First, the eligible municipalities are shown according to the conditions discussed in section 4.1.1. Accordingly, it should be clarified that this number oscillates due to logical methodological considerations such as the need for the existence of fibre to be able to analyse the variable connectivity rate or the existence of, for example, at least two operators to be able to carry out an analysis of concentration of the two majority operators (CR2).

Second, the municipalities that the PSM matching methodology has considered as suitable are discussed, taking into account the equilibrium conditions between the treatment and control groups discussed in section A.1.2. In this sense, most of the eligible municipalities are part of the analysis carried out using PSM, which shows that the quality of the variables used for matching is high. In addition, we see that for each column of Table 6, the number of municipalities treated (receiving aid) tends to be higher than that of the control municipalities (without

[67]The impact is centred on the mean treatment effect, ATT (*Average treatment effect on the treated).* the ATT is the expected difference in the estimated variable between municipalities with and without aid for those municipalities that are actually part of the treatment group.

aid). It is important to take into account that this circumstance does not affect the validity of the methodology used, to the extent that the equilibrium conditions of the variables used have been met, which guarantees the existence of matches of sufficient quality. Likewise, the use of pairings with replacement in this exercise allows control municipalities (without aid) to be reused for other pairings if they are within the range of another treatment municipality (with aid), increasing the possibilities of analysis.

Table 6. List of municipalities that are part of the quantitative analysis.

	Connectivity rate				
	Global	Population < 1,000	1,000 ≤ Population < 5,000	5,000 ≤ Population < 10,000	10,000 ≤ Population < 50,000
No. of elegible municipalities	**2,280**	**897**	**916**	**235**	**232**
No. of municipalities PSM	2,267	874	916	234	219
No. of municipalities without aid	666	333	201	64	68
No. of municipalities with aid	1,614	541	715	170	151

	Concentration CR1				
	Global	Population < 1,000	1,000 ≤ Population < 5,000	5,000 ≤ Population < 10,000	10,000 ≤ Population < 50,000
No. of elegible municipalities	**2,286**	**898**	**920**	**236**	**232**
No. of municipalities PSM	2,272	no matching due to lack of fulfillment of conditions for PSM	917	235	230
No. of municipalities without aid	669		202	65	68
No. of municipalities with aid	1,603		715	171	151

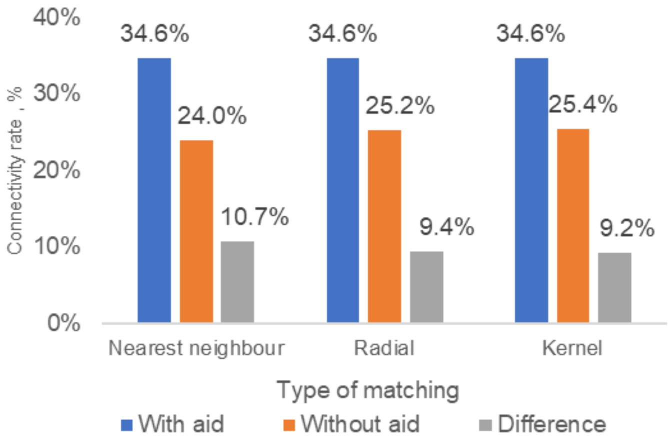
	Concentration CR2				
	Global	Population < 1,000	1,000 ≤ Population < 5,000	5,000 ≤ Population < 10,000	10,000 ≤ Population < 50,000
No. of elegible municipalities	**2,071**	**743**	**862**	**235**	**231**
No. of municipalities PSM	2,057	728	847	235	218
No. of municipalities without aid	527	232	163	64	68
No. of municipalities with aid	2	496	684	171	150

Source: by CNMC based on CNMC data.

4.3.2. Results global scenario.

In the first place, Figure 18 presents, through the ratio of active FTTH accesses over the theoretical maximum (home and premises connections), the results of the objective related to connectivity, that is, the connectivity rate. Thus, at the end of 2020, the municipalities with aid (both state and regional) **present an average ratio of accesses between 9.24 and 10.66 percentage points** (depending on the type of pairing used) **superior to the municipalities without aid**. This result denotes that **the aid has been effective** regarding its main aim of increasing the use of broadband.

Figure 18. Comparison of connectivity rates between the treated and control group according to the matching method



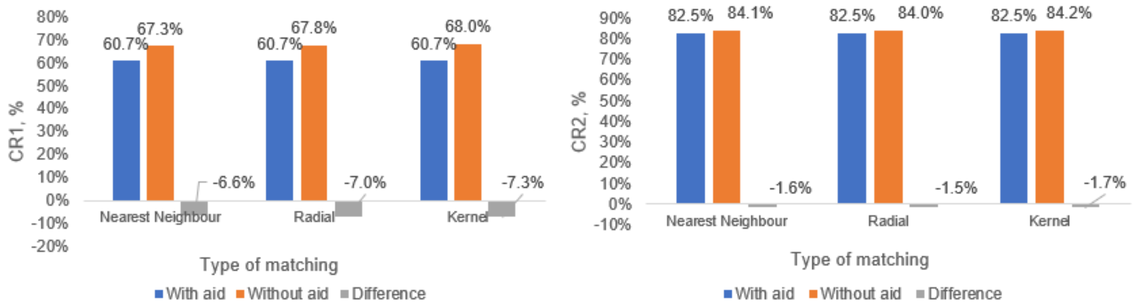
Source: Own elaboration based on data from the CNMC, MINECO and the CC.AA. (Autonomous Communities)

Note: the difference, in percentage points, in the connectivity rate in municipalities with and without aid is significant at a level of 1% in all types of matchings.

Second, we proceed to analyse whether the granting of aid has had any effect on **the competition of the operators that offer the service**. In this sense, figure 19 shows, according to the share of active accesses, the difference in the concentration ratios of the majority operator (CR1) and the two majority operators (CR2) between the municipalities with and without aid.

So, in 2020, **municipalities with aid have lower concentration levels than municipalities without aid**, obtaining robust results in all the models used. Specifically, both the ratio **CR1** (share of the majority operator), such as the ratio **CR2** (share of the two majority operators) are **significantly lower** (between 6.6 and 7.3 percentage points for CR1, and between 1.5 and 1.7 percentage points for CR2, depending on the type of pairing used). Logically, the amount of the effect is less in CR2, given that most of the aid has been allocated to municipalities with a low population, where the size of the market makes it difficult for a larger number of operators to enter.

Figure 19. Comparison of the concentration between the treatment group and the control group according to types of matching



Source: Own elaboration based on data from the CNMC, MINECO and the CC.AA. (Autonomous Communities)

Note: the difference, in percentage points, in the concentration in municipalities with and without aid is significant at a level of 1% in all types of pairings, except in the cases of radial pairing in CR2 (5%) and in the case of "nearest neighbour" in CR2, where it is 10%.

4.3.3. Results analysis according to population bands

Given that the population of the municipality constitutes a fundamental variable, in this section we have proceeded to replicate the previous analysis based on the population bands that the CNMC usually uses in its Geographic Reports. Before analysing the results, it should be noted that the distribution of the number of municipalities in Spain based on their population means that the larger the population band considered, the smaller the number of municipalities susceptible to analysis.[68] . In addition, to this we must add the fact that the aid has been concentrated especially in small municipalities (see chapter 3). This means that the chances of finding significant effects, if any, are potentially lower for the highest segments of the population.

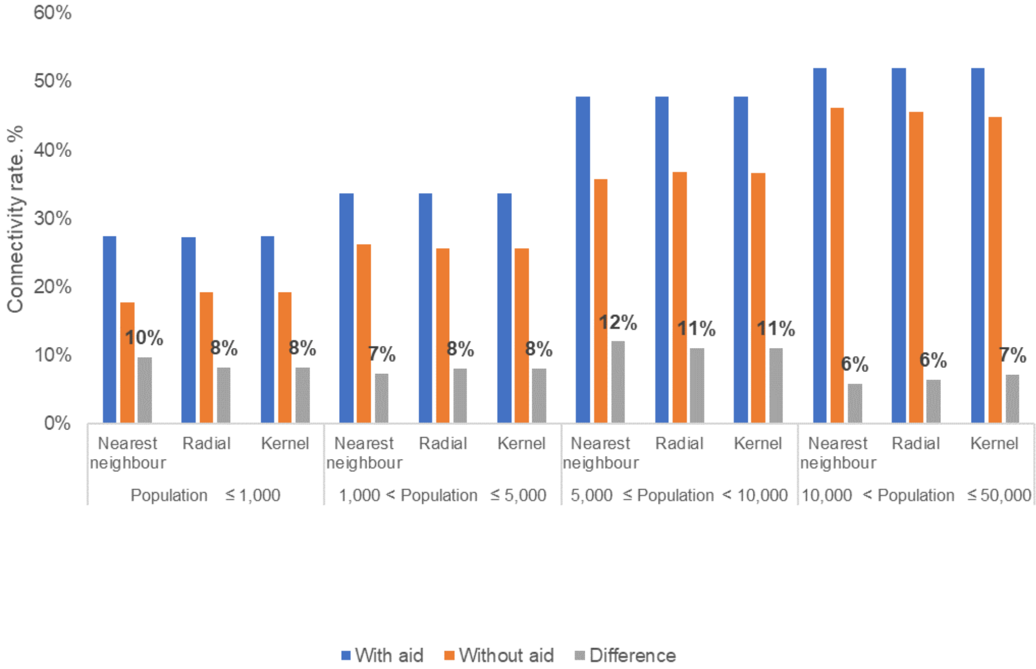
Starting with the related variable **with the** connectivity rate (Figure 20), it can be affirmed that there has been an **increased access to FTTH technology** in those municipalities benefitting from state and regional aid. The **positive difference** (between 7 and 11 percentage points) and statistically significant at the aggregate level, remains stable and robust **for all bands**. There are no large differences between the groups of municipalities with less than 10,000 inhabitants. The most notable results occur in the range of towns with over 5,000 and up to 10,000 inhabitants, where the municipalities treated have, as a whole, a connectivity rate of around 11 percentage points higher than those that did not receive aid. Finally,

[68]There are three main reasons: i) in Spain there are only 150 municipalities with more than 50,000 inhabitants and, on the other hand, there are 7,500 municipalities with less than 10,000 inhabitants; ii) as previously indicated, those municipalities with more than 50,000 inhabitants in 2013 have been excluded (given that the aid calls are focused on municipalities below that figure) and iii) they have also been excluded, to homogenise the starting point of the analysis, those municipalities that already had active fibre optic accesses at the retail level in 2013, the vast majority of municipalities with more than 10,000 inhabitants.

in the largest municipalities, between 10,000 and 50,000 inhabitants, the effect of the aid is not statistically significant.

These conclusions endorse the aggregate results of the previous section, denoting that **aid would have been effective** in its commitment to increase the use of broadband networks (in this case FTTH), especially for municipalities with up to 10,000 inhabitants.

Figure 20. Comparison of the connectivity rate between the treatment and control groups in different population groups and according to the matching method



Source: Own elaboration based on data from the CNMC, MINECO and the CC.AA. (Autonomous Communities)

Note: The difference, in percentage points, in the connectivity rate in municipalities with and without aid is significant at a level of at least 5% in all types of pairings, except in the range between 10,000 and 50,000 inhabitants, where the difference is not statistically significant

With reference to **concentration** (Figures 21, 22 and 23), although the results generally remain significant and robust with respect to the global scenario, it is necessary to delve into the different situations for each of the bands.

Regarding the **smaller municipalities** (less than 1,000 inhabitants), it is observed that there are no significant effects or that they do not meet the equilibrium conditions necessary for the analysis. This is logical to the extent that 91% of the municipalities without aid and with less than 1,000 inhabitants are in a situation of lack of access to FTTH (which makes analysis difficult). However, it is important to highlight that the data at a descriptive level show that 75% of the municipalities with fewer than 1,000 inhabitants with completed aid have more than one operator at the end of 2020, pointing to a possible positive effect on competition.

Regarding **the rest of the bands**, the **significant differences in concentration tend to be smaller the larger the population.** This would imply that **aid has been especially effective where private enterprise seems less likely**, in keeping with the possible failure of the market that motivates the aid programmes.

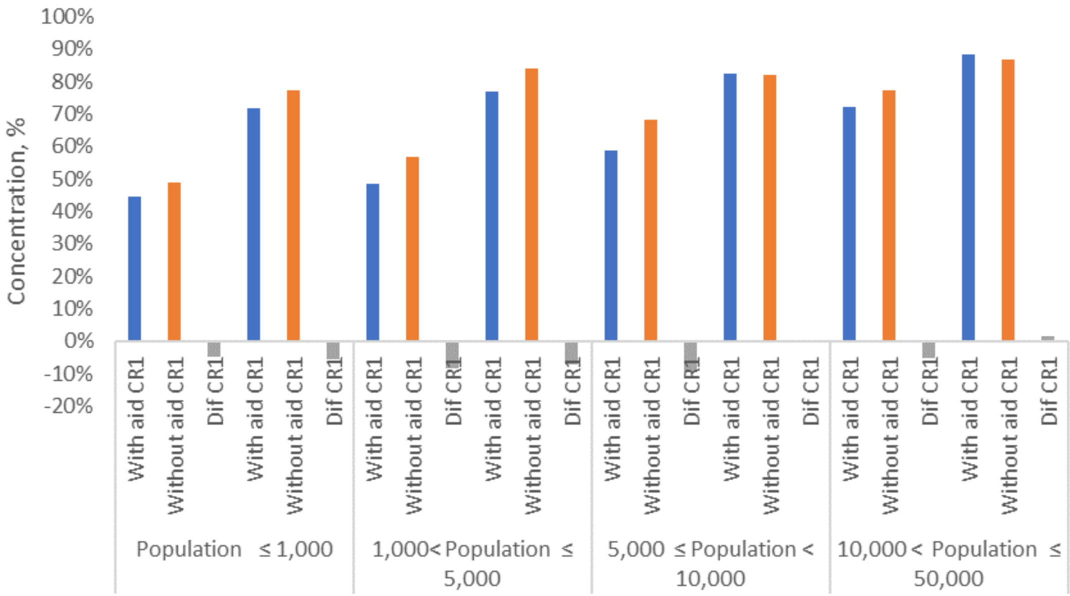
Regarding the market share of the majority operator (CR1), the difference in concentration ranges between 7.82 and 10.45 percentage points for the bands with less than 10,000 inhabitants, while the effects for municipalities with more than 10,000 inhabitants are smaller and statistically less significant: between 3.66 and 4.02 percentage points. This could be because **in large municipalities**, mostly with several operators, the private interest of the operators to deploy networks or enter the market is **similar for municipalities with and without aid**. In this sense, it should be noted that the EU Broadband Guidelines establish the existence of the **incentive effect** of the aid measure as one of the necessary conditions for it to be compatible with the internal market. The incentive effect supposes that, as a consequence of the aid, there is a change of behaviour in the beneficiary in line with the pursued objectives of public interest.

Regarding the share of the two majority operators (CR2), non-significant effects are observed in municipalities with less than 5,000 inhabitants. This could be explained by the fact that the CR2 ratio needs at least two operators to be calculated, which tends to occur less frequently in small municipalities.[69] . However, in municipalities with upwards of 5,000 inhabitants, where there tends to be a competitive environment, [70] **the municipalities with aid do indeed show concentrations between 4.14 and 7.32 percentage points lower than the municipalities without aid.**

[69]Only 20% of municipalities with fewer than 1,000 inhabitants report active accesses from more than one operator.

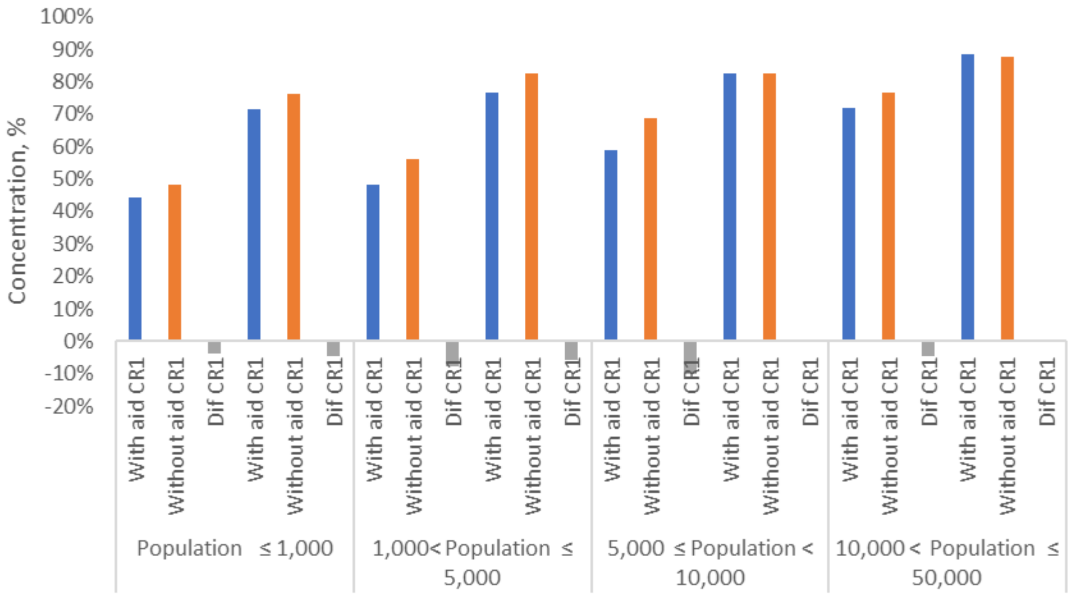
[70]94% of the municipalities between 5,000 and 10,000 inhabitants report active accesses from more than one operator. This figure is around 99% in municipalities with more than 10,000 inhabitants.

Figure 21. Comparison of concentration with nearest neighbour matching



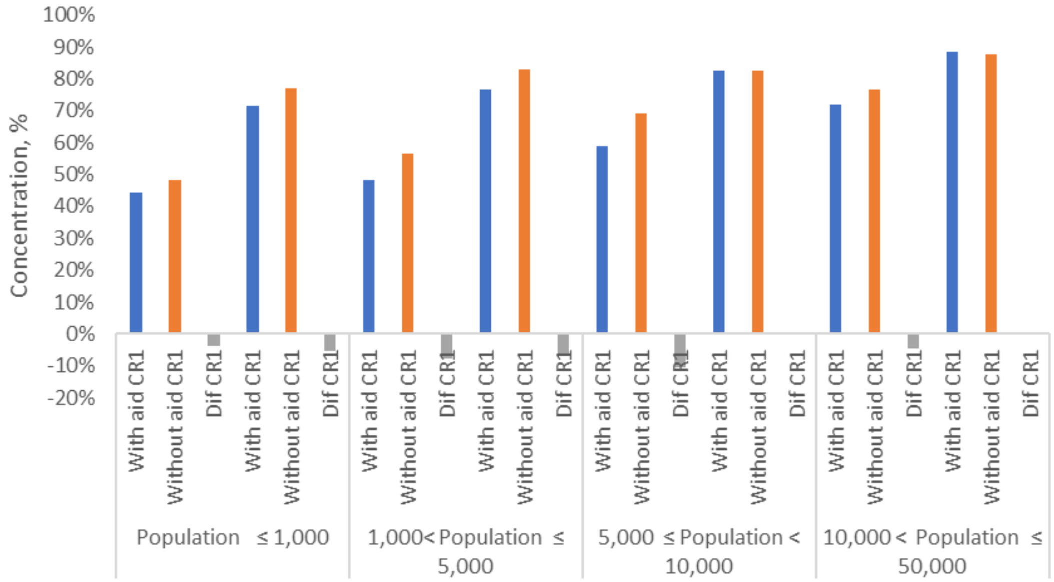
Source: Own elaboration based on data from the CNMC, MINECO and the CC.AA. (Autonomous Communities)
Note: the difference, in percentage points, is significantly different at a level of at least 10%.

Figure 22. Comparison of concentration with radial matching



Source: Own elaboration based on data from the CNMC, MINECO and the CC.AA. (Autonomous Communities)
Note: the difference, in percentage points, is significantly different at a level of at least 10%.

Figure 23. Comparison of concentration with kernel matching



Source: Own elaboration based on data from the CNMC, MINECO and the CC.AA. (Autonomous Communities)
Note: the difference, in percentage points, is significantly different at a level of at least 10%.

5. CONCLUSIONS

This study confirms the notable evolution of the broadband market in Spain between 2013 and 2020. In 2013, Spain was in 18th position of EU countries with the greatest digital connectivity (DESI, 2014), while, in 2020, the situation had improved, reaching 3rd position (DESI, 2021).

However, with regard to connectivity in rural areas, the European Commission highlights in its DESI 2021 report that " *Spain has a high performance in connectivity and has considerably improved the implementation of fibre optic networks, but the great digital divide between rural and urban areas persists*." Likewise, the 2020 coverage report prepared by the Ministry of Economic Affairs and Digital Transformation confirms that, despite the improvements in coverage in rural areas, both at a general level and in fibre (which stands at 60% of the rural households), there are still differences regarding coverage in urban areas.

The evolution experienced in the broadband market between 2013 and 2020 has not only meant greater connectivity, but also greater benefits thanks to the progressive adoption of fibre optic technology. Between 2013 and 2020, there has been an evolution **from almost an absence of active fibre access in most Spanish municipalities to the majority adoption of this technology**, to the cost of other technologies using cable solutions (xDSL and HFC). So, **the number of municipalities with active fibre access has gone from 270 in 2013 to 3,964 in 2020**. More than 95% of the municipalities with more than 10,000 inhabitants had fibre access in 2020.

This evolution has also led to a **greater penetration and diversity of operators, both in global active broadband accesses and in the fibre optic network**. Although Telefónica continues to be the majority operator in the provision of broadband accesses in 2020 (37% of active retail accesses in the national total), its share has fallen twelve percentage points compared to 2013. Regarding the fibre network, compared to the situation in 2013, when Telefónica was the only fibre provider in 97% of the municipalities where it was available, in 2020 there were 3,632 municipalities with fibre access from more than one operator (45 % of the total), and only 9% of municipalities with a single fibre supplier (mostly in rural areas) were reported.

Although most of these deployments have taken place under commercial conditions under a favourable regulatory framework, especially due to regulated access to civil infrastructure, aid is playing an important role in increasing coverage where private investment does not reach.

The deployment of broadband networks between 2013 and 2020 was accompanied by **public aid programmes, focused mainly on the rollout of networks with high capacity and quality levels, resulting in the deployment of fibre optic networks (FTTH), and an example of the successes that public-private collaboration can achieve**.

In the eight-year period analysed, these programmes mobilised **672 million euros in total investment** (635 million euros from the PEBA-NGA projects and 37 million euros from the regional programmes), of which **public aid accounted for 51%** (318 million euros of state aid and 27 million of regional aid).

More than 70% of state and regional aid was directed towards **municipalities with less than 5,000 inhabitants**, where it is foreseeable that they will consist of largely rural areas. In fact, the conditions required between 2013 and 2019 were that the aid be directed exclusively to areas that lacked NGA coverage and where there were no plans to provide it within a period of three years (NGA white zones). Subsequently, the 2020 and 2021 calls, with the aim of continuing to develop the maximum possible connectivity, without distorting competition, also reached areas with poor NGA (Next Generation Access) coverage, understood as that provided or planned by a single operator (NGA grey areas) at a speed of less than 100 Mbps, also increasing the speed of the new networks to 300 symmetrical Mbps, scalable to 1 Gbps.

From the point of view of competition, it should also be noted that these programmes have been establishing wholesale access obligations to the subsidised infrastructures for the beneficiaries of the aid.

The purpose of this report has been to analyse the **impact of aid programmes on improving connectivity and competition**. For this reason, the analysis has focused not on the availability or extension of broadband networks (coverage), but on the levels of adoption or use of networks (connectivity based on active accesses), fibre optics, as it is the technology that has received the most subsidies in aid programmes.

To analyse the relationship between the granting of public aid and the adoption of fibre, a quantitative analysis has been carried out based on the propensity score matching (PSM) methodology, which makes it possible to establish a causal relationship between the existence of aid and the observed results.

The results of the analysis show a **significant improvement in the use of fibre optics and the level of competition** in those municipalities that have benefitted from an aid programme (state or regional) for the deployment of fibre optics. The main conclusions are:

- **The connectivity rate for fibre optic has improved significantly as a result of public aid**. So, in 2020, a municipality that received aid would have, on average, a fibre optic penetration of around **10 percentage points higher** than the counterfactual situation where no aid would have been received. By population groups, this effect is significant (with some differences in terms of intensity depending on the average size of the municipalities) in the **municipalities with up to 10,000 inhabitants**. For municipalities with more than 10,000 inhabitants, the econometric analysis is not conclusive (which may be due both to the lower number of large municipalities and to the possible presence of similar connectivity rates between municipalities with and without aid, which is logical to the extent that the differences in this population band are practically non-existent between both types of municipalities).

- **The concentration ratio has also improved as a result of public aid**. The analysis shows that overall in the municipalities, the market share of the leading fibre optic operator is **7 percentage points lower in municipalities that have received aid** (with respect to the counterfactual scenario), while **the combined quota of the first two operators is 1.5 percentage points lower** as a result of the existence of aid. By population bands, **the most significant effects are observed in the group of municipalities with between 1,000 and 10,000 inhabitants**, where the share of the operator with the highest market share is around 8-10 **percentage points** lower when the municipality has received aid. In larger municipalities (between 10,000 and 50,000 inhabitants), the impact of aid in reducing concentration is less (the share of the leading company is around 4 **percentage points** lower when the municipality has received aid). In the smallest municipalities (less than 1,000 inhabitants), the analysis does not yield conclusive results, which is related to the fact that 91% of the municipalities without aid in this band do not have fibre in 2020.

The analysis carried out has, however, some limitations. One of the main ones is that **the methodology does not make it possible to identify the marginal impact of public aid, but only its average global impact from a comparative point of view between municipalities with aid compared to municipalities without aid**. The applied methodology does not allow us to conclude what would be the impact of an increase in public aid on connectivity or concentration indicators, nor if the overall volume of aid channelled has been the most efficient when considering its possible alternative uses. Nor is it possible to carry out an analysis based on the amount of aid actually received by each territorial entity, since these data are only available at file level. These are aspects in which it would be interesting to have more evidence and analysis to improve the design of public policies.

In any case, despite the limitations indicated, the results of the analysis confirm that, in general, the aid under study has been **effective to increase connectivity** (contracted active accesses) of the smaller Spanish communities. In addition, this increase in the deployment of fibre optics has gone hand in hand with an **increase in market competition**, and in general with an appreciable lower concentration in the municipalities with aid compared to those without aid. It cannot be ruled out that the design of these programmes, by imposing the aforementioned wholesale access conditions, may have contributed to these results.

Regarding population bands, **these effects are more intense in municipalities with fewer than 10,000 inhabitants**. This result is quite intuitive, reflecting that public aid has a greater incentive effect in municipalities where, *a priori*, less interest from the private sector could be expected given the smaller scale of operations, and it can serve as a guide for public authorities when choosing where to focus their efforts.

Not surprisingly, despite the improvements observed, there are still 4,167 Spanish municipalities (92% of them with less than 1,000 inhabitants) without access to fibre optics. In this sense, as previously mentioned, the European Commission, in the recent DESI reports (2021 and 2022), confirms that in Spain (and in the rest of the European Union) there is still a **persistent gap in terms of connectivity between urban and rural areas,** despite corrective progress being made[71]. Therefore, the **progressive development of wireless technologies** increasingly less expensive in terms of infrastructure and with increasing capacities makes it advisable to analyse whether the deployment of fibre optics is the most efficient option in sparsely populated areas with adequate mobile coverage.

Based on these conclusions, the CNMC considers it appropriate to underscore some **general recommendations** to improve the effectiveness of public intervention, in line with the recommendations of its mandatory reports on public aid programmes for the deployment of broadband:

- First, to underscore the importance of **coordination between national and regional administrations**, in order to avoid overlapping and duplication in the granting of aid.

- Second, in line with what was mentioned in the Plan for Connectivity and Digital Infrastructures prepared by MINECO within the framework of the

[71]In this sense, the DESI 2021 file for Spain highlights that "Spain's already high score in connectivity has improved even more, so that the country has risen to third place in the EU. Spain has a particularly high performance in very high-capacity networks since they are beginning to bridge the persistent gaps between rural and urban areas."

key objectives of the 2030 Agenda, to seek the **incentive effect of public aid**, seeking to promote public-private collaboration and that these promote changes in the behaviour of private investors.

- Third, support the pro-competitive effect of public aid in the broadband markets, seeking to maintain, as far as possible, the principle of **technological neutrality** in the calls for aid, as well as the use of existing physical infrastructures and the conditions of **third party access** to networks financed with public aid, in line with the provisions of the Broadband Guidelines and the RGEC[72] .

- Finally, extend the culture of the **(ex post) evaluation of aid programmes by public administrations**.

The study will be sent to the Ministry of Economic Affairs and Digital Transformation, the Institute of Fiscal Studies (IEF) and the Independent Authority for Fiscal Responsibility (AIREF). It will also be published on the website of the Spanish National Markets and Competition Commission (www.cnmc.es).

[72]Regulation (EU) 651/2014 of the Commission of June 17, 2014 declaring certain categories of aid compatible with the internal market in application of articles 107 and 108 of the Treaty modified by the Regulations: Commission Regulation (EU) 2017/1084 of June 14, 2017, Commission Regulation (EU) 2020/972 of July 2, 2020, Commission Regulation (EU) 2021/452 of March 15, 2021 and Commission Regulation (EU) 2021/1237 of July 23, 2021.

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ANNEX 1: QUANTITATIVE ANALYSIS METHODOLOGY

A.1.1. Municipal level aggregation

Although the data for the outcome variables (active accesses) and the control variables or covariates used (population, area, income and proportion of the population between 16 and 65 years of age) are available at the municipal level, in the case of aid, it has been necessary to make an aggregation at the municipal level for those aids that did not have the entire municipality as their objective.

Specifically, the aggregation of municipalities affects the following variables, to which the following criteria were applied:

- Affected population: The population of each population level receiving the aid has been added and divided by the total population of the municipality. If the municipality has received state and regional aid, the maximum value of the affected population has been chosen, to avoid duplication.
- Finish date: In order to capture the largest possible temporal dimension, the date of completion of the first aid to that municipality has been chosen. In the case of receiving state and regional aid, the criterion is maintained, choosing the date of the first completed aid.
- Number of grants for certain technology by municipality: In order to avoid biases by including municipalities where aid for fibre was in the minority, the number of population entities with aid for each municipality and each technology have been added, dividing by the total aid the entities that make up the municipality. For municipalities that received both state and regional aid, the procedure is maintained, calculating the total number of subsidies granted regardless of their origin.
- Operators benefitting from aid for technology: The same type of aggregation is carried out for the number of subsidies, that is, taking into account the aid for a given technology, the beneficiaries of each aid are added at the infra-municipal level for each municipality, dividing by the total number of subsidies for each municipality.

A.1.2. Selection of variables

According to economic theory, introducing a large number of relevant variables (covariates) in sufficiently large databases can be positive, since it allows the control of factors that may affect the probability of being chosen according to the *propensity score*[73]. However, it is important to note that including too many variables can create a large number of dimensions, reducing the region of common support[74] and making estimates difficult[75] .

In this study, the following covariates have been used[76] :

- **Population** the number of inhabitants listed on the continuous register by population unit prepared by the INE in the year of the first call for analysis (2013). The population variable, usually contained in rounds of aid, establishing maximum limits (generally 50,000 inhabitants) or, in general, relating it to population density (low-density areas), aims to capture differences between more and less populated municipalities. It is one of the main variables to attract operators (competition) as it is related to potential profitability.

- **Surface area:** square kilometres in 2020 (latest data available according to the National Geographic Institute). Its inclusion responds to the greater difficulty of coverage in larger municipalities (keeping the population constant), as stated in the aid rounds, identifying areas with low population density as more prone to the existence of market failures that discourage investment.

- **average income per person** : Data from 2015, the first year available according to the INE (Household income distribution atlas). The economic power of the users influences the contracting of broadband services, especially in the case of fibre optics.

- **Percentage of population aged between 16 and 65 years:** using the last INE population and housing census (2011), the inclusion of this variable aims to capture different behavioural patterns regarding use according to the composition of the population with respect to their age, based on the reports contained in the Survey on Equipment and Use of

[73]In this sense, Holland (1986) considers that the fundamental problem of causal inference is the possible absence of sufficient information since it is not possible to observe the results of the same unit under treatment conditions and in the absence of it.

[74]For the development of the common support concept, see A.2.3.

[75]Bryson et al. (2002) recommends not including non-significant covariates since this fail to reduce bias and may increase the variance and inconsistency of the results.

[76]For a description of the descriptive (mean) values of these variables, see the tables in section A.1.2. of the Annex.

Information and Communication Technologies in Homes by the INE. According to the latest data published, there is a differential decrease in daily internet use from the age of 65. A greater propensity to use is related to a greater attractiveness for operators, which could potentially generate greater competition, so its inclusion is advisable.

From a methodological point of view, in addition to compliance with the conditions of conditional independence and common support, it is necessary to verify that there is a similar distribution **of each of the covariates between the treatment and control group**. This condition can be contrasted by means of statistical tests of mean differences. Since the use of the mean difference test could be biased by the size of the sample (Ho et al., 2007; Austin 2009), they also include, as recommended by some authors (Rosenbaum and Rubin, 1983 and 1984), standardised mean differences (taking into account both the mean and the variance)[77] .

Tables 9 and 10 below show the results of the balance tests for each covariate according to the different types of pairing used.

Table 9 represents the global scenario pairings for connectivity (connectivity rate) and Table 10 for majority carrier concentration (CR1). The first two rows of each covariate present the reference situation (baseline situation before matching), which is compared with the following pairs of rows for each type of matching. For the evaluation of the pairings, the following metrics are presented in tables 9 and 10:

i) Number of paired observations: The comparison of the number of observations matched with the reference situation allows us to observe that, by replacing the control observations performed by the PSM, the vast majority of the treatment observations have been matched (1,601 of 1,614 in the case of rate of connectivity and 1,603 of 1,617 in the case of CR1).

ii) The means of each covariate for the treatment and control group.

iii) The reduction of the standardised mean differences or standardised bias reduction (in percentage terms): the greater the reduction, the more homogeneous the paired groups turn out to be, placing their value within the aforementioned reference ranges (between 10% and 25%).

The p-value of the evaluation of the hypothesis of equality of means between the matched treatment and control groups: p-values indicate a greater probability of

[77] There is no clear rule of how much imbalance is acceptable, but many of the proposals, in the case of using standardised means, are in a maximum range of between 10% and 25% of standardised difference (Austin, 2009, Stuart et al., 2013), which in the current exercise are fulfilled in all scenarios and types of pairing, reinforcing the validity of the construction of the methodology used.

equality of means between the treatment and control groups the closer they are to one. The hypothesis of the test of equality of means of the treatment and control groups is validated (not rejected) with a significant level of 1% for the PSM pairings. Likewise, in order to include all the methodologies used in this study, the balancing results with Mahalanobis distances are also presented, which will be detailed in section A.1.5 of this annex. It is interesting to see the improvement in the inclusion of kernel-type matching in the Mahalanobis method, as a result of the use of weights according to the distance of the controls with respect to the treatment, obtaining a higher quality match with fewer observations.

The results of the tests for equality of means demonstrate a correct selection and pairing of the municipalities in the two groups, which makes it possible to imitate a random selection taking into account the covariates included and thereby eliminating potential selection biases. In this way, the different matching methods are validated, which serve to find the effects of public aid for broadband expansion on connectivity and operator concentration.

Table 7. Mean difference test of the covariates used to estimate the effects on the broadband connectivity rate.

Global Scenary	Matching type	Group	No. obs	Average	Bias reduction₁	p-value
Proportion of population between 16 and 65 years of age	No matching	With PEBA aid (treatment)	1,614	0.657	Reference couple	Reference couple
		Without PEBA aid (control)	666	0.647		
	PSM: NN1	With PEBA aid (treatment)	1,601	0.657	93%	0.685
		Without PEBA aid (control)	666	0.658		
	PSM: radial	With PEBA aid (treatment)	1,601	0.657	86%	0.398
		Without PEBA aid (control)	666	0.658		
	PSM: kernel	With PEBA aid (treatment)	1,601	0.657	87%	0.433
		Without PEBA aid (control)	666	0.658		
	Mahalanobis (ATT)	With PEBA aid (treatment)	1,614	0.657	82%	0.273
		Without PEBA aid (control)	511	0.655		
	Mahalanobis (ATT & kernel)	With PEBA aid (treatment)	659	0.647	95%	0.832
		Without PEBA aid (control)	396	0.647		
Area in km2	No matching	With PEBA aid (treatment)	1,614	77	Reference couple	Reference couple
		Without PEBA aid (control)	666	52		
	PSM: NN1	With PEBA aid (treatment)	1,601	72	89%	0.359
		Without PEBA aid (control)	666	75		
	PSM: radial	With PEBA aid (treatment)	1,601	72	97%	0.795
		Without PEBA aid (control)	666	71		
	PSM: kernel	With PEBA aid (treatment)	1,601	72	84%	0.182
		Without PEBA aid (control)	666	68		
	Mahalanobis (ATT)	With PEBA aid (treatment)	1,614	77	72%	0.039
		Without PEBA aid (control)	511	70		
	Mahalanobis (ATT & kernel)	With PEBA aid (treatment)	659	37	98%	0.761
		Without PEBA aid (control)	396	36		
Population in 2013	No matching	With PEBA aid (treatment)	1,614	4,061	Reference couple	Reference couple
		Without PEBA aid (control)	666	3,694		
	PSM: NN1	With PEBA aid (treatment)	1,601	3,961	71%	0.64
		Without PEBA aid (control)	666	3,856		
	PSM: radial	With PEBA aid (treatment)	1,601	3,961	63%	0.552
		Without PEBA aid (control)	666	4,096		
	PSM: kernel	With PEBA aid (treatment)	1,601	3,961	79%	0.725
		Without PEBA aid (control)	666	4,040		
	Mahalanobis (ATT)	With PEBA aid (treatment)	1,614	4,061	-12%	0.059
		Without PEBA aid (control)	511	3,650		
	Mahalanobis (ATT & kernel)	With PEBA aid (treatment)	659	1,544	70%	0.35
		Without PEBA aid (control)	396	1,433		
Net income per person in 2015	No matching	With PEBA aid (treatment)	1,614	9,452	Reference couple	Reference couple
		Without PEBA aid (control)	666	10,594		
	PSM: NN1	With PEBA aid (treatment)	1,601	9,456	94%	0.377
		Without PEBA aid (control)	666	9,521		
	PSM: radial	With PEBA aid (treatment)	1,601	9,456	96%	0.515
		Without PEBA aid (control)	666	9,504		
	PSM: kernel	With PEBA aid (treatment)	1,601	9,456	93%	0.272
		Without PEBA aid (control)	666	9,536		
	Mahalanobis (ATT)	With PEBA aid (treatment)	1,614	9,452	97%	0.639
		Without PEBA aid (control)	511	9,487		
	Mahalanobis (ATT & kernel)	With PEBA aid (treatment)	659	9,605	100%	0.964
		Without PEBA aid (control)	396	9,600		

Note: (1) Reduction of bias (in %) is based on standardized bias according to Rubin and Rosenbaum (1984), this is the difference between the treatment and control group sets expressed as a percentage of the root square of the variances of the two groups. (2) NN1 (next neighbour 1) refers to the nearest neighbour method matching.

Source: Own elaboration based on data from the CNMC, MINECO and the CC.AA. (Autonomous Communities)

Table 8. Test of mean differences of the covariates used for the estimation of the effects on the concentration (CR1) of broadband.

Global Scenary	Matching type	Group	No. obs	Average	Bias reduction[1]	p-value
Proportion of population between 16 and 65 years of age	No matching	With PEBA aid (treatment)	1,617	0.657	Reference couple	Reference couple
		Without PEBA aid (control)	669	0.647		
	PSM: NN1	With PEBA aid (treatment)	1,603	0.657	92%	0.648
		Without PEBA aid (control)	669	0.658		
	PSM: radial	With PEBA aid (treatment)	1,601	0.657	86%	0.395
		Without PEBA aid (control)	666	0.658	93%	0.685
	PSM: kernel	With PEBA aid (treatment)	1,601	0.657	86%	0.428
		Without PEBA aid (control)	666	0.658		
	Mahalanobis (ATT)	With PEBA aid (treatment)	1,617	0.657	81%	0.265
		Without PEBA aid (control)	514	0.655		
	Mahalanobis (ATT & kernel)	With PEBA aid (treatment)	664	0.647	95%	0.822
		Without PEBA aid (control)	398	0.647		
Area in km2	No matching	With PEBA aid (treatment)	1,617	77	Reference couple	Reference couple
		Without PEBA aid (control)	669	52		
	PSM: NN1	With PEBA aid (treatment)	1,603	72	80%	0.103
		Without PEBA aid (control)	669	77		
	PSM: radial	With PEBA aid (treatment)	1,601	72	97%	0.793
		Without PEBA aid (control)	666	71		
	PSM: kernel	With PEBA aid (treatment)	1,601	72	84%	0.187
		Without PEBA aid (control)	666	68		
	Mahalanobis (ATT)	With PEBA aid (treatment)	1,617	77	72%	0.037
		Without PEBA aid (control)	514	70		
	Mahalanobis (ATT & kernel)	With PEBA aid (treatment)	664	37	98%	0.745
		Without PEBA aid (control)	398	37		
Population in 2013	No matching	With PEBA aid (treatment)	1,617	4,057	Reference couple	Reference couple
		Without PEBA aid (control)	669	3.692		
	PSM: NN1	With PEBA aid (treatment)	1,603	3,944	85%	0.81
		Without PEBA aid (control)	669	3,999		
	PSM: radial	With PEBA aid (treatment)	1,601	3,944	62%	0.534
		Without PEBA aid (control)	666	4,084		
	PSM: kernel	With PEBA aid (treatment)	1,601	4,058	-14%	0.054
		Without PEBA aid (control)	666	3,639		
	Mahalanobis (ATT)	With PEBA aid (treatment)	1,617	4,061	-12%	0.059
		Without PEBA aid (control)	514	3,650		
	Mahalanobis (ATT & kernel)	With PEBA aid (treatment)	664	1,550	69%	0.329
		Without PEBA aid (control)	398	1,435		
Net income per person in 2015	No matching	With PEBA aid (treatment)	1,617	9,451	Reference couple	Reference couple
		Without PEBA aid (control)	669	10,592		
	PSM: NN1	With PEBA aid (treatment)	1,603	9,454	93%	0.265
		Without PEBA aid (control)	669	9,536		
	PSM: radial	With PEBA aid (treatment)	1,601	9,454	96%	0.519
		Without PEBA aid (control)	666	9,502		
	PSM: kernel	With PEBA aid (treatment)	1,601	9,454	93%	0.276
		Without PEBA aid (control)	666	9,534		
	Mahalanobis (ATT)	With PEBA aid (treatment)	1,617	9,451	97%	0.639
		Without PEBA aid (control)	514	9,485		
	Mahalanobis (ATT & kernel)	With PEBA aid (treatment)	664	9,607	100%	0.959
		Without PEBA aid (control)	398	9,602		

Note: (1) Reduction of bias (in %) is based on standardized bias according to Rubin and Rosenbaum (1984), this is the difference between the treatment and control group sets expressed as a percentage of the root square of the variances of the two groups. (2) NN1 (next neighbor 1) refers to the nearest neighbor method matching.

Source: Own elaboration based on data from the CNMC, MINECO and the CC.AA. (Autonomous Communities)

A.1.3. Necessary conditions for the PSM

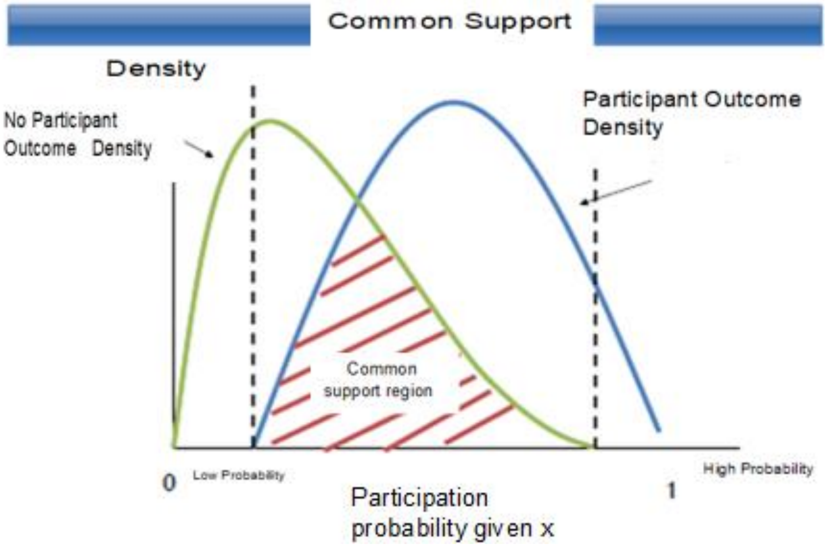
The PSM method is based on indicators *pscore* of each observation (municipality) created using a binary nonlinear model (*logit* or *probit*), which indicate the probability of belonging in the treatment group taking into account certain relevant observable variables (covariates)[78] . As in all matching methods, in PSM the elimination of selection bias is essential to obtain unbiased results. For this, it is necessary that two identification presumptions are fulfilled: i) conditional independence and ii) the existence of common support of the covariates.

The **conditional independence** implies that the potential outcomes of the treatment group [$\boldsymbol{Y_1}$] and the control group [$\boldsymbol{Y_0}$] are independent of the binary treatment variable [$\boldsymbol{T_i}$] taking into account the observed characteristics [$\boldsymbol{X}$], which is formally expressed as: $(\boldsymbol{Y_1}; \boldsymbol{Y_0}) \perp\!\!\!\perp \boldsymbol{T_i}|\boldsymbol{X}$. This implies that once all the relevant observed characteristics included are controlled, the municipalities with aid should have on average the same result (connectivity rate and concentration) as the municipalities without aid. For their part, some authors (Abadie, 2017) refer to covariates as confounding factors (*confounding factors*) when the treatment indicator variable [$\boldsymbol{T_i}$] And the result [$\boldsymbol{Y_i}$] have the same causes. The goal of matching is to avoid this relationship between [$\boldsymbol{T_i}$] and [$\boldsymbol{Y_i}$] by conditioning the observed characteristics [$\boldsymbol{X}$] *.*

The **common support assumption**, illustrated theoretically in figure 24, makes it possible to verify that the observations are really comparable between the treatment group and the control group. Thus, the pairing, based on the relevant covariates for each individual, obtains a positive probability of being treated or not (in our case, being selected as a recipient of aid or not). The effect on treaties is formalised as follows: $P(T = 1|X) \leq 1$. Figure 17 shows the density function of the *pscore* (score) obtained for the treatment (blue) and control (green) group, the area under the point of intersection of the two curves indicates the common support observations.

[78]Both the main analysis using PSM and the robustness analysis with Mahalanobis distances, which is presented in Annex 2 (section 5), have been performed in Stata software using the module *psmatch2* developed by Leuven and Sianesi (2003), which allows the use of different types of matching (nearest neighbour, radial, kernel, etc.), as well as commands that allow testing the common support hypothesis *(ps graph)* and the different equilibrium conditions between the treatment and control groups (*ptest).*

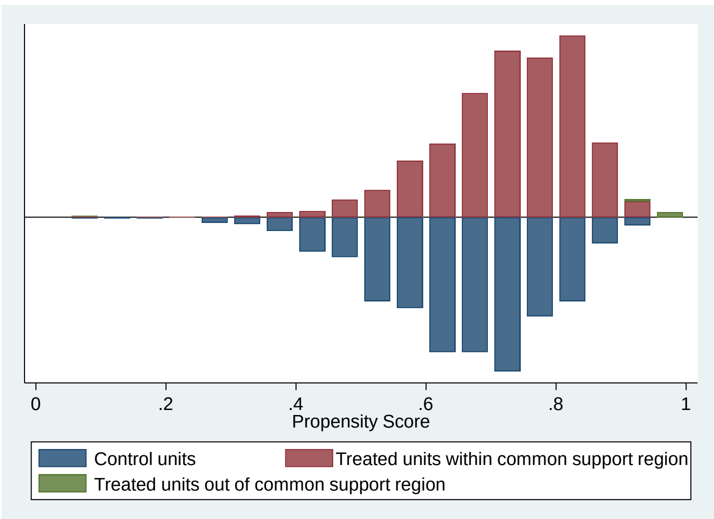
Figure 24. Illustration of the common support condition



Source: Caballero and Ferrer (2011).

Figure 25 presents an example of the fulfilment of the common support condition through the histograms of the distribution of the *pscores* calculated and matched according to the "nearest neighbour" methodology for the treatment and control groups in the global scenario of CR1 (main operator concentration ratio). The columns in blue represent the histogram of the *pscores* of the set of controls, the red columns represent the set of treated ones that have common support, and the green ones are those treatment observations that could not be matched. **The large overlap between the red and blue columns confirms the existence of sufficient common support for the assessment**. This requires the existence of a balance between each of the blocks into which the PSM divides the data subject to analysis, which is the case in all the models and scenarios used.

Figure 25. Pscore overlap between control and treatment group



Source: prepared in-house.

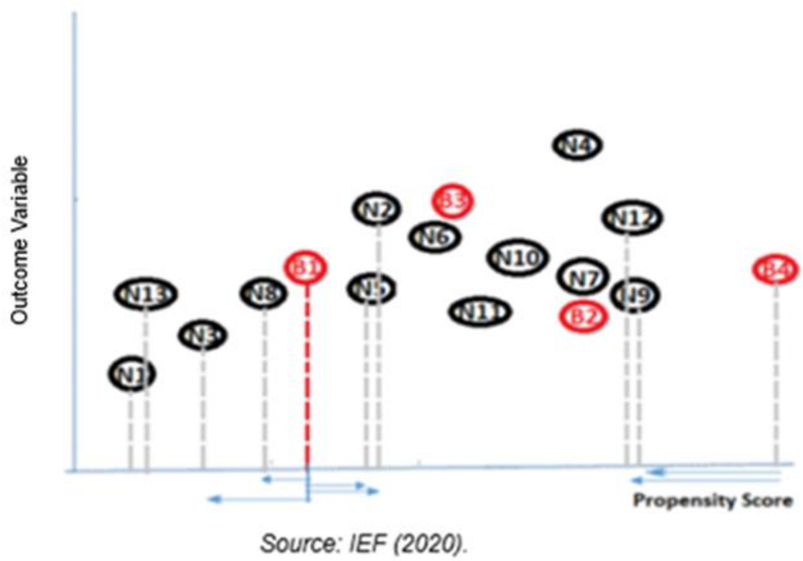
A.1.4. PSM Pairing Types

As previously indicated, there are different types of pairings to select the municipalities without aid that are most comparable to each municipality with aid. In this regard, there is no clearly superior method when choosing the type of matching, and the use of several methods is relatively common to assess which one best suits the data analysed (Ho et al., 2007; Luo et al., 2010). In addition, these methods allow the option of electing control units to be re-elected (replacement), which reduces matching bias (Abadie, 2004).

As indicated throughout the report, the following matching methods have been used in this study:

- **nearest neighbour**: for each observation (municipality) in the treatment group (for example, municipality B1 in figure 26) a control unit that has the most similar score is selected (the closest control municipality is N8). After matching, the impact is calculated as the difference in the outcome variable for both observations.

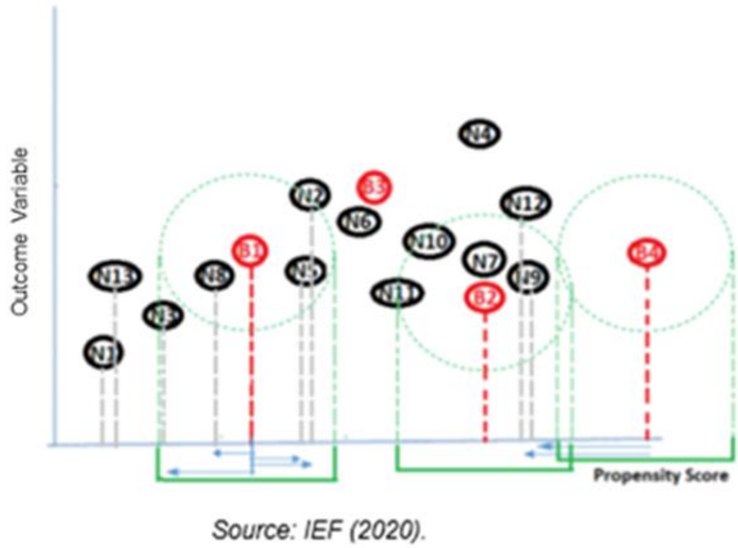
Figure 26. Nearest Neighbour Matching



Source: IEF (2020).

- **Radial:** In this case, instead of choosing the closest neighbour (with the most similar score), for each municipality in the treatment group, a maximum allowable score distance is established (the radius of the circles represented in figure 27), comparing each municipality in the treatment group (for example, B1) with the mean of the scores of the control municipalities that are within the defined radius (for B1, municipalities N8, N5 and N2)[79] . This type of methodology prevents the chosen control from being too far away (less similar score) and, therefore, less comparable.

Figure 27. Radial Matching

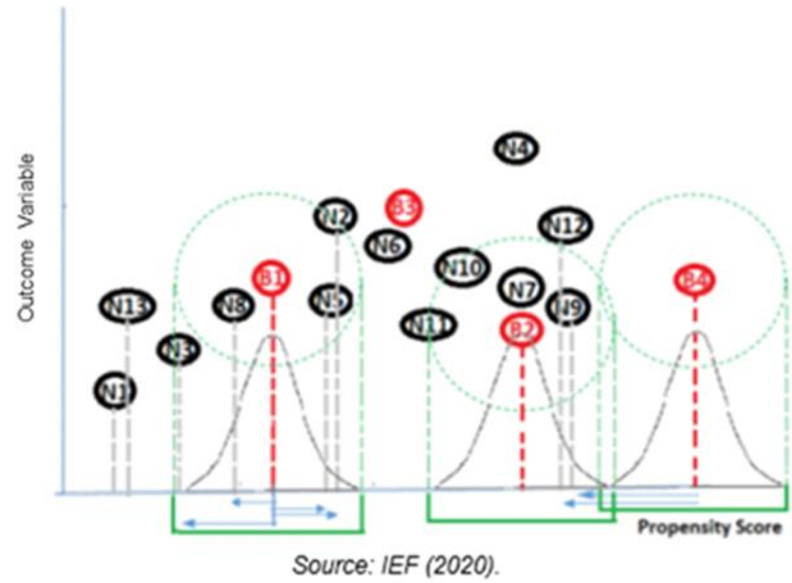


Source: IEF (2020).

- ***kernel matching*****:** is a variant of the radial methodology with the difference that each municipality in the control group is weighted (N2, N5 and N8 for the municipality with aid B1, represented in figure 28) within the maximum distance allowed (the radius of the circumferences) based on their distance from each municipality in the treatment group (municipality B1), giving more weight to the closest municipalities.

[79]When applying the radial method, a value equal to 0.2 times the standard deviation of the propensity score has been adopted (*pscore*), based on the publication by Austin (2011).

Figure 28. Kernel Matching



Source: IEF (2020).

By using the aforementioned three PSM methods to correct for potential selection bias issues and to create comparable treatment and control groups, it has been possible to isolate the effect of aid from other factors that may influence broadband deployment (such as the business interest of private operators). This allows the impact of the aid programme to be attributed to changes in the result variables, that is, changes in the level of connectivity and in the degree of competition in the markets.

A.1.5. Robustness analysis: Mahalanobis distance matching

The objective of this annex is to present a robustness analysis of the main results collected in section 4.3.1 for the purposes of aid for the deployment of broadband on the evolution of connectivity and concentration of operators. Although the propensity score matching (PSM) method is the main method described and applied in this analysis, there are other matching methods, such as the one calculated using Mahalanobis distances.[80] .

Both matching methods (PSM and Mahalanobis) aim to reduce potential selection bias through observable covariates; however, their main difference lies in how to create the pairs in both groups.

On the one hand, the PSM agglutinates all the covariates in a single value, the *pscore*, through a function *probit* or *logit,* and with this, it determines the probability of each observation (municipality) belonging to the treatment group. Mathematically, we can formulate this method as follows: $p(X) = P(T = 1|X)$.

On the other hand, the Mahalanobis method calculates the distances between all the observations taking into account the covariates and the inverse of its variance-covariance matrix,$\sum_X^{-1}$. This is$\left\|X_i - X_j\right\| = \sqrt{(X_i - X_j)' \sum_X^{-1} (X_i - X_j))}$, where the distance enters into it X_i andX_j is calculated as the difference between the covariate vectors for the treatment and control groups, respectively. This definition and normalisation means that the distances do not depend on the scale (magnitude) of the covariates and that variables expressed in different units (as is the current case of the covariates used for matching the municipalities such as population, surface area, income and a percentage of the population in a certain age range) can be treated in the same model. Thus, the dimension of the matching is not necessarily equal to 1, as in the case of a PSM, but is equal to the number of covariates used in the procedure. However, the main drawback of using this method must be pointed out, which is the loss of information due to the normalisation described.

When performing Mahalanobis distance matching with the nearest neighbour and kernel methods, **similar results to the calculations made with PSM have been obtained**, as shown in Table 9.

[80]Ripollone et al. (2017), Abadie (2017) and Troncoso et.al. (2006).

Table 9. Comparison of results with PSM and Mahalanobis distances

Effects of aid on the ratio of use and concentration CR1 and CR2				
Global Scenary		Effects on usage rate	Effects on CR1	Effects on CR2
Mahalanobis (ATT)		**10.46** ***	**-7.96** ***	**-1.72** **
no. municipalities		2,280	2,286	2,071
no. municipalities without aid		666	669	527
no. municipalities with aid		1,614	1,617	1,544
Mahalanobis (ATT & kernel)		**10.55** ***	**-9.05** ***	**-0.70**
no. municipalities		1,325	1,325	1,085
no. municipalities without aid		666	666	527
no. municipalities with aid		659	664	558
PSM	**Nearest Neighbour**	**10.66** ***	**-6.62** ***	**-1.58** *
	Radial with pscore	**9.45** ***	**-7.05** ***	**-1.48** **
	Kernel with pscore	**9.24** ***	**-7.27** ***	**-1.68** ***
	no. municipalities	2,267	2,272	2,057
	no. municipalities without aid	666	669	527
	no. municipalities aid	1,614	1,603	1,530

Note: * Significant at 90%; ** Significant at 95%; *** Significant at 99%.

Source: Prepared in-house based on data from the CNMC, MINECO and the CC.AA. (Autonomous Communities)