Gone with the wind? Local employment impact of wind energy investment*

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Abstract

Investment in wind power has grown remarkably in the past decades in the European Union, and in particular in Portugal. Although support for incentive policies is based on economic development arguments, little evidence exists as to their impact on overall job creation and local level effects. We assess the existence, distribution and duration of local level labor impacts of wind power investment using a panel of all 278 Portuguese mainland municipalities for the years 2001-2014. Our results show there are short term effects, mainly for low skilled labor, during the construction phase. We estimate a decrease of 0.37 percentage points in total unemployment rate for each 100MW installed. We find positive spatial spillovers for municipalities that are 30km or less away. We find no evidence of sustained effects or impact during the operations and maintenance phase. These insights highlight the need to couple incentive policies with labor market and educational reforms that reduce the mismatch in necessary skills.

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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 to reduce CO_2 emissions, as well as to increase energy independence and security. The climate and energy package set out the objective of raising the share of European Union energy consumption produced from renewable resources to 20% by 2020. In addition to environmental objectives, the European Commission estimated that meeting this target could have a net effect of creating up to 417000 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 aggregate. We aim at assessing the existence, magnitude, duration, and distribution of effects of investment in renewables on total local employment, by performing a panel data analysis of the wind industry in Portuguese municipalities.

Portugal has made large investments in renewable energy, in particular wind power, in the past decades, despite the economic slowdown. In 2014 the wind share in total electricity demand in Portugal was of 24%(e2p Endogenous Energies of Portugal, 2014). Total installed generating capacity increased from $27.22MW$ in 1997 to $4726.19MW$ in 2014, making Portugal the country with the fourth highest KW installed per km^2 in the EU (e2p Endogenous Energies of Portugal, 2014). Understanding local economic consequences of these investments is therefore important.

The Portuguese economy is highly energy intensive and has traditionally been very 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) estimates that in 2008 the wind industry generated a total of 2 200 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 high skilled labor (ILO, 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 what local labor market characteristics impact them are important questions for incentive policies to wind investment.

We perform the analysis for a panel of all the 278 Portuguese mainland municipalities for the years between 2001 and 2014. 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 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.

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, 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.

It is however possible that the central government, when granting permission for the construction of wind parks, gives preference to municipalities with lower income levels, in order to boost development there. In such a case, our estimations would be biased. While the granting process was traditionally non-restrictive and so based mainly on technical factors, we include growth of regional GDP in order to control for this possibility.

To the best of our knowledge only one study has performed a similar analysis, focusing on United States counties. 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. They find that personal income and employment increase 11000$ and 0.5 jobs respectively per MW. Panel data allows to surpass endogeneity issues by exploring within-municipality variation.

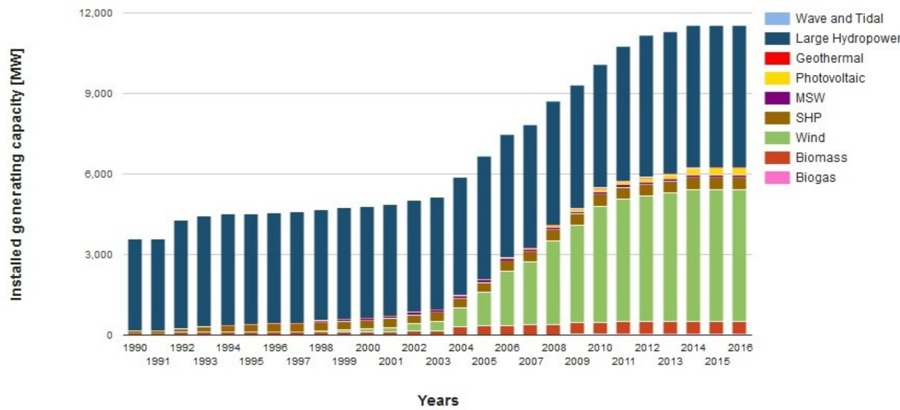
We find that wind power investment has a positive impact on employment levels during the construction and manufacturing phase. In particular, a 100MW increase in installed power leads to an average of 0.37 percentage point decrease in unemployment rates. This is a large effect that could result from incentive policies aiming at directing benefits to local communities. Our results show however that these impacts are felt mainly for unskilled labor (for workers not having reached secondary, or high school, education), which may indicate a dependence on international technology and skilled labor. Finally, we find evidence of spatial spillovers between close by municipalities. An increase in installed power in municipalities of less than $30km$ distance to a given municipality also decreases unemployment in the latter, during the construction phase. No effects were found for municipalities that are further away ($50km$ and $100km$), indicating possible commuting journeys for work, but not migration. Finally, we found no benefits for employment of wind power investment during the operations and maintenance phase.

Our findings have important implications for renewable investment incentive policies. First, they present for the first time a clear evaluation of the overall impact of wind power investment in local level employment in Portugal, a country where extremely large investment was made. Second, they offer an insight into the mechanisms behind this. If policy makers wish to increase benefits to local labor markets, there might be a case for targeting education and skill development towards the needs of this new market, in order to fully take advantage of possible local labor benefits.

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 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. It went from an installed capacity of 3 579.5MW in 1990, mostly from large hydropower, to 11 233.69MW in 2014, driven by large increases in wind power investment. 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. Figure 1 shows the evolution of installed RES capacity in Portugal.



Source: INEGI/APREN — January 2016

Figure 1: Evolution of installed RES capacity in Portugal

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 introduced a system of feed-in-tariffs. 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 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. The system of feed-in-tariffs was revised in 1999 (Decree-Law 168/99) and 2001 (Decree-Law 339-C/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.[1] The license-granting process for grid access was simplified and 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. With the same aim, in the 2005 process of releasing a tender for 1 800MW of wind power, in addition to technical requirements, a condition for being granted tendering conditions was working with local manufacturing companies. Additional conditions included limiting import of turbines, contributing to research and

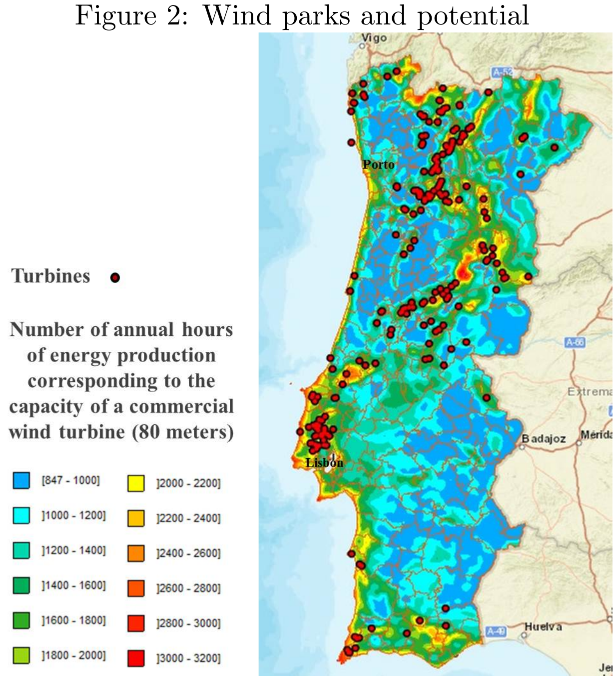
[1]This tariff is reduced by 200 hour blocks until a minimum of EUR 0.04/kWh after 2 600 hours).

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 current 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, reduced, or revoked, and wind power capacity started to grow slower. Installed wind power generating capacity increased from 27.22MW in 1997 to 4 726.19MW in 2014, with Portugal having the fourth highest KW installed per km^2 in the EU (e2p Endogenous Energies of Portugal, 2014). In 2014 the wind share in total electricity demand in Portugal was of 24%(e2p Endogenous Energies of Portugal, 2014).

Figure 2 overlays the wind park location on a map of the wind potential of continental Portugal. The red lines are municipality borders.

Figure 2: Wind parks and potential



Source: Data from LNEG and e2p/INEGI/APREN

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 3.3. We use as the main independent variable the amount of wind power installed in municipality i in a given year, in MW. This variable captures effects of installation of wind power in the year the turbines start producing energy, and therefore relates to the first year of the operations and maintenance phase of a wind park. In order to account for the effects of the construction and manufacturing phase, we use a variable measuring the amount of power installed in the following year. This is because it usually takes between 6 months and a year to build a wind park.[2] We also experiment with past lags, in order to investigate further effects of maintenance and operations.

The basic empirical specification is thus given by:

$$unemp_{it} = \alpha_1 + \gamma_1 power_{it+1} + \gamma_2 power_{it} + \alpha_2 X_{it} + \eta_i + \rho_t + \epsilon_{it} \tag{1}$$

where $unemp_{it}$ is the unemployment rate in municipality i year t, $power_{it+1}$ is the total power installed and starting operations in municipality i year $t+1$ (construction phase), $power_{it}$ the total installed power to enter into functioning in municipality i year t (maintenance phase), and X_{it} is a vector of economic and demographic variables in year t municipality i affecting employment. Finally, η_i is a municipality individual fixed effect, ρ_t a year fixed effect, and ϵ_{it} the error term. Because of the impact of the economic crisis, and in particular of the IMF intervention, assuming municipality fixed effects for the whole sample period is questionable. In addition to economic changes that might affect municipalities in a different way, wind development legislation suffered alterations and cuts, which again were likely to impact municipalities differently. We therefore include in all estimations a post 2009 municipality fixed effect.We also present results for the pre- and post-crisis periods separately.

The variables included in vector X_{it} are growth of GDP by NUTS3 region, in real *per capita* terms ($\Delta GDPregion_{it}$), that captures changes in

[2]In Portugal, depending on the size of the park and the economic conjuncture, it might take even longer. To account for this we also study effects more than one year before the wind park starts production.

regional economic conditions, transfers from the central government, in real *per capita* terms ($transf_{it}$), meant to capture a municipality's resources,[3] and three demographic variables (population density, $denspop_{it}$, share of population under 15 years old $young_{it}$, and number of cities in the municipality, $city_{it}$).
We additionally investigate the impact of wind investment in 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 respectively the estimated unemployment rate for workers without an education, with one, two, or three of the three levels of basic (pre-high school) education, with secondary (high school) education, and finally, with a university degree. We also investigate whether unemployment effects depend on gender, or if they are present for both men and women.

Finally, employment in municipality i may be affected by the power installed in neighboring 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 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 weighted. But Anselin (1988) argues this method may not account for the full degree of spatial interaction in the data. We thus follow Cliff and Ord (1981) and define neighbors according to the degree to which they affect municipality i based on 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 neighbors in the context of Portuguese municipalities can be found

[3]Transfers from the central government still make up the highest share of municipality revenue.

in Costa et al. (2013).
First we consider all municipalities neighbors, with a lower weight the further away they are. Second, we limit municipalities that are considered neighbors to those that distance x or less kilometers, 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.
Hence the weight of municipality j relative to municipality i, w_{ij}, is defined as:

$$w_{ij} = \frac{\frac{1}{dist_{ij}}}{\sum_j \frac{1}{dist_{ij}}} \tag{2}$$

in the case all municipalities are considered neighbors, or

$$w_{ij} = \begin{cases} \frac{\frac{1}{dist_{ij}}}{\sum_j \frac{1}{dist_{ij}}} & \text{if } 0 < d_{ij} \leq xkm \\ 0 & \text{otherwise} \end{cases} \tag{3}$$

in the case only municipalities that are less than a certain distance apart are considered neighbors. 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:

$$unemployment_{it} = \alpha_1 + \gamma_1 power_{it+1} + \delta W power_{jt+1} \alpha_2 X_{it} + \eta_i + \rho_t + \epsilon_{it} \tag{4}$$

where the other variables remain unchanged from Eq. (1) and we focus on the construction and manufacturing period.

In all estimations, because of various changes deriving from the economic crisis, and in particular the IMF intervention, assuming municipality fixed effects for the whole sample period is questionable. In addition to economic changes that might affect municipalities in a different way, wind development legislation suffered changes and cuts, which again were likely to impact municipalities differently. We thus define different fixed effects for the period before and after the crisis for each municipality, and use this throughout the estimations. This gives us a total number of 556 units with fixed effects, instead of 278. The results are very similar to those of estimating separately the pre and post crisis periods.[4]

[4]These estimations are available from the authors.

3.2 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 level and implemented equally across municipalities, and changes 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 restrictions. The former include the energy potential of the wind, or orography, the second set electric grid accessibility and general accessibility, and the latter include 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 and so, to avoid omitted variable bias, we include it in our analysis.

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 our measure of wind potential of each municipality is mostly time invariant, we cannot use it as an instrument and use fixed effects to control for all municipality-level unobservables. We thus include annual growth of regional GDP in order to account for this possibility.[5]

Figure 3 shows the location of all operational wind turbines in Portugal, as well as the energy potential of wind by municipality, measured by the number of annual hours equivalent to the nominal power of a commercial turbine.

[5] 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.

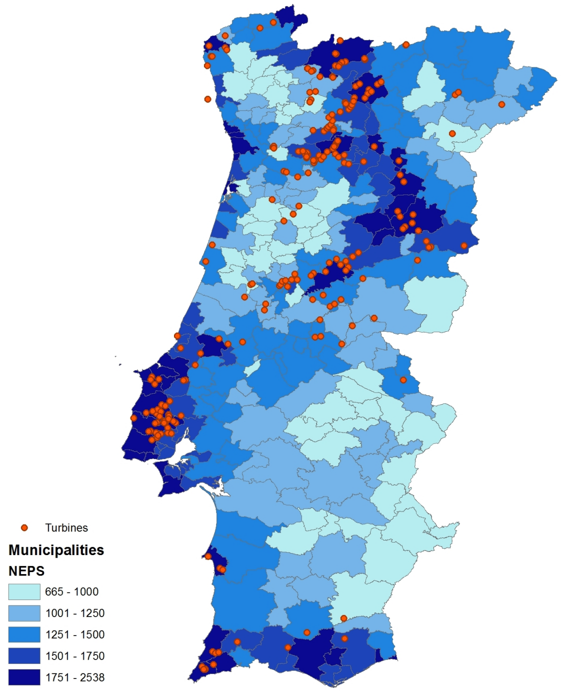


Figure 3: Turbine location and municipality wind capacity (NEPS)

3.3 Data and Sources

The dataset used covers all 287 Portuguese mainland municipalities for the period of 2001-2014 for a total of 3892 observations.

Table 1 summarizes the data. The first two variables correspond respectively to installed power (in MW) and to a dummy equal to one if there was at least one turbine installed in a given year and a given municipality. Data on the exact location of wind parks, time of production start, and capacity of turbines was retrieved from e2p Endogenous Energies of Portugal (2016), with permission from the institution. Installed power varies greatly, between a minimum of zero and a maximum of 222MW installed in a given year and a given municipality.

The unemployment rate is followed by six variables corresponding to the number of people unemployed by sex and level of education. The total unemployment rate varies between a minimum of 1.5 and a maximum of 18.3,

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.[6] A graph depicting the annual sum of unemployment rates across municipalities as well as the annual sum of installed power is presented in Annex 1. The number of people with different levels of education by municipality was used to estimate a measure of unemployment rate by level of education.
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, presented as an average by municipality. This information was ceded by the Portuguese National Laboratory of Energy and Geology (LNEG).
Total GDP *per capita* by NUTS3, used to calculate its growth rate, was retrieved from Instituto Nacional de Estatistica (1986-2006). Data on municipalities' local accounts was obtained from the DGAL's annual publication *Municipal Finances* (Direcçao Geral das Autarquias Locais, 1986-2000). That on population and consumer price indexes was collected from Marktest's Sales Index (Marktest, 2009) and the proportions of population under 15 and over 65 were collected from the Regional Statistical Yearbook of the Portuguese Institute of Statistics (Instituto Nacional de Estatistica, 1986-2006).

4 Results

Our empirical results are presented in Tables 2-4. Table 2 presents the results of the main empirical specification, and in Section 4.1 we justify our econometric estimation technique. In Table 3 we present the results for disaggregated unemployment rates, and finally, in Table 4 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.

4.1 Wind Investment and Unemployment Rate

The main results are presented in Table 2. Columns (1)-(3) present the estimation of Eq.(1) by ordinary least squares (OLS), random effects (RE)

[6]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.

Table 1: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Power installed (MW)	1.237	8.121	0	222	3892
New park	0.056	0.229	0	1	3892
Unemployment rate	7.002	2.665	1.517	18.295	3892
Unemployed (no educ)	97.327	171.481	0	2791	3892
Unemployed (1st)	486.246	869.659	8	8956	3892
Unemployed (2nd)	318.23	557.812	4	6095	3892
Unemployed (3rd)	326.535	608.377	3	6769	3892
Unemployed (Sec)	334.539	669.831	1	7513	3892
Unemployed (Uni)	177.49	418.299	0	7568	3886
Persons no education	5915.777	8038.753	416	82038	556
Persons secondary	2985.698	5826.967	92	52770	556
Persons university	2909.793	8375.449	43	125573	556
NEPS	1355.458	368.06	665.161	2537.657	3892
Population	35938.383	57600.114	1754	564657	3892
Area	32019.773	28355.97	826	172067	3892
Population density	3.101	8.68	0.045	75.296	3892
Weight of elderly (> 65)	22.788	6.677	8.642	44.608	3892
Weight of young (< 15)	13.953	2.575	4.979	22.5	3892
Revenues from transfers pc	690.01	456.029	78.288	3255.156	3892
GDP growth by NUTS3 pc	0.048	3.445	-15.882	14.133	3892

and finally fixed effects (FE). A Breush-Pagan test indicates the presence of heteroskedasticity so we use robust standard errors, clustered by municipality in all equations.

The OLS results are expected to be biased, as they fail to account for individual effects, but they are presented for the sake of comparison. A Breusch and Pagan Lagrange-multiplier test for random effects gives preference to RE over OLS and finally, a Hausman specification test gives preference to FE over RE, so we use FE throughout our estimations. All equations include time fixed effects to capture all variables affecting all municipalities at the same time. P-values are presented in parenthesis.

Column (3) presents the results for the basic specification, testing effects during the construction phase. The variable measuring the effect of wind power installation during the construction phase is negative and significant at a 1% level. In particular, it means that for a 1MW installation, unemployment in a given municipality falls by 0.0037 percentage points during the construction phase. Taking into account average number of unemployed people and average unemployment rates by municipality, this translates in an average effect of around 0.8 jobs per MW installed.

As expected, the richer the region where the municipality is becomes (ie, the higher the regional GDP growth, $\Delta GDPregion_{it}$), and the higher the government transfers are ($transf_{it}$), the lower the unemployment rate is. On average, municipalities with more cities have larger unemployment, and controlling for the number of cities, municipalities with higher population density have lower unemployment. Finally, the larger the share of young population below working age the lower unemployment.

Columns (4) and (5) present the results respectively excluding regional GDP growth and using the weight of population over 65 years of age (old_{it}) instead of the weight of young population,[7] without changes in the results. Column (6) presents an estimation including the interaction between the number of cities and the variable measuring the power being installed. Although the variable is not statistically significant, it is positive, indicating the effect of wind power investment could be higher in rural areas.

Finally, columns (7) and (8) present the estimations for, respectively, the sample period 2001-2008 and 2009-2014. The results do not change qualitatively, but the negative effect of investment on unemployment during the construction phase is higher in the post crisis period.

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

Table 2: Effects on total unemployment rate

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Estimation	OLS	RE	FE	FE	FE	FE	Pre	Post
$power_{it+1}$	-0.0101***	-0.0101***	-0.00365*	-0.00373*	-0.00852**	-0.00548**	-0.00398*	-0.00593**
	(0.00344)	(0.00344)	(0.00197)	(0.00198)	(0.00343)	(0.00211)	(0.00230)	(0.00299)
$power_{it}$	-0.00264	-0.00264	0.00239	0.00253	-0.00121	0.00237	0.00170	0.00168
	(0.00394)	(0.00394)	(0.00242)	(0.00243)	(0.00396)	(0.00245)	(0.00380)	(0.00306)
$\Delta GDPregion_{it}$	-0.00374	-0.00374	-0.0199***		-0.00495	-0.0198***	-0.0597***	-0.0219**
	(0.0158)	(0.0158)	(0.00579)		(0.0152)	(0.00579)	(0.0114)	(0.00981)
$transf_{it}$	0.00118***	0.00118***	-0.000432	-0.000440*	0.00184***	-0.000430	-0.000522*	-0.000532
	(0.000396)	(0.000396)	(0.000265)	(0.000266)	(0.000414)	(0.000265)	(0.000314)	(0.000336)
$city_{it}$	0.0636	0.0636	0.359*	0.348*	-0.0541	0.355*	0.405**	-0.228
	(0.179)	(0.179)	(0.200)	(0.207)	(0.180)	(0.200)	(0.167)	(0.471)
$denspop_{it}$	0.0234**	0.0234**	-0.212**	-0.211**	0.0165	-0.213**	0.291	-0.468**
	(0.0109)	(0.0109)	(0.106)	(0.103)	(0.0114)	(0.105)	(0.189)	(0.181)
$young_{it}$	0.223***	0.223***	-0.321***	-0.318***		-0.321***	-0.559***	0.124
	(0.0604)	(0.0604)	(0.0602)	(0.0604)		(0.0603)	(0.0829)	(0.0942)
old_{it}					-0.137***			
					(0.0276)			
$city_{it} * power_{it+1}$						0.00545		
						(0.00332)		
Constant	0.733	0.733	10.46***	10.39***	6.571***	10.46***	12.53***	7.330***
	(1.059)	(1.059)	(0.921)	(0.922)	(0.522)	(0.921)	(1.236)	(1.507)
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,614	3,614	3,614	3,614	3,614	3,614	1,946	1,390
R-squared	0.589		0.794	0.794		0.794	0.390	0.684
No of units		278	278	278	278	278	278	278
Post dummies	Yes	Yes	Yes	Yes	Yes	Yes		

Robust standard errors clustered by municipality. Standard errors in parentheses.
Significance level for which the null hypothesis is rejected: ***1%, **5% and *10%.

4.2 Distribution of Impacts by Type of Labor

We next focus on the distribution of the impacts on employment over skill levels. We distinguish unemployment for workers with no education, with first, second, and third level of basic education (from 1st to 9th grade), workers that have graduated from high school, and workers with university degrees. In order to have a proxy for unemployment rates, instead of the number of unemployed people of working age, we use the total number of inhabitants with no education, secondary, and university education to weight the number of unemployed people by education level.[8] These values are therefore not directly comparable to those of Table 2.

Table 3 presents the results regarding impacts by education levels. The results show no significant impact for workers with secondary and university degrees (Columns (5)-(6)), or workers with no education (Column (1)). There is a significant reduction of unemployment during the construction phase for workers with all three levels of basic education. The third level of basic education is the mandatory level of education in Portugal, and during which all the population receives the same type of education. These are therefore likely to be employees performing unskilled labor. 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 skilled labor is not available locally, developers import it from other countries. If the operations and maintenance phase requires more skilled labor, this could help explain the lack of a significant impact at this stage.

There are no effects during the maintenance phase for any of the education levels.

[8] Since there was no information on number of inhabitants with first, second, and third levels of basic education, we also used the number with secondary education.

Table 3: Effects on different unemployment rates

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.	None	1	2	3	Sec	Uni
$power_{it+1}$	0.163	-0.0256**	-0.0306***	-0.0191*	-0.00817	-0.00493
	(0.183)	(0.0119)	(0.00876)	(0.0114)	(0.00866)	(0.00735)
$power_{it}$	0.294	-0.0110	-0.00355	0.0101	-0.000396	-0.00503
	(0.230)	(0.0154)	(0.00978)	(0.00846)	(0.00890)	(0.00563)
$\Delta GDPregion_{it}$	-3.630***	-0.0539	-0.0509	-0.0881***	-0.139***	-0.0971***
	(1.298)	(0.0387)	(0.0322)	(0.0262)	(0.0210)	(0.0162)
$transf_{it}$	0.00259	-0.00220	-0.00200*	-0.000631	-0.00172**	-0.000722
	(0.0365)	(0.00164)	(0.00118)	(0.000870)	(0.000722)	(0.000618)
$city_{it}$	155.6**	2.052	1.786	0.0757	0.276	-0.127
	(78.41)	(1.731)	(1.183)	(0.573)	(0.449)	(0.333)
$denspop_{it}$	-478.5**	1.296	0.420	-0.00595	0.498	0.253
	(196.9)	(0.961)	(0.403)	(0.339)	(0.320)	(0.445)
$young_{it}$	42.04	-2.531***	-0.872***	-1.371***	-0.956***	-1.628***
	(27.99)	(0.555)	(0.279)	(0.236)	(0.218)	(0.206)
Constant	1,382***	61.03***	27.86***	29.60***	22.23***	28.22***
	(454.1)	(8.085)	(4.153)	(3.693)	(3.355)	(3.289)
Observations	3,614	3,614	3,614	3,614	3,614	3,608
R-squared	0.813	0.488	0.495	0.825	0.848	0.838
Number of units	278	278	278	278	278	278
Post dummies	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors clustered by municipality. Standard errors in parentheses.
Significance level for which the null hypothesis is rejected: ***1%, **5% and *10%.

4.3 Spatial Impacts

Finally, we 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.

Table 4: Neighboring effects

	(1)	(2)	(3)	(4)
Matrices	All	30km	50km	100km
$power_{it+1}$	-0.00418**	-0.00332*	-0.00383**	-0.00440**
	(0.00183)	(0.00194)	(0.00188)	(0.00180)
$power_{jt+1}$	0.0189	-0.0120***	-0.00439	0.0176
	(0.0350)	(0.00455)	(0.00774)	(0.0157)
$\Delta GDPregion_{it}$	-0.0200***	-0.0197***	-0.0200***	-0.0201***
	(0.00577)	(0.00579)	(0.00578)	(0.00576)
$transf_{it}$	-0.000429	-0.000435	-0.000431	-0.000426
	(0.000265)	(0.000265)	(0.000265)	(0.000264)
$city_{it}$	0.361*	0.357*	0.359*	0.362*
	(0.200)	(0.199)	(0.199)	(0.200)
$denspop_{it}$	-0.213**	-0.216**	-0.214**	-0.212**
	(0.106)	(0.104)	(0.105)	(0.106)
$young_{it}$	-0.322***	-0.320***	-0.321***	-0.322***
	(0.0603)	(0.0599)	(0.0601)	(0.0604)
Observations	3,614	3,614	3,614	3,614
R-squared	0.794	0.794	0.794	0.794
Number of units	278	278	278	278

Robust standard errors clustered by municipality. SE in parentheses.
Sig. level for which null hypothesis is rejected: ***1%, **5% and *10%.

Table 4 presents the results for spatial analysis, using the 4 distance decay matrices. We focus on the construction and manufacturing phase, as it is the only one where significant results were found. The main variable of interest is $power_{jt+1}$, measuring installed power in neighboring municipalities. In Column (1) the variable $power_{jt+1}$ includes as neighbors all other

municipalities, with their weight varying in inverse proportion to their distance, and columns (2)-(4) consider as neighbors only municipalities that are, respectively, 30, 50, and 100km apart, again 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 in municipalities less than 30km away. The effect is very large: an increase in installed power in neighboring municipalities of 1MW decreases unemployment in municipality i by 0.02 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.

5 Conclusion

The aim of this paper is to identify the existence, magnitude, duration, and distribution of local employment effects of wind power development. We perform an econometric analysis for a panel of all the 278 Portuguese mainland municipalities for the years between 2001 and 2014. 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 find investment in wind power has a significant and negative impact on local unemployment during the construction phase. In particular, we estimate that a 100KW increase in installed power leads to an average of over 0.37 percentage point decrease in unemployment rates. Based on average number of unemployed people and average unemployment rates, this translates into around 0.8 jobs per MW installed, a considerably large number. Our results show no evidence of any effect during the operations and maintenance phases.
We then focus on differentiated impacts on skilled and unskilled employment, by investigating impacts on workers with different education levels. We find the positive effect on employment rates is only present for workers with an education level below secondary education. 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 use a distance decay matrix to address possible local spillovers, such that geographically closer municipalities have a higher impact on each other. We find only an effect for municipalities that are 30km

or less from each other. This indicates migration does not seem to play an important role, but rather commuting for work does.
Our findings offer an insight on local labor market effects of incentive policies for renewable investment. If policy makers wish to increase benefits to local labor markets, there might be a case for targeting education and skill development towards the needs of this market, in order to fully take advantage of possible local labor benefits. If effects are not visible during the operating life of wind parks, this might indicate that a mismatch of skills requires wind park developers to import labor. While further investigation is needed for a complete understanding of the lack of sustained impact on employment during this phase, our results 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 large investment was made.

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Appendix

A Total yearly installed power and total unemployment

Figure A1 presents the total installed power by year in all municipalities, as well as the sum of municipality level unemployment rates.

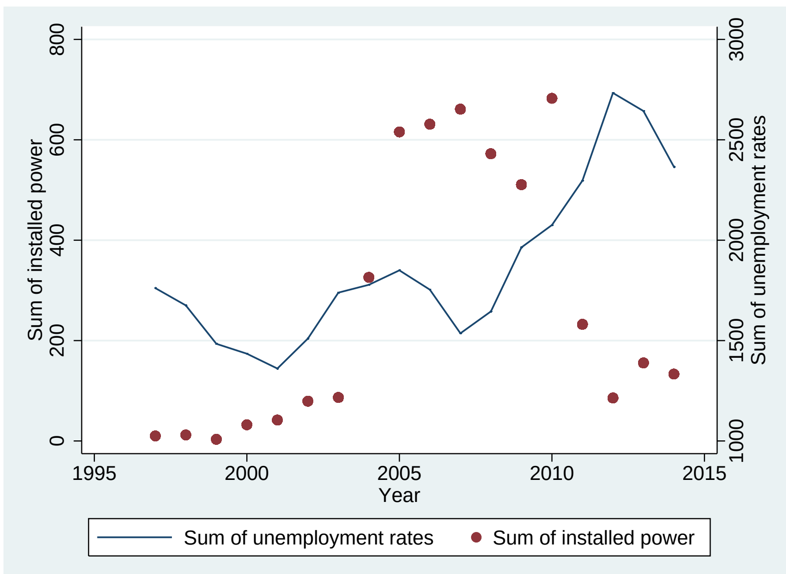

Figure A.1: Total new installed power and unemployment