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2023

BANCO DE ESPAÑA
Eurosistema

Documentos de Trabajo
N.º 2307

Natalia Fabra, Eduardo Gutiérrez,
Aitor Lacuesta and Roberto Ramos

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Natalia Fabra (**)

UNIVERSIDAD CARLOS III

Eduardo Gutiérrez (***)

BANCO DE ESPAÑA

Aitor Lacuesta (****)

BANCO DE ESPAÑA

Roberto Ramos (*****)

BANCO DE ESPAÑA

(*) We thank comments by Matteo Alpino, Óscar Jordà, Carlos Sanz, Jan Sthuler and Ulrich Wagner, and seminar participants at the Banco de España-CEMFI workshop, Universidad Carlos III, the UC3M-TSE-BSE Energy Workshop, the Coller School of Business (Tel Aviv), the OECD Expert Workshop on Environmental Policies, the EARIE conference (Vienna), the 1st Annual Workshop of the ESCB Research Cluster on Climate Change, Universitat de les Illes Balears, the FirmOrgDyn Conference at SciencesPo, the Simposio of the Spanish Economic Association, the Universidad of Navarra's workshop on "Current Issues in Energy Environmental Economics", and the State-of-the-Art Session at the EEA-ESEM Conference (Barcelona). This Project has received funding from Banco de España, the European Research Council (Grant Agreement No. 772331 ELECTRIC CHALLENGES), and the Spanish Research Agency (AEI, PID2019-107892GB-I00/ AEI/10.13039/501100011033).

(**) natalia.fabra@uc3m.es.
(***) eduardo.gutierrez@bde.es.
(****) aitor.lacuesta@bde.es.
(*****) roberto.ramos@bde.es.

https://doi.org/10.53479/29475

Documentos de Trabajo. N.º 2307

January 2023

ISSN: 1579-8666 (on line)

Abstract

Globally, renewable energy deployment often faces opposition from local communities. Why do residents oppose those investments, despite the expectation that the investments will create new jobs? Exploiting the monthly variation in the timing and size of the renewable investments across more than 3,900 Spanish municipalities over 13 years, we find that the new jobs do not always remain in the municipalities where the ventures are built. We find substantial heterogeneity in the magnitude and pattern of the impacts of solar and wind investments, reflecting differences in the tasks and skills involved. On average, solar investments increase employment by local firms and reduce unemployment of residents. Conversely, the impacts of wind investments on local employment and unemployment are weak and non-significant. These findings have important implications for public policy.

Keywords: renewable energy, employment, unemployment, NIMBY, spatial effects.

JEL classification: L94, C33, O25, R23.

Resumen

A escala mundial, el despliegue de energías renovables a menudo se enfrenta a la oposición de las comunidades locales. ¿Por qué los residentes se oponen a estas inversiones a pesar de la expectativa de que estas crearán nuevos empleos? Analizando la variación mensual y el tamaño de las inversiones en renovables de más de 3.900 municipios españoles a lo largo de 13 años, encontramos que los nuevos empleos creados no siempre permanecen en los municipios donde estas se realizan. Hallamos una sustancial heterogeneidad en la magnitud y el patrón de impactos entre la inversión solar y la eólica, lo que refleja diferencias en las tareas y habilidades involucradas. En promedio, las plantas solares incrementan el número de empleados de las empresas locales y reducen el desempleo de los residentes del municipio. Por el contrario, el impacto de las plantas eólicas en el empleo y el desempleo locales es débil y no significativo. Estos hallazgos tienen importantes implicaciones en términos de políticas públicas.

Palabras clave: energías renovables, empleo, desempleo, NIMBY, efectos espaciales.

Códigos JEL: L94, C33, O25, R23.

1 Introduction

A revolution is taking place in how we produce electricity as countries increasingly substitute fossil fuels for renewable energies. At a global level, installed renewable capacity tripled from 2006 to 2020, and it is expected to increase even faster during the next three decades (IRENA, 2022c). Investments in renewable energies seek a two-fold objective: to reduce carbon emissions but also to create socio-economic benefits. Indeed, the post-covid recovery plans have emphasized green investments under the expectation that they will fuel economic growth and create new employment opportunities (World Bank, 2021).[1]

Despite its environmental and economic benefits, deploying renewable energy faces a significant barrier: the opposition of local communities. Local residents oppose the construction of renewable plants because they fear negative impacts on land conservation, biodiversity, and the economy. More specifically, there are concerns that the visual impacts and the increasing costs of land and real estate might crowd-out other economic activities, including tourism. This movement, known as NIMBY (Not in My Backyard), is responsible for blocking global solar and wind developments.[2] While several papers have analyzed the costs imposed by renewable energy projects on local communities,[3] little attention has been devoted to understanding the other side of the equation: the local benefits. Do hosting communities oppose renewable investments because of the local costs or because they do not benefit enough to offset those costs?

In this paper, we estimate the effect of investments in renewable energy on local employment and unemployment, which can be understood as a proxy for local economic benefits. In particular, we ask: how many jobs associated with the deployment of renewable energy infrastructure stay within the municipality or county where they are located? To answer this question, we focus on one country which has already gone through a renewable energy revolution, Spain. From 2006 to 2020, the installed wind capacity in Spain increased by 250%, from 11,140MW to 27,485MW, while the installed solar photovoltaic capacity reached 11,714MW from being almost non-existent in 2006. These investment efforts implied that, by 2020, already 45% of

[1]For instance, the International Renewable Energy Agency estimates that investments in renewable energy and energy efficiency to meet the Paris Agreement would increase global GDP by 0.8% in 2050 and would allow the creation of 26 million jobs in the renewable energy sector by 2050 (IRENA, 2022a, 2017b). US President Biden's policies also emphasized the potential of clean energy and climate action to create millions of jobs (The White House, 2022). In this context, Batini et al. (2022) find that the economic multiplier of green activities is greater than 1.

[2]See Germeshausen et al. (2021), Jarvis (2021) and Rand and Hoen (2017) for analyses of the NYMBY effect in Germany, the UK, and the US, respectively. Several media articles have also covered this issue; for example, Noah Smith "The Left's NIMBY War Against Renewable Energy" Bloomberg Opinion, 12 September 2021, among many others.

[3]See Krekel et al. (2021), Dröes and Koster (2021), Gibbons (2015), Haan and Simmler (2018), Sunak and Madlener (2016), among others.

the country's total electricity demand was served by renewable energy (REE, 2021). Many other countries worldwide are expected to follow similar paths.

Approach. To identify the impacts of these investments, we exploit the variation in the timing and size of wind and solar investments across more than 3,900 Spanish municipalities over 13 years, providing a detailed characterization of the labor market dynamics around plant openings while controlling for potentially confounding effects. As our main outcome variables, we use figures on employment by local firms and unemployment by local residents, providing a rich understanding of the overall labour market effects of renewable investments.

From a methodological standpoint, we estimate the dynamic effects of renewable plant investments using local projections in a panel context (Jordà, 2005). This framework amounts to a difference-in-difference setting, where treatments are multiple, and there is variation in treatment timing. In this framework, the average treatment effect is uncovered under the assumptions of parallel trends and treatment effect homogeneity, both across groups and over time (de Chaisemartin and D'Haultfoeuille, 2022). By allowing for dynamic effects, our estimates explicitly account for overtime heterogeneity. Moreover, we apply a recently proposed new approach, LP-DiD, combining local projections with a 'clean control' condition that avoids the bias induced by variation in treatment adoption when treatment effects are heterogeneous (Dube et al., 2023).

Main Findings. The analysis reveals significant differences in the job multipliers across renewable technologies, with heterogeneous effects across the construction and maintenance phases. The mechanisms that explain these differences relate to the tasks and skills required for each technology and across time. On the one hand, for the baseline period 2006-2018, we find strong local employment multipliers during the construction of solar plants. In particular, local firms create 1.5 new jobs-year/MW within the municipality where the investment occurs or 4.5 within the county.[4] For instance, this implies that constructing a 10 MW solar farm creates 15 new jobs in the municipality. This effect is non-negligible, particularly for small towns in rural areas where most investments are located. The job multipliers get weaker once the construction of the plant ends (they fall to 0.7 jobs-year/MW at the municipality level and 3.5 jobs-year/MW at the county level). However, despite being smaller, the effects of the plant's maintenance seem to last

[4] In terms of the value of the investments, these multipliers imply that every million euros invested allowed creating 0.65 new local jobs during the first investment wave.

longer. In contrast, wind investments have very low and statistically non-significant effects on local employment during the construction and maintenance phases.[5]

The effects of solar investments are weaker on unemployment than on employment: during the construction phase, the unemployment multipliers are -0.19 jobs-year/MW and -1.4 jobs-year/MW at the municipality and county levels, respectively; during the maintenance phase, these multipliers are -0.58 and -0.135 although they remain non-significant. Comparison with the employment estimates suggests that local firms hire residents as well as workers in other municipalities or counties. As for wind, and consistently with the effects on employment, the results show small and almost non-significant effects on unemployment (multipliers are -0.08 and -0.09 jobs-year/MW during the construction and maintenance phases, respectively).[6]

We also measure the spatial effects to understand whether municipalities benefit from investments in neighboring areas, considering a radius of 60Km around the municipality.[7] These *spatial spillovers* do not impact employment but they strengthen the unemployment multipliers of solar investments, suggesting that solar investments in neighboring municipalities open job opportunities for local residents who commute to nearby plants. The local and spatial effects for wind investments remain broadly non-significant, as in our baseline results.

Mechanisms. Differences in the tasks and skills required to construct and maintain renewable plants underlay our empirical findings. In the case of wind power, investments are front-loaded and not necessarily local. Engineers, lawyers, and consultancy firms work on the project, but they do so from afar. The construction stage is relatively short, and it is carried out by contractors who often reside elsewhere and move on once the work is done. Only maintenance is carried out on site, but it usually involves workers who maintain remotely several sites at a time and do not permanently reside in the municipality where the investment is located. The multiplier effects in the municipality where the investment occurs tend to be small given that the profits and wages often go elsewhere (where the headquarters are located or where the workers reside). Matters

[5]As a benchmark, IRENA provides estimates for the human resources required to install and connect a 50MW plant: 39.38 persons/days in the case of solar (IRENA, 2017a), and 34.48 in the case of onshore wind (IRENA, 2017b). IRENA estimates that 35.5 persons/days are required for construction activities in the case of solar and 26.6 in the case of wind. The differences for operation and maintenance activities are more striking: 13.56 persons/days in the case of solar and 2.66 in the case of wind. Note however that these numbers refer to the overall effects, some of which are not necessarily local.

[6]These local multipliers are well below those found for other infrastructure projects in Spain. For instance, Alloza and Sanz (2021) analyze the impacts of the Spanish Plan for the Stimulus of the Economy and Employment (Plan E), by which public funds were transferred to municipalities to carry out small-scale construction projects. They find that 100,000 euros of stimulus reduced unemployment by 0.74 jobs-year. Our multipliers, expressed in euros, are -0.075 jobs/year in the pre-opening period for solar investments and -0.038 jobs-year in the post-opening period for wind investments, for each million euro invested (Table B.4).

[7]Results are robust to considering other distances from 30 Km to 60 Km.

are somewhat different in the case of solar investments. Since construction and maintenance requires less specialized skills, workers can often be hired locally (IRENA, 2022a).

Since solar projects are widespread nationwide, we can explore the underlying mechanisms in more detail. While skill data are not available at the municipality level, we conjecture that the skill mismatch is more likely in rural areas, where residents are less likely to possess the necessary skills for the new jobs being created (IRENA, 2022a). In line with this, we report larger effects on employment and unemployment in urban than rural municipalities. We also find higher multipliers for smaller than larger projects. This indicates that scale economies matter, an issue that could also be explained by the skill mismatch as it is more difficult to find enough skilled local workers the larger the project. We arrive at a similar conclusion when focusing on the most recent investments in solar plants (post-2019) when the average plant size reached 30MW (from an average of 0.5MW pre-2019), and the employment and unemployment multipliers per MW fell sharply. In turn, scale economies might contribute to explaining the stark difference between solar and wind multipliers, given that wind projects tend to be much larger than solar projects.

The fiscal multipliers provide another potential channel for local employment and unemployment effects. The new plants have to pay local property taxes and other permitting fees, which should allow for increases in public local spending. However, while the investments positively impact the public finances, this does not translate into statistically significant increases in fiscal spending.

The local effects provide a lower bound for the broader job creation potential of renewable investments. As argued above, some of the activities involved in deploying renewable energy (including R&D, design and planning of the projects, and equipment manufacturing, among others) take place in large cities, away from where the bulk of the investments occur.[8] Some of these effects might also exceed the national borders, as the necessary equipment is partly imported from abroad. In any event, our estimated multipliers for the second wave of solar investments show that this lower bound represents a small share of the total number of jobs that investments in renewable energies are expected to deliver (MITECO, 2020). It remains to be understood whether the national effect is overestimated, or whether the local job benefits are small relative to the overall job creation. In any event, these findings suggest that public policies should provide other means to ensure that the benefits from renewable investments are shared with the hosting communities (Gazmararian and Tingley, 2023).

[8] Consistent with this, our estimated employment and unemployment multipliers are much larger when we conduct the analysis at the county level compared to the municipality level. Estimates at the province level are even higher, although the results are increasingly noisy as we aggregate and reduce the number of observations.

The remainder of the paper is organized as follows. Section 2 summarizes related literature. Section 3 provides a background for renewable investments in Spain and the workloads involved in the construction of the plants. Section 4 provides an overview of the data used in the analysis. Section 5 describes the empirical strategy. Section 6 reports the impacts of investments in renewable energies on local employment and unemployment, including their spatial effects, and explores potential mechanisms explaining the results. Section 7 analyzes the labor market effects of the most recent investments in renewable energy. Section 8 concludes. The Appendix contains further results.

2 Literature Review

While there has been great policy interest in identifying the employment potential of renewable energy, there is little systematic evidence on this issue. As far as we know, only some have measured the impact of wind investments on local jobs, with mixed results. For Texas, Hartley et al. (2015) find no job impact of wind investments for 2001-2011, while Brown et al. (2012) find that 0.5 jobs were created per MW of wind power capacity installed over the period 2000-2008. For Portugal, over the period 1997-2017, Costa and Veiga (2021) find unemployment multipliers in the range -0.39 to -0.55 jobs/MW for wind capacity, which are slightly higher than our own estimates. Our paper is the first to analyze the local impacts of solar investments and to combine the effects on employment and unemployment to provide a richer picture of these investments' local job market impacts.

Despite their different focus and methodology, our paper is closely related to Feyrer et al. (2017), who analyze the job market impacts of the fracking revolution in the US using a differences-in-differences approach.[9] They show that every million dollars of additional oil or gas production generated an employment increase of 0.85 persons at the county level.[10] Methodologically, our analysis of the spatial effects differs from theirs in that we are interested in only measuring the inward spillovers (i.e., how a given municipality benefits from investments in surrounding municipalities). In contrast, they measure the inward spillovers together with the outward spillovers (i.e., whether the economic benefits of the investments accrue over a larger area).[11]

[9]See Bartik et al. (2019) for a related work.

[10]At the county level, for our baseline specification, we find employment multipliers for the solar investments of 0.86 and 0.51 jobs per million euros invested during the construction and maintenance phases, respectively. However, the multipliers in Feyrer et al. (2017) refer to the value of production, while ours refer to the costs of the investments. Hence, they are not directly comparable. In our context, the revenues generated by renewable production rarely remain within the local communities as firms' headquarters are located in the major cities.

[11]Other works on the employment effects of fossil fuel activities include Black et al. (2005), who find that each coal mining job added to a county during the coal boom created 0.17 additional jobs in other industries.

There are also several papers on the global employment effects of various environmental policies (including carbon pricing, emissions regulations, or increases in energy prices). For instance, in a recent paper Curtis and Marinescu (2022) provide estimates of new wind and solar jobs advertised in online postings in the US. They find that solar and wind job postings have tripled since 2010 and report strong growth of job postings before the increase in solar capacity. Unlike ours, their analysis does not focus on local jobs.[12]

Our interest in measuring the local economic impacts is also shared with a broader literature, which has paid special attention to the effects of major public spending programs (Kline and Moretti, 2014; Wilson, 2012; Feyrer and Sacerdote, 2011; Alloza and Sanz, 2021, among others). Inspired by Moretti (2010), some papers measure the local multipliers, i.e., the number of jobs created in the non-traded sector in response to an exogenous increase in the number of jobs in the trading sector. In the context of green investments, one example of this approach is provided by Vona et al. (2018), who measure the local impacts of green subsidies within the 2009 American Recovery and Reinvestment Act (ARRA). They find that one additional green job gave rise to 4.2 new local jobs in non-tradable non-green activities. Regarding the value of the investments, Popp et al. (2022) find that every million dollars of such green funds created approximately 10 long-run jobs. However, these numbers mask a significant heterogeneity depending on the types of investments involved and the skills required. As shown by Feyrer and Sacerdote (2011), different types of ARRA spending gave rise to considerable variation in the job multipliers.

Our empirical approach leverages variation in renewable investments across space in the same calendar period. In this regard, it also contributes to the literature that has estimated geographic cross-sectional spending multipliers (see Chodorow-Reich (2019) for a survey). While those works have mainly focused on assessing public expenditure programs' output and employment multipliers, we apply a similar approach to estimate the multipliers of green investments. Moreover, by exploiting the granularity of our dataset at both the spatial (municipality) and time (month) dimensions and by accounting for both employment and unemployment effects, we provide a rich characterization of the local labor market dynamics around those investments.

From a methodological standpoint, we rely on the local projections framework, developed by Jordà (2005), to construct the impulse response functions. This method imposes minimal structure (apart from linearity) by directly regressing the outcome of interest, e.g., future employment or unemployment, on the current value of the shock plus several controls. The impulse response function is then built from one separate regression for each time horizon, where

[12] For other references, see Morgenstern et al. 2002; Kahn and Mansur 2013; Marin and Vona 2021; Metcalf and Stock 2020.

the shock variable coefficient in each regression gives the estimated response at the specific horizon. In this regard, local projections are more robust to misspecification compared with other methods used to compute dynamic effects (e.g., vector autoregression models). Moreover, the local projection framework can easily accommodate non-linearities in the form of heterogeneous treatment effects.[13] For these reasons, local projections are becoming increasingly popular in estimating dynamic effects (for instance, see Alloza and Sanz (2021), Ramey and Zubairy (2018), Nakamura and Steinsson (2018), Ramey (2016), Leduc and Wilson (2013), and Auerbach and Gorodnichenko (2012)).

One related approach is to estimate the dynamic effects by designing an event study. In this framework, the impulse response function is estimated from a single regression of the current value of the outcome of interest on a set of leads and lags of the treatment variable (see Schmidheiny and Siegloch (2020)). The local projections framework bears a lot of resemblance with this model. In particular, in a panel data context, both models achieve identification using a difference-in-difference setting and are implemented via two-way fixed effect (TWFE) regressions. Schmidheiny and Siegloch (2020) show that, under a certain parametrization of the model, event study designs and distributed-lag models are numerically identical. In turn, Alloza et al. (2021) propose a method to establish an equivalence between distributed lag models and local projections. In Appendix A, we show that our baseline impulse response function estimated with local projections is similar to the one estimated from a generalized event study design.

It is worth noting that recent literature shows that TWFE estimates in generalized difference-in-difference settings with variation in treatment timing are only unbiased under certain assumptions, namely, constant treatment effects, both across cohorts and over time (see de Chaisemartin and D'Haultfoeuille (2022) for a survey).[14] In Section 5, we discuss how our context, characterized by multiple treatments of a continuous nature, fits into this literature. Our dynamic model accounts for heterogeneity in treatment effects over time. At the same time, we split the sample period to alleviate potential concerns of variation in treatment effects across cohorts. Moreover, we conduct an alternative estimation leveraging a new approach developed by Dube et al. (2023). This approach combines local projections with a sample restriction that prevents previously treated units from being used as controls, which is the source of the bias in the context of variation in treatment timing. This restriction drops all observations that might not be admissible controls, yielding TWFE estimates that are robust to heterogeneous treatment effects.

[13]We exploit this feature in Section 6.5, where we allow the treatment effect to vary along two dimensions (location and size of the plant).

[14]In this context, a cohort is a group of units that receive the treatment shock in the same time period.

3 Background: Investments in Renewable Energy

3.1 Renewable Investments in Spain

In this paper, we focus on the local impacts of renewable energy investments in one of the leading countries in this field, Spain. As shown in Figure 1, renewable investments in Spain have taken place in two main waves. A combination of significant cost reductions plus generous support schemes triggered the first wave. It started in 2008 and lasted until 2014, when the government implemented a moratorium on renewable investments. The second wave started in 2019, and it still lasts today. The economic recovery, the low interest rates, and the sharp reductions in the costs of renewable investments fostered the boom in investments.[15]

Interestingly, Figure 1 highlights important differences between these two investment waves and across technologies.[16] The first solar plants were small (their average size was 0.5MW), and two-thirds were located in rural areas widespread across the country.[17] In contrast, the more recent solar plants are much larger (their average size is 30MW) and are concentrated in fewer municipalities. Wind plants are much larger than solar plants, their size has not increased as much as those of solar plants (the average size of wind plants was 21MW in the first wave and 35MW in the second wave), and they are located in fewer municipalities in the northern and eastern parts of the country. For both technologies, one can see a spike in investments around September 2008 (most evident in Panels A and E for solar and B and F for wind) as the government announced a less generous support scheme for those plants that would start operating after that date.

The location of the investments is driven by the availability of natural resources (solar, wind) and spare transmission capacity. This explains why most wind plants are located in the northern and coastal regions of the country (Figure 2). Solar plants are more broadly spread but tend to be concentrated in the southern regions of Andalusia and Extremadura. Table 1 shows the characteristics of the investment locations. Solar plants are located in municipalities with higher temperatures, lower annual rainfall, less altitude, and less ruggedness than the average municipality. In contrast, relative to solar plants, wind farms tend to locate in more rural and less populated areas that have lost population over recent years. It is important to stress that labor market conditions are orthogonal to the choice of locations, as documented in Table 2. Also,

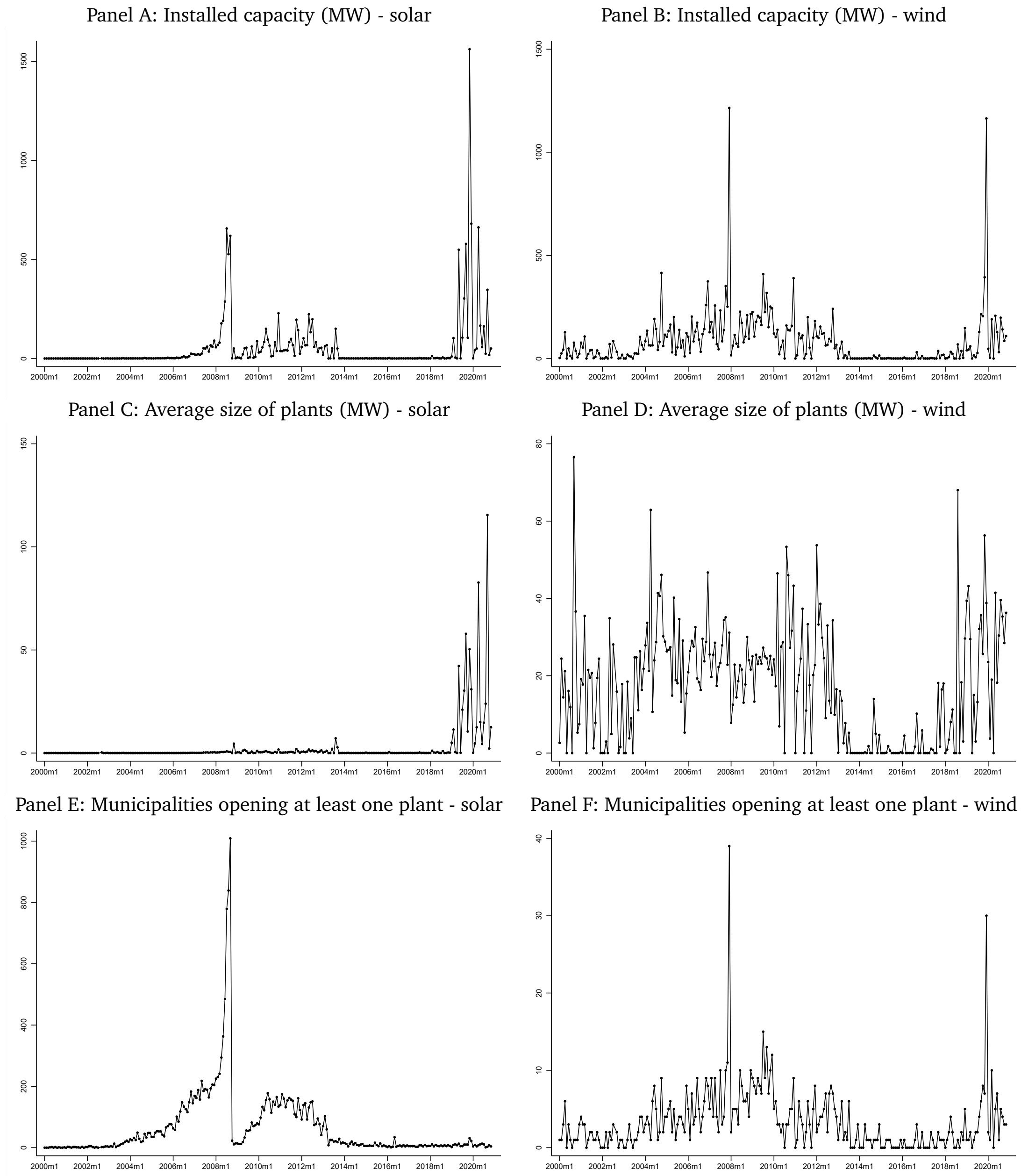
[15]As reported by IRENA (2022b), the costs of investing in wind and solar power plants in Spain fell by 50% and 84% respectively, from 2010 to 2020. Some new investments have been channeled through procurement auctions organized by the government (Fabra and Montero, 2023).

[16]Table B.2 in the Appendix provides information on the average size and location of the renewable investments during these two waves.

[17]Figure 1E shows that many municipalities opened solar plants during the first wave. Figure 2A also shows their spatial dispersion.

FIGURE 1

EVOLUTION OF RENEWABLE INVESTMENTS OVER TIME

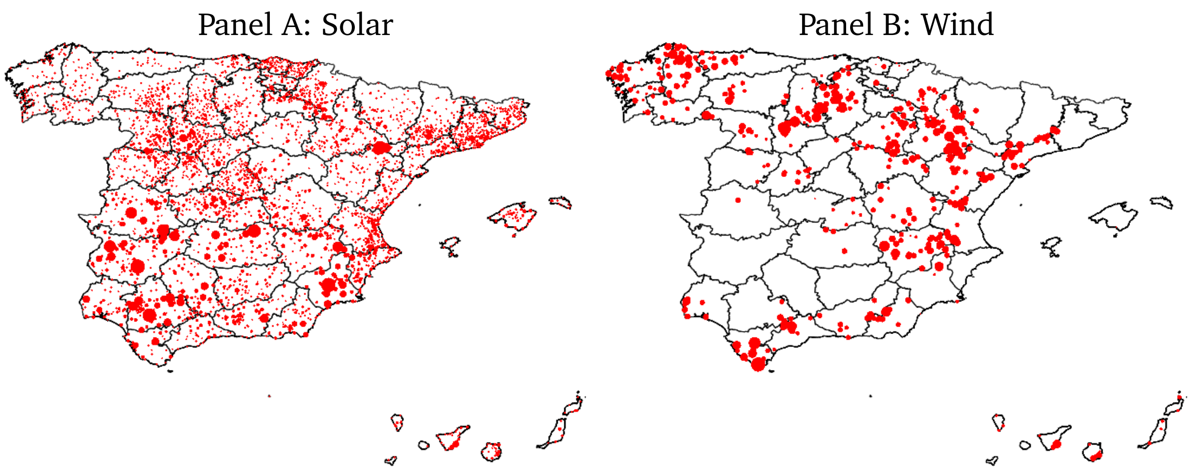


Notes: These figures show the evolution of renewable investments in Spain (MW), the average size of the plants (MW), and the number of municipalities opening at least one plant on a monthly basis. The data span from 2000 until 2020. Panels on the first column refer to solar, and those on the second column to wind. Table B.2 in the Appendix reports the average values.

the plants' regulatory regime is set at the national level. Hence, the regulated payments that investors receive are equal across all locations, conditional on vintage and technology. Similarly, the electricity price paid by consumers is set nationally. This implies that the labour market effects of the investments in renewable energy cannot be explained by changes in electricity prices at the hosting municipalities, as these are the same as in the non-hosting municipalities.

FIGURE 2

SPATIAL DISTRIBUTION OF INVESTMENTS IN WIND AND SOLAR ENERGY



Notes: These maps represent the location and size of the solar and wind projects in Spain between 2000 and 2020.

3.2 Employment Potential of Renewable Investments

The employment potential of renewable investments varies across the main phases of the investment process: project planning, manufacturing, transportation, installation, and operation and maintenance.[18] In turn, the amount and type of employment involved in each phase depend on the plant's size and technology. Employment in project planning is a small fraction of the total budget for large plants. It mainly involves legal, regulatory, real estate, taxation, or financial experts, often employed at the headquarters of the project developer. Industrial firms manufacture the equipment, which typically takes place far from the plants' sites.[19] Hence, even if manufacturing can be labor-intensive, the benefits are not necessarily felt locally. Transporting solar equipment is not very cumbersome and might be done by local truck drivers and loading staff. Transporting wind energy equipment requires special means (the most representative case is the need to use high-capacity trucks and trailers specifically designed for transporting blades). Consequently, finding local drivers and loading staff for this more specialized task might be difficult.

The installation phase can last between 12 and 18 months for solar plants and between 18 and 24 months for wind farms.[20] According to IRENA, this is the most labor-intensive phase, and it might require around 2-4 workers/year per MW, depending on the technology and size of the project. About 90 percent of the person-days involved in installing a solar plant require

[18] In order to understand better the employment creation of different technologies, we have benefited from several reports of the International Renewal Energy Agency. See IRENA (2017a) and IRENA (2017b).

[19] Spain manufactures 60% of the solar components and 90% of wind components. See https://www.energias-renovables.com/panorama/espana-fabrica-el-60-de-los-componentes-20201008.

[20] See, for instance, Baringa (2022), p.17.

TABLE 1
DESCRIPTIVE STATISTICS

	(1) No solar or wind	(2) Solar	(3) Wind
	(1)	(2)	(3)
# Municipalities	4,041	3,862	443
Geo-climatic characteristics			
Temperature (ºC)	12.21	13.77	12.66
	(0.0365)	(0.0374)	(0.110)
Rainfall (hundreds of ml)	6.030	5.838	6.459
	(0.0331)	(0.0371)	(0.132)
Height above sea level (m)	785.9	557.2	692.8
	(5.734)	(5.417)	(16.89)
Ruggedness (height std)	91.16	79.25	101.7
	(1.460)	(1.355)	(4.071)
Demographics			
Population (2018, '000s)	0.812	11.08	8.692
	(0.0352)	(1.089)	(1.799)
Population growth (2006-2018, %)	-11.14	-0.135	-7.580
	(0.366)	(0.513)	(0.912)
Population growth (2006-2009, %)	0.181	4.060	0.573
	(0.203)	(0.183)	(0.414)
Population growth (2009-2012, %)	-1.797	0.232	-1.161
	(0.149)	(0.118)	(0.331)
Population growth (2012-2015, %)	-5.298	-3.141	-4.019
	(0.141)	(0.0906)	(0.317)
Population growth (2015-2018, %)	-5.384	-2.539	-3.951
	(0.134)	(0.0882)	(0.258)
Rural (%)	96.44	69.83	81.94
	(0.292)	(0.739)	(1.830)
Urban (%)	3.563	30.17	18.06
	(0.292)	(0.739)	(1.830)

Notes: This table shows the mean and standard deviation (in parenthesis) of some characteristics of the Spanish municipalities, telling apart those that opened solar and wind plants between 2000 and 2021, and those without these investments. Temperature and rainfall data come from WorldClim. Height above sea is constructed with data from GTOPO30 (Data available from the U.S. Geological Survey). Ruggedness corresponds to the standard deviation of the altitude of the municipality's territory.

construction workers and technical personnel. Since highly specialized workers are not needed, they can often be found in the municipality where the investment occurs or in the surrounding area. Instead, for wind, only two-thirds of the person-days involved are more specialized construction workers.

The operation and maintenance phase starts right after the construction ends and lasts the whole plant's lifetime (between 25 to 30 years). Operating and maintaining solar and wind plants do not require many workers as it is usually automated and monitored remotely by the maintenance company. It might require regular visits to the plant's site or when repairs are needed.

Beyond the direct effects on employment and unemployment due to the construction and maintenance of the plant, there might also be indirect general equilibrium effects, as the increase

TABLE 2

UNEMPLOYMENT AND INVESTMENTS

	Solar			Wind		
	(1)	(2)	(3)	(4)	(5)	(6)
$unemp_{\tau-25}$	0.000146 (0.000114)			0.000097 (0.000096)		
$unemp_{\tau-30}$		0.000046 (0.000067)			0.000164 (0.000100)	
$\overline{unemp}_{\tau-25,\tau-30}$			0.000071 (0.000067)			0.000134 (0.000113)
# Obs.	626,550	626,550	626,550	626,550	626,550	626,550
# Municipalities	3,976	3,976	3,976	3,976	3,976	3,976

Notes: This table investigates the impact of unemployment (before the plants' construction) and wind and solar investments at the municipality level for May 2008-January 2021. The dependent variable is new renewable capacity over population at time t-36, $unemp_{\tau-25}$ refers to unemployment 25 months before the plant's start-up date normalized with population at time t-36, $unemp_{\tau-30}$ to unemployment 36 months before normalized with population at time t-36 and $\overline{unemp}_{\tau-25,\tau-30}$ to the average of unemployment between 30 and 25 months before the startup date normalized with population at time t-36. The specification includes municipality and time FE. Standard errors are clustered at the municipality level. In all cases, past unemployment has no significant effect on the choice of location.

in overall economic activity might give rise to further job creation. In this paper, we quantify renewable investments' local labor market effects through these two channels, even though we cannot disentangle one from the other.

4 Data Description

4.1 Renewable Investments Data

We use data on all wind and solar investments in Spain from February 2006 until January 2020. Because of the differences between the two investment waves, we split the sample into two periods. Our baseline analysis focuses on the first investment wave (2006-2018), and the study of the second wave of investments is reported separately in Section 7.

Our data comes from PRETOR, i.e., the administrative registry for all renewable, waste, and cogeneration plants in Spain.[21] The registry provides the individual plants' locations, sizes, and technologies, and it further contains information on three important dates: the registration request, the start-up, and the final registration. Since the plant must be able to produce electricity at the start-up date, the construction must have concluded by then.[22] The treatment starts when construction begins, but we do not know when that occurs. Therefore, we quantify the effects before and after the start-up date. One expects to find positive impacts 24 to 18 months before the start-up date, reflecting the construction activities, as well as after the start-up date, reflecting the maintenance activities.

[21] The data is publicly available at https://energia.serviciosmin.gob.es/Pretor/.

[22] There are delays across these three dates mainly due to bureaucratic issues. In particular, the difference between the registration request and the final registration was 6 months on average for solar and 21 months on average for wind plants. Only 2% of the plants did not file a final registration after the first. The median time lapse between the start-up date and the final registration was 28 and 52 days for solar and wind plants, respectively. We impute a few missing values of the start-up date (6.8% of the plants), leveraging information on the final registration and applying the above-mentioned median time lapse between the final registration and the start-up date by type of energy.

4.2 Employment and Unemployment Data

For employment data, we use the Social Security registers (affiliates) at the municipality level (beginning in January 2003). Workers are reported at the location of their employer, defined as the municipality where the employer's Social Security account is registered. The rule is that the firm must register *at least* one different account in each province where it owns certain infrastructure. In practice, firms create new accounts only when they are involved in big projects that are expected to last long or require physical infrastructure. For this reason, a municipality's employment figures need not reflect the number of people working there.[23] Instead, they report the number of workers employed by firms or plants registered in the municipality.[24]

We also use registered unemployment data at the municipality level (beginning in May 2005). Unlike the employment dataset, the unemployment data refer to the registered person's municipality of residence. Not all of the unemployed are registered in the local employment offices because they are not all entitled to unemployment insurance or because they do not want to benefit from the help provided by public employment offices to find a job.[25] Unlike the employment data, the unemployment registries are disaggregated by the sector in which the person worked before becoming unemployed (agriculture, construction, services, and non-employment), as well as by age-group and gender.

Since not all workers live in the municipality where they work and not all firms are registered where their employees work, the employment and unemployment data need not be a mirror image of each other. Two facts compound this: not all job creation is channeled through public employment offices, and workers can hold more than one affiliation, so not all new affiliations imply a reduction in registered unemployment.

One advantage of leveraging employment data is that, unlike unemployment data, it is not affected by changes in participation rates. However, since the employment dataset refers to the firm's location rather than the renewable plant's location, the local employment effects might

[23]The estimates conducted at the province level must therefore reflect the total number of new employments, given the requirement to register at least one account in the province where the investment occurs. While the estimates at the province level are noisier given the fewer number of observations (as there are 52 provinces in Spain), results are broadly consistent with those conducted at the municipality level.

[24]The dataset censors observations if the total number of employees in a municipality is below 5. Moreover, since February 2019, the number of employees is censored if the number of employees in one particular regime (general, self-employed, agrarian, sea, coal, and households) falls below 5. In this case, the total number of employees reported is the sum of the non-censored regimes (for instance, they report a total number of employees as "$> 1,067$" if the sum of employment in all non-censored regimes is "$1,067$" whereas the censored ones will be "< 5"). Given that we restrict the sample to municipalities with more than 500 inhabitants, the censoring of the dataset plays a minor role, since the bulk of censored observations are found in small villages. In the regressions for the second investment wave, we ignore the "$>$" sign in the total employment figures.

[25]Indeed, unemployment reported by the labor Force Survey is usually higher than unemployment figures from unemployment registries.

be underestimated, particularly in rural areas where firms are less likely registered. To mitigate this concern, we estimate the labor market effects also at the county level to capture the new jobs created by firms located within the municipality's nearby area.[26] The unemployment dataset is not subject to this potential bias, given that the data correspond to the workers' residence. These differences between the employment and unemployment data make it particularly useful to combine both types of results to obtain a richer picture of the labor market effects of renewable investments.

5 Empirical Strategy

We estimate the labor market effects of investments in renewable energy using local projections (Jordà, 2005).[27] Our baseline approach is to estimate the effects at the municipality level, but we also present results at a higher level of aggregation, i.e., at the county level.[28] In particular, we run a series of h regressions of the following form:

$$y_{i,t+h} = \beta^s_{\tau+h}\Delta k^s_{i,t} + \beta^w_{\tau+h}\Delta k^w_{i,t} + \gamma_h X_{i,t} + \alpha_{h,i} + \lambda_{h,t} + \epsilon_{i,t+h} \quad (1)$$

where t refers to the calendar month, τ represents the month of the start-up date, and $h \in [-36, 12]$ refers to the number of months before or after that month, i.e., our event-window.[29] The dependent variable, $y_{i,t+h}$, is either employment or unemployment in municipality (or county) i in month $t+h$. If t is the start-up month τ, then the key independent variables, $\Delta k^s_{i,t}$ and $\Delta k^w_{i,t}$, reflect the new renewable capacity for solar and wind, respectively, in municipality (or county) i. They take a value of zero for all other months $t \neq \tau$. We also include a vector of covariates $X_{i,t}$, a municipality (or county) fixed effect $\alpha_{h,i}$, and a month fixed effect $\lambda_{h,t}$. We normalize the dependent and treatment variables by the population at the municipality (or county) at time $t-36$, which allows interpreting the $\beta^s_{\tau+h}$ ($\beta^w_{\tau+h}$) coefficients as the employment or unemployment multipliers of investing 1 MW of solar (wind) capacity h months before or after the plant's start-up date τ. In particular, β^s_τ and β^w_τ reflect the effect at the start-up date, while the $\beta^s_{\tau+h}$ and $\beta^w_{\tau+h}$ coefficients reflect the effects due to the plant's construction ($h < 0$) or due to

[26]Counties refer to agrarian regions, a spatial unit between the municipality and the province. This category comprises areas with similar agrarian traits, encompassing the whole country. This division is helpful in managing funds related to the Common Agricultural Policy. In Spain, there are 326 counties.

[27]In Appendix A, we use an event study design. Results are very similar to those under our baseline approach. Yet, as discussed in Section 2, in the context of our study, using local projections provides more flexibility to account for heterogeneous effects as compared to using an event study design (see Section 6.5).

[28]If we aggregated even further, e.g. at the province level, we would capture bigger outward spillovers. However, the analysis would fail to address our main question of interest: whether the municipalities where the investments take place benefit from them.

[29]The interval we consider, $[\tau - 36, \tau + 12]$, is purposely not symmetric around the start-up date (τ) because the effects of the investment are likely to start during the construction process, i.e., for $h < 0$. Leaving extra time before the start-up date allows us to check for pre-treatment parallel trends.

the plant's maintenance ($h > 0$). Standard errors are clustered at the municipality (or county) level.[30]

As mentioned in Section 4.2, since at the start-up date the plant must be able to produce electricity, we expect that the employment or unemployment effects of the investment begin *before* that date, i.e., while the plant's construction is taking place.[31] For this reason, in vector $X_{i,t}$, we control for the dynamics of the dependent variable before the start of the event window, and leave them free thereafter. In particular, we include the value of the dependent variable in $t-37$. By going back to $t-37$, we can interpret the first set of coefficients in the event-window as a test for parallel pre-trends, since the construction process is set to start later on, at around 18 to 24 months before the start-up date, as described in Section 3.2. The vector $X_{i,t}$ also contains values of the treatment variables referring to past periods, as well as to future periods for horizons h larger than $\tau - 24$. Doing this allows to control for variations in the outcome variable that could potentially be affected by past or future investments. In particular, we add the values of the normalized variables $\Delta k^s_{i,t}$ and $\Delta k^w_{i,t}$ from $t-60$ to $t+h+24$. Hence, we control for past investments up to five years before the start-up date, as well as for future investments, accounting for the fact that the labor market effects could be felt two years before the start-up date.[32, 33]

To compute the cumulative effects one year before and one year after the start-up date, we collapse equation (1) into these two regressions:

$$\frac{1}{12}\sum_{h=-12}^{-1} y_{i,t+h} = \sum_{e=s,w} \beta^e_{pre}\Delta k^e_{i,t} + \gamma X_{i,t} + \alpha_i + \lambda_t + \epsilon_{i,t} \quad (2)$$

$$\frac{1}{12}\sum_{h=0}^{11} y_{i,t+h} = \sum_{e=s,w} \beta^e_{pos}\Delta k^e_{i,t} + \gamma X_{i,t} + \alpha_i + \lambda_t + \epsilon_{i,t} \quad (3)$$

Therefore, β^e_{pre} and β^e_{pos} are the job multipliers of a 1 MW investment in either solar ($e = s$) or wind ($e = w$) capacity one year before and one year after the start-up date, i.e., during the construction and maintenance phases.[34]

[30] This allows accounting for heteroskedasticity and serial correlation within municipalities. Results are robust to (i) clustering the standard errors at the municipality (or county) and month levels, (ii) allowing for heteroskedasticity and arbitrary serial correlation (HAC standard errors), and (iii) using Driscoll and Kraay standard errors, which are robust to disturbances that are common to panel units and that are autocorrelated. In the Appendix, see Table B.7 for the baseline results on employment and Table B.9 for the results on unemployment.

[31] These should not be interpreted as anticipation effects. The period before the start-up date corresponds to the construction phase. Hence, the effects on employment or unemployment before the start-up date should be attributed to the construction activities.

[32] For instance, at horizon $h = \tau + 12$, we include the lagged values of the treatment variables from $t-60$ to $t-1$, to control for past investments, as well as the lead values from $t+1$ to $t+36$. The set of forwards isolate the effect of the current investment from that of future investments whose start-up date might fall between $\tau + 12$ and $\tau + 36$, and hence, whose construction phase might contaminate the estimates at $\tau + 12$.

[33] As robustness, we consider not controlling for investments in the other energy (solar or wind), allowing for region-specific time fixed-effects, and accounting for different demographic trends at the municipality level. See Section 6.3.1.

[34] Tables 3 and 4 also report cumulative effects three and two years before the start-up date in order to check for pre-treatment effects and quantify the effect at the beginning of the construction period, respectively.

In our regressions, we restrict the sample in two directions. First, we exclude municipalities with less than 500 inhabitants, leaving out around 1.8 % of the Spanish population.[35]. Second, in municipalities that opened a plant in the second wave (i.e., after 2018), we exclude observations up to 24 months before the plant's opening. These could bias the estimated effects due to the labor market impacts of the construction phase of second-wave projects. The identification assumption is that the timing of renewable plant openings is not the result of factors correlated with the evolution of the labor market at the municipality level. As mentioned earlier, the coefficients at the onset of the event window provide a useful test for this assumption. Since the plant's construction process is unlikely to span more than 24 months before the start-up date, the coefficients $\beta_{\tau+h}$ for $h \in [-36, -25]$ are expected to be zero in the absence of such factors.[36]

5.1 Clean control condition

Recent research has documented that in settings with more than two time periods and variation in treatment timing, the commonly used TWFE estimator is unbiased for the average treatment effect if the parallel trends assumption holds *and* if the treatment effect is constant, both across groups (defined as a set of units receiving the treatment in the same period) and over time.[37] The reason for this is that in such settings, the TWFE is a weighted average of treatment effects across groups and time, with weights that need not be proportional to the number of observations in each group-time cell and that can even be negative. In particular, negative weights may arise from treatment effects obtained from comparing the outcome of a group that switches treatment with another group that is treated in both periods, or from comparing groups whose treatment change intensity differs across the two periods. Following these findings, this body of work has proposed estimators that are robust to heterogeneous treatment effects. The focus has been on developing estimators applicable to settings characterized by binary treatments and staggered adoption (meaning that the treatment can only be incremental and only changes once over time).[38]

As shown in equation (1), our baseline results rely on estimating a simple two-way fixed effects panel data model at every horizon. Hence, they are subject to the potential pitfalls associated with heterogeneous treatment effects. Three issues are worth noticing. First, our empirical strategy

[36]As an additional check, Table 2 investigates the relationship between unemployment and renewable investments before the plant's construction. The dependent variable is new renewable capacity over the population at time t-36. The first three columns investigate the impact of past levels of unemployment on the investment in solar plants, showing no significant effects, and columns 4-6 confirm these results in the case of wind farms.

[37]See, for instance, de Chaisemartin and D'Haultfœuille (2020), Goodman-Bacon (2021), Callaway and Sant'Anna (2021), Sun and Abraham (2021), Borusyak et al. (2022), and de Chaisemartin and d'Haultfoeuille (2022),.

[38]See de Chaisemartin and D'Haultfoeuille (2022) for a survey.

uncovers the month-to-month evolution of the treatment effect. Hence, it explicitly accounts for over-time treatment effect heterogeneity (i.e., it allows for dynamic treatment effects). Second, possible treatment effect heterogeneity across groups leads us to restrict the baseline regressions to the first renewable investment wave, for which plants are small and more similar (as opposed to the much larger plants opened during the second wave). And third, our strategy to dilute the incidence of negative weights is to include units that are never treated in the sample period, i.e., we include in our regressions the set of municipalities that never opened a renewable plant.[39]

In a recent paper, Dube et al. (2023) propose an approach that accommodates the possibility of heterogeneous treatment effects. This approach relies on the combination of local projections for the estimation of dynamic effects with a 'clean control' condition that avoids the bias associated with variation in treatment timing. In short, this technique avoids using previously treated units as controls. These units might be experiencing dynamic treatment effects, contaminating the treatment effect estimates of newly-treated units. Hence, the so-called LP-DiD estimator identifies a weighted average of potentially heterogeneous group-specific treatment effects, with weights that are always positive.

We apply the LP-DiD estimator by restricting the sample to observations that fulfill either one of two conditions. First, a municipality is considered treated if it is a newly-treated unit that has not received treatment for at least 24 months after the analyzed horizon h. Second, control units are those not treated for at least 24 months after the analyzed horizon. This approach guarantees that employment or unemployment changes stemming from the construction of future plants do not affect the estimates of newly-treated units during the maintenance phase.

Denoting with $k_{i,t}$ the cumulative sum of solar and wind investments in municipality i and time t, these conditions can be stated formally as follows:[40]

$$\text{treatment} \quad \begin{cases} \Delta k_{i,t} > 0; \quad k_{i,t-1} = 0 & \text{if} \quad h < -24 \\ \Delta k_{i,t} > 0; \quad k_{i,t-1} = 0; \quad k_{i,t} = k_{i,t+24+h} & \text{if} \quad h \geq -24 \end{cases} \tag{4}$$

[39]Note that our local projections setting is characterized by continuous treatment, non-staggered adoption, and the inclusion of covariates. In the event study literature, estimators applicable to this design are scarce; hence, developing such estimators can provide a fruitful avenue for future research. See de Chaisemartin and D'Haultfoeuille (2022). de Chaisemartin et al. (2022) design an estimator that applies to treatments distributed continuously at every period and non-staggered adoption. However, when there are multiple time periods and dynamic treatment effects, they show that interpreting each period treatment effect can be difficult (e.g., they cannot be interpreted as the average effect of increasing the treatment by one unit on the outcome). For this reason, they propose an aggregation of such dynamic effects.

[40]Note that the conditions stated in equation (16) of Dube et al. (2023) are less stringent, because in our setting the employment effects can arise before the start-up date τ. For this reason, admissible controls are restricted to municipalities that remain untreated for at least two years after each horizon h.

$$\text{clean control} \quad \begin{cases} k_{i,t} = 0 & \text{if} \quad h < -24 \\ k_{i,t} = k_{i,t+24+h} = 0 & \text{if} \quad h \geq -24 \end{cases}$$

It is worth underlining a few relevant differences between the LP-DiD estimator and our baseline. First, the clean control condition restricts the treatment effects estimation to each municipality's first treatment, discarding all the information in subsequent treatments. Second, since the restrictions on the estimation sample depend on h, the number of observations at each horizon does not remain constant. Moreover, it falls dramatically at long horizons. The reason is that, in those horizons, many municipalities are used solely in the period when they are first treated and never act as controls. Then, they are subsumed in the corresponding municipality fixed-effect, and hence they do not contribute to the estimation of the treatment effect. Therefore, the possibility of allowing for group-specific heterogeneous treatment effects comes at the cost of sample selection and a lower number of observations.[41] This problem is particularly salient in the case of the unemployment effects of solar investments, for which the number of observations is smaller, since the unemployment series are shorter and the plant sizes are more heterogeneous. Note finally that the clean control condition takes care of potential biases coming from past and future treatments (by dropping the observations). Hence, the estimated model is again equation (1), but now the vector X_{it} excludes all the lags and forwards of the treatment variables.

6 Results

6.1 Employment

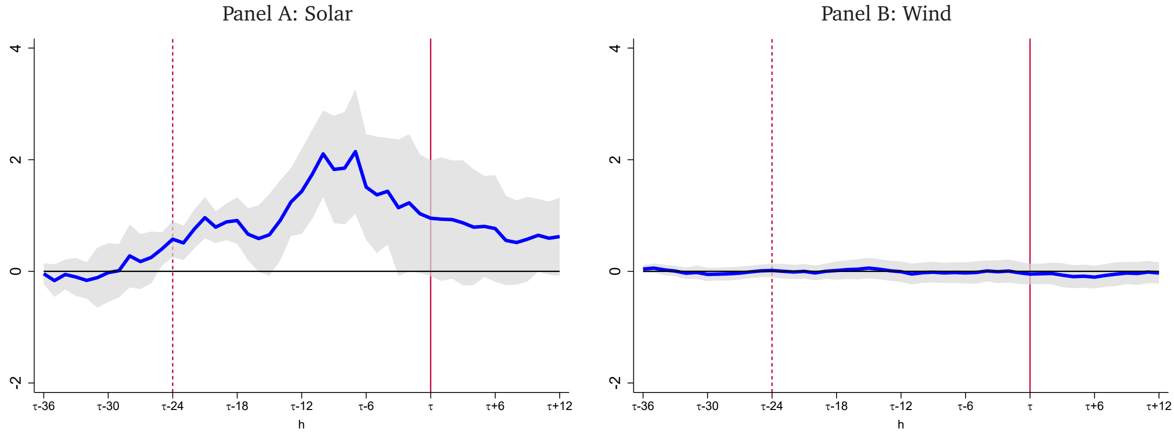
Figure 3 shows the results of estimating equation (1) for employment at the municipality level for investments in solar and wind plants during the baseline period 2006-2018.[42] For the two technologies, results are consistent with pre-treatment parallel trends, as shown by the zero effect when the construction had not reasonably started (i.e., two years before the start-up date). Furthermore, as described below, the estimated employment effects during the construction and maintenance phases are as expected, given the types of tasks and skills involved (see Section 3).

For solar investments, we observe a positive and significant impact on employment around 24 months before the plant's start-up, which is consistent with the start of the construction phase. This effect grows until 6 months before the start-up date, after which it becomes slightly weaker. This is also consistent with the fact that the major construction tasks are typically

[41] Figures B.9 and B.10 in the Appendix show the number of observations used as treatment and control units at each horizon h for employment and unemployment, respectively.

[42] Figure B.3 in the Appendix depicts the county-level results.

FIGURE 3
LOCAL EMPLOYMENT EFFECTS



Notes: These figures show the effects of investing 1 MW on employment by firms located at the municipalities where the investment occurs in the period February 2006-January 2018, h months before or after the start-up date (marked with a vertical solid red line). Panel (a) shows the results for solar investments and panel (b) for wind investments. Error bands depict the 95% confidence interval. Standard errors are clustered at the municipality level.

completed sometime before the plant is ready to produce electricity. As we enter the operation and maintenance phase, the effect goes further down, but it does not vanish during our post-opening year. As reported by IRENA (2017a), "solar plants do not require complex maintenance" (e.g., cleaning the panels and replacing failing components), most of which can be carried out locally.[43] These results are in stark contrast with the results for wind investments, for which there is no statistically significant impact in the pre-opening or post-opening periods.

Table 3 reports the multipliers of investing 1 MW of renewable capacity on employment at the municipality level before the construction has plausibly started, as well as during the construction and maintenance phases. As expected, the analysis shows that the coefficient before the construction (column 1) is not statistically different from zero. During the early stage of the construction (column 2, between 13 and 24 months before the start-up date), the job multiplier for solar investments becomes statistically significant (0.78 jobs-year/MW). During the year prior to the start-up date (column 3, 12 months before the start-up date), the job multiplier increases to 1.54 jobs-year/MW. During the maintenance phase (column 4, 12 months after the start-up date), the job multiplier for solar goes down to 0.74 jobs-year/MW, and remains significant. In contrast, the job multipliers for wind are statistically equal to zero across all periods.[44]

The impacts on employment for solar investments increase when we expand the area from municipalities to counties, a result which is consistent with Feyrer et al. (2017). The effects

[43] IRENA (2017a) reports that operation and maintenance activities for solar PV require 38% of the persons-day who are required for construction. This is in line with the relative multipliers we report for the construction and maintenance phases.

[44] Figure B.5 in the Appendix plots the results until 24 months after the start-up date instead of 12 months.

during pre-opening and post-opening increase to 4.49 jobs-year/MW and 3.53 jobs-year/MW, respectively (see Table B.3 in the Appendix). The reason is that some employers might locate in other municipalities within the same county, so the effects only appear when the analysis is conducted at the county level. However, the same does not apply to wind, for which the effect remains statistically equal to zero even at the county level, making the null effects of wind investments on employment very compelling.[45]

Another way to look at the results is to express the job multipliers per million euros invested (rather than MW).[46] As shown in Table B.4 in the Appendix, the local impact of investing one million euros in a solar plant during the construction phase was 0.65 new jobs.[47,48]

6.2 Unemployment

Figure 4 and Table 4 provide the impacts of the renewable investments on unemployment.[49] Reassuringly, as for employment, there are no effects on local unemployment three years before the start-up date, a result consistent with pre-treatment parallel trends.

For solar investments, unemployment goes down during the construction period, and while the timing of the effect is similar to the one for employment, the magnitude of the impact is

TABLE 3

LOCAL EMPLOYMENT EFFECTS

	Pre-construction (1)	Early construction (2)	Pre-opening (3)	Post-opening (4)
Solar Multiplier (Jobs/MW)	0.033	0.783^{***}	1.537^{***}	0.740^{*}
	(0.190)	(0.166)	(0.507)	(0.442)
Wind Multiplier (Jobs/MW)	-0.010	0.013	-0.023	-0.063
	(0.047)	(0.076)	(0.095)	(0.098)
# Obs.	568,261	568,261	568,261	568,261
# Municipalities	3,964	3,964	3,964	3,964

Notes: This table reports the results of estimating the employment effects through equations (2) and (3), at the municipality level for the baseline period February 2006-January 2018. The multipliers express the number of new jobs created by local firms per MW invested. The pre-construction period refers to the period between 25 and 36 months prior to the start-up date. The early construction period includes between 13 and 24 month before the opening. Lastly, the pre(post)-opening period is defined as the one year period before (after) the start-up date. Standard errors are clustered at the municipality level. Table B.7 in the Appendix shows the standard errors clustered at the municipality and month levels, as well as HAC and Driscoll and Kraay standard errors.

[45] These results are robust to clustering the standard errors at the municipality (or county) and month levels, as well as to HAC and Driscoll and Kraay standard errors, see Table B.7 in the Appendix.

[46] According to IRENA (2022b), the average cost for solar plants was 4.728 million US$/MW in 2010, and it fell to 0.760 million US$/MW by 2020. For wind, the cost was 2.479 million US$/MW in 2010 and 1.23 million US$/MW in 2020. We use the real cost estimates reported by IRENA (2022b). More specifically, the cost of solar plants in 2010 was 4.142 million euros/MW, and fell to 0.667 million euros in 2020. For wind, it was 2.172 million euros/MW in 2010 and 1.080 million euros/MW in 2020.

[47] Due to the fact that the cost estimates are available since 2010, we include in vector $X_{i,t}$ of equation (1) the normalized values of the treatment variables from $t-24$ to $t+h+24$, as well as the value of the dependent variable in $t-37$.

[48] The value of these multipliers is similar to the ones found by Feyrer et al. (2017) in the context of the US fracking revolution: 0.85 new jobs at the county level for every million dollars. However, they are not directly comparable as our multipliers refer to the cost of the investments while theirs refer to the value of the gas production.

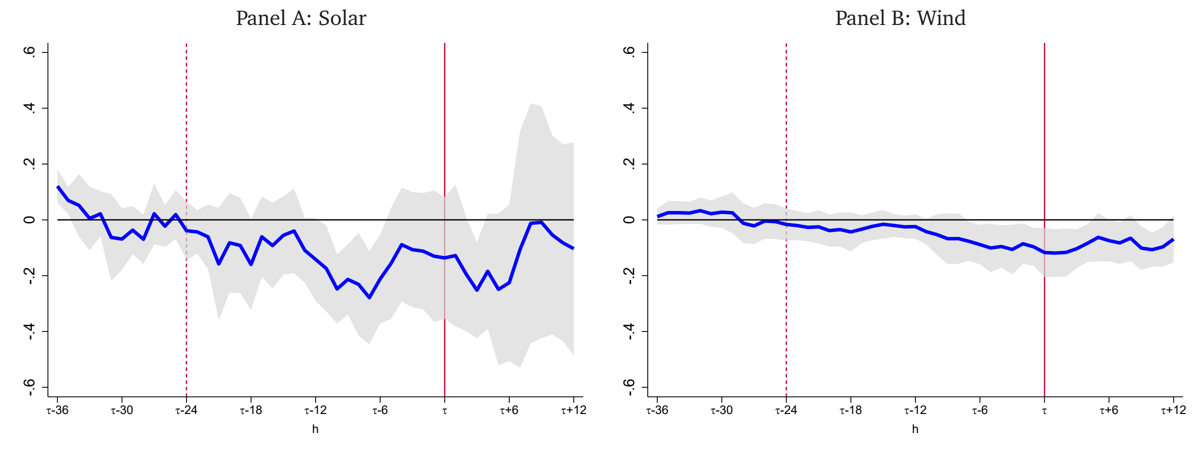
[49] Figure B.4 in the Appendix shows the county-level results.

smaller. In particular, the unemployment multiplier is -0.08 persons-year/MW during the early construction phase. During the pre-opening year the unemployment multiplier goes down to -0.19. Even though the effect during the maintenance phase is non-significant, there seems to be a reduction in unemployment after the start-up date (the multiplier is -0.13 persons-year/MW).[50]

While wind investments delivered no impact on employment, we now observe that they reduce unemployment slightly. In any event, the effect is much weaker than that of solar investments. The unemployment effects during pre-opening and post-opening reach -0.08 persons-year/MW and -0.09 persons-year/MW.[51] Although the numbers are economically small, the distinct employment and unemployment effects suggest that the new workers reside in the municipality but are hired by outside firms. A reduction in participation rates (not affecting employment) could also explain this finding, i.e., some people leave the local labor market because they become inactive or move to another location.

Just as we did in the case of employment, we can express these impacts as a function of the sums invested (Table B.4). During the construction phase, investing one million euros in a solar plant reduced the number of unemployed local people in the municipality by 0.075. For wind, during the maintenance phase, the reduction in the number of local unemployed in the municipality is 0.038 per million euros invested.

FIGURE 4
LOCAL UNEMPLOYMENT EFFECTS



Notes: These figures show the effects of investing 1 MW on unemployment by residents in the municipality where the investment occurs in the period June 2008-January 2018, h months before or after the start-up date (marked with a vertical solid red line). Panel (a) shows the results for solar investments, and panel (b) for wind investments. Error bands depict the 95% confidence interval. Standard errors are clustered at the municipality level.

[50] Figure B.6 in the Appendix shows the results until 24 months after the start-up date, instead of 12 months. Unemployment multipliers beyond the first year of the maintenance period are noisy, although they are negative on average.

[51] Table B.3 shows the multipliers in the pre-opening and post-opening phases at the county level.

TABLE 4
LOCAL UNEMPLOYMENT EFFECTS

	Pre-construction (1)	Early construction (2)	Pre-opening (3)	Post-opening (4)
Solar Multiplier (Jobs/MW)	0.003	-0.080*	-0.188***	-0.135
	(0.032)	(0.046)	(0.058)	(0.141)
Wind Multiplier (Jobs/MW)	0.011	-0.027	-0.076**	-0.094***
	(0.023)	(0.025)	(0.035)	(0.035)
# Obs.	458,711	458,711	458,711	458,711
# Municipalities	3,967	3,967	3,967	3,967

Notes: This table reports the results of estimating the local unemployment effects through equations (2) and (3), at the municipality level for the baseline period June 2008-January 2018. The multipliers express the number of residents who are no longer unemployed per MW invested. The pre-construction period refers to the period between 25 and 36 months prior to the start-up date. The early construction period includes between 13 and 24 month before the opening. Lastly, the pre(post)-opening period is defined as the one year period before (after) the start-up date. Standard errors are clustered at the municipality or at the county level. Table B.9 in the Appendix shows the standard errors clustered at the municipality and month levels, as well as HAC and Driscoll and Kraay standard errors.

Unlike the employment data, the unemployment data allows breaking the analysis by sector of previous employment, gender, and age. Results are reported in the Appendix, Tables B.10 to B.12.

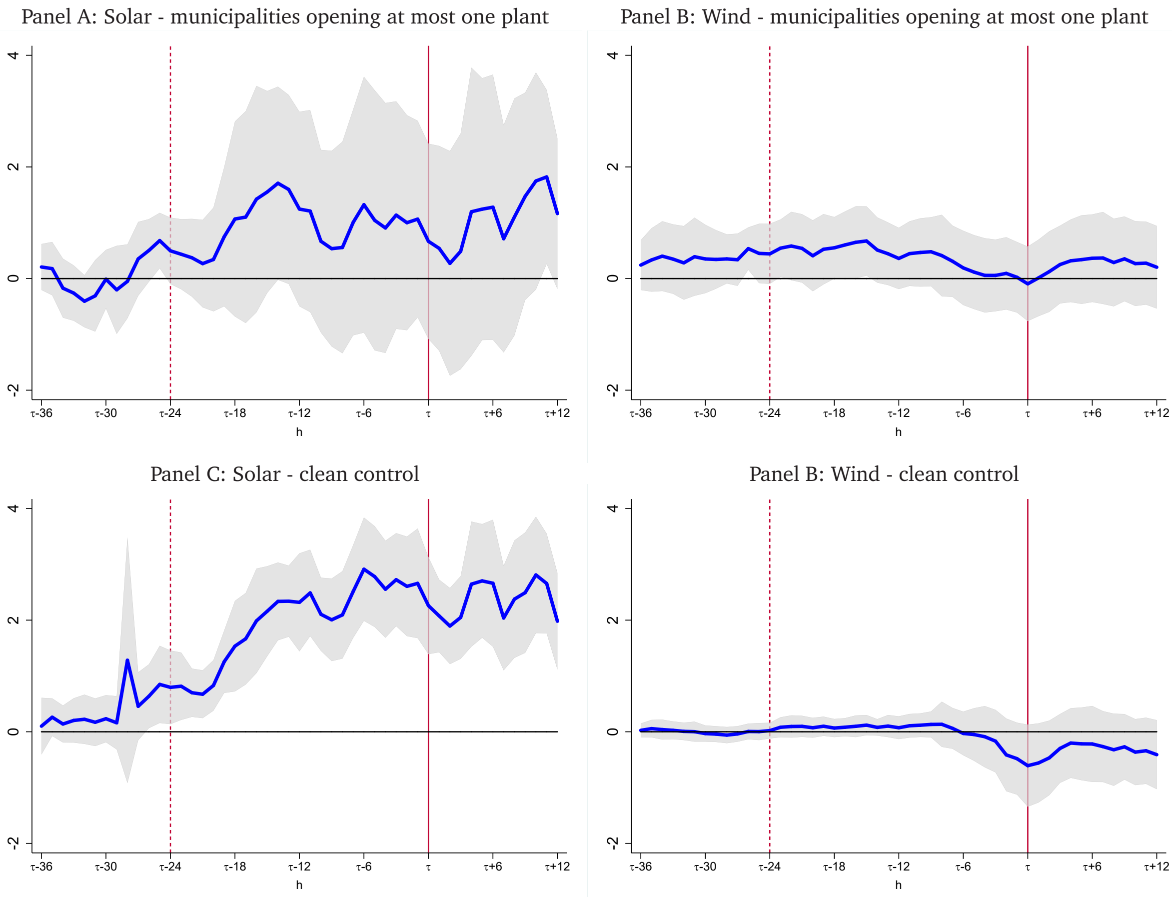
6.3 Clean control condition

Figure 5 and Table 5 report the estimated effects on employment when allowing for heterogeneous treatment effects at the group level, i.e., when restricting the sample observations as described in equation (4). As explained in Section 5.1, the clean control approach implies leveraging solely the first treatment of each municipality for the estimation of the treatment effects. For this reason, Figure 5 also depicts the baseline results when the sample is restricted to municipalities that opened at most one plant during the sample period. This provides a meaningful comparison, since it accounts, to a certain extent, for the sample selection incurred in the clean-control approach. Note yet that the clean-control approach, as opposed to restricting the municipalities with at most one renewable plant, implies that the number of observations falls during the estimation horizon.[52] As in the baseline, we find a significant increase of local employment around the time of the opening of solar plants when we restrict the sample to municipalities with at most one plant during the sample period. However, as opposed to the baseline, we find that this increase remains throughout the event-window, a departure that can be explained by the sample restriction described. The application of the clean-control condition yields a similar dynamic pattern, with effects that are higher than those in the baseline. In particular, we find that employment increases by 2.5 workers/MW in the pre- and post-opening periods. Regarding wind

[52] See Figure B.9 in the Appendix.

FIGURE 5

LOCAL EMPLOYMENT EFFECTS - MUNICIPALITIES OPENING AT MOST ONE PLANT AND APPLICATION OF THE CLEAN CONTROL CONDITION



Notes: These figures show the effects of investing 1 MW on employment by firms located at the municipalities where the investment occurs in the period June 2008-December 2018, h months before or after the start-up date (marked with a vertical solid red line). Panels (a) and (b) restrict the sample to municipalities that opened at most one solar or wind plant during the sample period. In panels (c) and (d) treatment and control observations are restricted in order to take into account the staggered adoption. Panels (a) and (c) show the results for solar investments, and panels (b) and (d) for wind investments. Error bands depict the 95% confidence interval. Standard errors are clustered at the municipality level.

plants, the inclusion of the clean-control condition or the sample restriction to municipalities with at most one plant do not change the baseline results, which report no local employment effects for wind investments.

As compared to the employment series, the unemployment data are available for a shorter time period. In particular, applying the clean control condition would reduce the number of municipalities in the sample to only 30% compared to the baseline.[53] This makes it inappropriate to apply the clean control condition in the case of unemployment.[54]

[53] See Figure B.10 in the Appendix.

[54] For completeness, Table B.5 in the Appendix reports the local unemployment multipliers under the clean control condition. The small number of observations implies that all estimates are very noisy and non-significantly different from zero.

6.3.1 Robustness of the Baseline Results

In our baseline specifications, we control for both solar and wind investments since $t-60$ until $t+h+24$. Here, we replicate the results for solar and wind investments without controlling for investments in the alternative technology. We also account for region-specific shocks, by interacting the time fixed-effects with province dummies.[55] Additionally, in order to verify that the labor market impacts are not biased by migration dynamics, we interact the monthly dummies

TABLE 5
LOCAL EMPLOYMENT EFFECTS - CLEAN CONTROL

	Baseline		Municipalities opening at most one plant		Clean Control	
	Pre-opening (1)	Post-opening (2)	Pre-opening (3)	Post-opening (4)	Pre-opening (5)	Post-opening (6)
Solar (Jobs/MW)	1.537***	0.740*	0.886	1.047	2.508***	2.544***
	(0.507)	(0.442)	(1.030)	(1.034)	(0.383)	(0.418)
Wind (Jobs/MW)	-0.023	-0.063	0.297	0.299	-0.167	-0.392
	(0.095)	(0.098)	(0.318)	(0.389)	(0.303)	(0.302)
Observations	568,261	568,261	244,459	244,459	181,443	180,420
# Municipalities	3,964	3,964	1,702	1,702	2,031	1,997

Notes: This table reports the results of estimating the employment effects through equations (2) and (3) at the municipality level for the baseline period February 2006-January 2018. The pre(post)-opening period is defined as the one year period before (after) the start-up date. Standard errors are clustered at the municipality level. In columns 3 and 4 the sample is restricted to municipalities that opened at most one renewable energy plant in the sample period. In columns 5 and 6, treatment and control observations are restricted in order to take into account the staggered adoption. In these last two specifications, lags and leads of the treatment variables are not added.

with population growth deciles between $t-48$ and $t-36$. The results of these tests do not significantly change our baseline findings, as can be seen in Figures B.11, B.12, B.14 and B.15.[56] Lastly, we have re-estimated our baseline results using quarterly and yearly data, instead of monthly data. As can be seen in Figures B.13 and B.16, the results remain similar. Importantly, the parallel trends assumption, i.e., the absence of an effect prior to the start of the construction period, is also validated by both the quarterly and yearly analyses.

Hence, we conclude that our baseline analysis remains robust.

6.4 Spatial Effects

It is plausible that municipalities benefit not only from their own investments but also from those taking place in neighboring areas. For instance, workers living in the municipality might find new job opportunities if a new plant opens close enough so that they can commute to work. Furthermore, there might be general equilibrium effects by which the direct increase (decrease) in employment (unemployment) due to investments in surrounding areas triggers further increases (decreases) in employment (unemployment) in other sectors within the municipality. Some of

[55] There are 52 provinces in Spain.

these spillover effects might be captured when moving from the municipality-level analysis to the county-level analysis of equation (1). However, the aggregation captures both the inward as well as the outward spillovers, while we are mostly concerned with the former. The reason is that we want to understand whether the local municipalities benefit from the investments, and not so much whether the effects span over a larger area.

To capture the spatial effects caused by the inward spillovers of renewable investments in surrounding municipalities, we adopt a similar specification as Alloza and Sanz (2021):[57]

$$y_{i,t+h} = \sum_{e=s,w} \beta^{e}_{\tau+h} \Delta k^{e}_{i,t} + \sum_{e=s,w} \rho^{r,e}_{\tau+h} \Delta k^{e}_{r,t} + \gamma_h X_{i,t} + \alpha_{h,i} + \lambda_{h,t} + \epsilon_{i,t+h} \tag{5}$$

where $\Delta k^{e}_{r,t}$ captures the investments in solar ($e = s$) or wind capacity ($e = w$) within a radius of r kilometers around municipality i normalized by the population in $t - 36$ in that area. For $e = s, w$:[58,59]

$$\Delta k^{e}_{r,t} = \frac{\sum_{j \neq i \in r} \Delta k^{e}_{j,t} pop_{j,t-36}}{\sum_{j \neq i \in r} pop_{j,t-36}}. \tag{6}$$

Last, additionally to the variables included in equation (1), $X_{i,t}$ contains lags 60 to $t + h + 24$ of $\Delta k^{e}_{r,t}$.

We can now distinguish the benefits of municipality i own renewable investments (local effects), as captured by $\beta^{e}_{\tau+h}$, from those resulting from renewable investments in the surrounding area (spatial effects), as captured by $\rho^{r,e}_{\tau+h}$. Note that, in order to obtain the average effect, we multiply the coefficients $\rho^{r,e}_{\tau+h}$ by the average population across neighboring regions over the average population across municipalities in $t - 36$. When reporting the spatial coefficients, we will use this normalization to make them directly comparable with the own, local coefficients. It is worth noticing that this specification serves as a robustness check on the baseline specification in equation (1). If there is spatial correlation in plant openings and spillover effects, there could be a correlation between the treatment variable and the error term, leading to bias in the estimates (James and Smith 2020; Feyrer et al. 2020). By controlling for nearby investments, the coefficients $\beta^{e}_{\tau+h}$ in equation (5) are free from such possible bias.

[57]Note that this specification differs from the one in Feyrer et al. (2017), given that they capture the inward and the outward spillovers by aggregating *both* the dependent and the independent variables over a larger radius. Purposely, we only capture the inward spillovers as we are interested in whether the local municipalities benefit from investments in the surrounding area, and not whether the area as a whole benefits from those investments. In this sense, our specification is closer to James and Smith (2020). However, unlike them and in line with Feyrer et al. (2020), we normalize the independent variable $k_{r,t}$ with the lagged population of the whole area, as explained below.

[58]Note that we first have to undo the normalization at the municipality level given that $\Delta k^{e}_{j,t}$ is defined as the investment in j divided by its population in $t - 36$.

[59]Distances are computed by applying the harversine formula to the geographic coordinates of the municipalities' centroids, i.e., they refer to the shortest distance over the Earth's surface.

Our baseline results might understate the true local impact of renewables, as the municipalities might benefit from nearby investments. Table 6 reports the results of estimating equation (5), which captures the local effects of investments within a 60 km radius of the municipality.[60]

TABLE 6

LOCAL AND SPATIAL EFFECTS ON EMPLOYMENT AND UNEMPLOYMENT - 60 KM RADIUS

	Employment		Unemployment	
	Pre-opening (1)	Post-opening (2)	Pre-opening (3)	Post-opening (4)
Baseline				
Solar Multiplier (Jobs/MW)	1.537***	0.740*	-0.188***	-0.135
	(0.507)	(0.442)	(0.058)	(0.141)
Wind Multiplier (Jobs/MW)	-0.023	-0.063	-0.076**	-0.094***
	(0.095)	(0.098)	(0.035)	(0.035)
Spatial				
Solar Local Effect	1.654***	0.806**	-0.131**	-0.102
	(0.446)	(0.393)	(0.060)	(0.150)
Solar Spatial Effect	0.086***	0.098***	-0.054***	-0.029***
	(0.016)	(0.016)	(0.007)	(0.007)
Wind Local Effect	-0.036	-0.099	-0.053	-0.063
	(0.096)	(0.101)	(0.039)	(0.038)
Wind Spatial Effect	-0.015	-0.008	-0.007*	-0.018***
	(0.011)	(0.012)	(0.004)	(0.004)

Notes: This table reports the results of estimating equation (5) for the local and spatial effects on employment and unemployment during the period February 2006-January 2018 in the case of employment and June 2008-January 2018 for unemployment. The pre(post)-opening period is defined as the one year period before (after) the start-up date. Standard errors are clustered at the municipality level. The baseline results are those reported in Tables 3 and 4 at the municipality level.

The first thing to highlight is that our baseline multipliers are quantitatively very similar to the sum of the local and spatial effects in these regressions, with only a slightly positive bias.[61]

Regarding the impact on employment, the spatial effects point to low spatial effects in the case of solar energy during the construction and mainteinance phases, while they remain non-significant for wind (Table 6). The spatial multipliers for unemployment account for a higher share of the total effect, particularly for municipalities close to a solar plant during the construction phase. In particular, the spatial effect for solar investments reaches 30% and 22% of the total effect during the construction and maintenance phases, and it remains significant. On the other hand, wind investments have spatial impacts on unemployment near zero during the construction and maintenance phases.

6.5 Mechanisms

The large number of solar projects spread across the country allows us to explore the mechanisms underlying our empirical findings.

[60] Figures B.19 and B.20 plot the impulse-response functions.

[61] From this, it follows that the critique of James and Smith (2020) to Feyrer et al. (2017) does not apply in our case.

Projects' locations. One of the bottlenecks for stronger local employment effects is the skill mismatch, i.e., whether residents possess the necessary skills for the new jobs being created (IRENA, 2022a).[62] In turn, this issue might depend on the project's location, whether it is in a rural or urban area,[63] as it is less likely to find enough skilled workers in rural areas. We explore the role of the project's location by allowing the coefficient of interest to vary depending on whether it is urban or rural.[64]

Table 7 reports the results.[65] Not surprisingly, we find that the effects on both employment and unemployment are larger in urban than in rural areas. In particular, during the construction phase, the employment multipliers are 3.28 and 1.51 for municipalities in urban and rural areas, respectively, while the corresponding unemployment multipliers are -1.38 and -0.18.[66] Beyond the skill mismatch, an additional explanation could be related to the fact that employers are most likely located in urban areas, making it more likely that the effects show up in urban municipalities. However, this reason alone would fail to explain why the effects on unemployment are also stronger.

Scale economies. Another potential determinant of the job multipliers has to do with the scale of the project. To explore this, we quantify the heterogeneous effects for projects with capacity above or below 49MW. As shown in Table 7, we find stronger employment and unemployment effects for small projects than for large projects (2.68 versus 1.43 employment multipliers and -0.80 versus -0.11 unemployment multipliers). This suggests the existence of important scale economies, but it is also consistent with the skill mismatch being more acute the larger the project given the greater need of skilled workers. This could also be an additional reason for the stark difference between the solar and wind multipliers, considering that wind investments tend to be much larger in size. In any event, note that the employment effect of small projects is very heterogeneous across municipalities, and it becomes non-significant.

Omitted Effects. There would be an attenuation effect of the employment multipliers if the firms carrying out the projects were not registered in the municipalities where the investment

[62] In a study of the employment effects of green investments within the 2019 US Recovery Act, Popp et al. (2022) find that the new jobs were primarily in occupations with higher training requirement than comparable occupations.

[63] Eurostat defines a municipality as rural if at least 50 % of the population lives outside urban clusters, consisting of a group of contiguous 1 km^2 cells with more than 5,000 citizens and more than 300 citizens/km^2. In our baseline sample, there are 67% rural municipalities and 41 large projects.

[64] We cannot run a similar analysis for wind, given the lower number of observations.

[65] Figures B.17 and B.18 in Appendix B.6.2 plot the results across time.

[66] Wald tests reject the null hypothesis that the coefficients are equal across urban and rural municipalities with a p-value below 0.1 in the case of unemployment during the pre-opening phase.

TABLE 7
LOCAL EMPLOYMENT AND UNEMPLOYMENT EFFECTS OF SOLAR - HETEROGENEITY

	Employment		Unemployment	
	Pre-opening (1)	Post-opening (2)	Pre-opening (3)	Post-opening (4)
Baseline				
Multiplier (Jobs/MW)	1.536***	0.739*	-0.188***	-0.136
	(0.507)	(0.441)	(0.058)	(0.141)
Urbanization				
Rural	1.510***	0.732	-0.177***	-0.138
	(0.512)	(0.450)	(0.056)	(0.142)
Urban	3.278*	0.388	-1.379**	-0.054
	(1.889)	(1.485)	(0.621)	(0.641)
Plant's Size				
$<$49MW	2.676	2.139	-0.797***	-0.848***
	(2.307)	(2.093)	(0.220)	(0.191)
$\geq$49MW	1.432***	0.642*	-0.108**	-0.044
	(0.422)	(0.339)	(0.051)	(0.178)
NACE -35 firms				
Municipality with NACE-35 firms	1.388***	0.647	-0.191***	-0.156
	(0.478)	(0.428)	(0.047)	(0.147)
Municipality without NACE-35 firms	2.192**	1.123	-0.193	-0.078
	(1.033)	(0.785)	(0.192)	(0.309)

Notes: This table reports the results of estimating the local employment and unemployment effects of solar, allowing the coefficient of interest to vary between rural and urban municipalities, large and small projects (above or below 49MW), and municipalities hosting firms in the NACE-35 industry category and otherwise. The pre (post)-opening period is defined as the one year period before (after) the start-up date. These results do not control for wind investments. Standard errors are clustered at the municipality level. The baseline results are those reported in Tables 3 and 4.

occurs. To explore this issue, we have divided the municipalities between those with and without firms in the NACE-35 category, which includes firms involved in the "Supply of electricity, gas, steam, and air conditioning". As shown in Table 7, the estimated results are not very different in the municipalities with and without NACE-35 firms. Hence, even municipalities that do not host NACE-35 firms benefit from renewable investments. This fact suggests two possibilities: the projects are carried out by firms spanning other industry categories, or other activities drive the employment effects. To explore the first possibility, we have used 2018 firm-level balance sheet data from Banco de España to compute the industry distribution of firms whose name contains the words "solar", "fotovoltaica", "viento", "wind", and "eólica". We have found that, while 80% belong to the NACE-35 category, the remaining 20% are classified into other industry categories, such as NACE-43 (specialised construction activities), NACE-68 (real estate activities) or NACE-46 (wholesale trade, except for motor vehicles and motorcycles), among others. In this regard, it is worth mentioning that almost all municipalities opening a renewable plant in our sample period (98%) host at least one firm in either NACE-35, NACE-43 or both.

Fiscal Spending. Last, we explore whether the impact of renewable investments on local finances could trigger labor market effects through fiscal spending.[67] Fiscal revenues include taxes on property, motor vehicles, economic activity and construction and building work, as well as current transfers from other bodies of government and asset revenues. These revenues finance the local provision of public services as investments in infrastructure, healthcare or transport. Both fiscal revenues and spending are established in constant terms - in adjusted 2021 euros - by using the consumer price index.

Figure 6 shows the multiplier effects when using fiscal revenues and spending as the outcome variables. Renewable investments increase fiscal revenues one year before and one year after the start-up date. However, the translation to increased fiscal spending is weak and non-significant. This suggests that the impact of renewable investments on public finances is not large enough to trigger stronger multiplier effects.

7 Solar Investments during the Second Wave

As already described in Section 3, the second investment wave in Spain started in 2019 (Figure 1). While the average size of wind parks increased from 21MW to 35MW, the increase in the mean size of the solar projects was much more pronounced, from 0.5MW to 30MW (Table B.2). To assess whether the employment and unemployment effects of the solar investments during the second wave differ from those of the initial investments, we have re-estimated the model for the entire period with installed capacities interacted with pre-2019 and post-2019 time dummies.[68]

Results are shown in Table 8. As expected, the estimated effects during the first wave remain similar to those in the baseline analysis. The second wave is characterized by quantitatively smaller local employment effects per MW, which go down to 0.56 jobs-year/MW during the construction phase and to 0.15 jobs during the maintenance phase, both being statistically significant. The local unemployment effects also get weaker. They fall to -0.04 and -0.02 persons-year/MW, respectively.[69] The weaker effects during the second wave can be explained by the presence of economies of scale and by the greater difficulties of finding enough local workers to construct large projects.

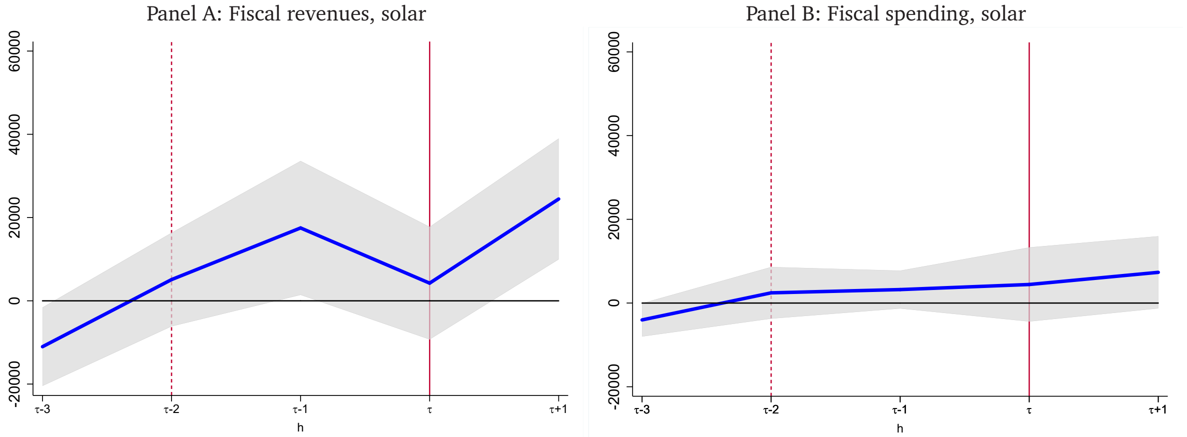
[67] Fiscal variables at the municipality level are provided by the Ministry of Finance and Civil Services. Since 2013, data is not available for the Basque Country and only around 24 % of municipalities report information for Navarre.

[68] The small number of observations for wind investments during the second wave does not allow us to reproduce the same exercise for the case of wind. The same applies to the county-level analysis. Also, to be able to estimate the multiplier for solar investments in the second wave at all horizons, the vector X_{it} includes the normalized values of the treatment variables from $t-60$ to $t+h$, rather than to $t+h+24$.

[69] Another difference between the two waves is the shorter duration of the construction phase.

Figure 6

Local fiscal effects of solar investments

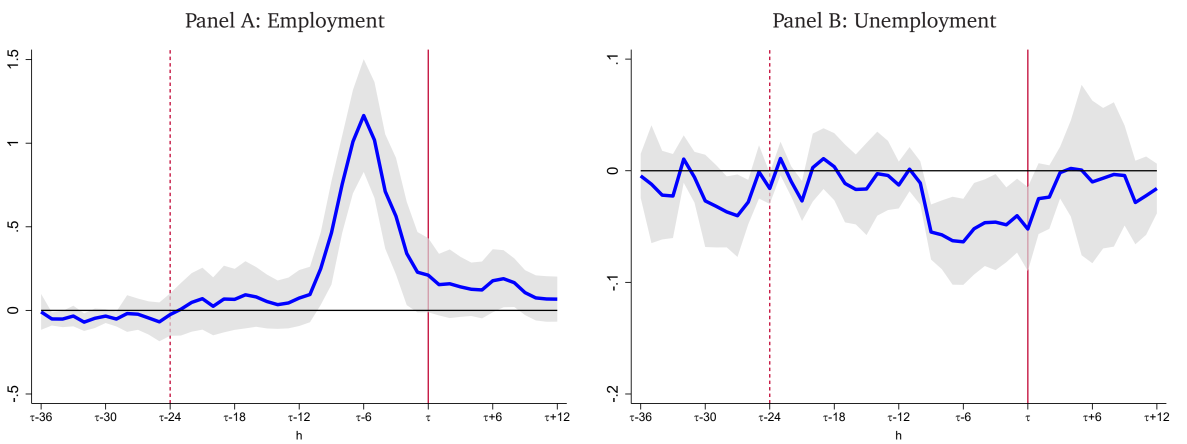


Notes: These figures show the effects of investing 1 MW on fiscal revenues and spending in the period 2007-2017, h years before or after the start-up date (marked with a vertical solid red line). Panel (a) shows the results for fiscal revenues and panel (b) for fiscal spending. Error bands depict the 95% confidence interval. Standard errors are clustered at the municipality level.

Given that investment costs fell sharply between 2010 and 2020, it is also relevant to express the job multipliers per million euros invested. As shown in Table B.13, during the construction phase, investing 1 million euros in a solar plant increased the number of workers in the municipality by 0.76, in line with the results for the first wave (0.77). Thus, although the multiplier per MW went down during the second wave, the lower investment cost delivered a similar multiplier per million euros across the two waves. During the maintenance phase, the multiplier per million euros reached 0.16, which is lower than in the first wave (0.20), consistent with the fact that most of the cost reductions accrue to construction and not so much to maintenance. The local unemployment effect per million euros invested reaches -0.08 and -0.05 during the construction and maintenance phases, respectively, for the plants that opened

Figure 7

Local employment and unemployment effects for solar



Notes: These figures show the effects of investing 1 MW of solar on employment by local firms (panel a) or unemployment of local residents (panel b), h months before or after the start-up date (marked with a vertical solid red line) for the period between January of 2019 and January of 2020. This specification controls for installed capacity until t+h in order to explore the second wave, in contrast with t+h+24 in the baseline. Thus, the first wave now includes the entire year 2018. Error bands depict the 95% confidence interval.

from 2019 onward. In contrast, during the first wave, these multipliers were -0.05 during the construction phase and positive during the maintenance phase (0.141).

7.1 Local jobs in Spain during the current decade

We can use our previous estimates to compute the potential for local job creation during the current decade when massive investments in renewable energy will take place. According to the *Spanish National Energy and Climate Plan (PNIEC)*, between 2021 and 2030, renewable capacity will sum up to 161GW, including 50GW of wind capacity and 39GW of solar photovoltaic capacity (MITECO 2020, p.12).[70] Considering the existing renewable capacity by the end of 2020 (27.5GW of wind and 11.6GW of solar), investments in these two technologies over the current decade will have to add 22.5GW and 27.4GW of wind and solar, respectively.

TABLE 8

LOCAL EMPLOYMENT AND UNEMPLOYMENT EFFECTS FOR SOLAR

	Employment		Unemployment	
	Pre-opening (1)	Post-opening (2)	Pre-opening (3)	Post-opening (4)
Fist wave (until 2018)	1.402***	0.543	-0.163***	-0.117
	(0.480)	(0.410)	(0.049)	(0.149)
Second wave (since 2019)	0.565***	0.155*	-0.042***	-0.016
	(0.122)	(0.082)	(0.014)	(0.022)
Observations	664,284	664,284	554,793	554,793
# Municipalities	3,969	3,969	3,971	3,971

Notes: This table reports the results of estimating the local employment and unemployment effects of solar investments during the period February 2006- December 2018 and between January of 2019 and January of 2020. For unemployment the first period starts in June 2008. In these regressions, installed capacity is interacted with pre-2019 and post-2019 time dummies. The multipliers in columns (1)-(2) express the number of new jobs created by local firms per MW invested and the multipliers in columns (3)-(4), the number of residents who are no longer unemployed per MW invested. The pre(post)-opening period is defined as the one year period before (after) the start-up date. Standard errors are clustered at the municipality level. Note that the results until 2018 are similar but not identical to those in Tables 3 and 4, given that we now consider a longer time span. In addition, this specification controls for installed capacity until t+h in order to explore the second wave, in contrast with t+h+24 in the baseline. Thus, the first wave now includes the entire year 2018.

Using our second-wave employment multipliers (Table 8), solar investments will allow creating 5,682 new local jobs on average per year during the current decade.[71] In particular, 1,548 local workers will be employed yearly in the construction of solar plants, while the number of local workers employed per year in maintenance activities will go from 2,223 in 2021 to 6,045 in 2030 as the cumulative capacity increases. Also, on average, local unemployment will decrease by 542 persons annually, from 345 in 2021 to 739 in 2030.

[70] The government increased the ambition of these objectives in June 2023. At the time of writing this paper the new objectives have not yet been approved by the European Commission.

[71] We have computed these estimates assuming that the construction lasts for a year (in line with our results) and that maintenance occurs from the end of the plant's construction until the end of its lifetime. Accordingly, the number of jobs created during the maintenance phase has been computed by applying the second-wave employment multiplier over the cumulative capacity that occurs from 2021 onward.

It is difficult to estimate what these numbers represent over the total impact of renewable investments on national employment and unemployment. However, they are far from the Spanish government's estimates, which indicate that, at the national level, the planned renewable investments will generate between 107,000 and 135,000 jobs per year in the period 2021 to 2030, as compared to the scenario without investment. Investments in solar represent approximately one-fourth of the total renewable investments. Even if we multiplied our local estimates by 4 to account for this, or even by a larger digit (allowing for the possibility that other renewable investments might have stronger local effects), the resulting local labor market effects would be far from the national estimates. There are two possibilities: either the national figures are over-estimated, or only a small fraction of the positive employment effects remain within the local municipalities where the investments occur.

8 Conclusions

Our work is one of the first comprehensive analyses of the effects of renewable investments on local employment and unemployment. We have found that the magnitude and pattern of the effects vary with the size, type, and timing of the renewable investments.

While investments in solar plants positively impact employment by local firms, the weak effects on unemployment suggest that some of the new jobs end up in the hands of non-residents. Compared to solar investments, the impacts of wind investments are much weaker, with only a very mild reduction in unemployment during the maintenance phase and no employment effects, even when we account for spatial effects.

The relatively small magnitude of the local effects, particularly in wind investments, does not mean that renewable investments do not create jobs on a broader scale. Indeed, it is plausible that a large fraction of the employment benefits accrue away from the hosting municipalities. However, since the acceptance of these investments by the local communities is a necessary condition for the broader deployment of renewable energies, our evidence suggests that the hosting municipalities should be compensated so as to share the gains from renewable investments more evenly. Several options have been proposed: promoting local energy communities so that residents have stakes in the new projects (Caramizaru and Uihlein, 2020),[72] reducing the electricity prices for local residents, increasing the local taxes paid by the renewable investors, reserving quotas for local projects in the national renewable auctions or prioritizing grid access to those projects that

[72] As an example of a local initiative in which the developer has allowed neighbors to have stakes in the project, see "Los vecinos podrán obtener rentabilidad económica de la Planta Solar de Puerto Lumbreras" SolarNews, Abril 2022. Gazmararian and Tingley (2023) propose solutions to build local support for the energy transition.

promise to provide greater local benefits.[73] To the extent that the weak local multipliers are explained by the lack of a skilled labour force, training programs at the local level might also contribute to strengthening the local labour market benefits of investing in renewable energies.

[73] These last two measures have already been put in place in Spain. Since June 2021, the tenders to grant access to the electricity grid may consider criteria such as the number of local jobs created or the fraction of profits invested in the areas where the projects are located. Also, in October 2021, the Spanish government ran a renewable auction in which 10% of the auctioned capacity (300 MW) was reserved for small local projects.

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Online Appendix

A Event study estimates

In this section we compare our baseline results with those obtained from an event study design. In particular, we estimate a generalized event study that accounts for multiple treatment events of different intensities, see Schmidheiny and Siegloch (2020). The model takes the following form:

$$y_{i,t} = \sum_{h=-36}^{12} \beta_h S_{i,t}^{\tau+h} + \sum_{h=-36}^{12} \zeta_h W_{i,t}^{\tau+h} + \alpha_i + \lambda_t + \epsilon_{i,t} \tag{7}$$

where $y_{i,t}$ is either employment or unemployment in month t, α_i are municipality fixed-effects, λ_t are month fixed-effects, and $S_{i,t}^{\tau+h}$ and $W_{i,t}^{\tau+h}$ are the treatment variables, which account for the variation in the cumulative renewable installed capacity in $t-h$ (with binned endpoints) for solar and wind, as formally defined below. As in Section 5, in order to measure the job multiplier of investing 1 MW of renewable capacity, we normalize both the dependent variable and the cumulative installed capacities by population in $t-36$.

The event-window spans the same time period as in the baseline, i.e., from $\tau-36$ to $\tau+12$, where τ is the start-up date. We assume that the treatment effects remain constant before $\tau-36$ and after $\tau+12$, which leads us to bin the treatment variable at the endpoints of the event-window. In particular, the treatment variable takes the following form:

$$S_{i,t}^{\tau+h} = \begin{cases} \sum_{m=-(\bar{t}-t)}^{-36} \Delta k_{i,t-m}^{s} & \text{if} \quad h=-36 \\ \Delta k_{i,t-h}^{s} & \text{if} \quad -36 < h < 12 \\ \sum_{m=12}^{t-\underline{t}} \Delta k_{i,t-m}^{s} & \text{if} \quad h = 12 \end{cases}$$

$$W_{i,t}^{\tau+h} = \begin{cases} \sum_{m=-(\bar{t}-t)}^{-36} \Delta k_{i,t-m}^{w} & \text{if} \quad h=-36 \\ \Delta k_{i,t-h}^{w} & \text{if} \quad -36 < h < 12 \\ \sum_{m=12}^{t-\underline{t}} \Delta k_{i,t-m}^{w} & \text{if} \quad h = 12 \end{cases}$$

where $k_{i,t}^{s}$ ($k_{i,t}^{w}$) is the solar (wind) cumulative installed capacity normalized by population from $\underline{t}$ to t and Δ is the first-difference operator: $\Delta x_{i,t} = x_{i,t} - x_{i,t-1}$. In constructing the treatment variable, we consider shocks since 2001, hence $\underline{t}$ is set to January 2001, whereas $\bar{t}$ is set to January 2021 (the last month with renewable investments data available). As in the baseline, we restrict the estimates to the first wave of renewable energy investments, by excluding the observations within a two-year period of a solar plant opening if it happens after 2018. Since the treatment effects in equation (7) are only identified up to a constant, we normalize the coefficient two years before the start-up date to zero ($\beta_{\tau-24} = 0$).[74, 75]

Figures A.1 and A.2 show the employment and unemployment results, respectively, for monthly, quarterly and yearly data. Table A.1 reports the average value of the coefficients, one year before and one year after the investments' start-up dates. The results of the event study are similar to those of our baseline analysis based on local projections, both regarding the value of the multipliers as well as their patterns over time.

TABLE A.1

LOCAL EMPLOYMENT AND UNEMPLOYMENT EFFECTS - EVENT STUDY ESTIMATES

	Employment		Unemployment	
	Pre-opening (1)	Post-opening (2)	Pre-opening (3)	Post-opening (4)
Solar Multiplier (Jobs/MW)	1.318***	0.883*	-0.074	-0.001
	(0.488)	(0.530)	(0.058)	(0.118)
Wind Multiplier (Jobs/MW)	0.107	0.241**	-0.028	-0.015
	(0.072)	(0.110)	(0.023)	(0.028)
# Obs.	718,995	718,995	609,571	609,571
# Municipalities	3,969	3,969	3,974	3,974

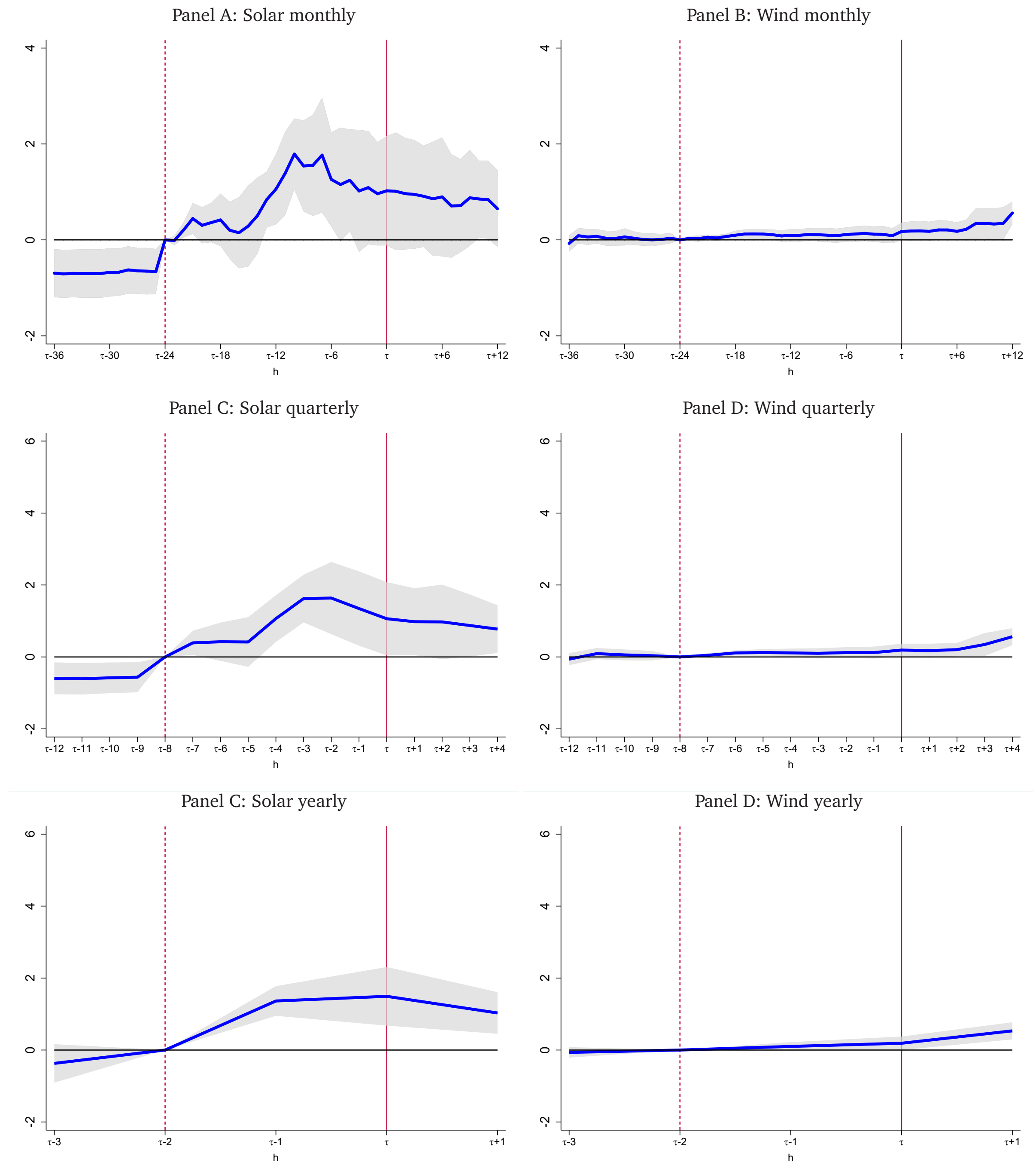
Notes: This table reports the results of estimating the employment and unemployment effects through the event study described in equation (7), for solar and wind at the municipality level for the baseline periods January 2003-December 2018 (employment) and May 2005-December 2018 (unemployment). The multipliers express the number of new jobs created by local firms per MW invested. The pre(post)-opening period is defined as the one year period before (after) the start-up date. Standard errors are clustered at the municipality level.

[74] Notice that there are some differences between the event study design displayed in equation (7) and the baseline local projection model of equation (1). First, the local projection model leverages leads and lags of the dependent variable in multiple regressions, whereas the event study employs a set of leads and lags of the treatment variable in one single regression. Second, the local-projection model controls for the dynamics of the dependent variable up to the start of the event window, and incorporates a different amount of lags and leads of the treatment variable. Third, in the event study the treatment variable is computed by fist-differencing the normalized *cumulative* installed capacity, and it is binned at the endpoints of the event window. In local projections, the treatment is normalized new capacity installed in month t. Fourth, the sample periods over which both models are estimated differ. For example, for the employment results, equation (1) is estimated from February 2006 to January 2018. This is so because the data starts in January 2003, and the first local projection regression leverages the $t - 36$ value of employment, plus one lag as control, and controls for renewable investments until $t + h + 24$. On the contrary, since the dependent variable in equation (7) is the t value of employment, the sample period starts in January 2003. Yet it ends in February 2018, because it uses the $t + 36$ value of the treatment, and the last month with renewable plants data is January 2021 (following Schmidheiny and Siegloch (2020), the February 2018 value of $S_{i,t}^{\tau+36}$ is assumed to be zero). Fifth, note that the $\beta_{\tau-24}$ estimated value in equation (7) is normalized and set to zero, since equation (7) is only identified up to a constant.

[75] As Schmidheiny and Siegloch (2020) show, the specification of equation (7) is equivalent to a distributed-lag model of the following form: $y_{i,t} = \sum_{h=-35}^{12} \gamma_{\tau+h} k_{i,t-h}^{s} + \sum_{h=-35}^{12} \delta_{\tau+h} k_{i,t-h}^{w} + \alpha_i + \lambda_t + \epsilon_{i,t}$, where the $\beta_{\tau+h}$'s and $\zeta_{\tau+h}$'s can be recovered from a combination of the $\gamma_{\tau+h}$'s and $\delta_{\tau+h}$'s, respectively.

FIGURE A.1

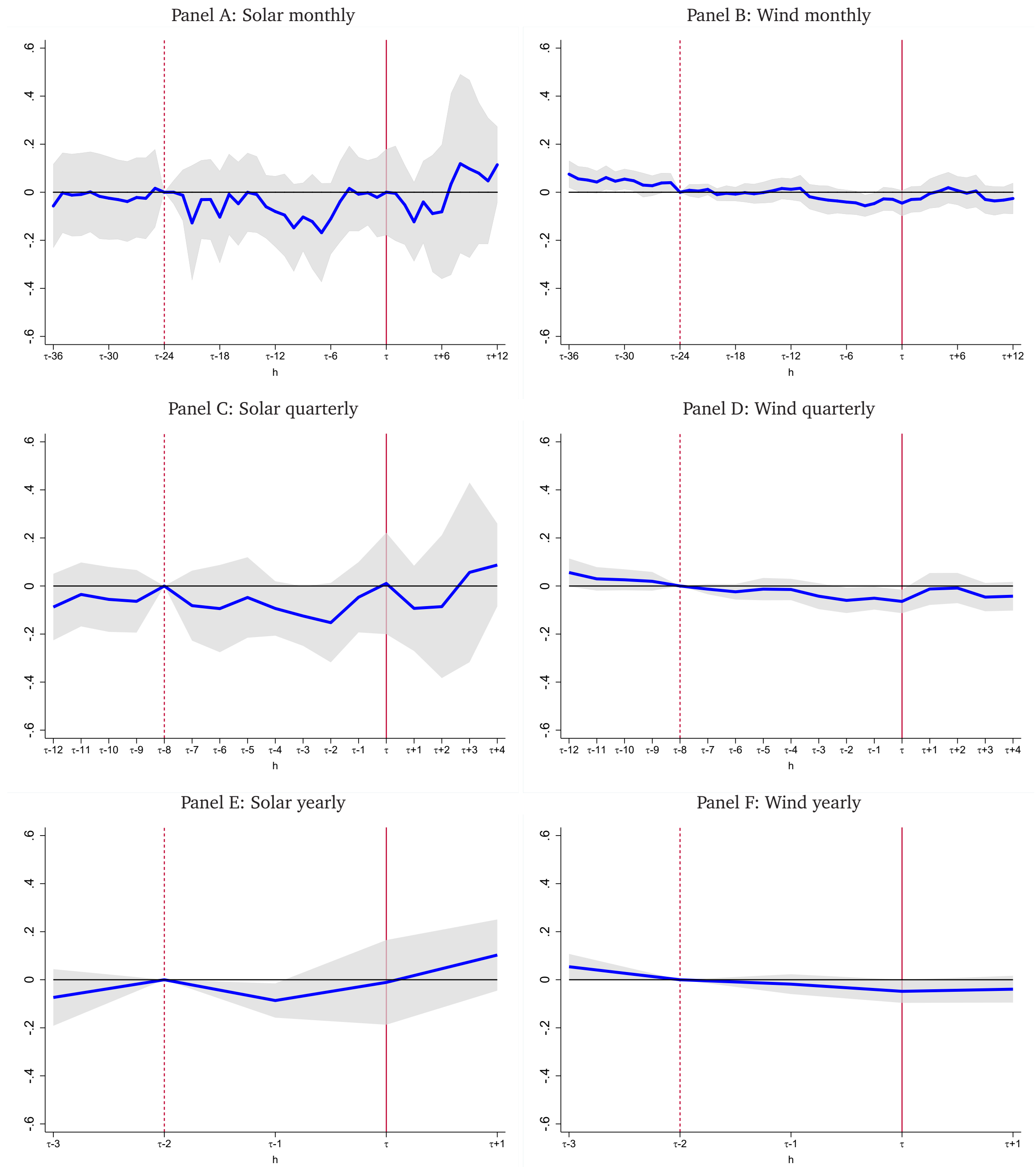
LOCAL EMPLOYMENT EFFECTS - EVENT STUDY ESTIMATES



Notes: These figures show the effects of investing 1 MW on employment by firms located at the municipalities where the investment occurs, h periods before or after the start-up date (marked with a vertical solid red line). The model is an event study described in equation (7). Panels (a) and (b) show the results for solar and wind investments using monthly data. Panels (c) and (d) show these results using quarterly information. Panels (e) and (f) show these results using yearly information. Standard errors are clustered at the municipality level.

Figure A.2

Local unemployment effects - event study estimates



Notes: These figures show the effects of investing 1 MW on unemployment by residents in the municipality where the investment occurs, h periods (months, quarters or years) before or after the start-up date (marked with a vertical solid red line). The model is an event study described in equation (7). Panels (a) and (b) show the results for solar and wind investments using monthly data. Panels (c) and (d) show these results using quarterly information. Panels (e) and (f) show these results using yearly information. Error bands depict the 95% confidence interval. Standard errors are clustered at the municipality level.

B Further Results

TABLE B.2

SAMPLE STATISTICS

	(1) Solar	(2) Wind
Municipalities opening at least one plant		
All (2006-2018)	2,698	205
All (2019-2020)	107	33
Rural (2006-2018)	1,556	142
Urban (2006-2018)	1,142	63
Size of shocks (2006-2018, MW)		
Mean	0.519	20.604
Percentile 25	0.015	5.250
Percentile 50	0.049	15.950
Percentile 75	0.110	30.000
Size of shocks (2019-2020, MW)		
Mean	29.512	35.101
Percentile 25	0.090	15.000
Percentile 50	0.840	27.852
Percentile 75	39.983	39.600

Notes: This table shows the number of municipalities opening renewable plants during the two investment waves, as well as the plants' size distribution.

B.1 Results at the county level

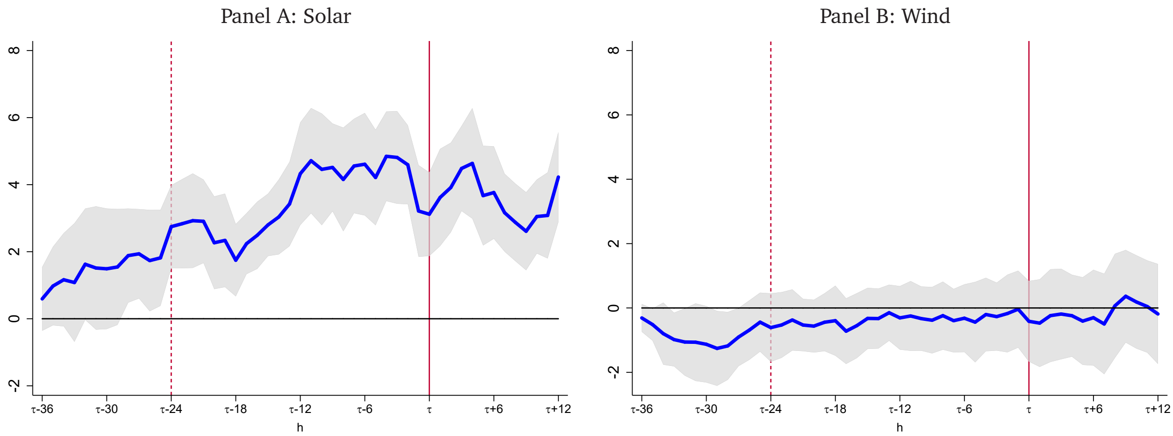
TABLE B.3

EMPLOYMENT AND UNEMPLOYMENT EFFECTS AT THE COUNTY LEVEL

	Employment		Unemployment	
	Pre-opening (1)	Post-opening (2)	Pre-opening (3)	Post-opening (4)
Solar Multiplier (Jobs/MW)	4.494***	3.535***	-1.419*	-0.580
	(0.437)	(0.544)	(0.736)	(0.726)
Wind Multiplier (Jobs/MW)	-0.329	-0.087	-0.124	-0.264*
	(0.543)	(0.784)	(0.160)	(0.152)
# Obs.	46,002	46,002	38,299	38,299
# Counties	321	321	321	321

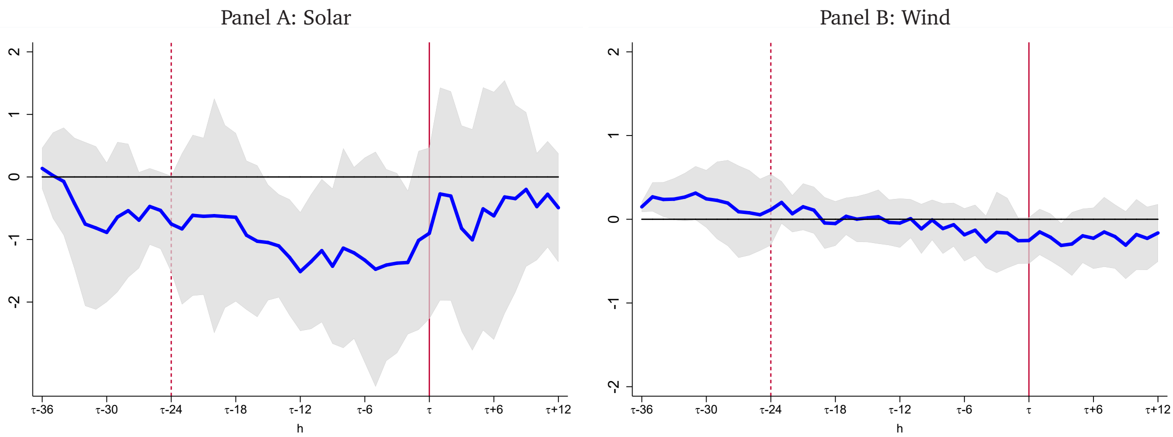
Notes: This table reports the results of estimating the local employment effects at the county level for the period February 2006-January 2018 and the local unemployment effects between June 2008 and January 2018. The multipliers express the number of new jobs created by local firms and the number of residents who are no longer unemployed per MW invested. The pre(post)-opening period is defined as the one year period before (after) the start-up date. Standard errors are clustered at the county level.

Figure B.3
Employment effects - County level



Notes: These figures show the effects of investing 1 MW on employment by firms located at the county where the investment occurs in the period February 2006-January 2018, h periods before or after the start-up date (marked with a vertical solid red line). Panel (a) shows the results for solar investments, and panel (b) for wind investments. Error bands depict the 95% confidence interval. Standard errors are clustered at the county level.

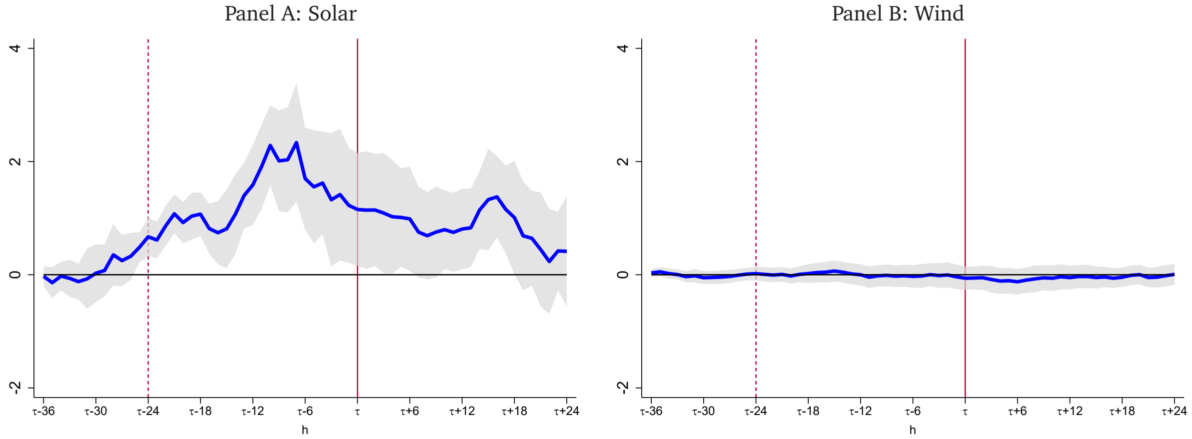
Figure B.4
Unemployment effects. County level



Notes: These figures show the effects of investing 1 MW on unemployment by residents in the county where the investment occurs in the period June 2008-January 2018, h periods before or after the start-up date (marked with a vertical solid red line). Panel (a) shows the results for solar investments, and panel (b) for wind investments. Error bands depict the 95% confidence interval. Standard errors are clustered at the county level.

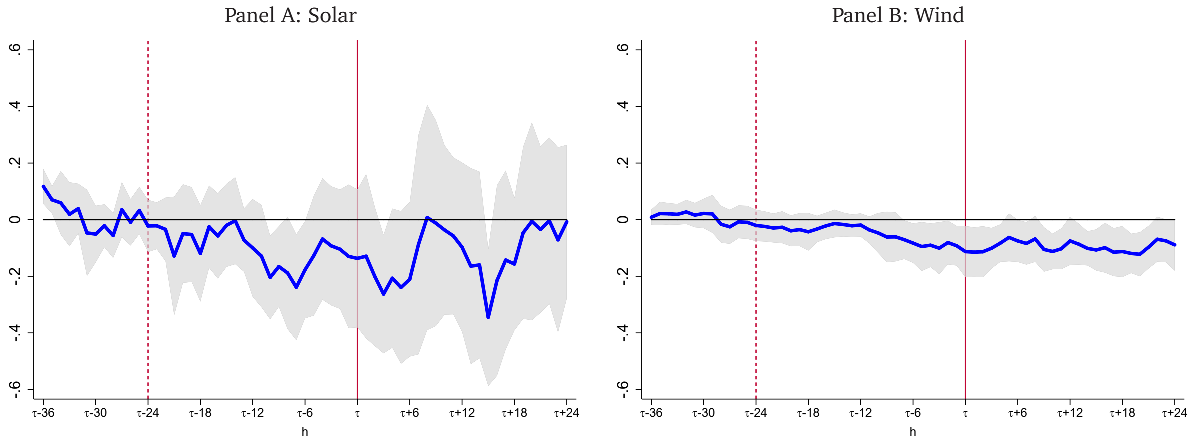
B.2 Results from $\tau - 36$ until $\tau + 24$

FIGURE B.5
LOCAL EMPLOYMENT EFFECTS



Notes: These figures show the effects of investing 1 MW on employment by firms located at the municipalities where the investment occurs in the period February 2006-January 2017, h months before or after the start-up date (marked with a vertical solid red line). Panel (a) shows the results for solar investments and panel (b) for wind investments. Error bands depict the 95% confidence interval. Standard errors are clustered at the municipality level.

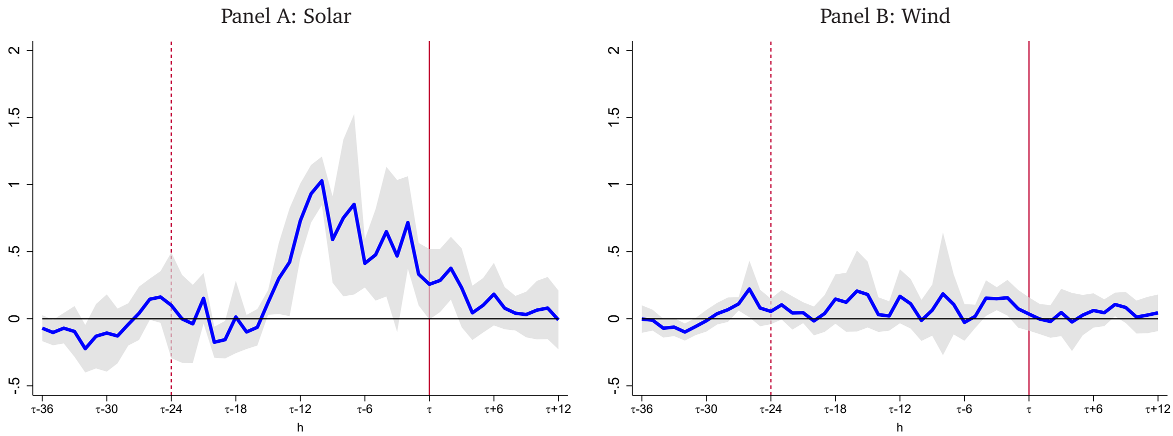
FIGURE B.6
LOCAL UNEMPLOYMENT EFFECTS



Notes: These figures show the effects of investing 1 MW on unemployment by residents in the municipality where the investment occurs in the period June 2008-January 2017, h months before or after the start-up date (marked with a vertical solid red line). Panel (a) shows the results for solar investments, and panel (b) for wind investments. Error bands depict the 95% confidence interval. Standard errors are clustered at the municipality level.

B.3 Results per million euros invested

FIGURE B.7
EMPLOYMENT EFFECTS PER 1 MILLION EUROS



Notes: These figures show the effects of investing one million euros on employment by firms located at the municipalities where the investment occurs in the period January 2012-January 2018, h periods before or after the start-up date (marked with a vertical solid red line). Panel (a) shows the results for solar investments, and panel (b) for wind investments. Error bands depict the 95% confidence interval. Standard errors are clustered at the municipality level.

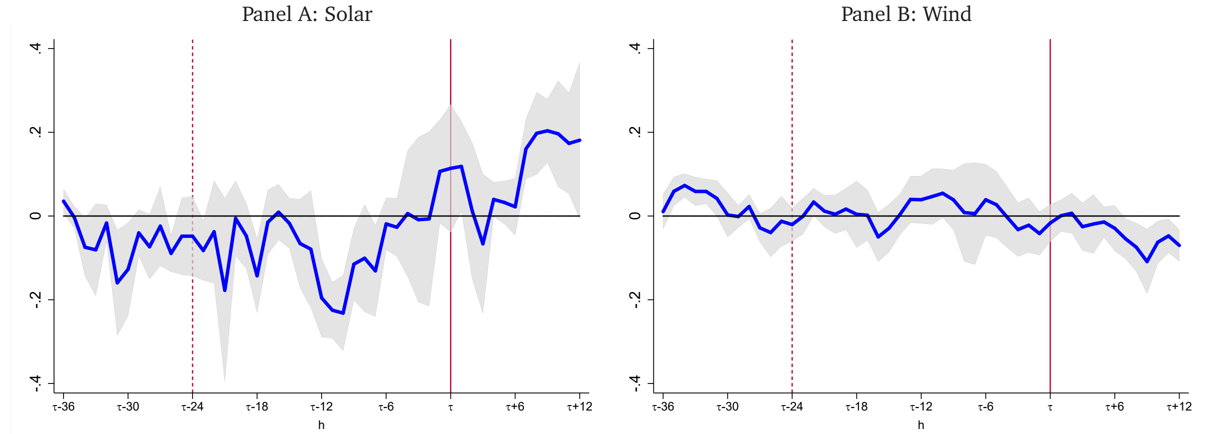
TABLE B.4
EMPLOYMENT AND UNEMPLOYMENT EFFECTS PER 1 MILLION EUROS

	Employment		Unemployment	
	Pre-opening (1)	Post-opening (2)	Pre-opening (3)	Post-opening (4)
Solar Multiplier (Jobs/million euros)	0.654***	0.147**	-0.075**	0.102***
	(0.053)	(0.067)	(0.037)	(0.024)
Wind Multiplier (Jobs/million euros)	0.095	0.034	0.012	-0.038*
	(0.076)	(0.061)	(0.033)	(0.021)
# Obs.	284,308	284,308	288,681	288,681
# Municipalities	3,966	3,966	3,969	3,969

Notes: This table reports the results of estimating the local employment and unemployment effects at the municipality level for the period January 2012-January 2018. The multipliers express the number of new jobs created by local firms and the number of residents who are no longer unemployed per million euros invested. The pre(post)-opening period is defined as the one year period before (after) the start-up date. Standard errors are clustered at the municipality level.

FIGURE B.8

UNEMPLOYMENT EFFECTS PER ONE MILLION EUROS

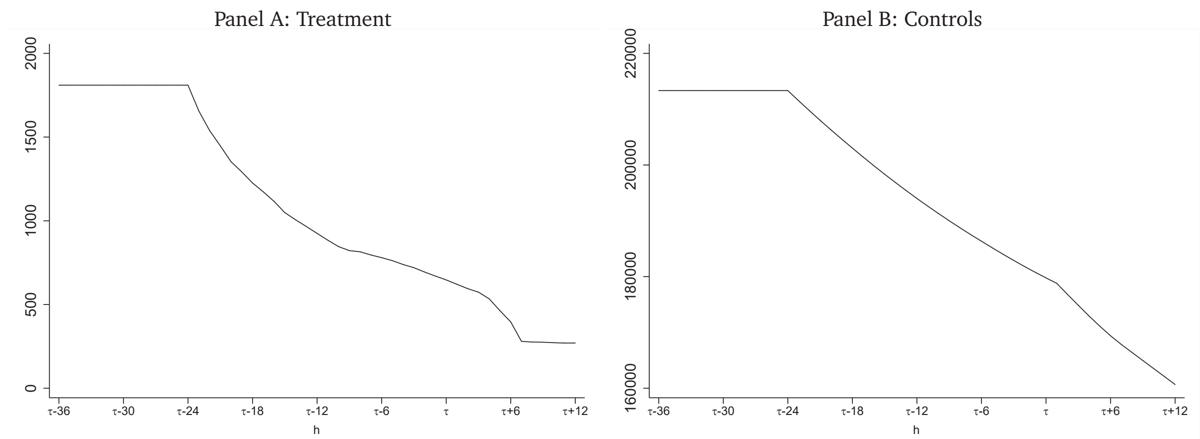


Notes: These figures show the effects of investing one million euros on unemployment by residents in the municipality where the investment occurs in the period January 2012-January 2018, h periods before or after the start-up date (marked with a vertical solid red line). Panel (a) shows the results for solar investments, and panel (b) for wind investments. Error bands depict the 95% confidence interval. Standard errors are clustered at the municipality level.

B.4 Clean control condition

FIGURE B.9

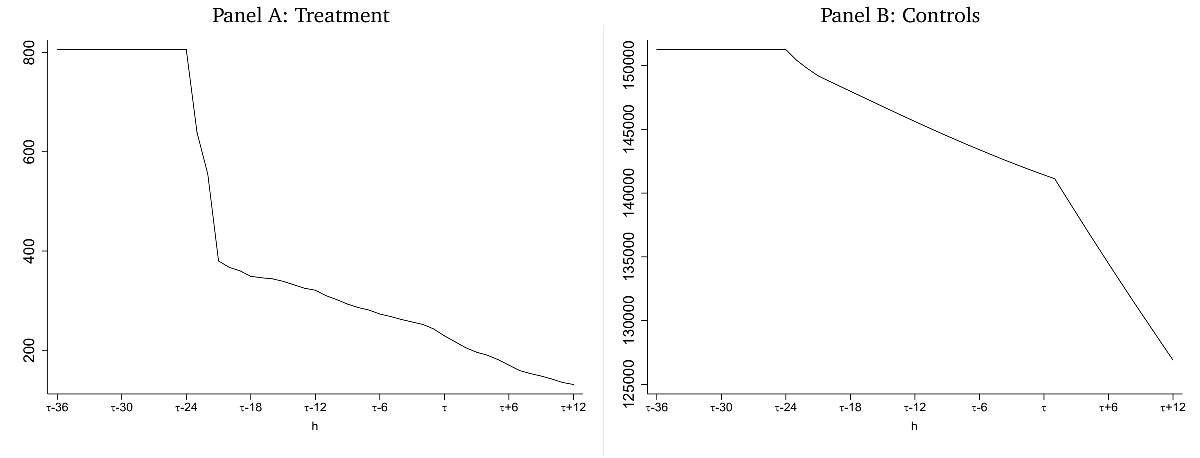
EMPLOYMENT EFFECTS - CLEAN CONTROL - NUMBER OF TREATED AND CONTROL OBSERVATIONS



Notes: This figure shows at each horizon *h* for employment the number of observations acting as treatment and control units in the regressions applying the clean control condition discussed in Section 5.1.

FIGURE B.10

UNEMPLOYMENT EFFECTS - CLEAN CONTROL - NUMBER OF TREATED AND CONTROL OBSERVATIONS



Notes: This figure shows at each horizon h for unemployment the number of observations acting as treatment and control units in the regressions applying the clean control condition discussed in Section 5.1.

TABLE B.5

LOCAL UNEMPLOYMENT EFFECTS - CLEAN CONTROL

	Baseline		Municipalities opening at most one plant		Clean Control	
	Pre-opening (1)	Post-opening (2)	Pre-opening (3)	Post-opening (4)	Pre-opening (5)	Post-opening (6)
Solar (Jobs/MW)	-0.188***	-0.135	-0.537**	-0.575***	0.007	0.121
	(0.058)	(0.141)	(0.216)	(0.179)	(0.136)	(0.251)
Wind (Jobs/MW)	-0.076**	-0.094***	-0.117*	-0.178***	-0.150	-0.028
	(0.035)	(0.035)	(0.067)	(0.061)	(0.130)	(0.049)
Observations	458,711	458,711	178,824	178,824	141,974	141,655
# Municipalities	3,967	3,967	1,545	1,545	1,380	1,364

Notes: This table reports the results of estimating the unemployment effects through equations (2) and (3) at the municipality level for the baseline period June 2008-January 2018. The pre(post)-opening period is defined as the one year period before (after) the start-up date. Standard errors are clustered at the municipality level. In columns 3 and 4 the sample is restricted to municipalities that opened at most one renewable energy plant in the sample period. In columns 5 and 6, treatment and control observations are restricted in order to take into account the staggered adoption. In these last two specifications, lags and leads of the treatment variables are not added.

B.5 Robustness of the Baseline Results

TABLE B.6

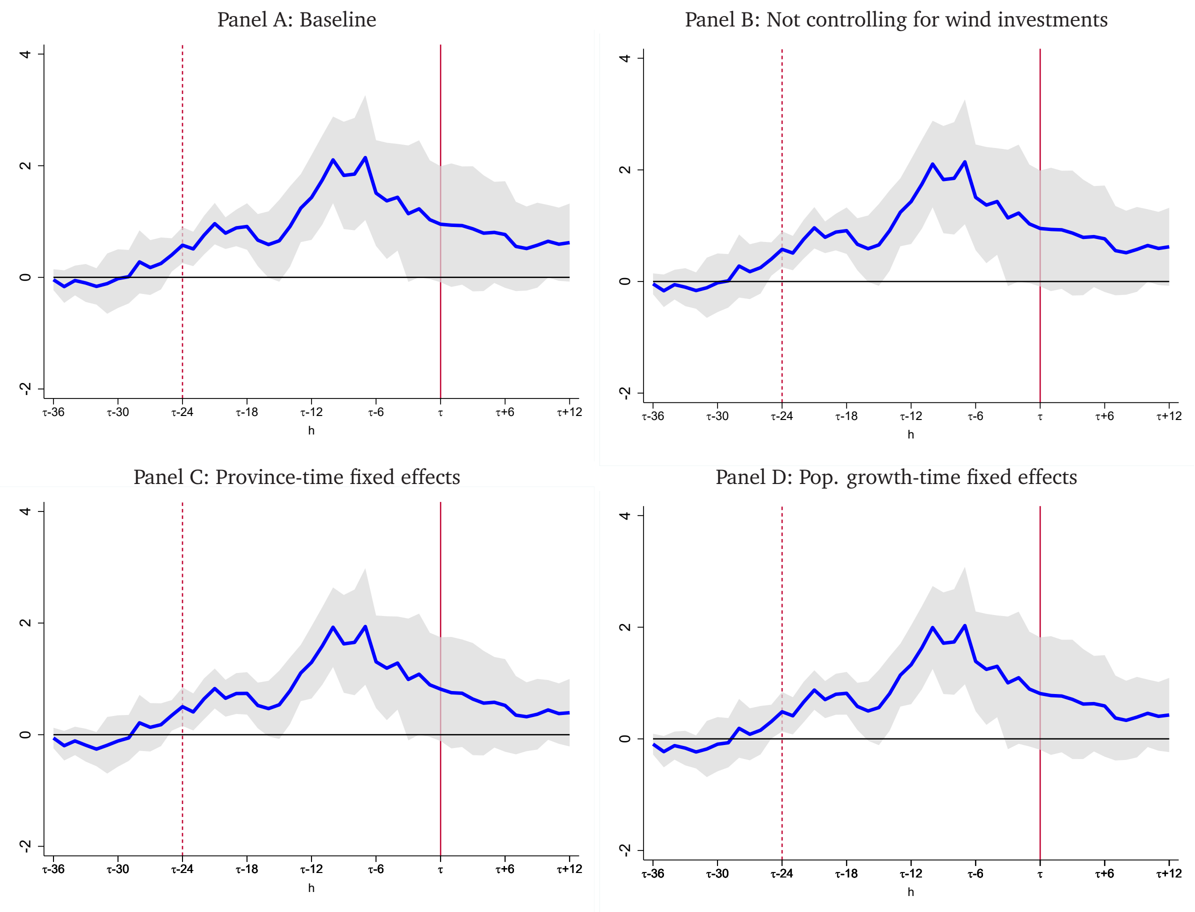
LOCAL EMPLOYMENT EFFECTS - ROBUSTNESS

	Baseline (1)	Only Solar (2)	Only Wind (3)	Province-time FE (4)	Pop.growth-time FE (5)
Pre-opening					
Solar Multiplier (Jobs/MW)	1.537***	1.536***		1.353***	1.415***
	(0.507)	(0.507)		(0.447)	(0.476)
Wind Multiplier (Jobs/MW)	-0.023		-0.019	0.017	0.013
	(0.095)		(0.095)	(0.095)	(0.098)
Post-opening					
Solar Multiplier (Jobs/MW)	0.740*	0.739*		0.537	0.567
	(0.442)	(0.441)		(0.381)	(0.419)
Wind Multiplier (Jobs/MW)	-0.063		-0.059	-0.026	-0.018
	(0.098)		(0.098)	(0.094)	(0.100)

Notes: This table reports the results of conducting several robustness tests for the impact of solar and wind investments on employment at the municipality level. Column 1 reports the baseline results. Columns 2 and 3 only account for solar and wind investments respectively. Column 4 interacts the time fixed-effects with province dummies. Columns 5 interacts the time fixed-effects with population growth decile between t-48 and t-36. All results remain similar as in the baseline.

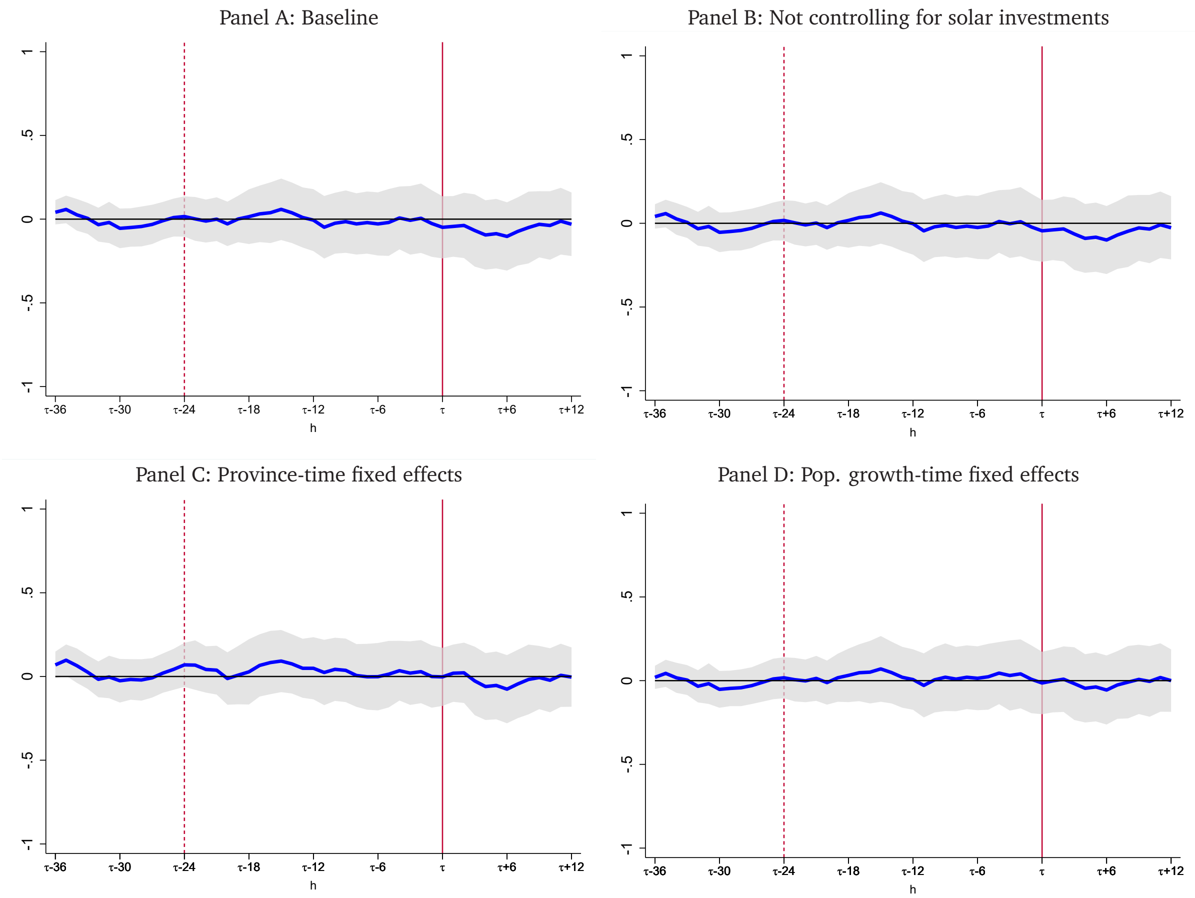
FIGURE B.11

EMPLOYMENT EFFECTS OF SOLAR ENERGY - ROBUSTNESS



Notes: These figures report the results of conducting several robustness tests for the impact of solar investments on employment at the municipality level. Panel A reports the baseline results. Panel B does not control for investments in the other technology (wind in this case). Panel C interacts the time fixed-effects with province dummies. Panel D interacts the time fixed-effects with population growth decile between t-48 and t-36. All results remain similar as in the baseline.

Figure B.12
Employment effects of wind energy - Robustness



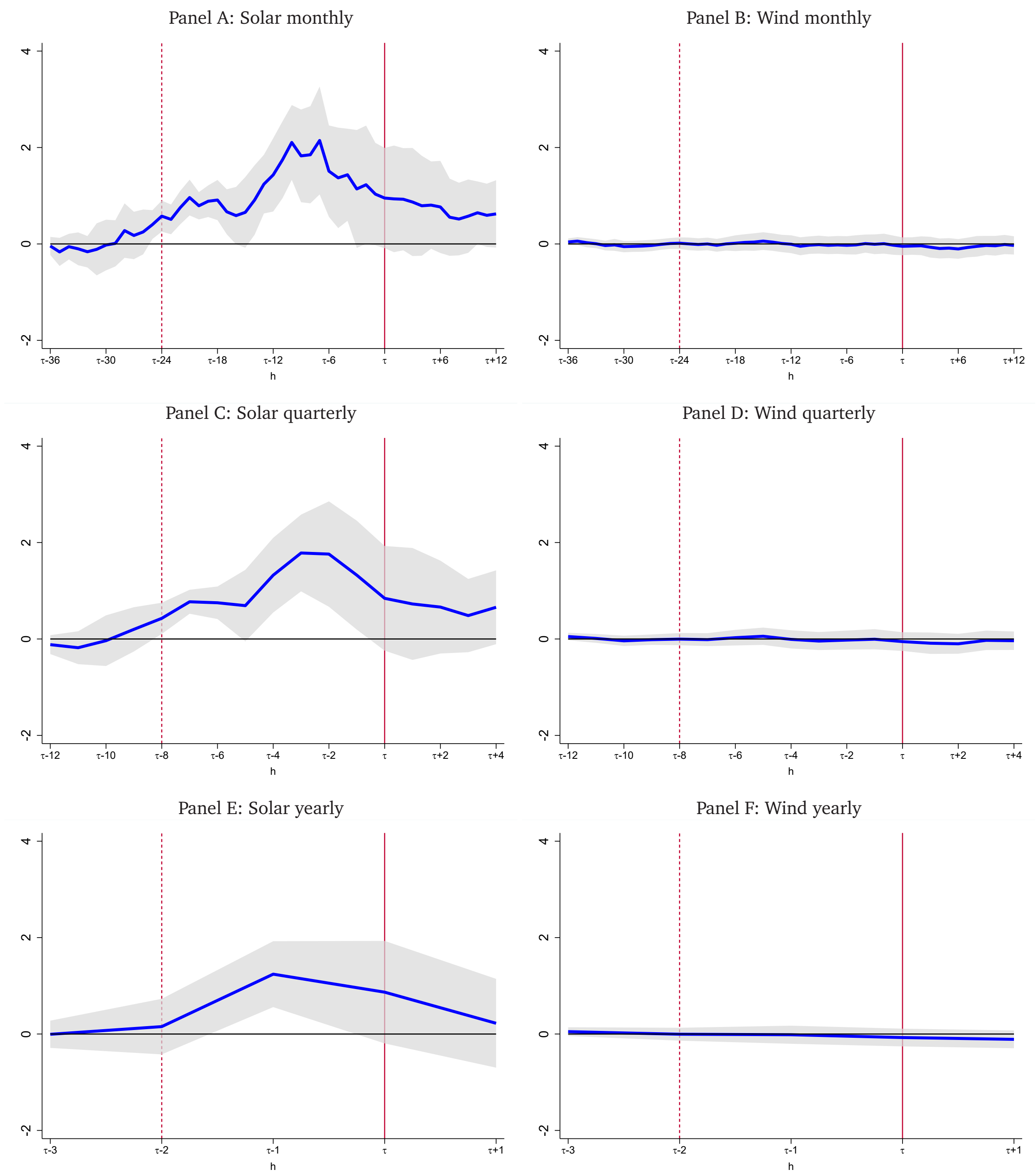
Notes: These figures report the results of conducting the same robustness tests as in the previous figure, but now for the impact of wind investments on employment at the municipality level. All results remain similar as in the baseline.

TABLE B.7
LOCAL EMPLOYMENT EFFECTS - ALTERNATIVE STANDARD ERRORS

	Municipality		County	
	Pre-opening (1)	Post-opening (2)	Pre-opening (3)	Post-opening (4)
Solar				
Multiplier (Jobs/MW)	1.537	0.740	4.494	3.535
Standard errors				
Baseline	0.507***	0.442*	0.437***	0.544***
Two-way clustering	0.584***	0.524	0.657***	0.811***
HAC	0.442***	0.388*	0.845***	0.869***
Driscoll and Kraay	0.451***	0.423*	0.777***	0.959***
Wind				
Multiplier (Jobs/MW)	-0.023	-0.063	-0.329	-0.087
Standard errors				
Baseline	0.095	0.098	0.543	0.784
Two-way clustering	0.126	0.136	0.660	0.903
HAC	0.078	0.081	0.387	0.624
Driscoll and Kraay	0.084	0.089	0.378	0.657
# Obs.	568,261	568,261	46,002	46,002
# Municipalities/counties	3,964	3,964	321	321

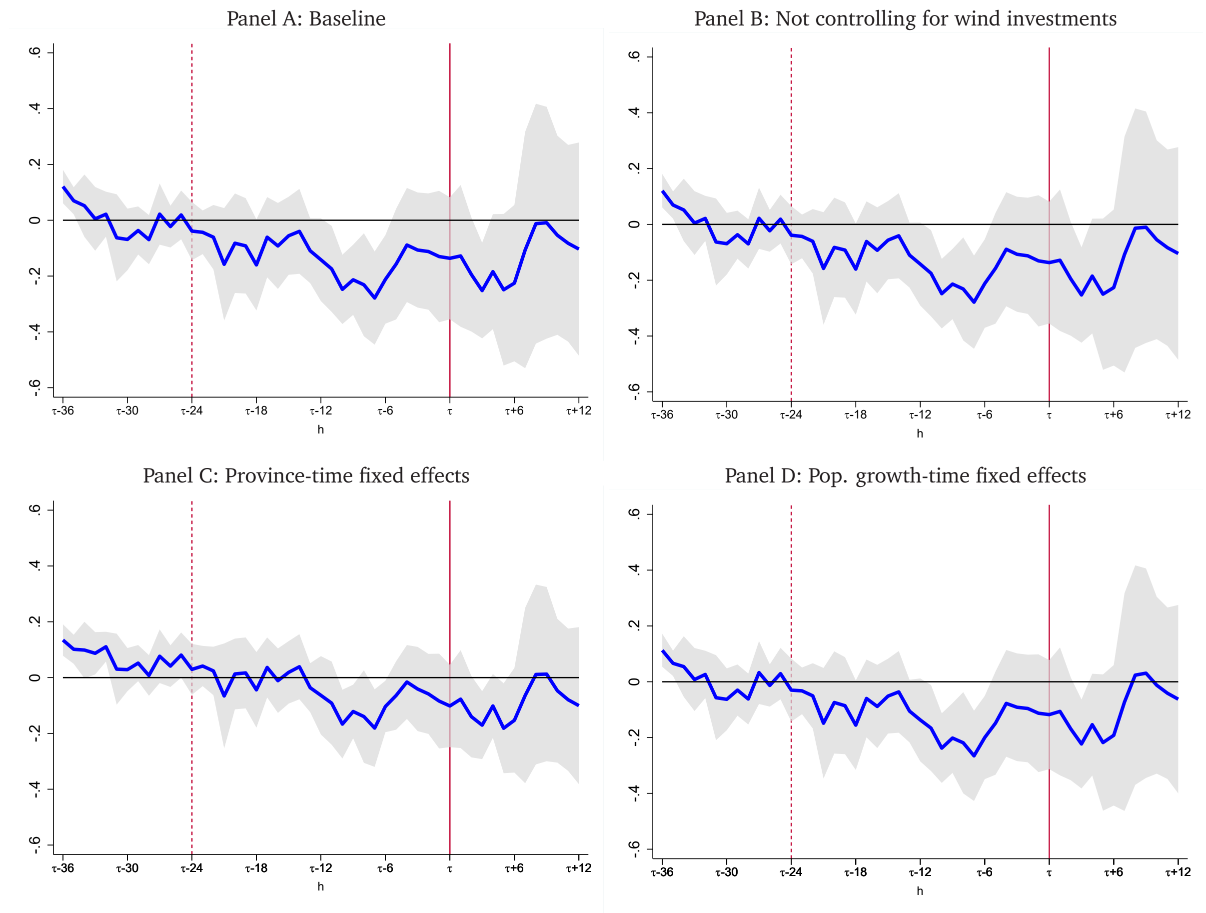
Notes: This table reports the cumulative multipliers (equations (2) and (3), and Table 3), under different strategies of computing the standard errors. In particular, two-way clustered (by municipality or county and month) standard errors, standard errors robust to heteroskedasticity and autocorrelation (HAC), and Driscoll and Kraay standard errors are reported. The last two uses a bandwidth of 3.

FIGURE B.13
LOCAL EMPLOYMENT EFFECTS - MONTHLY, QUARTERLY AND YEARLY DATA



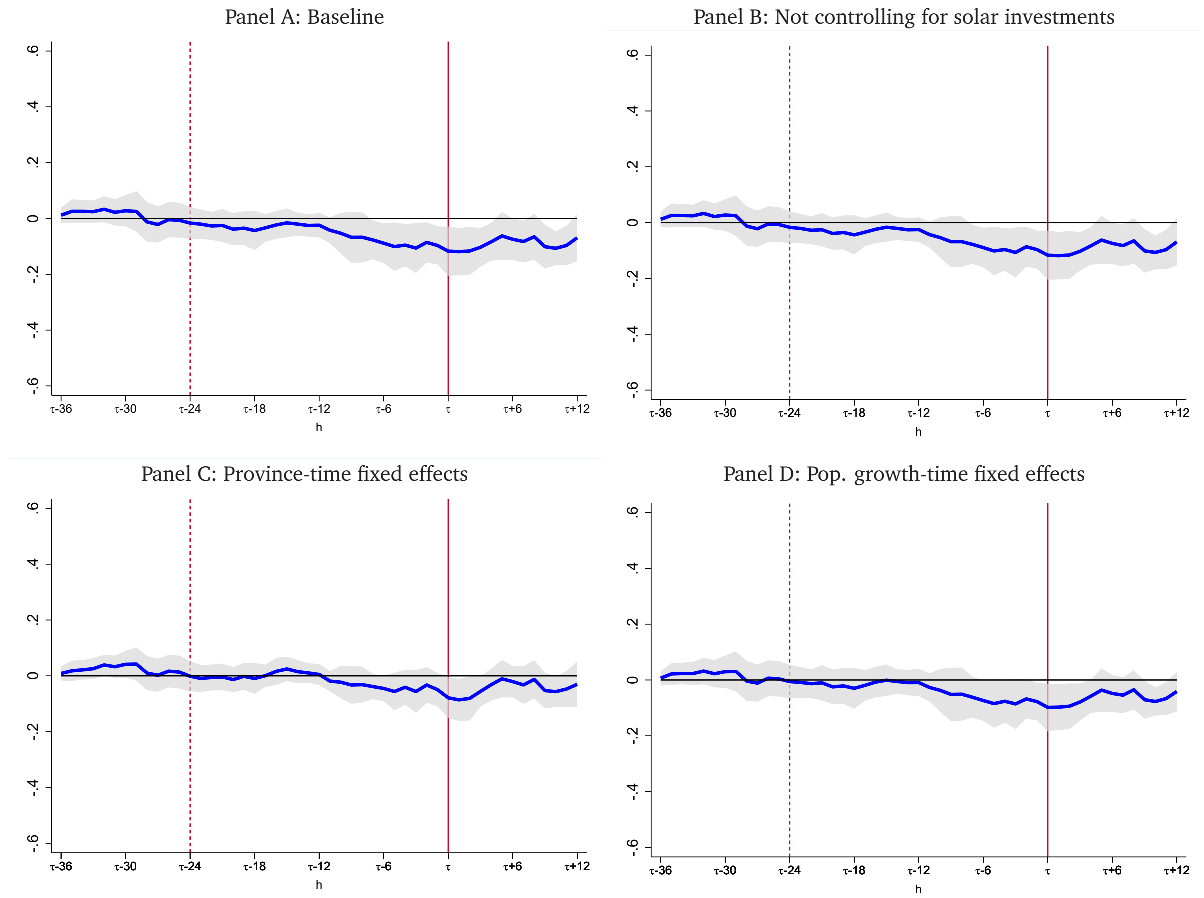
Notes: These figures show the effects of investing 1 MW on employment by firms located at the municipalities where the investment occurs, h periods before or after the start-up date (marked with a vertical solid red line). Panels (a) and (b) show the results for solar and wind investments using monthly data. Panel (c) and (d) show these results using quarterly information. Panels (e) and (f) show the results using yearly data. Error bands depict the 95% confidence interval. Standard errors are clustered at the municipality level.

FIGURE B.14
UNEMPLOYMENT EFFECTS OF SOLAR ENERGY - ROBUSTNESS



Notes: These figures report the results of conducting the same robustness tests as in figure B.11, but now for the impact of solar investments on unemployment at the municipality level. All results remain similar to the baseline.

Figure B.15
Unemployment effects of wind energy - Robustness



Notes: These figures report the results of conducting the same robustness tests as in figure B.11, but now for the impact of wind investments on unemployment at the municipality level. All results remain similar to the baseline.

Table B.8
Local unemployment effects - Robustness

	Baseline (1)	Only Solar (2)	Only Wind (3)	Province-time FE (4)	Pop.growth-time FE (5)
Pre-opening					
Solar Multiplier (Jobs/MW)	-0.188***	-0.188***		-0.099***	-0.173***
	(0.058)	(0.058)		(0.030)	(0.054)
Wind Multiplier (Jobs/MW)	-0.076**		-0.076**	-0.035	-0.058
	(0.035)		(0.035)	(0.027)	(0.036)
Post-opening					
Solar Multiplier (Jobs/MW)	-0.135	-0.136		-0.090	-0.104
	(0.141)	(0.141)		(0.095)	(0.124)
Wind Multiplier (Jobs/MW)	-0.094***		-0.093***	-0.047	-0.067**
	(0.035)		(0.035)	(0.029)	(0.031)

Notes: This table reports the results of conducting several robustness tests for the impact of solar and wind investments on unemployment at the municipality level. Column 1 reports the baseline results. Columns 2 and 3 only account for solar and wind investments respectively. Column 4 interacts the time fixed-effects with province dummies. Columns 5 interacts the time fixed-effects with population growth decile between t-48 and t-36. All results remain similar as in the baseline.

Table B.9

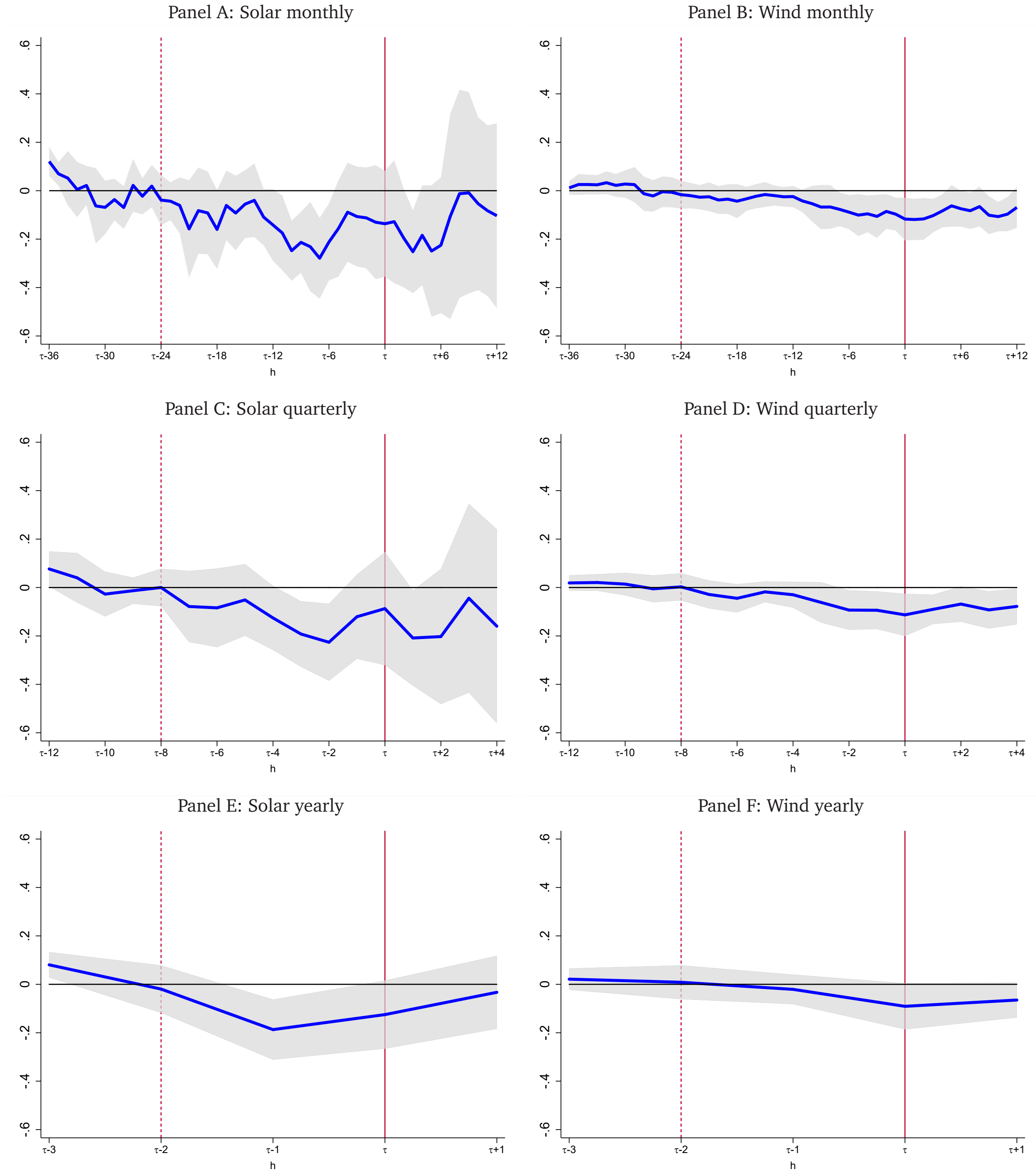
Local unemployment effects - alternative standard errors

	Municipality		County	
	Pre-opening (1)	Post-opening (2)	Pre-opening (3)	Post-opening (4)
Solar				
Multiplier (Jobs/MW)	-0.188	-0.135	-1.419	-0.580
Standard errors				
Baseline	0.058***	0.141	0.736*	0.726
Two-way clustering	0.070***	0.152	0.812*	0.799
HAC	0.059***	0.083	0.539***	0.602
Driscoll and Kraay	0.073**	0.099	0.650**	0.676
Wind				
Multiplier (Jobs/MW)	-0.076	-0.094	-0.124	-0.264
Standard errors				
Baseline	0.035**	0.035***	0.160	0.152*
Two-way clustering	0.042*	0.041**	0.239	0.205
HAC	0.030**	0.026***	0.118	0.128**
Driscoll and Kraay	0.026***	0.023***	0.124	0.125**
# Obs.	458,711	458,711	38,299	38,299
# Municipalities/counties	3,967	3,967	321	321

Notes: This table reports the cumulative multipliers (equations (2) and (3), and Table 4), under different strategies of computing the standard errors. In particular, two-way clustered (by municipality or county and month) standard errors, standard errors robust to heteroskedasticity and autocorrelation (HAC), and Driscoll and Kraay standard errors are reported. The last two uses a bandwidth of 3.

FIGURE B.16

LOCAL UNEMPLOYMENT EFFECTS - MONTHLY, QUARTERLY AND YEARLY DATA



Notes: These figures show the effects of investing 1 MW on unemployment by residents in the municipality where the investment occurs, h periods (months, quarters or years) before or after the start-up date (marked with a vertical solid red line). Panels (a) and (b) show the results for solar and wind investments using monthly data. Panel (c) and (d) show these results using quarterly information. Panels (e) and (f) show the results using yearly data. Error bands depict the 95% confidence interval. Standard errors are clustered at the municipality level.

B.6 Additional Results

B.6.1 Results by sector, gender and age

The unemployment data allows breaking the analysis by sector of previous employment (reported in Table B.10), by gender, and by age (Tables B.11 and B.12).[76] In particular, we estimate a version of equation (1) in which the dependent variable is unemployment in a given sector, gender, or age range.

In the case of solar investments, we find that the reduction in unemployment comes from people that used to work in industry and agriculture. In the case of wind investments, the decline in unemployment is focused on people who used to work in the services sector. However, some effects are also felt during the post-opening period by people previously employed in industry and construction. These findings suggest that the local employment and unemployment effects are felt mainly by workers with non-specialized skills, as people from outside carry out the more specialized tasks. They are also consistent with the idea that these multipliers also capture general equilibrium effects, as renewable investments trigger an increase in overall activity that is felt across sectors.

TABLE B.10
LOCAL UNEMPLOYMENT EFFECTS BY SECTOR

	Baseline (1)	Services (2)	Industry (3)	Construction (4)	Agriculture (5)	No previous sector (6)
Pre-opening						
Solar Multiplier (Jobs/MW)	-0.188***	-0.012	-0.023***	-0.065	-0.058*	-0.016
	(0.058)	(0.036)	(0.008)	(0.053)	(0.031)	(0.015)
Wind Multiplier (Jobs/MW)	-0.076**	-0.058**	-0.003	-0.014	-0.003	0.005
	(0.035)	(0.028)	(0.005)	(0.010)	(0.007)	(0.006)
Post-opening						
Solar Multiplier (Jobs/MW)	-0.135	-0.039	-0.013	-0.046	-0.025	-0.001
	(0.141)	(0.048)	(0.008)	(0.089)	(0.042)	(0.024)
Wind Multiplier (Jobs/MW)	-0.094***	-0.065**	-0.009	-0.009	-0.008	-0.001
	(0.035)	(0.028)	(0.007)	(0.013)	(0.009)	(0.006)

Notes: This table reports the results of estimating the local unemployment effects in the various sectors through equations (2) and (3) at the municipality level. Unemployment figures refer to the sector in which the worker was previously employed. The pre(post)-opening period is defined as the one year period before (after) the start-up date. Standard errors are clustered at the municipality level. The baseline results are those reported in Table 4.

Regarding the gender and age of previously unemployed people, a robust finding emerges: unemployed males benefit the most during the construction phase, particularly males in the 25 to 45 years old range in the case of wind investments. The effects on females are of smaller

[76] The employment data only allows to break the results in: General Regime, Self-employed and Agriculture. Not surprisingly, our analysis shows that all the local employment effects are felt in the General Regime, which is the largest.

magnitude and mostly non-significant. In the case of wind, the benefits are more evenly spread across age groups and gender, above all during the maintenance phase.[77]

TABLE B.11

LOCAL UNEMPLOYMENT EFFECTS FOR MALES BY AGE GROUP

	Baseline (1)	Males (2)	Males <25 (3)	Males 25-45 (4)	Males >45 (5)
Pre-opening					
Solar Multiplier (Jobs/MW)	-0.188***	-0.160***	-0.037***	-0.033	-0.086***
	(0.058)	(0.042)	(0.013)	(0.047)	(0.024)
Wind Multiplier (Jobs/MW)	-0.076**	-0.045**	-0.008	-0.024***	-0.012
	(0.035)	(0.021)	(0.006)	(0.007)	(0.012)
Post-opening					
Solar Multiplier (Jobs/MW)	-0.135	-0.088	-0.005	-0.010	-0.069*
	(0.141)	(0.070)	(0.013)	(0.025)	(0.040)
Wind Multiplier (Jobs/MW)	-0.094***	-0.045**	-0.010**	-0.025**	-0.010
	(0.035)	(0.021)	(0.004)	(0.010)	(0.011)

Notes: This table reports the results of estimating the local unemployment effects for males by age groups through equations (2) and (3) at the municipality level. Unemployment figures refer to the sector in which the worker was previously employed. The pre(post)-opening period is defined as the one year period before (after) the start-up date. Standard errors are clustered at the municipality level. The baseline results are those reported in Table 4.

B.6.2 Heterogeneous effects for solar investments

TABLE B.12

LOCAL UNEMPLOYMENT EFFECTS FOR FEMALES BY AGE GROUP

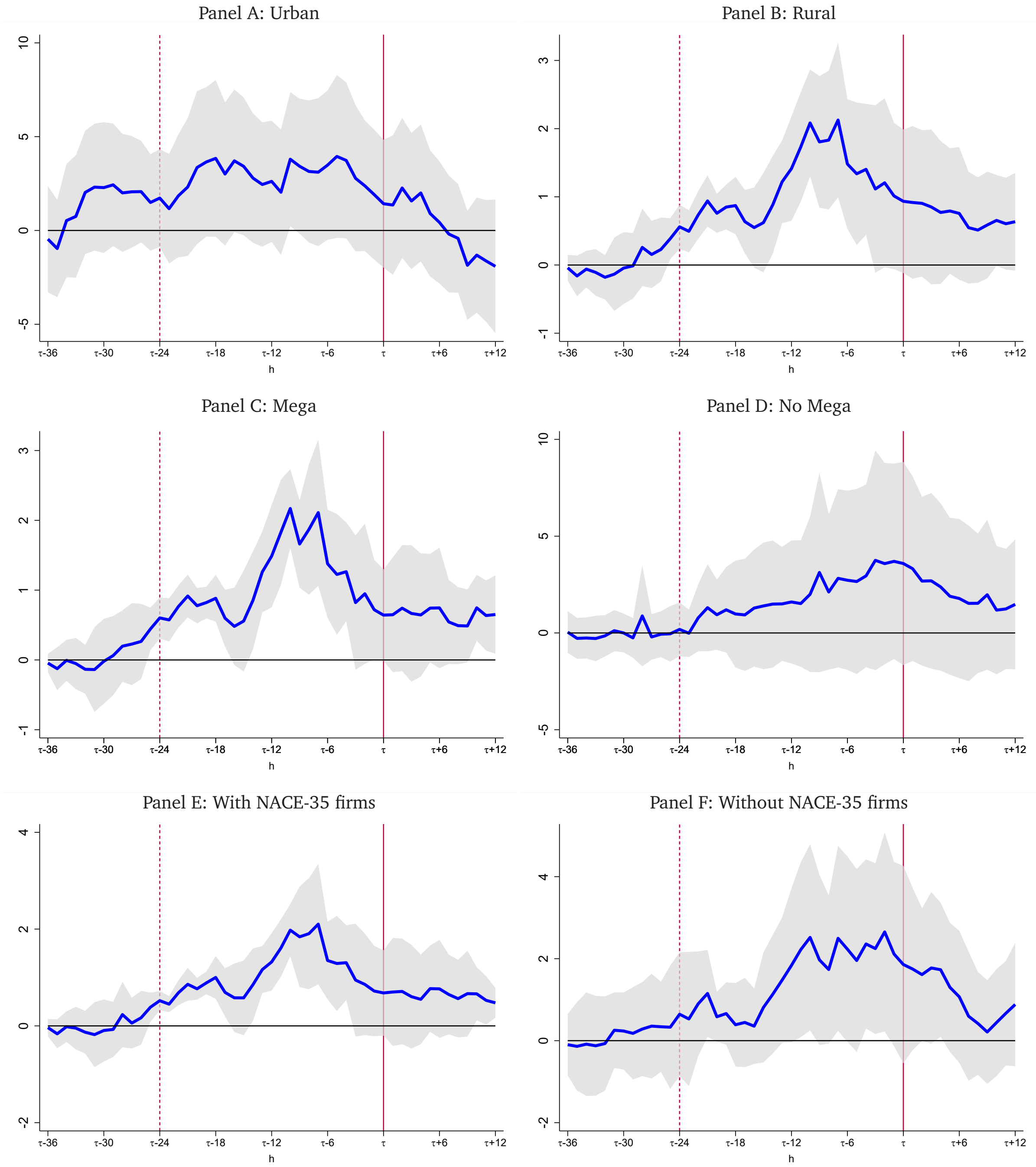
	Baseline (1)	Females (2)	Females <25 (3)	Females 25-45 (4)	Females >45 (5)
Pre-opening					
Solar Multiplier (Jobs/MW)	-0.188***	-0.022	-0.015	-0.034	0.025
	(0.058)	(0.041)	(0.015)	(0.022)	(0.016)
Wind Multiplier (Jobs/MW)	-0.076**	-0.029*	-0.013	-0.016**	-0.001
	(0.035)	(0.017)	(0.008)	(0.008)	(0.007)
Post-opening					
Solar Multiplier (Jobs/MW)	-0.135	-0.040	-0.015	-0.024	-0.000
	(0.141)	(0.075)	(0.026)	(0.039)	(0.017)
Wind Multiplier (Jobs/MW)	-0.094***	-0.050***	-0.016**	-0.032***	-0.004
	(0.035)	(0.018)	(0.006)	(0.009)	(0.008)

Notes: This table reports the results of estimating the local unemployment effects for females by age groups through equations (2) and (3) at the municipality level. Unemployment figures refer to the sector in which the worker was previously employed. The pre(post)-opening period is defined as the one year period before (after) the start-up date. Standard errors are clustered at the municipality level. The baseline results are those reported in Table 4.

[77] These findings are consistent with the analysis of Costa and Veiga (2021) for wind investments in Portugal. They find a higher impact in male work at the early stage of the construction phase, while female work also benefited at later stages.

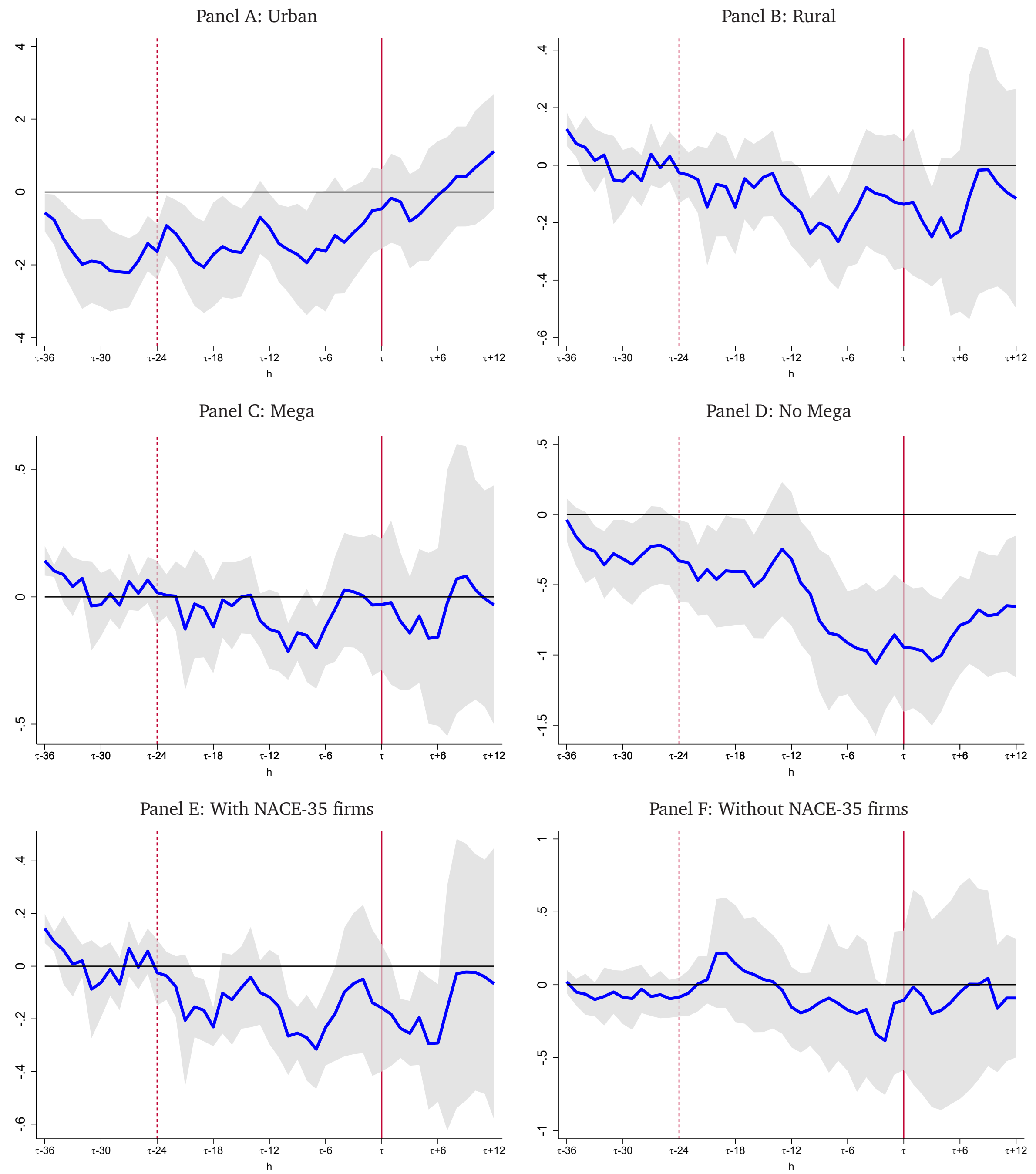
FIGURE B.17

EMPLOYMENT EFFECTS - HETEROGENEITY



Notes:These figures show the effects of investing 1 MW on employment by firms located at the municipality where the investment occurs, allowing the coefficient of interest to vary between rural and urban municipalities (according to Eurostat), large and small projects (above or below 49MW), and municipalities hosting firms in the NACE-35 industry category and otherwise. Results are depicted h periods before or after the start-up date (marked with a vertical solid red line).

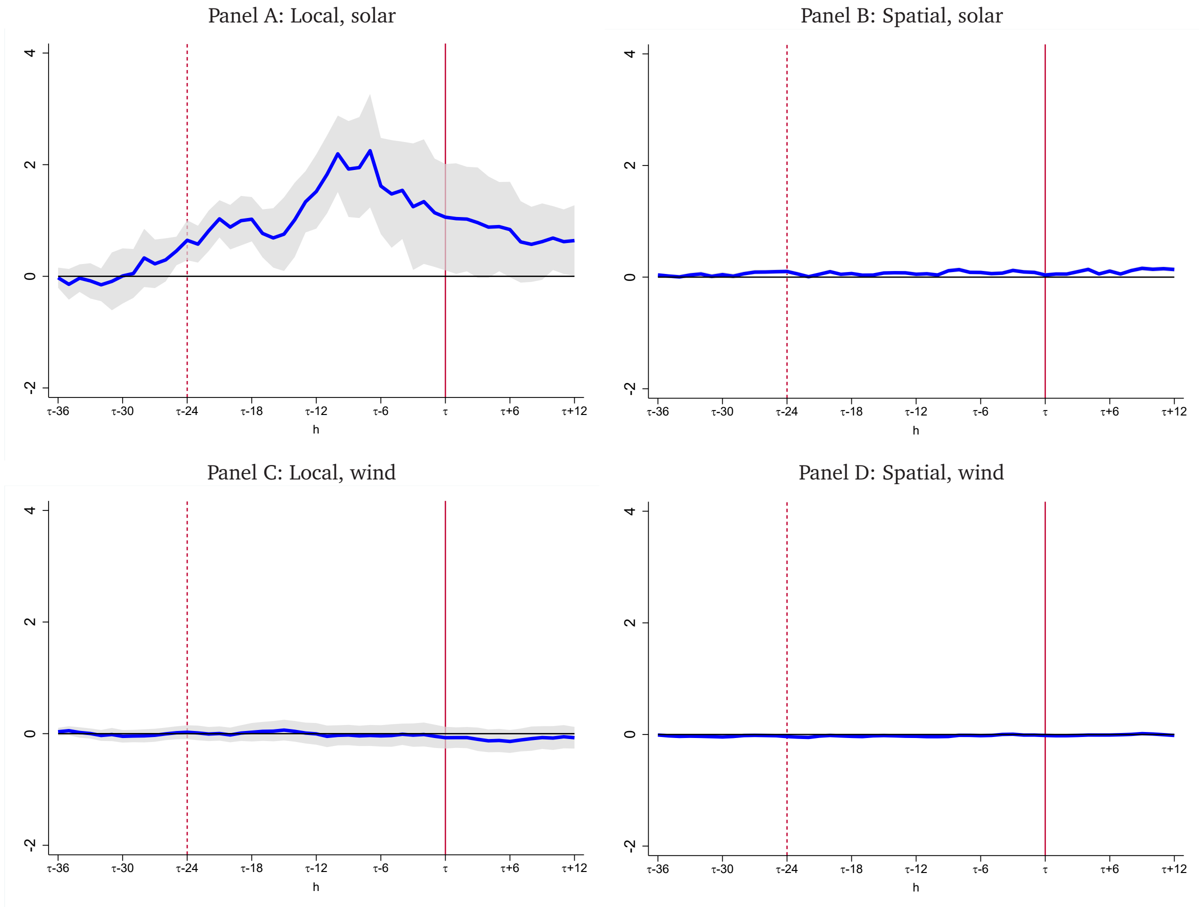
FIGURE B.18
UNEMPLOYMENT EFFECTS - HETEROGENEITY



Notes: These figures show the effects of investing 1 MW on unemployment by residents in the municipality where the investment occurs, allowing the coefficient of interest to vary between rural and urban municipalities (according to Eurostat), large and small projects (above or below 49MW), and municipalities hosting firms in the NACE-35 industry category and otherwise. Results are depicted h periods before or after the start-up date (marked with a vertical solid red line).

B.7 Spatial Effects

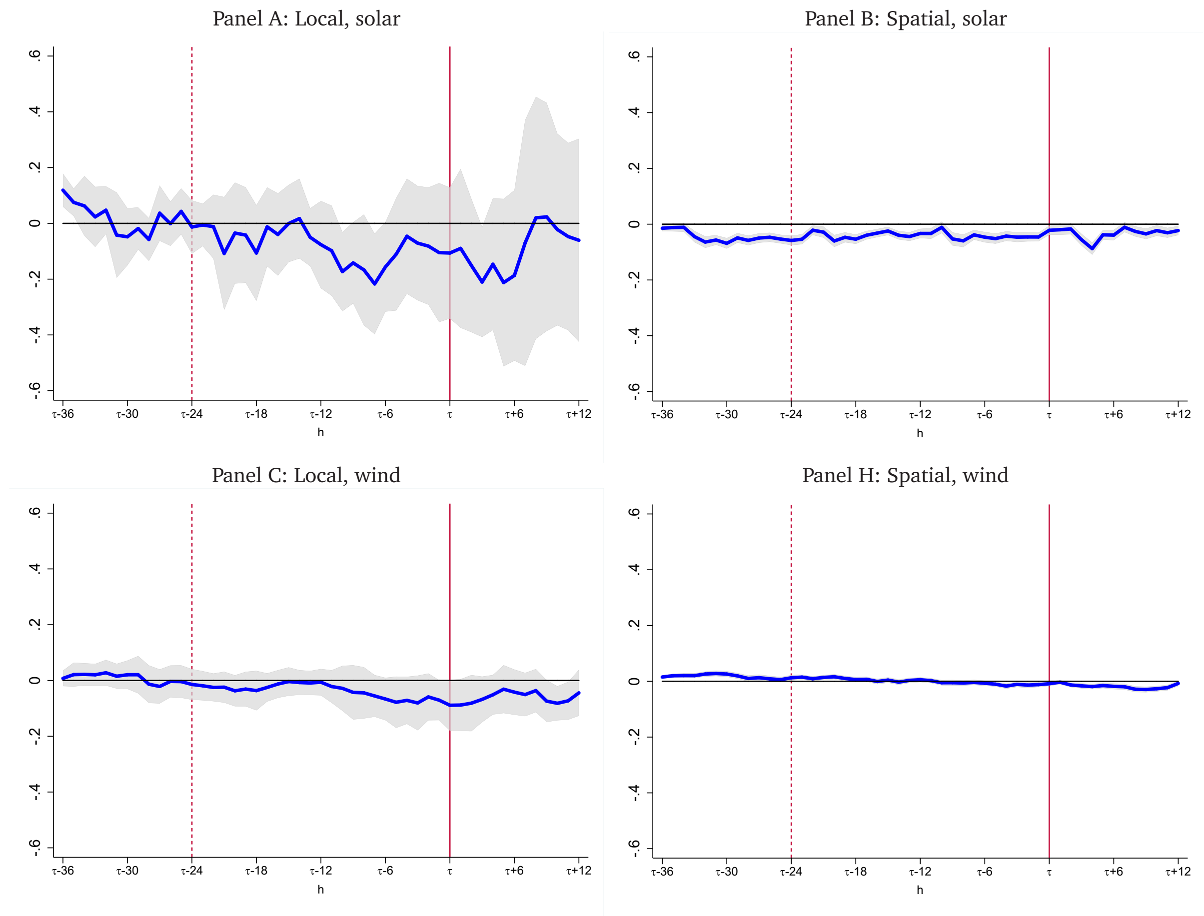
FIGURE B.19
EMPLOYMENT LOCAL AND SPATIAL EFFECTS (60 KM)



Notes: These figures show the local effects of investments occurring within the municipality on employment by firms located at the municipality, as well as the spatial effects of a MW investment in municipalities at a distance of less than 60 kilometers. Results depicted h periods before or after the start-up date (marked with a vertical solid red line). Panel (a) shows the local effects for solar investments panel (b) the spatial effects for solar investments, panel (c) the local effects for wind investments, and panel (d) the spatial effects for wind investments.

FIGURE B.20

UNEMPLOYMENT LOCAL AND SPATIAL EFFECTS (60 KM)



Notes: These figures show the local effects of investments occurring within the municipality on unemployment by residents in the municipality , as well as the spatial effects of a MW investment in municipalities at a distance of less than 60 kilometers. Results depicted h periods before or after the start-up date (marked with a vertical solid red line). Panel (a) shows the local effects for solar investments panel (b) the spatial effects for solar investments, panel (c) the local effects for wind investments, and panel (d) the spatial effects for wind investments.

B.8 Solar Investments during the Second Wave

TABLE B.13

EMPLOYMENT AND UNEMPLOYENT EFFECTS FOR SOLAR PER ONE MILLION EUROS

	Employment		Unemployment	
	Pre-opening (1)	Post-opening (2)	Pre-opening (3)	Post-opening (4)
Until 2018	0.766***	0.204***	-0.047	0.141***
	(0.077)	(0.079)	(0.031)	(0.036)
Since 2019	0.756***	0.160	-0.082***	-0.055
	(0.169)	(0.101)	(0.024)	(0.034)
# Obs.	380,187	380,187	380,801	380,801
# Municipalities	3,969	3,969	3,972	3,972

Notes: This table reports the results of estimating the local employment and unemployment effects of solar investments during the period January 2012-December 2018 and between January of 2019 and January of 2020. The multipliers in columns (1)-(2) express the number of new jobs created by local firms per million euros invested and the multipliers in columns (3)-(4), the number of residents who are no longer unemployed per million euros invested. Standard errors are clustered at the municipality level. This specification controls for solar and wind installed capacity between t-24, as costs data is only available since 2010, and t+h, in order to explore the second wave in contrast with t+h+24 in the baseline. Thus, the first wave now includes the entire year 2018.

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