Does Broadband Internet Promote Digital Labor and Territorial Cohesion? Empirical Evidence from the New Generation Broadband Extension Program in Spain

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Abstract

Exploiting the New Generation Broadband Extension Program (PEBA) in Spain as a source of exogenous variation in the broadband-internet status at the regional level and using unique company data from a large European online labor market, we study the effect of the deployment of broadband internet on digital labor and territorial cohesion. In terms of digital labor, we provide empirical evidence for a positive impact of the deployment of broadband internet on the number of online workers and online jobs done in PEBA-treated regions. In terms of territorial cohesion, we find that, while workers located in urban areas have higher *expected* wages than workers in PEBA-treated rural areas, there are no essential differences in the *actual* wages they obtain. We also find that the PEBA program led to a small and statistically significant increase in the population of PEBA-treated regions.

JEL Codes: C32, J31, L96

Keywords: State aid, ex-post evaluation, broadband internet, digital labor, future of work, territorial cohesion, exogenous variation, wages, New Generation Broadband Extension Program, PEBA

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1. Introduction

The spread of broadband internet plays a crucial role in economic and labor market developments. Broadband networks enable economic growth through different mechanisms (Czernich et al., 2011; Falk, 2017). First, they increase innovative capacity, generating newly developed products and processes that foster growth. Second, they improve the transmission of information, facilitating the adoption of new technologies. However, the economic literature has not obtained conclusive evidence of the role that broadband networks play in the labor market. While some papers have shown an overall positive but economically constrained relationship between local employment and local broadband infrastructure, other papers have found that the deployment of these infrastructures can make some jobs obsolete, especially jobs based on routine tasks (Kolko, 2012). There is also inconclusive evidence on the effects of broadband internet in rural areas. While some papers provide evidence of a positive effect of broadband deployment on employment in rural areas (Atasoy, 2013; Isley and Low, 2022), there is also suggestive evidence of an asymmetric urban-rural impact (Forman et al., 2012; Briglauer et al., 2019).

Related to the internet diffusion, one important recent phenomenon affecting employment creation is the upsurge of online labor markets (OLMs). OLMs are an emerging key element with high potential to disrupt the functioning of the traditional labor market (ILO, 2021, 2022; OECD/ILO/European Union, 2023). These platforms connect employers and workers and allow them to communicate and work remotely (Horton, 2010). OLMs have grown substantially in economic size and relevance in recent years generating efficiency gains due to greater flexibility, better information, lower costs due to teleworking and virtual migration (Farrell and Greig, 2016; Horton, 2010; Kuek et al., 2015; Mueller-Langer and Gomez-Herrera, 2022). Recent evidence from the Online Labor Index (OLI) by Stephany et al. (2021) suggests that the use of online work has increased by approximately 50% in the past two years. According to ILO (2021), the estimated annual revenue on OLM was $2.5 billion in 2019-2020. The political implications of these new business models are huge. The workers of these platforms are motivated by the income they obtain from this activity, but they do not need to be geographically located in the same geographical area as the employer. It is in this respect that OLMs multiply the scope of labor relations and level the playing field for different geographical areas.

In this paper, we analyze the effectiveness of the New Generation Broadband Extension Program (henceforth, PEBA, by its Spanish acronym[1]) that provided public grants to extend broadband internet access to rural areas, with the final aim to close the geographical digital divide, address the demographic challenge, and build a more inclusive society. Notably, this is an important target within the Spanish government program for rural inclusion[2]. We focus on the specific objectives of labor promotion and territorial cohesion. More specifically, we examine employment opportunities provided by OLMs in terms of participation and wages as well as their effect on wage levelling and population.

Overall, we make three contributions. First, we contribute to the evaluation of policy programs targeted at increasing internet access by exploiting PEBA as a source of exogenous variation in the broadband-internet status at the regional level. Using a detailed dataset – which allows us to isolate the broadband effect from other potential confounders – and merging it with unique company data from a large European OLM, we find a positive impact of the deployment of broadband internet on digital labor as measured by the number of online workers and online jobs done. It is in this respect that we provide evidence of an alternative channel of broadband impact on local employment, i.e., the creation of OLM jobs. To the best of our knowledge, this alternative channel is relatively understudied in the literature on the effect of broadband internet on local employment. Second, we contribute to the debate on the regional-urban divide by showing that, while workers located in urban areas have higher expected wages than workers in PEBA-treated rural areas, there are no essential differences in the actual wages they obtain on the studied OLM. Third, we find that the PEBA program led to a small and statistically significant increase in the population of PEBA-treated regions.

The remainder of the paper is organized as follows. Section 2 outlines the related literature. In Section 3, we describe the data and methodology. Section 4 summarizes the main results of the analysis. In Section 5, we discuss the policy implications of our results. Section 6 concludes.

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[1] More information on the program is available here: https://portalayudas.mineco.gob.es/banda-ancha/Paginas/Index.aspx (last access June 19, 2023)

[2] https://cincodias.elpais.com/companias/2023-06-26/el-gobierno-lanza-el-plan-5g-rural-con-mas-de-500-millones-en-ayudas.html (last access June 29th, 2023).

2. Related Literature and Conceptual Framework

2.1. Related Literature

Recent evidence suggests that access to high-speed internet via broadband infrastructure promotes economic growth and local employment (Aldashev and Batkeyev, 2021; Czernich et al., 2011; Greenstein and McDevitt, 2011). Kolko (2012) finds a positive relationship between broadband expansion and economic growth in the US between 1999 and 2006, especially in industries that rely more on information technology and in areas with lower population densities. Koutroumpis (2019) finds that broadband adoption increased GDP by 4.34% in the OECD area for the period 2002–2016 when fixed broadband connections grew from 3.8 to 31.3 per 100 people.

There is also evidence of positive effects of broadband adoption on firm productivity (Bertschek et al., 2013; Grimes et al., 2012; Canzian et al., 2019) and the creation of new firms (Kim and Orazem, 2017; Deller, Whitacre and Conroy 2022; Duvivier et al., 2021; Conroy and Low, 2022; Duvivier and Bussiere, 2022). DeStefano et al. (2018) find that broadband internet provided small and medium sized firms low-cost access to internet technologies allowing them to create websites, develop e-commerce sales and extend their market reach.

A related strand of literature evaluates specific aid programs for broadband deployment (Aldashev and Batkeyev, 2021; Benseny et al., 2019). Bourreau et al. (2023) examine the efficiency of the French State aid plan for broadband deployment. Their results suggest that the plan was relatively successful, enabling deployment in areas that would otherwise not have been covered by the private sector and stimulating overall coverage. Duso et al. (2021) use a difference-in-differences framework to study the impact of public subsidy schemes for the development of broadband infrastructure in rural areas in Germany. Their results show that the aid was effective in increasing broadband coverage. Finally, Liu et al. (2021) evaluates the effectiveness of the “Broadband Village” initiative implemented by the Chinese government since 2014. It led to substantial investments in internet construction in rural areas in six western provinces. Their results also show a positive effect of broadband adoption on residents’ income.

Another strand of literature has stressed the advantages and the importance of online work, e.g., work from home (Mongey et al., 2020). Dingel and Neiman (2020) find that 37% of jobs in the US can be performed entirely from home. Their results show that remote jobs typically pay more than jobs that cannot be done at home. In addition, there is evidence of positive impacts of remote work on productivity (Bloom et al., 2015; Emmanuel and Harrington, 2020).[3] Recently, the increase in the extent of remote work determined by the COVID-19 pandemic has led to a substantial shift of economic activity across geographical areas (De Fraja et al., 2020; Barrero et al., 2020; Brynjolfsson et al., 2020). In this respect, OLMs constitute an important channel of the creation of remote work. OLMs are operationalized through websites and apps that mediate between buyers and sellers of remotely deliverable knowledge work (Horton, 2010). By providing effective formal and informal mechanisms of enforcing cooperation, OLMs enable users to hire and find work across distance (Braesemann et al., 2020). In analyzing data from a leading OLM in more than 3,000 urban and rural counties in the US, Braesemann (2020) finds that rural workers made relatively more use of the studied OLM than urban workers. Using data from Stack Overflow, Apatsidis et al. (2021) shows that remote jobs attract the interest of the industry, particularly in matters related to software production and engineering or the manipulation and handling of data.

We contribute to these interrelated strands of literature by analyzing a specific national aid program rolled-out in Spain between 2013 and 2021 using data from a large European OLM. While the impact of broadband internet deployment in traditional labor markets is relatively well studied, there is only scarce empirical evidence on its impact on digital labor. To the best of our knowledge, our analysis is one of the first attempts to fill this gap.

2.2. Conceptual Framework

2.2.1. Internet access and digital labor

Bick et al. (2023) set up a theoretical model to examine the drivers of the substitution of on-site work with online work, i.e., work from home. Their results suggest that the cost of working on-site, i.e., the cost that workers incur when they work away from home rather than at home, is an important driver of this substitution. According to Bick et al. (2023), these costs include the time spent commuting to work and any other costs associated with an equal amount of time worked on-site rather than at home. In addition, recent works suggest that online work is a substitute for on-site work for employers (Del

[3] Remote work also provides organizations with the opportunity to cut down on infrastructure and physical expenses (Apatsidis et al., 2021).

Rio-Chanona et al., 2020; Dunn et al., 2020; Stephany et al., 2020). Recent evidence also suggests that higher internet access quality may promote online work as it increases work-from-home productivity and decreases the relative cost of online work as compared to on-site work, e.g., it reduces the commuting cost (Barrero et al., 2021; Bick et al, 2023). Based on the aforementioned findings, we propose the following hypothesis:

Hypothesis 1 (Online workers): The number of online workers *ceteris paribus* increases when the internet access quality increases.

Now, we consider the effect of broadband internet on employment. Atasoy (2013) analyzes the effects of the expansion of broadband internet access from 1999 to 2007 on labor market outcomes in the US. Their findings suggest that broadband positively affects local employment. Lobo et al. (2020) and Isley and Low (2022) also find evidence of a positive impact of broadband adoption on local employment in traditional labor markets. Finally, Barrero et al. (2021) find that higher internet access quality increases work-from-home productivity. Based on these findings, we put the following hypothesis to the test in an environment that is already conducive to online work, e.g., an OLM:

Hypothesis 2 (Online employment): The number of online jobs done *ceteris paribus* increases when the internet access quality increases.

Hypotheses 1 and 2 lead to the following corollary:

Corollary 1 (Online income): The overall income generated from online work *ceteris paribus* increases when the internet access quality increases.

2.2.2. Internet access and territorial cohesion

Rural areas face problems of isolation, accessibilities, depopulation and social cohesion (Townsend et al., 2013). This problem is often referred to as the ‘rural penalty’ (Blanks Hindman, 2000). Briglauer et al. (2019) evaluate the impact of a major European state aid program for speed upgrades in broadband internet availability applied to rural areas in Germany throughout 2010 and 2011. Their findings suggest that state aid protects rural areas from depopulation. Kolko (2012) also provides empirical evidence that broadband expansion is associated with population growth in the US. Based on this, we put the following hypothesis to the test using population data from Spain:

Hypothesis 3 (Rural population): The population in rural areas *ceteris paribus* increases when the internet access quality increases.

3. Data and Methodology

3.1. Data

Our data comes from two main sources. First, we use data on the Annual Broadband Extension Program for white areas[4] (PEBA) implemented by the Ministry of Economic Affairs and Digital Transformation. This program provided public funds aimed at supporting the investment efforts of private operators in order to expand the deployment of high-speed broadband networks (over 100 Mbps) to rural areas and areas with low population density. As these areas are typically less attractive to private investment due to lower potential profits, there is a market failure, i.e., the market alone cannot efficiently provide the necessary infrastructure. By using public funds, the PEBA program attempts to correct this market failure and promote the provision of broadband services to underserved regions. Every year between 2013-2021, the Ministry of Economic Affairs and Digital Transformation publishes a call for projects to extend broadband internet to rural areas. The call provides a detailed list of white areas at a level of Singular Population Entity[5] (henceforth, SPE) eligible to receive public funds. Telecommunications operators apply for public grants by submitting projects to provide internet access to a set of SPEs that are white areas included in the list published in the call. The process concludes with the publication of the grant resolution indicating whether a grant was accepted or denied.

Through the PEBA program, 798 projects by over 100 telecommunications operators have been subsidized between 2013 and 2021[6], with investments totalling 1.123 billion Euro, of which 621 million Euro correspond to public grants. As a result, high-speed broadband coverage with fiber-to-the-home (FTTH) networks have been provided to 6.3 million properties in over 20,000 unique SPE throughout the entire Spanish geography,

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[4] The term "white areas" refers to geographic regions or locations that have limited or no access to high-speed internet or broadband services.

[5] In Spain, the territory is divided into 50 provinces, which are further subdivided into 8,116 municipalities. Within the municipality, the lower administrative division is the SPE. In Spain, there is a total of 61,578 SPEs. An SPE is defined as *"any inhabited area within a municipality, inhabited or exceptionally uninhabited, clearly differentiated within that municipality and that is known by a specific name that identifies it without the possibility of confusion*". See Instituto Nacional de Estadistica (INE) for further information on this concept (last access January 19th, 2023).

[6] From 2013 to 2019, the grants were exclusively directed towards areas lacking Next Generation Access coverage (henceforth, NGA) and plans for its provision within a 3-year timeframe (NGA white areas). In the 2020 and 2021 calls, areas with deficient NGA coverage were also included (NGA gray areas). These areas have been excluded from our analysis so as to limit the definition of the treatment to white areas, before and after the access to broadband internet.

representing more than 20% of existing premises and contributing to over 50% of the FTTH coverage increase experienced during this period.

From the public information available on the website of the Ministry of Economic Affairs and Digital Transformation, we construct a database that contains information on the list of areas without broadband access that were eligible to receive public aids, resolution of requests (approved/denied and execution status) as well as data on the amount of the investment and percentage subsidized. Our dataset constitutes a balanced panel where the observation level is an SPE for each year of the period 2013-2021. Note that an SPE is part of a municipality and that there are several SPEs in each municipality. Similarly, each municipality is part of a wider area, named province. In total, there are 50 provinces in Spain.

Table 1 presents the summary statistics for SPEs. We have information on 58,926 SPEs, which in 2013 had an average population of 795 inhabitants, although with high dispersion. The 5^{th} and 95^{th} percentiles are 2 and 1,611 inhabitants, respectively. The average population of the municipality where SPEs are located was 15,539 inhabitants in 2013, and its average per capita income was €11,887 with a standard deviation of €2,312. Table 1 also provides information on the subsamples of SPEs based on whether they were white areas or not in 2013. In comparison with the SPEs that were white areas in 2013, SPEs that already had broadband in that year had a larger size (average of 4,777 inhabitants, compared to 530) and their municipality had a higher per capita income (average of €13,132, compared to €11,804). For the observations corresponding to SPEs that were white areas in 2013, 37% of them were subject to the PEBA treatment, i.e., they received assistance from the PEBA program. The average number of SPEs affected per project is 409, the average budget per project is almost €3 million and the average percentage of aid to finance such a budget of 68.5%.

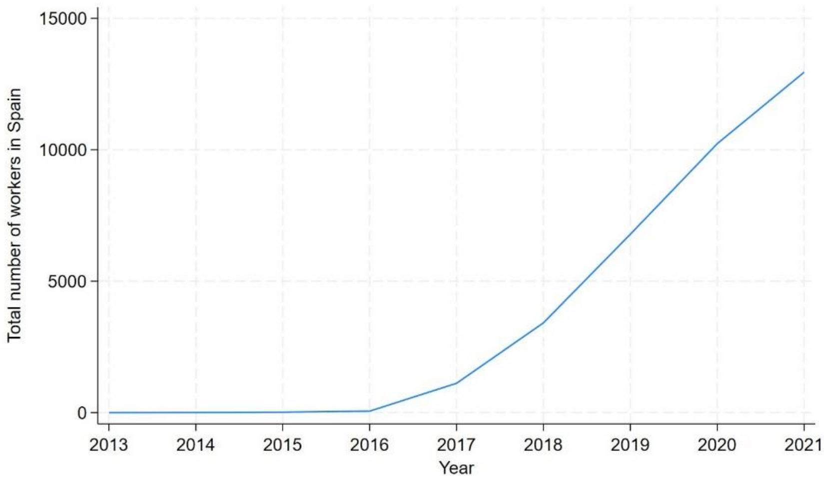
Table 1. Summary statistics at the SPE level, by classification as white/non-white areas in 2013.

	Number SPE	Average	Sd	Median	P5th	P95th
TOTAL						
Id(Aid Received)	58,926	0.34	0.47	0	0	1
Project Budget (€)	20,269	2,970,169	1,104,787	3,474,467	401,961	3,944,192
Percentage Aid (%)	20,269	68.46	15.17	76.00	34.99	80.00
Number SPE per project	20,269	409	638	138	12	2246
Population SPE 2013	58,859	795	16,871	30	2	1,611
Population municipality 2013	58,859	15,569	48,349	3,696	157	58,985
Income per capita 2013	58,300	11,887	2,312	11,731	9,174	15,810
NON-WHITE AREAS in 2013						
Id(Aid Received)	3,670	0	0	0	0	0
Project Budget (€)	0	-	-	-	-	-
Percentage Aid (%)	0	-	-	-	-	-
Number SPE per project	0	-	-	-	-	-
Population SPE 2013	3,670	4,777	60,689	163	4	13,463
Population municipality 2013	3,670	42,240	110,782	5,666	260	294,997
Income per capita 2013	3,658	13,132	3,793	11,996	9,284	22,665
WHITE AREAS in 2013						
Id(Aid Received)	55,256	0.37	0.48	0	0	1
Project Budget (€)	20,269	2,970,169	1,104,787	3,474,467	401,961	3,944,192
Percentage Aid (%)	20,269	68.46	15.17	76.00	34.99	80.00
Number SPE per project	20,269	409	638	138	12	2246
Population SPE 2013	55,256	530	7,588	28	2	1,128
Population municipality 2013	55,256	13,797	40,343	3,695	154	46,667
Income per capita 2013	54,642	11,804	2,152	11,694	9,162	15,080

Notes: Income per capita from data Spanish Statistical Institute2015-2021. We use machine learning to predict 2013 using distribution of population across economic sectors, age groups and unemployment rate.

Second, we use company data from a large European OLM that has more than 120,000 registered users in more than 120 countries around the world. Our data allows us to track the complete hiring process on the marketplace in real time during the whole implementation period of the PEBA program. Figure 1 shows the evolution of the number of online labor workers in Spain for the period under analysis. The platform under analysis started operating in Spain in 2013. As Figure 1 shows, there is a significant number of OLM workers starting in 2016. It increases until the end of the observation period.

Figure 1. Evolution of online workers in Spain, 2013-2021



Notes: Figure 1 shows the total number of active online workers located in Spain during the period 2013-2021.

We observe the municipality where the worker is located, along with the latitude and longitude for her location. We also observe other workers' characteristics, as described in Appendix Table 1.

A crucial step for this empirical exercise is the identification of the exact location of each online worker. This is required to identify the specific SPE in which each worker is located. To this aim, we use the latitude and longitude for each worker, and calculate the distance to the center of each SPE, whose coordinates are provided by the Spanish Statistical Institute. Then, we assign each worker the nearest SPE according to this distance.

3.2.Empirical strategy

The specific intervention that we propose to analyze is the implementation of the PEBA program during the period 2013-2021. The exogeneity that allows identification in our analysis derives from the granting of aid to private operators within the PEBA program to guarantee broadband in rural areas. To assess the impact of the aid, we propose the use of a difference-in-difference (DiD) estimator where we compare SPEs that requested and implemented the aid to SPEs *in the same municipality* that did not. We compare the PEBA effect on the group of white areas that are granted with a subsidy to extend the broadband internet access (treated group) with a group of white areas that are not (control group).

The identification of the causal impact of the PEBA program on labor market outcomes presents several challenges. First, the control group might include SPEs that are heterogeneous compared to SPEs in the treated group. Second, the treatment (i.e., accepted project) can be determined by the socioeconomic characteristics of the SPEs, in such a way that those SPEs that are granted with the public aid could be more likely to be selected by private operators as targets of their applications. Third, the OLM database represents only a subset of the entire population of online workers, as some individuals may have opted to utilize other platforms to offer their services. Therefore, the presence of zeros in the data may not necessarily indicate a complete absence of online workers in a specific SPE, even in white areas. It is plausible that these zeros could be masking the existence of online workers who are not registered on the platform.

To tackle these challenges and ensure comparability between the control and treated groups, we implement the following measures. First, depending on the specification, we include Municipality fixed effects and, where possible, SPE fixed effects in our regressions. This allows us to compare treated and control SPEs within the same municipality in the first case, or the evolution of a single SPE before and after the treatment in the second case. We also include province-time fixed effects to absorb the evolution of unobserved heterogeneity across provinces. Second, our baseline -and more restricted- specification includes only SPEs that are treated during the sample period, exploiting the different years of treatment at the SPE level as a source of exogenous variation. Thus, in our baseline regression, treated SPEs before the treatment will constitute the control group, and treated SPEs after the treatment will constitute the treatment group. Third, to alleviate potential endogeneity concerns, we define the control group in the most restrictive possible way, i.e., we restrict the sample to those SPEs where at least one online worker is available at any point during the sample period. Hence, if an SPE never had a registered online worker, it is excluded from the sample. This restricts our database considerably because a large share of the SPEs under study never had a registered online worker. Finally, we use propensity score matching to define a control group that consists of non-treated SPEs with similar socioeconomic characteristics to the treated SPEs in the treated group.

Our main specification is as follows:

$$Ln\, workers_{s,t} = \alpha + \beta Treated_{s,t} + \gamma X_{s,t} + \mu_s + \mu_{p,t} + \varepsilon_{s,t}, \qquad (1)$$

where $Ln\_workers_{s,t}$ is the log number of active online workers in SPE s in year t. $Treated_{s,t}$ takes value 1 if a given SPE received the aid from the PEBA program in year t and the subsequent years and zero otherwise. $X_{s,t}$ is a vector of observable characteristics for each SPE and year. SPE fixed effects and municipality-year fixed effects are given by μ_s and $\mu_{p,t}$, respectively.

In the proposed estimation, the treatment group is composed by those SPEs included in the sample that have ceased to be a white zone in 2013 to 2021 due to the implementation of the PEBA program. The platform under analysis started operating in 2013, though it is not until 2016 that we observe a significant number of OLM workers all over the country (see Figure 1). Hence, to avoid potential underrepresentation of OLM workers in the first years of the platform, we exclude the period 2013-2015 for the estimation.

To explore the effectiveness of the PEBA program in terms of levelling up urban and rural areas, we explore the wage levels for individuals located in SPEs affected by the program and compare them to individuals located in the two largest cities in Spain, i.e., Madrid and Barcelona. We control for all individual characteristics that could affect wages, including previous experience of the worker, gender or qualification in the platform, or job characteristics, among other variables (see Appendix Table 1). Finally, we also explore the impact of the PEBA program on population patterns.

4. Results

4.1. Impact of broadband internet on digital labor

We examine whether the deployment of broadband internet induced by the PEBA program had a direct impact on (a) the number of online workers, (b) the amount of online work done, and (c) the income generated from work done on the studied OLM. Table 2 presents our baseline results from regression model (1). The unit of observation is an SPE and year. In all columns, the dependent variable is the logarithm of one plus the number of registered online workers in SPE s and period t. We include SPE and province-time fixed effects in all specifications. The treatment group is constituted by SPEs that during the 2013-2021 period have ceased to be a white zone due to the PEBA program.

First, we explore the impact of the PEBA program on the number of online workers. In column (1), SPEs that have not yet received the aid from the PEBA program, i.e., they have not yet been treated, constitute the control group. We impose the restriction that SPEs in the control group have at least one online worker at the end of the sample period for the sake of comparability. In column (1), we focus on the overall effect, including the average effect on an SPE during all years after being treated. The PEBA coefficient is positive, large in magnitude (+0.121) and statistically significant at the 1% level. In column (2), we add to the control group other SPEs that ceased to be white areas at some point during the sample period, but were not targeted by the program, i.e., never treated SPEs. We argue that the observations during the years when SPEs are white zones can be a valid control group, since being a white zone, by definition, implies no expectations of being targeted by a project in a three-year time horizon. Results are consistent with those obtained in column (1), i.e., the PEBA coefficient is positive, large in magnitude (+0.083) and statistically significant at the 1% level. These results suggest that the deployment of broadband internet due to the PEBA program increased the number of online workers in PEBA-treated provinces by between 8.3% and 12.1%. It is in this respect that our results provide empirical support for Hypothesis 1 (Online workers).

Second, we analyze the impact of the PEBA program on the total number of jobs done on the studied OLM. In column (3), we use the SPEs that are not yet treated as control group. In column (4), we add the SPEs that are never treated to the control group. In both cases, we find that the PEBA program had a positive and significant impact on the total number of jobs done by those workers. The PEBA coefficient is positive and large in magnitude ranging between +0.076 and +0.105. These results suggest that the deployment of broadband internet due to the PEBA program increased the number of online jobs done in PEBA-treated provinces by between 7.6% and 10.5%, as proposed in our Hypothesis 2 (Online employment).

Finally, in columns (5) and (6) we investigate the impact of the PEBA program on the total income generated by online workers. Again, we subsequently exclude and include never treated SPEs in the control group. Although in the most restrictive case, i.e., when including never treated SPEs, the coefficient is only significant at 10%, we still find a positive and significant effect when using the least restrictive definition of control group, in line with our Corollary 1 (Online income).

Table 2. Impact of the PEBA program on digital labor and income

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	Log nb online workers	Log nb online workers	Log nb jobs	Log nb jobs	Log income	Log income
Control group:	Not yet treated SPEs	Not yet treated and never treated SPEs	Not yet treated SPEs	Not yet treated and never treated SPEs	Not yet treated SPEs	Not yet treated and never treated SPEs
Broadband internet	0.121***	0.083***	0.105***	0.076***	0.305***	0.169*
(PEBA treatment)	(0.029)	(0.027)	(0.028)	(0.025)	(0.109)	(0.100)
SPE FE	YES	YES	YES	YES	YES	YES
Province-time FE	YES	YES	YES	YES	YES	YES
Observations	3,041	3,245	3,041	3,245	3,041	3,245
R-squared	0.783	0.782	0.626	0.623	0.569	0.577

Notes: Observations are at the SPE-year level. All specifications include SPE and province-time fixed effects. Robust standard errors in parentheses. Constant not reported. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

4.2. Impact of broadband internet on territorial cohesion

Wages and population across different provinces are key determinants of territorial cohesion. Empirical evidence suggests that, in traditional "offline" labor markets, workers in urban areas obtain higher salaries than those in rural areas (Echeverri-Carroll and Ayala, 2011; Glaeser et al., 1992). To explore this aspect for online labor, in what follows we restrict our sample to workers located in a main city of Spain (i.e., Madrid or Barcelona) or in a treated SPE. We analyze the wage difference across urban and rural areas by estimating the following equation:

$$Ln\_wage_{i,d} = \alpha + \beta MainCity_i + \gamma X_{i,d} + \mu_d + \mu_c + \mu_e + \varepsilon_{i,d}, \qquad (2)$$

where $Ln\_wage_{i,d}$ is the log wage of worker i in day d and $MainCity_i$ takes value 1 if the worker is located in Madrid or Barcelona and zero if she is located in a treated SPE after treatment. *MainCity* is our main variable of interest. X_{id} is a vector of observable characteristics for each worker and day (see Table 2) and μ_d , μ_c and μ_e are vectors of day, job category and employer fixed effects, respectively. The level of observation is worker and day. We analyze the impact of *MainCity* on two alternative dependent variables. First, we focus on the *expected* wage of a given worker, as self-declared in her own OLM profile. Second, we examine the *actual* wage that the worker receives after completing a job in the OLM under study.

Table 3 reports the results of this exercise. First, in Columns (1) to (4), we analyze the impact of *MainCity* on the expected wage that each worker shows on her profile. In column (1), we explore the raw effect, when refraining from including any control variables for worker characteristics or fixed effects. In columns (2) to (4), we subsequently include all observable worker characteristics and fixed effects. Second, in columns (4) to (8), we study the impact that being located in Madrid or Barcelona has on the actual wage of the worker, i.e., the payment that the worker receives for a specific project after completing it. We again include controls and fixed effects subsequently going from columns (5) to (8).

Table 3. Wage expectations and actual wages of online workers in urban and rural areas

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable:	Log worker expected wage				Log actual wage			
Main city	0.175***	0.351***	0.134***	0.098***	0.438***	0.539**	0.064***	-0.006
	(0.001)	(0.031)	(0.004)	(0.002)	(0.020)	(0.063)	(0.002)	(0.006)
Certification badge 1				0.130***				0.159***
				(0.012)				(0.015)
Certification badge 2				0.197***				0.602***
				(0.003)				(0.007)
Certification badge 3				0.153***				0.413***
				(0.005)				(0.017)
Female worker				-0.055***				-0.105**
				(0.001)				(0.023)
Worker experience				0.195***				0.205***
				(0.005)				(0.010)
Frequency				-0.019***				-0.006***
				(0.001)				(0.001)
Ratings				-0.014**				-0.071***
				(0.003)				(0.003)
Proposal is locked				0.000				0.000
				(0.000)				(0.000)
Employer is new client				0.100***				0.303***
				(0.005)				(0.004)
Worker Initiative				-0.004**				-0.120***
				(0.001)				(0.009)
Contract is new				0.090***				0.070***
				(0.008)				(0.003)
Job subchannel: Open				-0.092**				0.201***
				(0.018)				(0.019)
FE included[a]	NO	NO	YES	YES	NO	NO	YES	YES
Constant	5.199***	5.206***	5.385***	4.919***	5.940***	5.921***	6.312***	5.966***
	(0.004)	(0.035)	(0.003)	(0.033)	(0.016)	(0.068)	(0.001)	(0.032)
Observations	107,265	3,409	3,409	3,409	22,007	3,408	3,408	3,408
R-squared	0.019	0.086	0.917	0.931	0.009	0.016	0.892	0.897

Notes: Observations are at the worker-day level. Robust standard errors clustered at worker-country level in parentheses. Going from column (1) to (4), and from (5) to (8), the number of observations is dropped because of missing values in the control variables. To check the robustness of our results, we replicate the estimation of the raw effect in column (2) using the same sample as in columns (3) and (4), and in column (6) using the same sample as in columns (7) and (8), respectively. Constant not reported. Appendix Table 1 provides the description of the variables included in this table.

[a]Fixed effects included: Day, Job Category, Job Family, Employer.

*** p<0.01, ** p<0.05, * p<0.1

The results reported in columns (1) to (4) suggest that workers located in Madrid or Barcelona have higher expectations about their wages than workers in treated SPEs. The coefficient of *MainCity* is statistically significant at the 1% level across columns (1) to (4) ranging from +0.098 in column (4) to +0.351 in column (2). As the R-squared is highest in column (4) and remarkably high (0.931) for an expected wage estimation, it is our preferred specification. This suggests that workers located in Madrid or Barcelona have 9.8% higher expectations about their wages than workers in treated SPEs. Consider now the results on the effect of *MainCity* on the actual wages as reported in columns (5) to (8). The coefficient of *MainCity* is statistically significant at least at the 5% level across columns (5) to (7) ranging from +0.064 in column (7) to +0.539 in column (6). However, the coefficient is statistically insignificant and virtually zero in magnitude (-0.006) once we include additional controls in column (8). As the R-squared is highest in column (8), i.e., 0.897, it is our preferred specification. Overall, these results suggest that while workers located in Madrid or Barcelona have higher *expected* wages than workers in treated SPEs there are no essential differences in the *actual* wages they obtain.

However, note that – while we cannot derive causal effects from the results reported in Table 3 – these results are informative with respect to territorial cohesion in terms of population for the following reasons (see Section 5.2. "Impact of broadband internet on territorial cohesion" where we discuss these aspects in more detail). As the wage disparity between urban and rural areas is significant in traditional labor markets, higher salaries constitute one central reason for migration from rural to urban areas. If, however, as the results reported in Table 3 suggest, actual wages for online work are virtually the same in urban and rural areas, there may arguably be less incentives to migrate to main cities, i.e., there may arguably be more incentives to stay in rural areas and do online work.

Based on the aforementioned arguments, we now analyze the impact of the PEBA program on population in a causal manner by using a DiD methodology. We estimate equation (1) using the logarithm of population as dependent variable. The results of this exercise are reported in Table 4.

In line with our Hypothesis 3 (Rural population), these results show that the PEBA program led to a small yet statistically significant increase in the population of treated areas. This suggests that the program may be considered a helpful initiative in revitalizing rural areas and addressing the challenge of depopulation. Further research in this direction would be useful to better understand the implications of the program in terms of population policies.

Table 4. Impact of the PEBA program on population

	(1)	(2)
Dependent variable:	Log population	Log population
Control group:	Not yet treated SPEs	Not yet treated and never treated SPEs
Broadband internet	0.005***	0.005***
(PEBA treatment)	(0.001)	(0.001)
SPE FE	YES	YES
Province-time FE	YES	YES
Observations	106,081	124,210
R-squared	0.998	0.998

Notes: All specifications include SPE and province-time fixed effects. Robust standard errors in parentheses. Constant not reported. *** p<0.01, ** p<0.05, * p<0.1

4.3. Robustness checks

In Table 5, we show a number of robustness checks for our baseline results. All specifications use the sample of not yet treated SPEs and never treated SPEs that cease to be white zones during the 2013-2021 period. In column (1), we use registered workers instead of active workers, i.e., we include all workers registered in the studied OLM, regardless of whether they have ever received a job offer. We could interpret that being registered in the OLM already provides the workers with the possibility of working. It is also plausible that these workers are also registered in a different OLM, since multi-homing is a frequent practice in digital platforms (Allon, 2023). In column (2), we include municipality FE instead of SPE FE. In column (3), we exclude years from 2020 onwards, to avoid potential distortions due to the COVID-19 pandemic. In all cases, results are consistent with previous estimates. Finally, in column (4) and (5), we do not impose the restrictions that the SPEs have at least one online worker. In column (4), the control group includes all the observations of not yet treated and never treated SPEs, whereas in column (5) the control group is determined with a propensity score matching procedure that each treated SPE requires 10 control SPEs with replacement and a maximum caliper of 0.01. In columns, column (4) and column (5), the number of observations increases dramatically because we incorporate SPE with one or no online worker. The coefficient remains statistically significant although, not surprisingly, its magnitude decreases due to the relative increase in the number of zeros in the treated group.

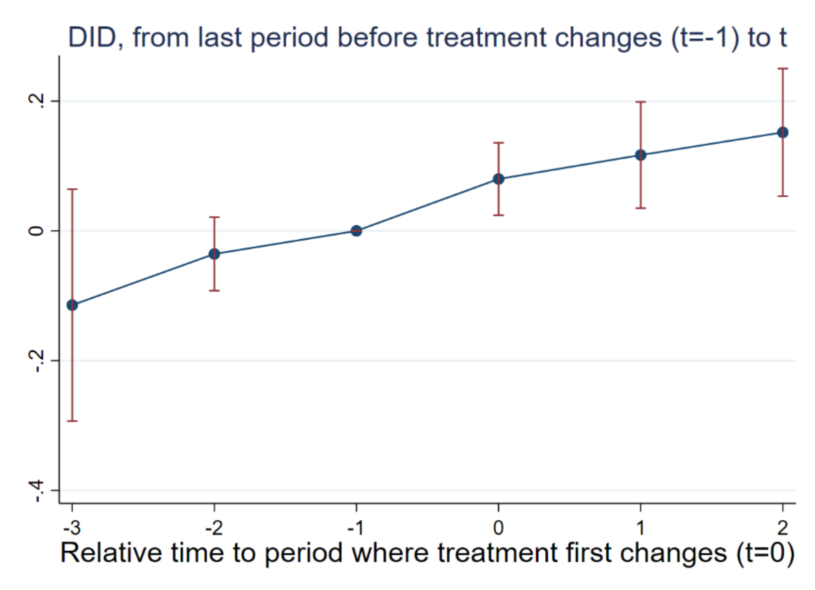
Table 5. Robustness checks, log number of online workers

	(1)	(2)	(3)	(4)	(5)
Dependent variable:	Log nb online workers	Log nb online workers	Log nb online workers	Log nb online workers	Log nb online workers
Robustness:	All registered workers	Municipality FE	Exclude after 2020	Not restricting to at least one worker	Not restricting to at least one worker. Propensity Score Matching
Broadband internet (PEBA treatment)	0.116*** (0.032)	0.108*** (0.029)	0.088** (0.044)	0.001** (0.000)	0.001** (0.000)
SPE FE	YES	NO	YES	YES	YES
Municipality FE	NO	YES	NO	NO	NO
Province-time FE	YES	YES	YES	YES	YES
Observations	3,245	3,249	2,189	430,161	381,225
R-squared	0.835	0.740	0.736	0.556	0.555

Notes: Observations are at the SPE-year level. Robust standard errors in parentheses. Constant not reported. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Importantly, the treatment in our sample does not occur simultaneously. Instead, different SPEs receive the treatment in different periods. Recent literature has raised concerns related to the causal interpretation in standard DiD estimation when there exists variation in treatment timing and dynamic treatment effects (see, for instance, De Chaisemartin and d'Haultfoeuille (2020), Callaway and Sant'Anna (2021), or Athey and Imbens (2022)). Since the PEBA program was implemented in a rolling window of nine years, one could argue that the treatment effect may vary across different units, exhibit dynamics or change across different time periods. To alleviate this concern, we implement the staggered DiD methodology proposed by Callaway and Sant'Anna (2021) to analyze the impact of the program on the number of online workers. The staggered DiD estimator provides a unified framework for average treatment effects in DiD setups with multiple time periods, variation in treatment timing, and when the parallel trends assumption holds potentially only after conditioning on observed covariates. Figure 2 presents the results of the estimation.

Figure 2. PEBA impact on the number of online workers, staggered DiD estimator



Notes: Figure 2 shows the results of the Callaway and Sant'Anna (2021) staggered DiD estimator. The vertical axis measures differences in log of workers with respect to year 0.

For three years prior to the treatment, there are no essential differences between treatment and control group SPEs. Starting immediately in the year of treatment, and each year after, we observe an increase in the log number of online workers. These results are consistent with our previous results from Table 2.

5. Discussion and Policy Implications

We first discuss the policy implications of our results on the impact of broadband internet on digital labor. Then, we discuss their policy implications with respect to territorial cohesion.

5.1. Impact of broadband internet on digital labor

Our results suggest that the deployment of broadband internet due to the PEBA program increased the number of online workers by between 8.3% and 12.1% and the number of online jobs by between 7.6% and 10.5%, respectively. We also find evidence that the PEBA program had a positive effect on the total income generated by online workers. Overall, our results suggest that the PEBA program had a positive effect on digital labor outcomes in terms of participation, employment and income. Based on this, our findings have the following policy implications.

First, broadband deployment programs have been implemented by many countries in recent years, for instance, in China (Liu et al., 2021), Finland (Benseny et al., 2019), France (Bourreau et al., 2023), or Germany (Duso et al., 2021). Ferrandis et al. (2021) analyze the deployment of high-speed broadband networks in the European Union to assess the investment required to meet the targets set by the European Commission for 2025. They find that substantial investments are still needed to meet the goals and that this is particularly the case for suburban, semi-rural, and rural areas. Robust empirical evidence on the impact that these programs have on employment is essential for the design of future internet-related policies. This is particularly relevant in the context of the European Commission's strategy on Connectivity for a European Gigabit Society by 2025. It is in this respect that our analysis is at the core of the European Commission’s Digital Decade policy programme 2030 (European Commission, 2023) and the Territorial Agenda 2030 (European Commission, 2020).

Second, Goal 9 of the United Nation’s Sustainable Development Goals aims at providing universal affordable broadband globally (Oughton, 2023). In this respect, our results on the impact of the PEBA program on online labor in Spain could also inform policy makers in developing countries, where broadband policies are currently being implemented or planned to be implemented in the near future, for instance, in Kazakhstan (Aldashev and Batkeyev, 2021).

Lastly, our results also have implications for OLM managers and online workers. Our results suggest that broadband internet deployment increases the number of online workers as well as the number of jobs done and income earned by online workers. It is in this respect that broadband adoption policies may have positive spillovers on OLM managers and workers. On the one hand, policymakers may take these positive spillovers on digital labor into account when designing their internet adoption policies. On the other hand, OLM managers may take these findings into account when designing their expansion strategies.

5.2. Impact of broadband internet on territorial cohesion

An important goal of the PEBA program was to promote territorial cohesion in Spain. In this sense, a key determinant of cohesion is the level of wages within different provinces. Arguably, if the wage disparity is significant, there is a strong incentive for individuals to migrate from low to high-wage provinces, i.e., higher salaries constitute one central reason for migration. In addition, the continuous depopulation of numerous small towns and municipalities in Spain has become a significant concern, sparking an intense debate in science and policy. This phenomenon, often referred to as "Empty Spain" or "España vaciada", has far-reaching consequences, not only for the affected regions but for the country as a whole. In this respect, we find no essential differences in the actual wages in urban areas as compared to rural areas with broadband internet coverage.

In line with this, we hypothesize that, given this similarity of salaries, there would be less incentives to migrate to main cities, i.e., there would be more incentives to stay in rural areas and work only digitally. The economic cost of living is significantly higher in urban areas as compared to rural areas. Saving costs could hence constitute an incentive for digital workers to stay in rural areas and increase competitiveness as compared to workers in located urban areas. It is in this respect that our results that the PEBA program led to a small and statistically significant increase in the population of PEBA-treated regions provides empirical support for our hypothesis.

6. Conclusions

In this paper, we exploit the Annual Broadband Extension Program for white areas (PEBA) implemented by the Ministry of Economic Affairs and Digital Transformation in Spain as a source of exogenous variation in the broadband status at the regional level. To this aim, we use unique company data from a large European OLM as well as data from broadband deployment at the SPE level during the period 2013-2020. The granting of aid to private operators within the PEBA to guarantee broadband in rural areas allows us to identify causal effects. We use a DiD estimator to compare SPEs that requested and implemented the aid to SPEs *in the same municipality* that did not.

Our results suggest that the PEBA program has been effective in terms of creating digital employment opportunities. They also suggest that the program may be an important potential driver to close the urban-rural divide by increasing the population in rural areas. Our results emphasize the role that OLMs may play as significant intermediaries to scale the impact of broadband policies.

Finally, we explore the relation between wages and workers' location. Our findings suggest that differences among urban and rural areas are attenuated in a setting that is already conducive to remote work, i.e., an OLM. Future research on this aspect would be important to properly understand the levelling effects of the investment in broadband deployment.

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Appendix Table 1. Definition of variables

	Definition	Mean	Sd
Dependent Variables			
$Workers_{s,t}$	Number of active online workers in SPE s and year t	1.46	11.54
$WorkersR_{s,t}$	Number of registered online workers in SPE s and year t	6.52	76.23
$Nbjobs_{s,t}$	Number of active online workers in SPE s and year t	0.47	4.04
$Income_{s,t}$	Income generated by online workers in SPE s and year t (in Euros)	1628	38431
Expected daily wage (€)	Expected daily wage as declared by worker in her profile	267.7	134.6
Actual wage per contract (€)	Total wage received for a contract	3,086	15,444
$Population_{s,t}$	Number of inhabitants in SPEs at year t	963	9,985
Independent Variables			
$Id(Aid\ Received)_{s,t}$	Dummy variable that takes the value of 1 if the SPE *s* is a beneficiary of the PEBA program in the year of approval *t* and in the subsequent years, and 0 otherwise.		
$Main\ city_{s}$	Dummy variable that takes the value of 1 if the SPE s is located in Madrid or Barcelona, and 0 otherwise	0.833	0.373
Certification badge 1	Worker is certificated as "Entry" worker by the platform	0.167	0.373
Certification badge 2	Worker is certificated as "Intermediate" worker by the platform	0.127	0.333
Certification badge 3	Worker is certificated as "Expert" worker by the platform	0.152	0.359
Female worker	Worker is a female	0.32	0.466
Worker Experience	Experience level of the worker (0-3)	2.661	0.509
Ratings	Worker ratings in the platform (0-5)	4.901	0.4
Proposal Locked	Worker proposal has been locked by the employer	0.001	0.0279
Employer is New	Employer involved in the contract has recently joined the platform	0.348	0.476
Job Created By Worker Initiative	The contract is created after a proposal by the worker	0.368	0.482
Job subchannel: Open	The employer brings the worker into the platform	0.108	0.31