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Local labor impact of wind energy investment: an analysis of Portuguese municipalities

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Abstract

Investment in wind power has grown remarkably in the past decades in Portugal. Although economic development is an argument for investment incentive policies, little evidence exists as to their net impact on local-level unemployment. Using data for all 278 Portuguese mainland municipalities for the years 1997-2017, we assess the existence, distribution and duration of local-level labor impacts of wind power investment. Our results show there are short-term effects during the construction phase. We estimate a decrease of 0.17 and 0.23 percentage points in the total unemployment rate per 100MW of installed power in each of the two years of the construction phase. These effects are felt mainly for unskilled labor and male workers. Further analysis of spatial interaction finds positive spatial spillovers for municipalities that are 30km or less away but not farther, implying workers are willing to commute but not migrate. We find a very small sustained impact during the operations and maintenance phase, despite both short- and long-term impacts on municipalities' revenues.

JEL classification: C23, H70, Q50

Keywords: Wind power, labor effects, local economy, panel data

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1 Introduction

The aim of this paper is to evaluate the impact of wind power investments on the local labor market. Renewable energy has been a key part of the environmental strategy of the European Union (EU) to reduce CO_2 emissions, as well as to increase energy independence and security. The EU 2020 climate and energy package, enacted in 2009, set out the objective of raising the share of European Union's member states energy consumption produced from renewable resources to 20% by 2020. In addition to environmental objectives, the European Commission estimated that meeting this target could create up to $417,000$ new jobs by 2020 (Ragwitz et al., 2009). However, doubts remain as to whether these effects translate into an increase in overall employment - rather than a displacement of resources - as well as into effects at the local-level rather than at the aggregate level only. This is of major importance to the local communities that house these projects, sometimes with negative impacts for example in terms of housing prices (Lang et al., 2014, Gibbons, 2015, Sunak and Madlener, 2016).[1] We aim at assessing the existence, magnitude, duration, and distribution of effects of investment in wind energy on total local employment for a panel of Portuguese municipalities.

Portugal has made large investments in renewable energy, in particular wind power, in the past decades, despite the economic slowdown. In 2017 the wind share in total electricity demand in mainland Portugal was of 24.2%, the second highest in the EU (WindEurope, 2018). Total installed generating capacity increased from 27.22 megawatt (MW) in 1997 to 5332 MW in 2017, making Portugal the country with the third highest kilowatt (KW) installed per km^2 in the EU (e2p Endogenous Energies of Portugal, 2017a). Understanding local economic consequences of these investments is therefore important.

The Portuguese economy is highly energy intensive and has traditionally been especially dependent on imports of primary fossil fuels. Consequently, one of the main benefits of investment in renewables, and in particular in wind power, is to decrease the weight of these imports in national Gross Value Added. Additionally, the development of the wind industry is expected to increase competitiveness and contribute to the creation of jobs. Deloitte (2009) estimated that in 2008 the wind industry generated a total of 2200 direct and indirect jobs, expected to increase to 5850 by 2015. The International Labor Organization predicts that, worldwide, one megawatt of wind energy could create between 0.43 and 2.51 jobs at the construction and manufacturing phase, and 0.27 during the operations and maintenance phase, with a mix of low, medium, and

[1] Despite concerns that offshore wind development would decrease tourism in coastal areas, Carr-Harris and Lang (2019) find no support for this claim.

high skilled labor (ILO, 2011). Similar ranges are estimated by input-output models in various settings (e.g. Slattery et al., 2011).

These project-level or input-output studies that typically focus on gross impacts may not measure the total net impact of wind investment. The overall impact of a wind park might be smaller than estimated by these studies if it displaces other kinds of investment, or larger if the macroeconomic impact resulting from the investment generates further employment. By performing an econometric analysis with historic data we can account for these effects and estimate the total net impact. Whether benefits are accrued at the local-level and how they are determined and distributed are important questions for designing regulation and policies related to wind investment.

We perform the analysis for a panel of all the 278 Portuguese mainland municipalities for the years between 1997 and 2017. We study the impact of the installation of wind power in a given municipality on its unemployment rate, and distinguish between the construction phase, and the operations and maintenance phase. We further investigate how these impacts vary with the gender and educational levels of workers. Moreover, we explore the possibility of local spillovers between municipalities. Development in one region may affect employment in another through migration or indirect economic impacts (such as the increase in demand for goods and services). We use a distance decay matrix to address this possibility. Finally, we further our understanding of the local economic impacts of wind energy investment by studying its effect on local governments' finances. Municipal revenues may increase in the short-run because energy companies buy public land or in the long run because they rent land or pay taxes and other services.

Our identification strategy is based on the fact that the main determinants of the location of wind investment within the country, such as the wind energy potential for commercial turbines, orography, or slope of the land, are time invariant. They are thus captured by municipality-level fixed effects. While incentive schemes for investment in wind power are strong determinants of the decision to invest, these are decided at the country or European level and implemented equally across municipalities, and are therefore captured by time fixed effects.

To the best of our knowledge only a few studies have performed similar analyses.[2] Brown et al. (2012) perform a cross section econometric analysis of employment and income impacts of wind power installation using county total variation in wind power from 2000 to 2008, in the U.S. They find that personal income and employment increase 11000$ and 0.5 jobs respectively per MW. Using a cross section variation of installed wind power from 2001 and 2011 in Texas coun-

[2] Other studies have instead focused on country level impacts (eg. Inglesi-Lotz, 2016).

ties, De Silva et al. (2016) find positive impacts of employment at the industry, but not at the county level, as well as modest income impacts. Xia and Song (2017a) use a similar method to estimate the impact of wind power development from 2005 to 2011 in Chinese counties on GDP, finding positive impacts. Panel data allows to surpass endogeneity issues by exploring within-region variation. Hartley et al. (2015) use monthly data to compare the employment impacts of wind and shale gas investments for a panel of counties in the state of Texas. They focus on the impact in the six months after turbines are installed and find no significant impact for the case of wind.

We find that wind power investment reduces unemployment levels during the construction and manufacturing phase. In particular, a 100MW increase in installed power leads to an average of 0.17 and 0.23 percentage point decrease in unemployment rates in each of the two years of construction.[3] This amounts to roughly 0.39 and 0.55 jobs per MW installed.[4] We find that effects over these two years are felt mainly for male workers and unskilled labor – i.e., for workers without a college education. Female unemployment also decreases in the last year of construction. Moreover, we find evidence of spatial spillovers only between close by municipalities, indicating possible commuting journeys for work, but not migration. Finally, we found no benefits for total employment of wind power investment during the operations and maintenance phase nor any long-term impacts.[5] We also found both short and long-term positive impacts of wind energy investment on total municipal revenues. These findings have important implications for renewable investment policy and regulation, which we discuss in the conclusion.

The remainder of the paper is organized as follows. Section 2 describes the evolution of wind investment in Portugal and its legal framework. Section 3 describes the econometric model, the empirical strategy, and the data. Section 4 presents and discusses the results, and Section 5 concludes the paper.

2 Wind Energy in Portugal

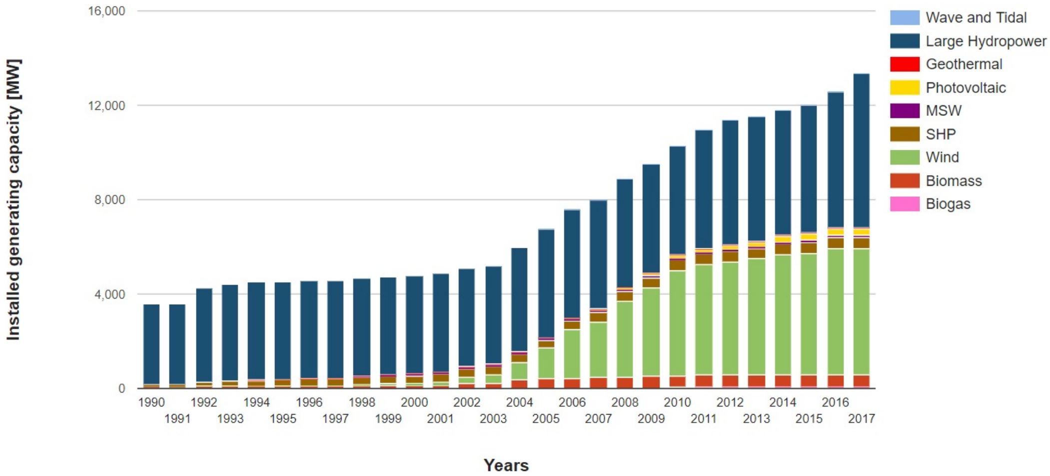
Renewable energy (RES) development has surged in the past decades in Portugal. In 2009, and in the context of the European Union's (EU) Renewable Energy Directive (Directive 2009/28/EC), Portugal committed in its National Action Plan to achieve 31% of final consumption energy from renewable sources in 2020. Figure 1 shows the evolution of installed RES capacity in Portugal.

[3] More precisely, we estimate a 0.059 and 0.082 percentage points decrease in the unemployment rate for 1 KW *per capita* installed.

[4] This includes both part- and full-time work.

[5] With the exception of a very small decrease in unemployment for workers with a college degree and the second level of basic education.

Figure 1: Evolution of installed RES capacity in Portugal



Source: INEGI/APREN — December 2017

Legislation guaranteeing grid access for independent power producers using RES came into force in 1988 (Decree-Law 188/88 and Decree-Law 189/88). It covered only small hydropower, but in 1995 it was extended to cover other sources such as wind power (Decree-Law 313/95) and a system of feed-in-tariffs was introduced. Limited knowledge of wind resource potential and wind technology in Portugal rendered investment in wind power very modest during the 1990's (Bento and Fontes, 2014). The lack of clarity of the process of connection to the grid until 2001 further contributed to this (Peña et al., 2017). The development of new wind technology in Europe, coupled with a favorable Portuguese and European regulatory context, led to the takeoff of wind power investment in the late nineties.

A series of initiatives were meant to stimulate renewable electricity production and regulate the process more clearly. The system of feed-in-tariffs was revised in 1999 (Decree-Law 168/99) and 2001 (Decree-Law 339-C/2001 and Decree-Law 312/2001) to account for avoided costs of investing in conventional power plants and differentiated between technologies, with the first 2 000 hours of wind energy production each year being paid EUR 0.082/KWh.[6] The same documents simplified the license-granting process for grid access and introduced a special tax of 2.5% of total wind revenue to be paid to local municipalities was introduced, with the aim of increasing local benefits.[7] With the same aim, in the 2005 process of releasing a tender for 1800 MW of wind power, in addition to technical requirements, a condition for being granted

[6]This tariff is reduced by 200 hour blocks until a minimum of EUR 0.04/KWh after 2 600 hours).

[7]The special tax was to be applied not only to new wind plants but also for existing ones, if bilateral agreements between wind plant developers and municipalities did not foresee higher sums being paid.

tendering conditions was working with local manufacturing companies. Additional conditions included limiting import of turbines, contributing to research and development, and pursuing the transfer of technology to Portugal. As a result national incorporation of inputs rose from 20% to 100% for this tender (Bento and Fontes, 2014).

In the context of the Portuguese economic crisis, and in particular with the 2011 intervention by the International Monetary Fund (IMF), incentives for wind power development such as feed-in-tariffs were slowly revised, and wind power capacity started to grow slower.

Nevertheless, installed wind power generating capacity increased from 27.22 MW in 1997 to 5332 MW in 2017, with Portugal having the third highest KW installed per km^2 in the EU (e2p Endogenous Energies of Portugal, 2017a). In 2017 the wind share in total electricity demand in Portugal was of 24.1%(e2p Endogenous Energies of Portugal, 2017a).

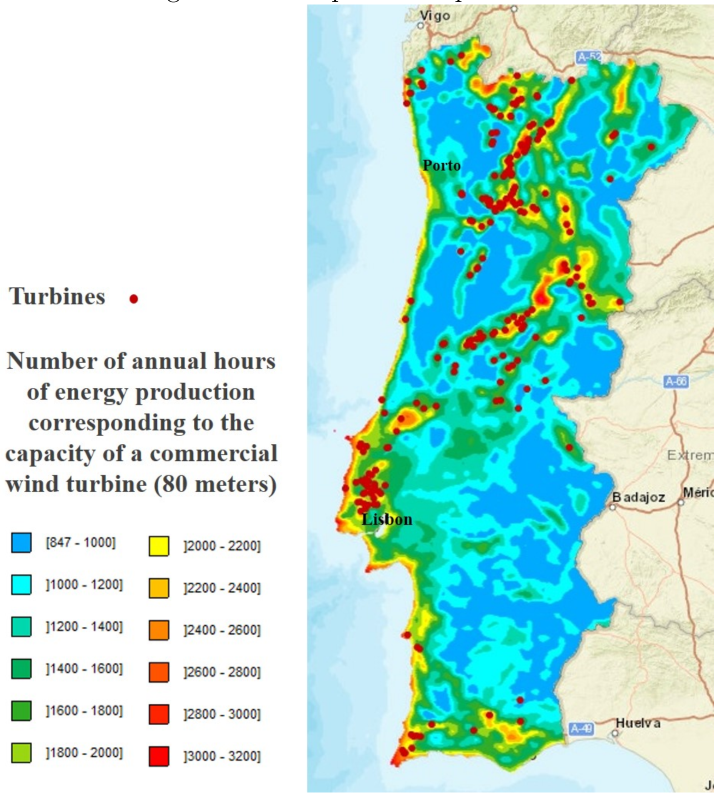
Permission for the exploration of wind energy is granted by the central government,[8] and the main determinants of location of wind parks are set out in Section 3.3, the most important of those being wind potential and access to the grid.

Figure 2 overlays the location of all existing wind parks in 2017 on a map of the wind potential of continental Portugal, as measured by the total number of annual hours of energy production corresponding to the capacity of a commercial wind turbine.[9]

[8]Specifically, the Directorate General for Energy and Geology (DGEG) either grants access directly for wind parks or grid connection licences may be granted through a public tender, where specific conditions apply. Most licences where awarded in public tenders in the years 2001, 2003, and 2005 (Peña et al., 2017).

[9]Further information on the use of this variable and its source is presented in Section 3.

Figure 2: Wind parks and potential



Source: LNEG and e2p/INEGI/APREN, data from 2017

3 Empirical Model

3.1 Empirical Strategy

The aim of the analysis is to investigate municipality-level effects of investment in wind power in Portugal. Our dependent variable is the unemployment rate at the municipal level, the estimation of which is described in Section 3.2. Our main independent variable of interest is the amount of accumulated wind power installed in municipality i in a given year, in KW *per capita*. This variable captures effects of the total power that is installation of a wind park in each year, and therefore relates to the operations and maintenance phase. It measures whether there are sustained long-term impacts of installed wind power. In order to account for the effects of the construction and manufacturing phase, we use two variables measuring the amount of power *per capita* that is installed and starts producing in the following one and two years. This is because it usually takes between 6 months and a year to build a wind park, but in Portugal, depending on the size of the park and the economic conjuncture, it might take even longer. We also experiment with past lags, in order to investigate further effects of maintenance and operations that might only have an impact in the future.[10]

The basic empirical specification is thus given by:

$$unemp_{it} = \alpha_1 + \gamma_1 power_{it+2} + \gamma_2 power_{it+1} + \gamma_3 Apower_{it} + \alpha_2 X_{it} + \eta_i + \rho_t + \epsilon_{it} \qquad (1)$$

where $unemp_{it}$ is the unemployment rate in municipality i year t; $power_{it+1}$ and $power_{it+2}$ are the total power *per capita* installed and starting operations in municipality i in years $t+1$ and $t+2$, respectively, (construction phase); $Apower_{it}$ is the accumulated installed KW *per capita* in municipality i in year t (long-term); and X_{it} is a vector of economic and demographic variables affecting unemployment in municipality i in year t. Finally, η_i is a municipality individual fixed effect, ρ_t a year fixed effect, and ϵ_{it} the error term.

Included in vector X_{it} are growth of Gross Domestic Product (GDP) by NUTS3 region,[11] in real *per capita* terms and in the previous year ($\Delta GDPreg_{it-1}$), that captures changes in regional economic conditions, and total spending by municipalities in the previous year, in real *per capita* terms ($expend_{it-1}$), because past expenditures can stimulate employment. These two variables are lagged one period in order to avoid endogeneity issues.[12] Additionally, it includes two demographic variables (population density, $denspop_{it}$, and share of population under 15 years old, $young_{it}$). In order to account for possible impacts of urbanization we estimate the model including the interaction between installed power and a dummy variable equal to one if a municipality includes at least one city, $city_{it}$.

We additionally investigate the impact of wind investment for skilled versus unskilled labor. As a proxy for the level of skill of a job, we use the level of completed education of the worker. We thus repeat the estimation using as the dependent variable the weight on the working age population of unemployed individuals with, respectively, one, two, or three levels of basic (pre-high school) education, corresponding to 4, 6, and 9 years of schooling, with secondary (high school) education, and finally, with a university degree.[13] We also investigate whether unemployment effects depend on gender, by testing the impacts for female and male unemployment.

Finally, employment in municipality i may be affected by the power installed in neighboring

[10]To test the robustness of the results, we tried different lags and leads of *power* and *Apower*. These results are presented in Appendix B.

[11]NUTS stands for Nomenclature of Units for Territorial Statistics. The NUTS is developed by the European Union for referencing the subdivisions of countries for statistical purposes. For each EU country, a hierarchy of three NUTS levels is established by Eurostat. The subdivisions do not correspond necessarily to administrative divisions within the country. On mainland Portugal there are 23 NUTS3.

[12]NUTS3 regions include a varying number of municipalities. A measure of GDP is not available at the municipal level.

[13]The third level of basic education was the level of mandatory education in Portugal until 2009, when it changed to secondary (high school) education.

municipalities. For example if there is sufficient labor mobility or if development in neighboring municipalities creates demand for good and services that spill over into municipality i, then investment by neighbors might have a positive effect in own employment. It may also happen that development in neighboring municipalities diverts investment away from municipality i, thereby impacting negatively its levels of employment.

We account for this by including in the regression a measure of the power installed in neighboring municipalities. We weight this power by a matrix based on geographic proximity, such that closer neighbors have a larger effect in a given municipality's unemployment rate. In order to define this matrix, a commonly used method is to assign weights based on binary contiguity. This would imply that municipalities sharing a border are weighted equally, and others are not considered neighbors. Since Anselin (1988) argues this method may not account for the full degree of spatial interaction in the data, we follow Cliff and Ord (1981) and define neighbors according to the geographical distance between them. Specifically, we define neighbors according to the Euclidean distance between the centers of the municipalities, and construct the weights as the inverse of this measure. We then standardize the weights $w_i j$ such that for a given municipality i, $\sum_j w_{ij} = 1$. More discussion on the appropriate choice of economic neighbors in the context of Portuguese municipalities can be found in Costa et al. (2015).

We then limit municipalities that are considered neighbors to those that are x or less kilometers apart, with $x = 30$, $x = 50$, and $x = 100km$. The former aims at capturing commuting travelling for work, and the two latter possible migration for work effects. For the municipalities considered neighbors, a lower weight is assigned the further away they are.

Hence the weight of municipality j relative to municipality i, w_{ij}, is defined as:

$$w_{ij} = \begin{cases} \frac{\frac{1}{dist_{ij}}}{\sum_j \frac{1}{dist_{ij}}} & \text{if } 0 < d_{ij} \leq xkm \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

Thus, Eq. (1) is augmented with the term $Wpower_{jt} = \sum_{j \neq i} w_{ijt} power_{jt}$, where j are municipality i's neighbors, becoming:

$$unemp_{it} = \alpha_1 + \gamma_1 power_{it+2} + \gamma_2 power_{it+1} + \gamma_3 Apower_{it} + \delta WP_{jt(+1/2)} + \alpha_2 X_{it} + \eta_i + \rho_t + \epsilon_{it} \quad (3)$$

where the other variables remain unchanged from Eq. (1) and $P_{jt(+1/2)}$ stands for, respectively, $power_{jt+1}$, $Wpower_{jt+2}$, and $WApower_{jt}$, the spatially weighted variables of interest.[14]

[14]To avoid the correlation between the variables measuring neighboring levels of installed and accumulated

3.2 Data and Sources

The dataset used covers all 278 Portuguese mainland municipalities for the period of 1997-2017 for a total of 5832 observations. Table 1 summarizes the data.[15]

Table 1: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Unemployment rate	6.722	2.699	1.38	18.477	5,832
Male unemp.	2.812	1.314	0.315	9.174	5,832
Female unemp.	3.893	1.643	0.804	13.775	5,832
Unemployment (1st)	2.812	1.314	0.315	9.174	5,832
Unemployment (2nd)	1.284	0.611	0.143	5.367	5,832
Unemployment (3rd)	1.185	0.636	0.083	4.348	5,832
Unemployment (Sec)	1.212	0.689	0.029	8.449	5,832
Unemployment (Uni)	0.542	0.378	0	2.743	5,826
Power installed (KW)	878.969	6,970.495	0	22,2000	5,832
Power installed (KW pc)	0.073	0.765	0	32.123	5,832
Power accum. (KW pc)	0.778	2.964	0	43.114	5,832
NEPS[16]	1,355.592	368.071	665.161	2,537.657	5,832
Population	35,706.598	57,252.778	1,634	606,480	5,832
Population density	306.178	856.243	4.017	7,670.162	5,832
City	0.424	0.494	0	1	5,832
Weight of young (< 15)	13.703	2.686	4.841	23.878	5,832
Weight of elderly (> 65)	22.343	6.358	8.116	45.568	5,832
GDP growth NUTS3 pc	1.416	3.568	-15.645	25.94	5,832
Total spending pc	1,064.109	538.782	177.106	8,606.569	5,832
Total revenue pc	1,069.657	539.903	270.275	8,601.380	5,832

The total unemployment rate varies between a minimum of 1.4 and a maximum of 18.5, and is calculated based on the number of people enrolled in the Portuguese centers of employment (IEFP), weighted by the total number of working age inhabitants, where the total number of working age inhabitants is calculated as the total population of the municipality minus those aged 15 years old or younger, and those aged 65 or older. A graph depicting the annual sum of unemployment rates across municipalities as well as the annual sum of installed power is

power – $Wpower_{jt+1}$, $Wpower_{jt+2}$, and $WApower_{jt}$ – we chose to include them one at a time in the estimation. We present results for the final year of construction as a similar analysis for the first year of construction and for the maintenance period does not yield any significant results and is not presented in the paper but is available upon request.

[15] Summary statistics by two groups, one with all 171 municipalities that never had power installed, and one with all 108 municipalities that did, is available in Appendix A.

[16] NEPS stands for the number of annual hours of energy production corresponding to the capacity of a commercial wind turbine (80 meters), and measures the energy productive capacity of the wind. The variable is presented here as an average by municipality. This information was ceded by the Portuguese National Laboratory of Energy and Geology (LNEG).

presented in Appendix A.

The unemployment rate is followed by six variables that allow us to analyse the effect of wind investments on unemployment by gender and education level. The first two variables represent the weight of unemployed male and female workers, respectively, on the working age population of each municipality. The next four variables measure the weights of unemployed individuals, by educational level, on the working age population of the municipality. As can be seen from Table 1, on average unemployed women represent a larger proportion of the working age population than men and, among the four levels of education considered, unemployed individuals with a university degree the smallest weight.

The following three variables correspond respectively to installed power in KW, installed power in KW *per capita*, and to total installed power accumulated by a given municipality in a given year. Data on the exact location of wind parks, time of production start, and capacity of turbines was retrieved from e2p Endogenous Energies of Portugal (2017b), with permission from the institution. Whenever a wind power plant was installed between two municipalities the total power was assumed to be divided equally between these municipalities. Installed power varies greatly, between a minimum of zero and a maximum of 222 MW installed in a given year and a given municipality. There was a total of 237 increases in power installed in the period of analysis. All power installed is onshore.[17]

Total GDP *per capita* by NUTS3, used to calculate its growth rate, was retrieved from the National Institute of Statistics (INE). Data on municipalities' local accounts was obtained from the DGAL's annual publication *Municipal Finances* (DGAL, 1986-2017). These variables were deflated using the 2017 consumer price index. Data on the consumer price index, municipal population, the proportions of population under 15 and over 65, as well as the number of cities were collected from the National Institute of Statistics.

3.3 Identification Strategy

Wind investment in Portugal has grown remarkably mainly due to the national and European level regulation described in Section 2. This regulation is decided at the national or international (European) level and implemented equally across municipalities, and therefore changes to it are captured by time fixed effects. Our identification strategy is based on the fact that within country determinants of wind power location are mainly time-invariant. Casadinho (2014) distinguishes three set of criteria for the location of wind parks: location criteria, accessibility criteria, and

[17] An experimental offshore wind turbine was constructed in 2011 and deactivated in 2016. For the purpose of homogeneity it is left out of our analysis.

restrictions. The former includes the energy potential of the wind, or orography, the second set electric grid accessibility and general accessibility, and the latter includes restrictions imposed, such as environmentally protected areas, areas with high slopes, areas with existing wind parks, and areas with high population density. Of these, population density might vary considerably over time and so, to avoid omitted variable bias, we include it in our analysis.

To measure wind potential, we use the number of annual hours equivalent to the nominal power of a commercial turbine – introduced in 2 – averaged at the municipality level.

Permission is granted by the government for the exploration of wind energy. While the granting process was traditionally non-restrictive and so based mainly on technical factors, it is possible that the central government gives preference to investment in municipalities with lower income or employment levels, in order to boost development here. In such a case, our estimations would be biased. Given that measures of wind potential of each municipality are mostly time invariant, we cannot use this as an instrument and still use fixed effects to control for all municipality-level unobservables. We instead include annual growth of regional GDP in order to account for this possibility. We lag this variable one period in order to avoid endogeneity issues. The exclusion of this variable does not change results.[18]

Table 2 further investigates possible endogeneity of investment in wind energy. The dependent variable in regressions (1)-(4) is wind investment in municipality i in year t. The first three columns investigate the possible impact of past levels of unemployment in the choice of location of wind parks, showing no significant effect. The fourth column investigates the impact of past levels of GDP growth in the choice of investment, again with no significant impact.[19]

Finally, column five shows the impact of population density ($denspop_i$) and of the energy potential of wind by municipality, measured by the number of annual hours equivalent to the nominal power of a commercial turbine ($neps_i$). The dependent variable in this regression is the total power accumulated *per capita* by 2017, as the energy potential is time invariant.[20] Both these variables have a significant impact on the choice of investment in wind energy. In line with the theory (Casadinho, 2014), population density negatively affects investment levels, while the energy potential affects it positively.

These findings seem to corroborate our hypothesis that factors that influence the location of wind parks at the municipal level are time invariant (as is the case of NEPS) or can be accounted for (in the case of population density). In particular, it does not seem that past unemployment

[18] We furthermore include the average unemployment rate of the 4 years prior to construction without a change in results, but decide against this due to endogeneity issues.

[19] This is consistent with the analysis of Xia and Song (2017b) for Chinese municipalities.

[20] The population density used is also that of 2017, since this does not vary significantly.

Table 2: Further tests for identification

	(1)	(2)	(3)	(4)	(5)
Dep. Var.	$power_{it}$	$power_{it}$	$power_{it}$	$power_{it}$	$apower_{it}$
			Full Sample		Year: 2017
$unemp_{it-1}$	-103.4	-197.7	-213.9		
	(64.09)	(129.3)	(142.3)		
$unemp_{it-2}$		88.53	60.29		
		(99.46)	(99.88)		
$unemp_{it-3}$			17.77		
			(78.72)		
$GDPregtot_{it-1}$				29.21	
				(35.65)	
$denspop_i$					-8.671***
					(1.980)
$neps_i$					30.46***
					(5.961)
Constant	697.8*	639.0	766.3*	-64.36	-20,139***
	(382.8)	(387.6)	(444.8)	(189.1)	(6,882)
Observations	5,554	5,276	4,998	5,554	278
R-squared	0.017	0.017	0.016	0.017	0.093

Robust standard errors clustered by municipality. SE in parentheses.
Null hypothesis is rejected: ***1%, **5% and *10%.
Columns 1-4 include time dummies and municipality fixed effects.

levels affect the development of wind energy. We thus consider wind capacity installed in a given municipality in a given year exogenous in our analysis, and control for time and municipality fixed effects only.

4 Results

Our empirical results are presented in Tables 3-6. In Section 4.1 we justify the econometric estimation technique and present the results of the main empirical specification (Table 3). In Table 4 we show the results for disaggregated unemployment rates, and in Table 5 we present the results of the spatial analysis based on geographic proximity. Throughout the analysis we implement the same estimation method and include similar control variables to facilitate comparison. Finally, Section 4.4 discusses the results and further investigates local-level impacts of investment on local public finance.

4.1 Wind Investment and Unemployment Rate

The main results are shown in Table 3. Column (1) presents the estimation of Eq.(1) by Fixed Effects (FE). A Wald test indicates that the dummies for municipalities are jointly statistically significant and a Hausman specification test gives preference to FE over Random Effects, so we use FE throughout our estimations. The Breush-Pagan test suggests the presence of heteroskedasticity so we use robust standard errors, clustered by municipality in all equations.[21] All equations include time fixed effects to capture all variables affecting all municipalities at the same time. Standard errors are presented in parenthesis.

FE attributes the same weight to all observations, but population varies considerably across municipalities. On average, the number of inhabitants was above 529 thousand in Lisbon, while in Barrancos it was below two thousand (these are the two extreme municipalities in the dataset). Therefore, the estimation procedure requires special treatment for the aggregate time-series cross-sectional nature of the data. Columns 2-7 present the estimation of Eq. (1) by FE, using the average number of inhabitants in each municipality as weights.

Column (2) presents the results for the basic specification, testing effects during the construction and maintenance phases. The coefficients measuring the effect of wind power installation during the construction phase, $power_{it+2}$ and $power_{it+1}$, are negative and highly statistically significant. In particular, they indicate that a 1KW *per capita* installed decreases unemployment, in a given municipality during the construction phase, by 0.08 percentage points one year before the wind plant starts producing and by 0.06 percentage points two year before. Taking into account the average population (35,706.598) by municipality, this translates in an average effect of around 0.39 and 0.55 jobs per MW installed in each of the two years, in line with previous estimations. The coefficient measuring the impact in the maintenance phase, $Apower_{it}$, is not statistically significant.

As expected, the more dynamic the region where the municipality is (ie, the higher the regional GDP growth, $\Delta GDPregion_{it}$), the lower the unemployment rate is. Population density ($denspop_{it}$) and the share of young population below working age ($young_{it}$) also turned out to be statistically significant and negatively signed.[22] Finally, the amount of municipal public expenditures *per capita* ($expend_{it-1}$) does not seem to influence unemployment.[23]

Columns (3) and (4) present the results respectively excluding regional GDP growth and mu-

[21] With the exception of the spatial analysis, where we cluster them at the NUTS3 region level.

[22] One explanation for these results is that municipalities more densely populated and with a large share of young population in Portugal tend to be economically more dynamic, while those less densely populated and with a large share of old population tend to be less dynamic and to face a reduction in population.

[23] Municipal expenditures *per capita* are in thousands in all estimations where $expend_{it-1}$ is an explanatory variable to make coefficient reading easier.

Table 3: Effects on total unemployment rate

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Estimation	FE	FE using the average number of inhabitants as weights					
$power_{it+2}$	-0.0147	-0.0587**	-0.0583**	-0.0623**	-0.0441*	-0.0562**	-0.0922***
	(0.0155)	(0.0266)	(0.0267)	(0.0277)	(0.0259)	(0.0259)	(0.0340)
$power_{it+1}$	-0.0426***	-0.0821***	-0.0845***	-0.0863***	-0.0647***	-0.0852***	-0.0980***
	(0.0154)	(0.0245)	(0.0248)	(0.0254)	(0.0249)	(0.0245)	(0.0337)
$Apower_{it}$	0.0061	-0.0115	-0.0111	-0.0182	0.0069	-0.0100	-0.0378
	(0.0190)	(0.0309)	(0.0308)	(0.0319)	(0.0313)	(0.0307)	(0.0325)
$\Delta GDPreg_{it-1}$	-0.0215**	-0.0285*		-0.0284*	-0.0078	-0.0288*	-0.0284*
	(0.0088)	(0.0147)		(0.0147)	(0.0152)	(0.0148)	(0.0147)
$expend_{it-1}$	-0.3818**	-0.3080	-0.3065		-0.0496	-0.3020	-0.3088
	(0.1738)	(0.2902)	(0.2915)		(0.2924)	(0.2891)	(0.2906)
$denspop_{it}$	-0.0007	-0.0011***	-0.0011***	-0.0011***	-0.0008	-0.0011***	-0.0011***
	(0.0008)	(0.0004)	(0.0004)	(0.0004)	(0.0006)	(0.0004)	(0.0004)
$young_{it}$	-0.2496***	-0.2665***	-0.2577***	-0.2583***		-0.2675***	-0.2663***
	(0.0560)	(0.0650)	(0.0652)	(0.0638)		(0.0651)	(0.0651)
old_{it}					-0.0153		
					(0.0717)		
$city_{it}$						-0.6394**	
						(0.2623)	
$city * power_{it+1}$						0.0408	
						(0.0748)	
$after07_{it} * power_{it+2}$							0.0609
							(0.0421)
$after07_{it} * power_{it+1}$							0.0265
							(0.0423)
$after07_{it} * Apower_{it}$							0.0248
							(0.0376)
Constant	10.4989***	11.7979***	11.5145***	11.4514***	7.0083***	12.2884***	11.7949***
	(0.9152)	(1.3710)	(1.3973)	(1.3116)	(1.2938)	(1.3996)	(1.3723)
Observations	4,998	4,998	4,998	4,998	4,998	4,998	4,998
R-squared	0.5973	0.7223	0.7216	0.7218	0.7082	0.7227	0.7223

Notes: Estimated coefficients indicate the effects of a one unit change in the explanatory variables on the unemployment rate, in percentage points. All estimations include year and municipal fixed effects. Robust standard errors (SE) clustered by municipality. SE in parentheses. Significance level for which the null hypothesis is rejected: ***1%, **5% and *10%. The number of units in FE is 278.

nicipal public expenditures, without changes in the results. Column (5) uses the weight of population over 65 years of age (old_{it}) instead of the weight of young population,[24] again without significantly affecting the main results. Column (6) presents an estimation including a dummy for municipalities with at least one city ($city_{it}$) and the interaction between this dummy and the variable measuring the power being installed. Although the interaction variable is not statistically significant, it is positive, suggesting the effect of wind power investment could be higher in rural areas.

Finally, we analyse if the requirement, introduced in the 2005 tender, of working with local manufacturing conditions (please recall Section 2) influenced local unemployment effects of wind

[24]The two cannot be included at the same time since they are very highly correlated (-0.85).

energy investments. This tender was distributed in three phases (1200MW in 2006, 400MW in 2007 and 200MW in 2008) and due to delays over the financial crisis (Bento and Fontes, 2014) the capacity contracted in the earliest phase only began deployment in 2008. We thus created a dummy variable for the years after 2007 ($after07_{it}$) and interacted it with the power variables. As can be seen from column (7), none of the new variables turned out to be statistically significant, which suggests that the effect (reduction) in the unemployment rate associated with the installation of new wind power plants was not influenced by the change in the requirements for being granted tendering after 2005.

4.2 Distribution of Impacts by Type of Labor

We next focus on the distribution of the impacts on employment over gender and workers estimated skill levels. As described in Subsection 3.2, we use the weight of unemployed male and female workers on total working age population. We also measure the weight of unemployed workers with the first, second, and third level of basic education (from first to ninth grade), workers that have graduated from high school, and workers with a university degree.

Table 4 presents these results. The results in columns (1) show significant impacts for male workers in both the two years before the wind plant starts producing, consistent with the impact being felt during the construction phase. For female workers, the effect is only visible in the year immediately before the deployment of the park. Although women tend to work less on construction, it is likely that wind energy investments streamline the local economy and create indirect jobs, other than construction, namely on local shops and restaurants.

There is a significant reduction of unemployment during the construction phase for workers with all three levels of basic education (columns (3)-(5)). The third level of basic education was the mandatory level of education in Portugal, during which all the population receives the same type of education, until 2012 when secondary education became the mandatory level (Law 85/2009). These are therefore likely to be employees performing unskilled labor. There is also an impact for workers with secondary education and no impact at the level of workers with a university degree, during the construction phase. Possibly, the high skill, white collar jobs are concentrated in big cities and not where the wind energy is actually being developed.

There are no effects during the maintenance phase for any of the education levels, except for a small effect for workers with the second level of basic education and workers with university degrees. The latter is consistent with the operation and maintenance phase requiring more skilled labor. This impact is however very small – it amounts to around 0.056 jobs per MW

Table 4: Effects on different unemployment rates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dep. Variable	Men	Women	Basic 1	Basic 2	Basic 3	Sec	Uni
$power_{it+2}$	-0.0309**	-0.0198	-0.0246**	-0.0197***	-0.0107	-0.0089**	-0.0012
	(0.0120)	(0.0163)	(0.0123)	(0.0066)	(0.0065)	(0.0035)	(0.0026)
$power_{it+1}$	-0.0354***	-0.0455**	-0.0279**	-0.0285***	-0.0177***	-0.0121***	-0.0038
	(0.0122)	(0.0191)	(0.0110)	(0.0066)	(0.0054)	(0.0045)	(0.0034)
$Apower_{it}$	0.0019	-0.0221	0.0065	-0.0156**	0.0060	-0.0069	-0.0085**
	(0.0140)	(0.0199)	(0.0149)	(0.0075)	(0.0057)	(0.0054)	(0.0034)
$\Delta GDPreg_{it-1}$	-0.0132*	-0.0008	-0.0175***	-0.0097***	0.0001	0.0010	0.0045***
	(0.0070)	(0.0083)	(0.0064)	(0.0032)	(0.0025)	(0.0026)	(0.0015)
$expend_{it-1}$	0.0810	-0.4088**	-0.1137	-0.1447**	0.0609	-0.0458	-0.0495
	(0.1261)	(0.1736)	(0.0930)	(0.0613)	(0.0571)	(0.0526)	(0.0411)
$denspop_{it}$	-0.0005***	-0.0005***	-0.0002**	-0.0002*	-0.0002	-0.0001	-0.0003***
	(0.0002)	(0.0002)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
$young_{it}$	-0.0832***	-0.1979***	-0.1265***	-0.0533***	-0.0684***	-0.0117	-0.0216*
	(0.0305)	(0.0409)	(0.0332)	(0.0155)	(0.0156)	(0.0150)	(0.0130)
Constant	4.4110***	7.6040***	4.4501***	2.4415***	2.1247***	1.2105***	1.0271***
	(0.6543)	(0.7907)	(0.5651)	(0.3405)	(0.3100)	(0.2680)	(0.2741)
Observations	4,998	4,998	4,998	4,998	4,998	4,998	4,992
R-squared	0.8026	0.5615	0.2225	0.4440	0.8097	0.8732	0.8583

Notes: Estimated coefficients indicate the effects of a one unit change in the explanatory variables on the unemployment rate, in percentage points. All estimations include year and municipal fixed effects. Robust SE clustered by municipality. SE in parentheses. Significance level for which the null hypothesis is rejected: ***1%, **5% and *10%. The number of units in FE is 278.

installed – which could indicate a lack of locally available skilled labor. If the operations and maintenance phase requires more skilled labor, this could help explain the reduced significant impact outside of workers with a university degree locally at this stage. An ILO report (ILO, 2011) predicts increased demand of labor stemming from wind development for all skill levels, so these results might indicate a skill gap in the Portuguese labor market. It is possible that if workers with the necessary technical skills are not available locally, developers import this work from other countries.[25]

4.3 Spatial Impacts

We also study the existence of spatial impacts in wind investment. When power is installed in a given municipality, neighboring municipalities might benefit if they can commute for work or migrate, or because additional demand for their goods and services boosts local economy. If mobility is low, however, a displacement of benefits and activities might take away from neighboring municipalities' economic development. We study which effect prevails.

[25] Alternatively, they could import it from neighboring municipalities. A spatial analysis for the maintenance phase, available from the author, shows that this is not the case.

Table 5: Neighboring effects

	(1)	(2)	(3)
Matrices	30km	50km	100km
$power_{it+2}$	-0.0520	-0.0538	-0.0643
	(0.0361)	(0.0357)	(0.0401)
$power_{it+1}$	-0.0741**	-0.0746***	-0.0893**
	(0.0280)	(0.0259)	(0.0345)
$Apower_{it}$	-0.0115	-0.0113	-0.0117
	(0.0365)	(0.0364)	(0.0362)
$power_{jt+1}$	-0.1694*	-0.2166	0.4374
	(0.0954)	(0.2388)	(0.5087)
$\Delta GDPreg_{it-1}$	-0.0275	-0.0277	-0.0300
	(0.0242)	(0.0242)	(0.0247)
$expend_{it-1}$	-0.3031	-0.3027	-0.3167
	(0.5772)	(0.5748)	(0.5704)
$denspop_{it}$	-0.0011***	-0.0011***	-0.0011***
	(0.0002)	(0.0002)	(0.0002)
$young_{it}$	-0.2674***	-0.2676***	-0.2629***
	(0.0756)	(0.0759)	(0.0761)
Constant	11.8040***	11.8067***	11.7573***
	(1.4359)	(1.4393)	(1.4388)
Observations	4,998	4,998	4,998
R-squared	0.7225	0.7225	0.7226

Notes: Estimated coefficients indicate effects of a unit change in the explanatory variables on unemployment rate, in percentage points. All regressions include time dummies. Robust SE clustered by NUTS3 region. SE in parentheses. Sig. level for which null hypothesis is rejected: ***1%, **5% and *10%. The number of units in FE is 278.

Table 5 presents the results for spatial analysis, using the three distance decay matrices. We focus on the construction and manufacturing phase, as it is the only one where significant results were found.[26] The main variable of interest is $power_{jt+1}$, measuring installed power in neighboring municipalities that starts producing in the following year. In Columns (1)-(3) the variable $power_{jt+1}$ considers as neighbors only municipalities that are, respectively, 30, 50, and $100km$ apart, with weights in inverse proportion to their distance.

The results show that there is only a significant impact in terms of a reduction in unemployment in a given municipality when investment is made on municipalities less than $30km$ away (10%

[26] We started by including all the spatial variables, both for the the short and long-term impacts, together in the same estimation but none of variables turned out as statistically significant. We then proceeded by including just one variable at a time. Results are available from the authors.

significance level). The effect is large: an increase in installed power in neighboring municipalities of 1MW *per capita* decreases unemployment in municipality i by 0.17 percentage points. The fact that effects are only significant at $30km$ or less seems to indicate an impact through commuting to work, but not effects through migration for work purposes.

4.4 Local public finance

During the first year of production, and in subsequent years, no significant impacts in total municipality employment were found. It is possible that this is the result solely of the fact that the maintenance and operations phase is less labor demanding (ILO, 2011), or due to the fact that this phase requires specific skilled labor (for example electrical and computer engineers) that is not available at the local-level. However, it is also possible that the short lived effects on employment are due to investments in wind energy that are too small to have a lasting impact for the local economy. In order to understand whether this is the case, and in the absence of a municipality-level GDP measure, we focus on local governments' revenues. We expect the development of a wind plant in Portugal to lead to an increase in local governments revenues because developers will often pay to use land that belongs to the municipality, they can be subject to municipal taxes, and, additionally, they are required to pay the municipality 2.5% of their revenue. We thus expect wind energy investment to have a positive impact over municipalities' finances.

We estimate the impact of wind energy investment in total revenues and some of its components as well as total expenditures. Descriptive statistics of all these variables and a graph depicting the annual sum of real revenues *per capita* across municipalities, as well as the annual sum of installed power, are presented in Appendix C (Table C.1 and Figure C). Own revenues are all municipality revenues with the exception of transfers from the central government, which are not expected to be impacted by wind energy investment. Sales of goods and services, property revenues and direct and indirect taxes are current revenues and capital sales are capital revenues. All dependent variables are logged.

The estimation includes dummies for the year before the wind park starts producing $power_{it+1}$, to account for the construction period, and the year before that $power_{it+2}$, to account for activities taking place before that, such as land sales. Finally, $Apower_{it}$ measures lasting impacts of wind power investment once the park starts producing. We control for economic variables, namely unemployment levels and the lagged growth of regional GDP, as well as demographic variables, specifically population density and the percentage of young population.

Table 6: Impact of wind investment over public finances

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep. Var.	Total Rev	Own Rev	Sales R	Property R	Direct T	Indirect T	Cap sale R	Total Exp
$power_{it+2}$	0.0104***	0.0163***	0.0009	0.0929***	0.0098	0.0302	0.0578*	0.0086***
	(0.0035)	(0.0053)	(0.0073)	(0.0198)	(0.0061)	(0.0303)	(0.0338)	(0.0033)
$power_{it+1}$	0.0086**	0.0196***	-0.0006	0.0940***	0.0114**	-0.0033	-0.0272	0.0075*
	(0.0039)	(0.0044)	(0.0086)	(0.0232)	(0.0047)	(0.0197)	(0.0388)	(0.0039)
$Apower_{it}$	0.0182***	0.0374***	0.0191**	0.0298	0.0408***	0.0515**	0.0834**	0.0190***
	(0.0045)	(0.0083)	(0.0076)	(0.0228)	(0.0091)	(0.0238)	(0.0322)	(0.0048)
$unemp_{it}$	-0.0053	-0.0120**	-0.0194	0.0713*	-0.0131*	-0.0245	-0.0868**	-0.0055
	(0.0069)	(0.0060)	(0.0192)	(0.0389)	(0.0066)	(0.0261)	(0.0438)	(0.0064)
$\Delta GDPr_{it-1}$	0.0031*	-0.0004	-0.0013	0.0127	0.0028	-0.0316***	0.0041	0.0022
	(0.0019)	(0.0023)	(0.0060)	(0.0147)	(0.0018)	(0.0112)	(0.0206)	(0.0016)
$denspop_{it}$	-0.0001	-0.0002**	-0.0001	-0.0005	-0.0002**	0.0015	-0.0010***	-0.0001
	(0.0001)	(0.0001)	(0.0002)	(0.0004)	(0.0001)	(0.0012)	(0.0004)	(0.0001)
$young_{it}$	-0.0391***	-0.0460***	-0.0460**	-0.1222*	-0.0468***	-0.1456***	-0.1592**	-0.0405***
	(0.0066)	(0.0081)	(0.0215)	(0.0647)	(0.0065)	(0.0502)	(0.0703)	(0.0058)
Constant	7.1821***	6.5981***	4.4278***	3.4521**	5.9708***	3.4683***	5.9182***	0.2810*
	(0.1898)	(0.2123)	(0.5267)	(1.5300)	(0.1726)	(1.0275)	(1.6330)	(0.1674)
Observations	4,998	4,998	4,998	4,989	4,998	4,916	4,376	4,998
R-squared	0.2199	0.3290	0.1762	0.2210	0.3852	0.2013	0.1368	0.2459

Notes: Estimated coefficients indicate the effects of a one unit change in the explanatory variables on the real per capita fiscal variables, in percentage changes. Robust standard errors clustered by municipality. SE in parentheses. All regressions include time dummies. The number of units in FE is 278. Sig. level for which null hypothesis is rejected: ***1%, **5% and *10%.

Table 6 presents the results of this analysis. In columns (1)-(7) we investigate impacts in total revenue and its components and in column (8) resulting impacts in total spending. We find that there are small but sustained positive impacts on total revenues. The coefficient measuring increases in installed and operating wind energy ($Apower_{it}$) is positive and statistically significant at a 1% significance level. Specifically, we find that a 1KW *per capita* increase in operating capacity generates a 1.82% increase in *per capita* municipal revenues, or of around 19.5 euros.[27] Significant increases in total expenditures are also visible one and two years before the new power goes into functioning.

Unpacking this result, we find a strong and significant impact of wind energy investment at all stages on municipality generated revenues (own revenues). An increase of 1KW *per capita* in total power installed increases own revenues by 3.7%. Further unpacking these effects, we turn to current revenues. We find a positive effect of installed and operating wind energy on revenues from sales of goods and services. This is because wind energy developers pay 2.5% of their revenues to the municipality. Revenues from property, for example from renting municipality owned property, increase only in the period before wind energy goes into functioning. Revenues from direct taxes also increase with installed and operating capacity because wind energy developers pay the municipal tax on corporate income (*derrama*) and the municipal property tax (*Imposto Municipal sobre Imoveis*). We also find a positive impact on indirect tax revenues, which takes place for example if investment in wind generated increased demand for licenses and other fees by firms. Finally, turning to capital revenues, we find a positive impact on revenues from the sale of capital goods on the year before construction. This is likely to be due to wind energy developers buying municipality owned land in order to install wind power.

The last column shows that the impact in revenues translates into an increase in expenditures once the wind energy installed starts operating, and also in the years before. Results show that a 1KW *per capita* increase in installed and operating wind energy increases expenditures by 1.9%, or 20 euros *per capita*, similar to the effect on total revenues.

5 Conclusion

We find that investment in wind power reduces local unemployment during the construction phase. In particular, we estimate that a 1KW increase in installed power *per capita* leads to 0.6 and 0.8 percentage point decrease in unemployment rates in the first and second year of

[27] Taking into account the average municipal population, this means that the impact of an extra 1MW of energy operating in a given municipality increases municipal revenue by around 50 cents *per capita*.

construction. Based on the average population of municipalities and average unemployment rates, this translates into around 0.39 and 0.55 jobs per MW installed, respectively. Our results show no evidence of any effect during the operations and maintenance phases in aggregate unemployment. These results are broadly consistent with previous estimates in different settings.

We then focus on differentiated impacts by gender and on skilled and unskilled employment, by investigating impacts on workers with different education levels. We find the decrease in unemployment rates during the construction phase is only present for workers without a university degree, consistent with construction work. There are decreases in male unemployment in the two years before the park starts producing, and a decrease in female unemployment in the last year. The short-run increases in overall municipality employment during the construction phase of wind parks are thus likely caused not only by a direct increase in demand for labor due to the construction of the parks, but also by wind energy development spilling over to other sectors in a municipality. There seem to be only very small long-term impacts on unemployment of workers with college degrees, indicating that a small part of the demand for skilled labor necessary during the maintenance phase could be met locally.

We further investigate the possibility of local spillovers between municipalities. Development in one region may affect employment in another through migration, if job seekers find it optimal to move in search of employment, or indirect economic impacts, like the increase in demand for goods and services in neighboring municipalities. We find only an effect for municipalities that are $30km$ or less from each other during the construction phase. This indicates migration does not seem to play an important role, but rather commuting for work does.

Finally, we also found both short and long-term positive impacts of wind energy investment on total municipal revenues.These were driven specifically by short-term increases in property revenues and long-term increases in revenues with direct and indirect taxes and sale of goods and services.

Our findings offer an insight on local labor market effects of incentive policies for renewable investment. First, they present for the first time a clear evaluation of the overall net impact of wind power investment in local-level employment in Portugal, a country where extremely large investments were made. Despite the focus put on job creation, local employment impacts seem to be mostly short lived. Second, they provide information on the distributional impacts of such policies. The short-term unemployment local benefits are more visible for male and unskilled workers. Finally, they offer an insight into the mechanisms behind these impacts. The absence of aggregate long-term impacts, along with the low mobility of labor, could indicate that, if policy makers wish to increase benefits to local labor markets, there might be a case for targeting skill development towards the needs of this new market, in order to fully take advantage of possible local labor benefits. If effects are not visible – or are close to zero – during the operating life of wind parks, this might indicate that a mismatch of skills requires wind park developers to import labor. What is more, we find that sustained increases in local governments' revenues did not translate into gains in employment, for example through an increase in public spending. While further investigation is needed for a complete understanding of the lack of sustained impact on employment during this phase, our results present a first step into evaluating the impact of wind power investment at the local level.

The empirical strategy followed in the paper can be easily generalized to other countries, particularly those with centralized policy regarding wind energy investment. However, certain aspects are specific to the Portuguese setting. For example, we abstract from substitution effects between renewable energy and traditional energy sources. Despite accounting for a negligible share of employment in Portugal, coal and gas extraction industries have the capacity to generate large employment impacts in producing countries (e.g. Paredes et al., 2015 and Maniloff and Mastromonaco, 2017). But while our results are specific to the Portuguese setting, the insights generated are useful for parallel analyses. The impact of wind investment on employment on other settings will depend on factors such as the mobility of the workforce and the availability of specialized labor at the local level, and policies aiming at promoting local job markets need to help translate possible increased local revenues to employment gains.

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Declaration of interest

Declarations of interest: none.

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Appendix

A Data description

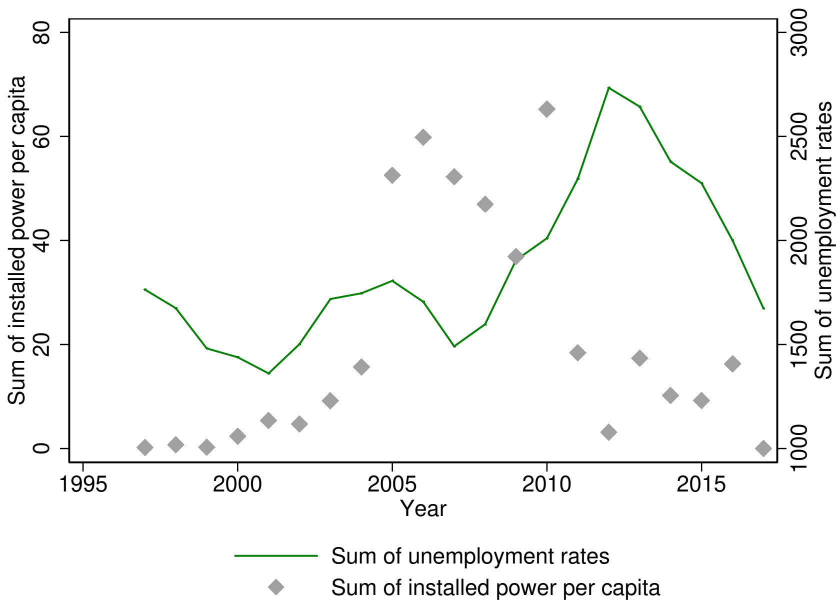

Figure A.1: Total new installed power and unemployment

Table A.1: Summary statistics

	Some power					No power				
Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**
Unemployment rate	6.272	2.609	1.484	18.295	2142	6.983	2.716	1.38	18.477	3690
Female unemp	7.733	3.196	1.723	25.718	2142	8.589	3.483	1.606	26.275	3690
Male unemp.	5	2.428	.853	17.459	2142	5.496	2.452	.589	15.054	3690
Unemployment (1st)	4.412	2.218	.629	17.306	2142	5.23	2.623	.498	18.637	3690
Unemployment (2nd)	10.397	4.829	1.386	37.444	2142	11.784	5.256	.975	38.214	3690
Unemployment (3rd)	10.544	4.354	1.935	33.304	2142	10.854	4.306	1.727	39.696	3690
Unemployment (Sec)	10.751	4.669	.417	37.405	2142	10.586	4.334	1.562	42.276	3690
Unemployment (Uni)	6.134	2.849	0	20.706	2139	6.082	2.901	0	20.86	3687
Power installed (KW)	2393.161	11344.74	0	222000	2142	0	0	0	0	3690
Power installed (KW pc)	0.199	1.253	0	32.123	2142	0	0	0	0	3690
Power accum. (KW pc)	2.119	4.592	0	43.114	2142	0	0	0	0	3690
NEPS	1516.127	354.264	896.581	2537.657	2142	1262.403	343.002	665.161	2420.788	3690
Population	28026.985	46798.876	2643	461981	2142	40164.519	62096.262	1634	606480	3690
Population density	109.345	176.818	4.939	1444.458	2142	420.438	1051.262	4.017	7670.162	3690
City	0.351	0.477	0	1	2142	0.466	0.499	0	1	3690
Weight of young (< 15)	13.217	2.655	4.841	22.457	2142	13.985	2.663	6.038	23.878	3690
Weight of elderly (> 65)	23.419	6.097	9.867	43.664	2142	21.718	6.423	8.116	45.568	3690
GDP growth NUTS3 pc	1.587	3.382	-15.645	25.94	2142	1.316	3.669	-15.645	25.94	3690
Total spending pc	1088.086	535.689	330.666	8606.569	2142	1050.191	540.153	177.106	5778.896	3690
Total revenue pc	1093.394	535.936	327.843	8601.380	2142	1055.878	541.788	270.275	5800.221	3690

B Further results

Table B.1: Further testes to baseline specification

	(1)	(2)	(3)	(4)	(5)
VARIABLES	FE	FE	FE	FE	FE
$power_{it+2}$	-0.0536**				
	(0.0256)				
$power_{it+1}$	-0.0777***	-0.0750***	-0.0749***	-0.0805***	-0.0747***
	(0.0232)	(0.0238)	(0.0236)	(0.0237)	(0.0239)
$Apower_{it}$		0.0108	0.0001		
		(0.0296)	(0.0325)		
$Apower_{it-1}$			0.0119		
			(0.0395)		
$power_{it}$	-0.0204			-0.0030	0.0027
	(0.0254)			(0.0319)	(0.0325)
$power_{it-1}$				-0.0140	-0.0112
				(0.0244)	(0.0242)
$power_{it-2}$					-0.0011
					(0.0354)
Constant	11.7923***	11.0727***	11.0733***	11.0799***	9.5523***
	(1.3702)	(1.4344)	(1.4349)	(1.4327)	(1.4597)
Observations	4,998	5,276	5,276	5,276	4,998
R-squared	0.7223	0.7035	0.7035	0.7035	0.7273
Number of municipalities	278	278	278	278	278

Robust standard errors clustered by municipality. SE in parentheses.

Null hypothesis is rejected: ***1%, **5% and *10%

All regressions include time dummies and all baseline control variables.

C Summary statistics: Revenues

Table C.1: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Total Revenues pc	1,069.657	539.903	270.275	8,601.380	5,832
Own Revenues pc	324.218	204.789	42.069	2,713.208	5,832
Revenue Sale Goods Services pc	86.996	66.53	0.004	691.193	5,832
Property Revenues pc	27.161	35.101	0	621.794	5,832
Direct Tax Revenues pc	152.168	130.791	6.225	1,470.485	5,832
Indirect Tax Revenues pc	11.43	21.635	-4.098	554.811	5,832
Revenue Capital Sale pc	13.162	36.925	-0.206	1,771.438	5,832
Total Expenditures pc	1,064.109	538.782	177.106	8,606.569	5,832

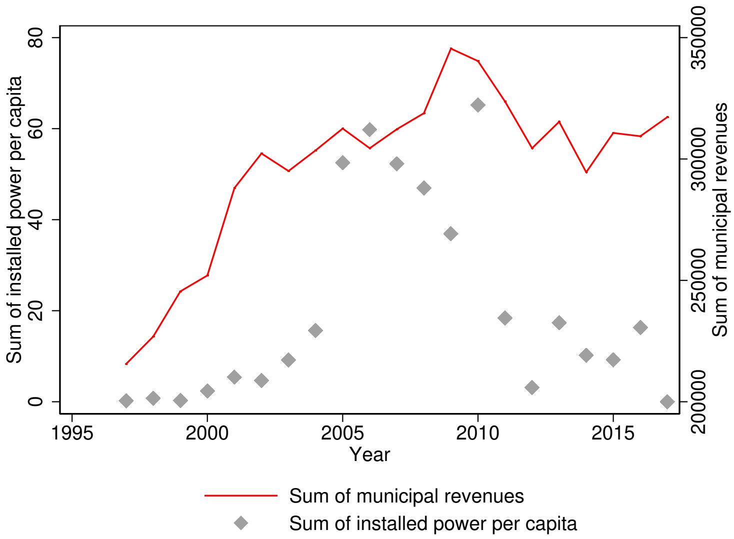

Figure C.1: Total new installed power and municipal revenues