DISCUSSION PAPER SERIES

DP17206
(v. 3)

DO RENEWABLES CREATE LOCAL JOBS?

Natalia Fabra, Eduardo Gutierrez, Aitor Lacuesta and Roberto Ramos

INDUSTRIAL ORGANIZATION AND LABOUR ECONOMICS

ISSN 0265-8003

DO RENEWABLES CREATE LOCAL JOBS?

Natalia Fabra, Eduardo Gutierrez, Aitor Lacuesta and Roberto Ramos

Discussion Paper DP17206
First Published 10 April 2022
This Revision 08 January 2023

Centre for Economic Policy Research
33 Great Sutton Street, London EC1V 0DX, UK
Tel: +44 (0)20 7183 8801
www.cepr.org

This Discussion Paper is issued under the auspices of the Centre's research programmes:

- Industrial Organization
- Labour Economics

DO RENEWABLES CREATE LOCAL JOBS?

Abstract

Worldwide, attempts to deploy renewable energies face the opposition of the local communities. Why do residents oppose those investments, despite the expectation that they will generate new jobs? Exploiting the monthly variation in the timing and size of the renewable investments across more than 3,200 municipalities in Spain over 13 years, we find that 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, but the effects on local unemployment are weak. The impacts of wind investments on local employment and unemployment are non-significant. These findings have important implications for public policy.

JEL Classification: L94, C33, O25, R23

Keywords: Renewable energy, Employment, Unemployment, Nimby, Job multipliers, Spatial effects

Natalia Fabra - nfabra@eco.uc3m.es
Universidad Carlos III de Madrid

Eduardo Gutierrez - eduardo.gutierrez@bde.es
Bank of Spain

Aitor Lacuesta - aitor.lacuesta@bde.es
Bank of Spain

Roberto Ramos - roberto.ramos@bde.es
Bank of Spain

Acknowledgements
We thank comments by Matteo Alpino, Òscar 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, and the \textit{Simposio} of the Spanish Economic Association. 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). The views expressed in this paper are those of the authors and do not necessarily coincide with those of the Banco de España or the Eurosystem.

Do Renewables Create Local Jobs?*

Natalia Fabra,[a] Eduardo Gutiérrez,[b]
Aitor Lacuesta,[b] and Roberto Ramos[b]

[a]Universidad Carlos III de Madrid and CEPR [b]Banco de España

January 8, 2023

Abstract

Worldwide, attempts to deploy renewable energies face the opposition of the local communities. Why do residents oppose those investments, despite the expectation that they will generate new jobs? Exploiting the monthly variation in the timing and size of the renewable investments across more than 3,200 municipalities in Spain over 13 years, we find that 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, but the effects on local unemployment are weak. The impacts of wind investments on local employment and unemployment are non-significant. These findings have important implications for public policy.

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

JEL Classification: L94, C33, O25, R23.

*We thank comments by Matteo Alpino, Òscar 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, and the *Simposio* of the Spanish Economic Association. 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). The views expressed in this paper are those of the authors and do not necessarily coincide with those of the Banco de España or the Eurosystem. Emails: natalia.fabra@uc3m.es, eduardo.gutierrez@bde.es, aitor.lacuesta@bde.es, and roberto.ramos@bde.es.

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.

[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.

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 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 compare the monthly performance of employment and unemployment across Spanish municipalities at different moments in time. In particular, we exploit the variation in the timing and size of wind and solar investments across more than 3,200 Spanish municipalities over 13 years, providing a detailed characterization of the labor market dynamics around plant openings while controlling for potentially confounding effects.

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., 2022).

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, as explained below. 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 2.5 new jobs-year/MW within the municipality where the investment occurs or 4.6 within the county.[4] These effects get weaker once the construction of the plant ends, with these job multipliers falling to 1.5 jobs-year/MW (municipality level) and 3.5 jobs-year/MW (county level). However, despite being smaller, the effects of the plant's maintenance seem to last longer. In contrast, wind investments have very low and statistically non-significant effects on local employment during the construction and maintenance phases.

The effects of solar investments are weaker on unemployment than on employment: during the construction phase, the unemployment multipliers are -0.18 jobs-year/MW and -1.1 jobs-year/MW at the municipality and county levels, respectively; they are non-significant during the maintenance phase. These findings suggest that local firms hire workers in other municipalities or counties. Interestingly, we find a slight unemployment increase once the solar plant construction ends (+0.10). This may be evidence that the plant's construction attracts new residents to the municipality, who become unemployed once the construction finishes.

As for wind, the results show that investments slightly reduce unemployment during the construction and maintenance phases (-0.19 and -0.35, respectively),[5] which contrasts with the lack of employment effects. These findings do not contradict each other: they are consistent with investments being carried out by firms not registered in the municipality, who might nevertheless hire local workers or trigger an increase in local economic activity. The former effect does not appear in the employment figures, while the latter shows up in the unemployment figures. The combination of the employment and unemployment effects thus provides a richer understanding of the overall effects of renewable investments.

Since solar projects are widespread across the country, we can explore the existence of heterogeneous effects. Interestingly, the effects on employment and unemployment tend to be larger in urban than in rural municipalities and for smaller than larger projects (suggesting the presence of scale economies). We arrive at a similar conclusion when focusing on the most recent investments in solar plants (post-2019) when the average plant size reached 27MW (from an

[4]In terms of the value of the investments, these multipliers imply that every million euros invested allowed creating 0.77 new local jobs during the first investment wave.

[5]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, 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 -0.094 jobs/year in the pre-opening period for solar investments and -0.114 jobs-year in the post-opening period for wind investments, for each million euro invested (Table B.4).

average of 0.5MW pre-2019). In particular, while the employment and unemployment multipliers per MW fall sharply, the multipliers per million euros invested remain fairly unchanged, a result that can be explained by the combination of scale economies and the reduction in investment costs.

We also measure whether municipalities benefit from investments in neighboring areas, considering a radius of 30 km around the municipality. These *spatial spillovers* do not impact employment but they strengthen the unemployment multipliers of solar investments. These results suggest that solar investments in neighboring municipalities open job opportunities for local residents who commute to nearby plants. The local and spatial effects for wind remain non-significant as in our baseline results.

Mechanisms. The mechanisms underlying our empirical findings are related to the nature of the tasks and skills required for the construction and maintenance of renewable plants. 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). Local taxes could help strengthen the multiplier effects, but these are relatively small compared to the total amount invested.

Matters are somewhat different in the case of solar investments, for which the construction bears a higher weight in the projects' total cost. Also, since maintenance requires less specialized skills, workers can often be hired locally. Indeed, one of the bottlenecks for stronger local employment effects is the skill mismatch, which tends to be stronger in rural areas where people are less likely to possess the necessary skills for the new jobs being created (IRENA, 2022a).[6]

The local effects provide a lower bound for the broader job creation potential of renewable

[6]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.

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. 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 this reflects an overestimation of the national effect, the fact that the local job benefits are small relative to the overall job creation or both. 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.

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 provides several robustness tests. 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.[7] They show that every million dollars of additional oil or gas production generated an employment increase of 0.85 at the county level.[8] 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).[9]

There are also several papers on the employment effects of various environmental policies (including carbon pricing, emissions regulations, or increases in energy prices; see Morgenstern et al. 2002; Kahn and Mansur 2013; Marin and Vona 2021; Metcalf and Stock 2020), but they do not focus on the local impacts of such policies.

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 2019 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),

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

[8] At the county level, for our baseline specification, we find employment multipliers for the solar investments of 1.11 and 0.55 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.

[9] 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.

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 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.[10] 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.

[10] We exploit this feature in Section 6.5.2, where we allow the treatment effect to vary along two dimensions (location and size of the plant).

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). 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. (2022). 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.

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.[11]

[11] 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, 2022).

Interestingly, Figure 1 highlights important differences between these two investment waves and across technologies.[12] The first solar plants were small (their average size was 0.5MW), and two-thirds were located in rural areas widespread across the country.[13] In contrast, the more recent solar plants are much larger (their average size is 27MW) 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 18MW in the first wave and 27MW 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.

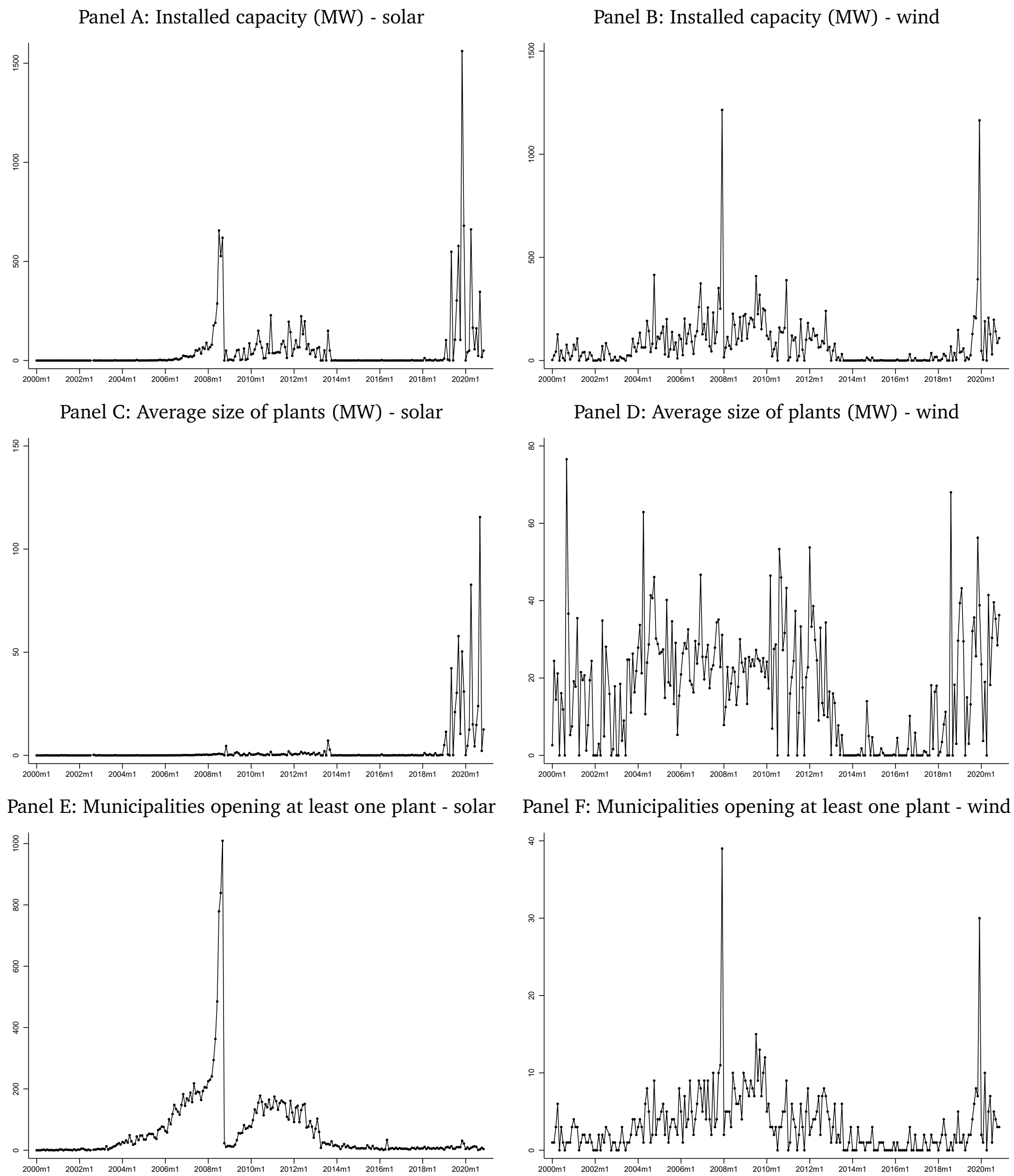
The location of the investments is driven by the availability of natural resources (solar, wind) and spare transmission capacity. This explains why most wind plants are located in the northern and coastal regions of the country (Figure 2). Solar plants are more broadly spread but tend to be concentrated 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 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, 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.

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

[13] 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



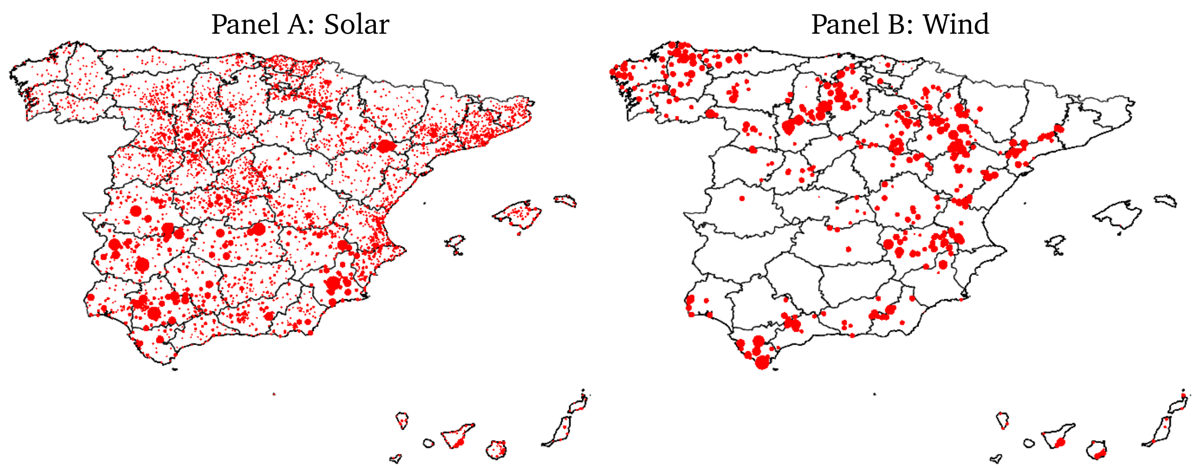
Notes: These figures show the evolution of renewable investments in Spain (MW), the average size of the plants (MW), and the number of municipalities opening at least one plant on a monthly basis. The data span from 2000 until 2020. Panels on the first column refer to solar, and those on the second column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

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

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.

and maintenance.[14] 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.[15] 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.[16] 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

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

[15]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.

[16]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)
Rural (%)	98.96	80.94	85.55
	(0.160)	(0.632)	(1.672)
Urban (%)	1.039	19.06	14.45
	(0.160)	(0.632)	(1.672)

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. A t-test shows that the means of those variables for municipalities with solar and wind plants are statistically different from those without those investments.

TABLE 2
UNEMPLOYMENT AND INVESTMENTS

	Solar			Wind		
	(1)	(2)	(3)	(4)	(5)	(6)
$unemp_{-25}$	0.000161	0.000024		0.000014	0.000020	
	(0.000150)	(0.000100)		(0.000032)	(0.000044)	
$unemp_{-36}$		0.000182			-0.000008	
		(0.000112)			(0.000046)	
$unemp_{-25,-36}$			0.000142			0.000016
			(0.000109)			(0.000039)
# Obs.	496,885	496,885	496,885	496,885	496,885	496,885
# Municipalities	3,251	3,251	3,251	3,251	3,251	3,251

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, $unemp_{-25}$ *refers to unemployment 25 months before the start-up date normalized with population at time t-36,* $unemp_{-36}$ *to unemployment 36 months before normalized with population at time t-36 and* $unemp_{-25,-36}$ *to the average of unemployment between 36 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.*

require 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 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 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.[17] 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.[18] The treatment starts when

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

[18]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

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.

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. Instead, they report the number of workers employed by firms or plants registered in the municipality.[19]

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.[20] 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

to the above-mentioned median time lapse between the final registration and the start-up date by type of energy.

[19] 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 1,000 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.

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

image of each other. In fact, according to Social Security data, 50% of workers do not live where they work, a phenomenon which is particularly common in small villages, where people often commute to work in bigger nearby cities.[21] 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 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.[22] 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 (see Jordà, 2005; Chodorow-Reich, 2019; Alloza and Sanz, 2021).[23] 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.[24] In particular, we run a series of h regressions of the following form:

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

[21] To compute this percentage, we use Social Security matched employer-employee data (Panel de Empresa Trabajador 2013-2016, Tesorería General de la Seguridad Social).

[22] 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.

[23] 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 6.5.2).

[24] 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.

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.[25] 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 the plant's maintenance ($h > 0$). Standard errors are clustered at the municipality (or county) level.[26]

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.[27] 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

[25]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.

[26]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.6 for the baseline results on employment and Table B.8 for the results on unemployment.

[27]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.

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.[28, 29]

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.[30]

In our regressions, we restrict the sample in two directions. First, we exclude municipalities with less than 1,000 inhabitants. In these municipalities, few people registering for employment or unemployment could trigger steep changes in the employment or unemployment rate. Moreover, censored observations in the employment data prevent us from including very small municipalities (see footnote 19). 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

[28]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 $\tau+12$.

[29]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 6.4.

[30]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.

absence of such factors.[31]

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.[32] 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 change once over time).[33]

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 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.,

[31] 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.

[32] 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),.

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

we include in our regressions the set of municipalities that never opened a renewable plant.[34]

In a recent paper, Dube et al. (2022) 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:[35]

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

It is worth underlining a few differences between the LP-DiD estimator and our baseline. First,

[34]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.

[35]Note that the conditions stated in equation (26) of Dube et al. (2022) 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.

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.[36] 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

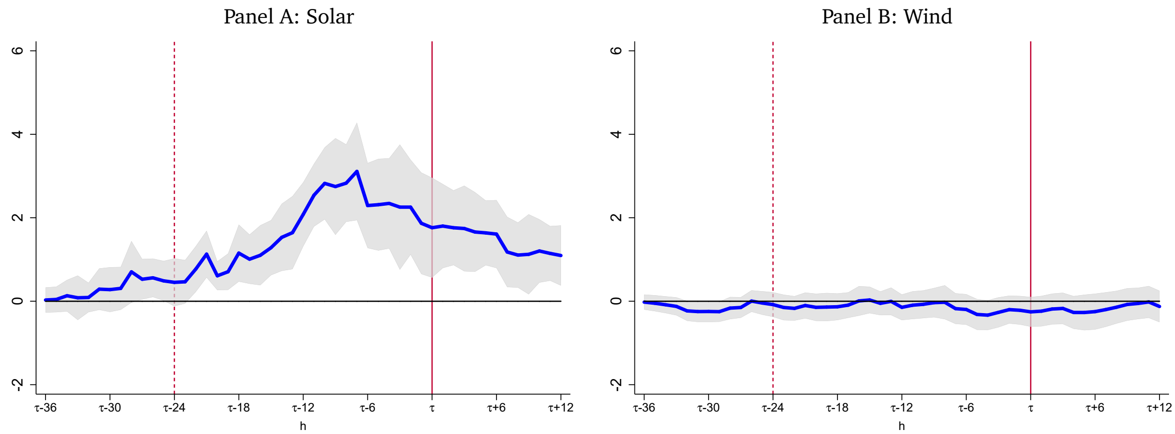
Figure 3 shows the results of estimating equation (1) for employment at the municipality level for investments in solar and wind plants during the baseline period 2006-2018.[37] For the two technologies, results are consistent with pre-treatment parallel trends, as shown by the zero effect when the construction 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 22 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 completed sometime before the plant is ready to produce electricity. As we enter the maintenance phase, the effect goes further down, but it does not vanish during our post-opening year. These results are in

[36]Figures B.7 and B.8 in the Appendix show the number of observations used as treatment and control units at each horizon h for employment and unemployment, respectively.

[37]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 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.

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 (1.00 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 2.47 jobs-year/MW. During the maintenance phase (column 4, 12 months after the start-up date), the job multiplier for solar goes down to 1.47 jobs-year/MW, and remains significant. In contrast, the job multipliers for wind are statistically equal to zero across all periods.

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 during pre-opening and post-opening increase to 4.55 jobs-year/MW and 3.48 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.[38]

Another way to look at the results is to express the job multipliers per million euros invested (rather than MW).[39] 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 0.77 new jobs.[40]

TABLE 3

LOCAL EMPLOYMENT EFFECTS

	Pre-construction (1)	Early construction (2)	Pre-opening (3)	Post-opening (4)
Solar Multiplier (Jobs/MW)	0.294	1.003***	2.468***	1.471***
	(0.193)	(0.215)	(0.450)	(0.411)
Wind Multiplier (Jobs/MW)	-0.133	-0.082	-0.186	-0.182
	(0.104)	(0.140)	(0.167)	(0.191)
# Obs.	460,634	460,634	460,634	460,634
# Municipalities	3,213	3,213	3,213	3,213

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.6 in the Appendix shows the standard errors clustered at the municipality and month levels, as well as HAC and Driscoll and Kraay standard errors.

6.2 Unemployment

Figure 4 and Table 4 provide the impacts of the renewable investments on unemployment.[41] 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 one year before the start-up, and while the timing of the effect is similar to the one for employment, the magnitude of the impact is much smaller. In particular, the unemployment multiplier is -0.18 persons-year/MW during the construction (pre-opening) phase, and it then vanishes out. Even though the effect during the

[38]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.6 in the Appendix.

[39]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), which we convert into Euros. 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.

[40]The value of these multipliers is very 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.

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

maintenance phase is non-significant, there seems to be a slight increase in unemployment after the start-up date (the multiplier is 0.096 persons-year/MW), even relative to the pre-construction phase. This suggests that some people may have moved to the municipality to work in the plant but may have become unemployed once the construction ended.[42] Last, the fact that the employment effects are greater than the unemployment effects might be explained by two facts: local firms hire people residing outside the municipality, or they hire residents who are not registered in the local employment agency.

While wind investments delivered no impact on employment, we now observe that they reduce unemployment, particularly so during the maintenance phase (the multiplier is -0.35).[43] The distinct effects suggest that the new workers reside in the municipality but are hired by outside firms. A reduction in participation rates 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 0.094. For wind, during the maintenance phase, the reduction in the number of local unemployed in the municipality is 0.114 per million euros invested.

TABLE 4
LOCAL UNEMPLOYMENT EFFECTS

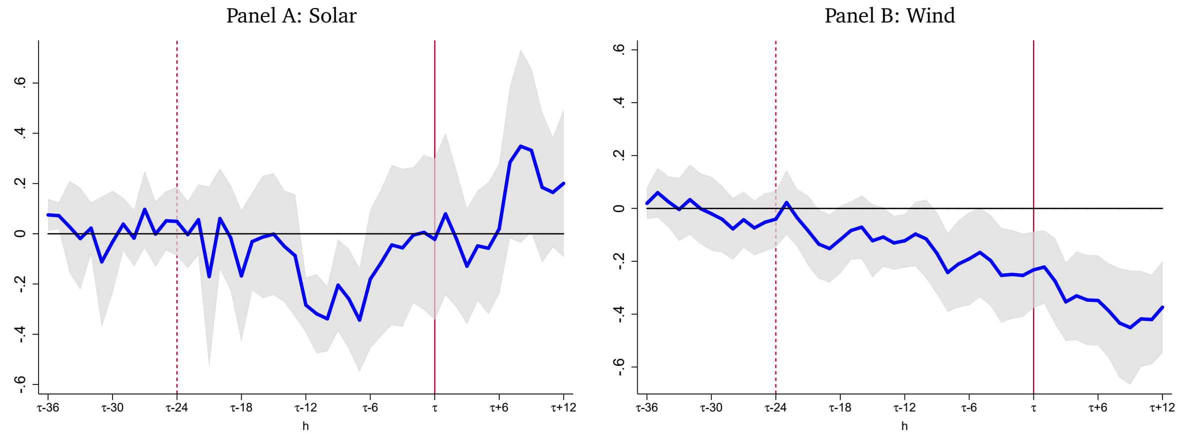
	Pre-construction (1)	Early construction (2)	Pre-opening (3)	Post-opening (4)
Solar Multiplier (Jobs/MW)	0.022	-0.027	-0.182*	0.096
	(0.052)	(0.061)	(0.095)	(0.121)
Wind Multiplier (Jobs/MW)	-0.013	-0.091*	-0.192***	-0.352***
	(0.042)	(0.053)	(0.072)	(0.076)
# Obs.	375,861	375,861	375,861	375,861
# Municipalities	3,251	3,251	3,251	3,251

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.8 in the Appendix shows the standard errors clustered at the municipality and month levels, as well as HAC and Driscoll and Kraay standard errors.

[42] An alternative explanation is that, having worked in the plant's construction, residents now have incentives to register in the employment agency in order to get unemployment benefits. As the results by sector will show, most of the people who become unemployed during the post-opening phase were previously employed in the construction sector (see Table 7).

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

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 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.

6.3 Clean control condition

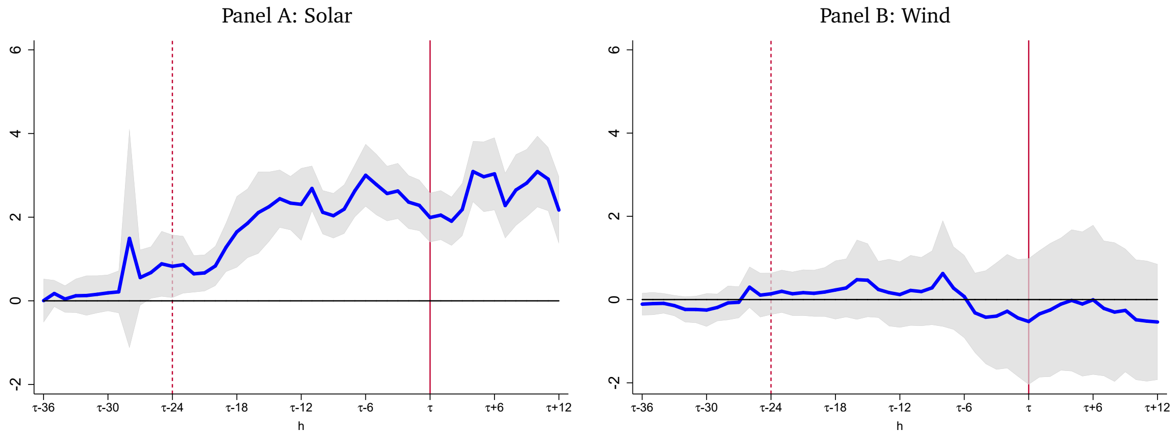
Figure 5 and Table 6 report the estimated effects on employment when allowing for heterogeneous treatment effects at the group level, i.e., when restricting the sample observations as described in equation (4).

As in the baseline, we find a significant increase of local employment around the time of the opening of solar plants. In particular, we find that one-year before the start-up date, employment increases by 2.5 workers/MW, a value that is similar to the baseline estimate. 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 selection inherent to clean control. Regarding wind plants, the application of the clean-control condition does not change the baseline result showing no local employment effects.

Figure 6 and Table 6 show the unemployment estimates. In this case, small decrease of unemployment during the construction of solar plants found under the baseline vanishes under the clean-control condition. In contrast, the spike of unemployment at the end of the event window found under the baseline now becomes even more pronounced. Regarding wind investments, the application of the clean control condition yields similar results during the construction phase as under the baseline, but the effects now converge to zero during the

FIGURE 5

LOCAL EMPLOYMENT EFFECTS - CLEAN CONTROL



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 red line). Treatment and control observations are restricted in order to take into account the staggered adoption. 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 5

LOCAL EMPLOYMENT EFFECTS - CLEAN CONTROL

	Baseline		Clean Control	
	Pre-opening (1)	Post-opening (2)	Pre-opening (3)	Post-opening (4)
Solar Multiplier (Jobs/MW)	2.468***	1.471***	2.527***	2.507***
	(0.450)	(0.411)	(0.297)	(0.360)
Wind Multiplier (Jobs/MW)	-0.186	-0.183	0.025	-0.284
	(0.167)	(0.191)	(0.805)	(0.887)
# Obs.	460,645	460,645	122,615	108,675
# Municipalities/counties	3,213	3,213	1,495	1,005

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, treatment and control observations are restricted in order to take into account the staggered adoption. As, lags and leads of the treatment variables are not added this specification uses data until December-2018.

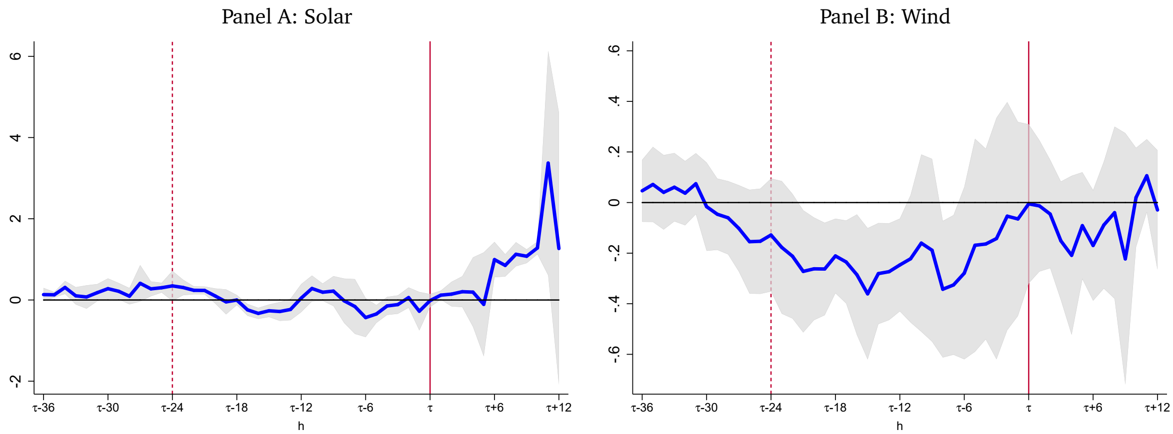
maintenance phase.

6.4 Robustness

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

FIGURE 6

LOCAL UNEMPLOYMENT EFFECTS - CLEAN CONTROL



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 red line). Treatment and control observations are restricted in order to take into account the staggered adoption. 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 6

LOCAL UNEMPLOYMENT EFFECTS - CLEAN CONTROL

	Baseline		Clean Control	
	Pre-opening (1)	Post-opening (2)	Pre-opening (3)	Post-opening (4)
Solar Multiplier (Jobs/MW)	-0.182*	0.096	-0.045	0.297
	(0.095)	(0.121)	(0.131)	(1.247)
Wind Multiplier (Jobs/MW)	-0.192***	-0.352***	-0.251	-0.102
	(0.072)	(0.076)	(0.170)	(0.170)
# Obs.	375,861	375,861	97,325	87,610
# Municipalities/counties	3,251	3,251	986	860

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, treatment and control observations are restricted in order to take into account the staggered adoption. As, lags and leads of the treatment variables are not added this specification uses data until December-2018.

interacting the time fixed-effects with province dummies.[44] Additionally, in order to verify that the labor market impacts are not biased by migration dynamics, we interact the monthly dummies 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.9, B.10, B.12 and B.13.[45] Lastly, we have re-estimated our baseline results using quarterly and yearly data, instead of monthly data. As can be seen in Figures B.11 and B.14, the results remain similar. Importantly,

[44] There are 50 provinces in Spain.

[45] Tables B.5 and B.7 depict the coefficients for the pre-opening and post-opening phases.

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.

6.5 Additional Results

6.5.1 Results by sector, gender and age

The unemployment data allows breaking the analysis by sector of previous employment (reported in Table 7), by gender, and by age (Tables 8 and 9).[46] 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. Interestingly, in the post-opening period, the increase in unemployment for workers previously employed in the construction sector is consistent with workers involved in building the plant becoming unemployed once the construction ends. 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.

Regarding the gender and age of previously unemployed people, a robust finding emerges: unemployed males in the 25 to 45 years old range benefit the most during the construction phase. The effects on females are of smaller 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.[47]

[46]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.

[47]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.

TABLE 7

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)	-0.182*	-0.009	-0.041***	0.016	-0.099***	-0.027***
	(0.095)	(0.051)	(0.012)	(0.028)	(0.038)	(0.011)
Wind Multiplier (Jobs/MW)	-0.192***	-0.150***	-0.017	-0.029	-0.014	0.029
	(0.072)	(0.050)	(0.019)	(0.028)	(0.020)	(0.031)
Post-opening						
Solar Multiplier (Jobs/MW)	0.096	0.017	0.007	0.110**	-0.032	0.019
	(0.121)	(0.065)	(0.012)	(0.045)	(0.074)	(0.017)
Wind Multiplier (Jobs/MW)	-0.352***	-0.222***	-0.055**	-0.047*	-0.033	0.010
	(0.076)	(0.049)	(0.024)	(0.027)	(0.021)	(0.023)

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.

TABLE 8

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)	-0.182*	-0.173***	-0.021	-0.106***	-0.045***
	(0.095)	(0.047)	(0.014)	(0.033)	(0.017)
Wind Multiplier (Jobs/MW)	-0.192***	-0.127***	-0.030**	-0.068***	-0.031
	(0.072)	(0.046)	(0.013)	(0.025)	(0.021)
Post-opening					
Solar Multiplier (Jobs/MW)	0.096	0.045	0.024***	0.012	0.009
	(0.121)	(0.061)	(0.009)	(0.038)	(0.020)
Wind Multiplier (Jobs/MW)	-0.352***	-0.210***	-0.037***	-0.120***	-0.056***
	(0.076)	(0.051)	(0.014)	(0.032)	(0.020)

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.

6.5.2 Heterogeneous effects for solar investments

Since there are many solar projects, we can explore heterogeneous treatment effects. We allow the coefficient of interest to vary with two sources of heterogeneity: the project's location, whether it is in a rural or urban area,[48] and the project's capacity, whether it is above or below

[48]Eurostat defines a municipality as rural if at least 50 % of the population live in low-density 1 km^2 cells. These low-density cells do not belong to a group of contiguous cells with more than 5,000 citizens and more than 300 citizens/km^2.

TABLE 9

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)	-0.182*	-0.005	-0.001	-0.025	0.017
	(0.095)	(0.062)	(0.020)	(0.025)	(0.026)
Wind Multiplier (Jobs/MW)	-0.192***	-0.063*	-0.032***	-0.019	-0.016
	(0.072)	(0.037)	(0.011)	(0.026)	(0.020)
Post-opening					
Solar Multiplier (Jobs/MW)	0.096	0.061	0.019	0.028	0.013
	(0.121)	(0.067)	(0.021)	(0.033)	(0.021)
Wind Multiplier (Jobs/MW)	-0.352***	-0.142***	-0.044***	-0.061**	-0.042*
	(0.076)	(0.040)	(0.014)	(0.024)	(0.022)

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.

49MW. In our baseline sample, there are 68% rural municipalities and 38 large projects.

Table 10 reports the results.[49] 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 3.09 and 2.45 for municipalities in urban and rural areas, respectively, while the corresponding unemployment multipliers are -1.42 and -0.17.[50] This can be explained by two facts. First, since employers are mostly located in urban areas, the new jobs are also more likely registered in urban areas. Second, it is easier for employers to find local workers in urban areas instead of hiring people from elsewhere. Thus, the effects on unemployment are also more likely to show up in urban municipalities.

Lastly, we find stronger employment and unemployment effects for small projects than for large projects (6.51 versus 2.08 employment multipliers and -1.45 versus -0.07 unemployment multipliers). The lower multiplier for large projects suggests the existence of important scale economies. However, note that the employment effect of small projects is very heterogeneous across municipalities, and it becomes non-significant.

[49]Figures B.15 and B.16 in Appendix B.5.1 plot the results across time.

[50]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 10

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)	2.466***	1.470***	-0.184*	0.092
	(0.449)	(0.410)	(0.096)	(0.122)
Urbanization				
Rural	2.452***	1.487***	-0.165*	0.097
	(0.455)	(0.421)	(0.091)	(0.123)
Urban	3.086*	0.383	-1.416**	-0.313
	(1.795)	(1.464)	(0.614)	(0.636)
Plant's Size				
$<$49MW	6.518	5.490	-1.446***	-1.229***
	(4.746)	(4.091)	(0.258)	(0.324)
$\geq$49MW	2.077***	1.115***	-0.065	0.215*
	(0.087)	(0.198)	(0.071)	(0.115)

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, and large and small projects (above or below 49MW). 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.

6.6 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 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):[51]

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

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 $e = s, w$:[52,53]

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

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.

Our baseline results might understate the true local impact of renewables, as the municipalities might benefit from nearby investments. Table 11 reports the results of estimating equation (5), which captures the local effects of investments within a 30 km radius of the municipality.[54]

[51] 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.

[52] 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 $t - 36$.

[53] 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.

[54] Figures B.18 and B.18 plot the results for the 30 km radius.

TABLE 11

LOCAL AND SPATIAL EFFECTS ON EMPLOYMENT AND UNEMPLOYMENT - 30 KM RADIUS

	Employment		Unemployment	
	Pre-opening (1)	Post-opening (2)	Pre-opening (3)	Post-opening (4)
Baseline				
Solar Multiplier (Jobs/MW)	2.468***	1.471***	-0.182*	0.096
	(0.450)	(0.411)	(0.095)	(0.121)
Wind Multiplier (Jobs/MW)	-0.186	-0.183	-0.192***	-0.352***
	(0.167)	(0.191)	(0.072)	(0.076)
Spatial				
Solar Local Effect	2.506***	1.435***	-0.127	0.141
	(0.470)	(0.416)	(0.095)	(0.125)
Solar Spatial Effect	0.022	0.071***	-0.043***	-0.032*
	(0.022)	(0.024)	(0.015)	(0.017)
Wind Local Effect	-0.174	-0.195	-0.148**	-0.289***
	(0.171)	(0.190)	(0.064)	(0.072)
Wind Spatial Effect	-0.013	-0.010	-0.008**	-0.014***
	(0.010)	(0.011)	(0.004)	(0.004)
# Obs.	450,720	450,720	365,881	365,881

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 local effects in these regressions, with only a slightly positive bias.[55] The reason is that the spatial effects appear relatively small and often non-significant.

Regarding the impact on employment, the spatial effects point to low spatial effects in the case of solar energy during the mainteinance phase and remain non-significant for wind (Table 11). The spatial multipliers for unemployment account for a slightly higher share of the total effect, particularly for municipalities close to a solar plant during the construction phase. In particular, the unemployment multiplier for solar investments during the construction phase reaches -0.04 while during the maintenance phase it attains -0.03, and they are all significant. On the other hand, wind investments have spatial impacts on unemployment near zero during the construction and maintenance phases (around 0.01 in both cases).

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

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 19MW to 27MW, the increase in the mean size of the solar projects was much more pronounced, from 0.5MW to 27MW (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.[56]

Results are shown in Table 12. 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 0.49 jobs-year/MW during the construction phase and to 0.09 jobs during the maintenance phase, both being statistically significant. The local unemployment effects also get weaker. They fall to -0.06 and -0.03 persons-year/MW, respectively.[57] 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. As pointed out by IRENA (2022a), one of the bottlenecks for stronger local employment effects is the skill mismatch, which tends to be stronger the greater the size of the projects.[58]

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.9, during the construction phase, investing 1 million euros in a solar plant increased the number of workers in the municipality by 0.7, in line with the results for the first wave (0.8). 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 0.05, which is substantially lower than in the first wave (0.19), consistent with the fact that most of the cost reductions accrue to the construction and not

[56]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.

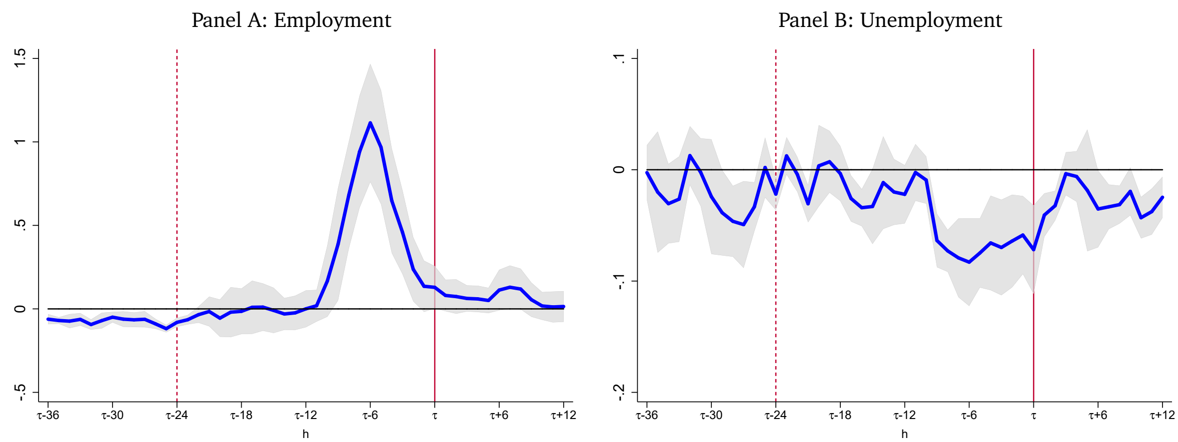
[57]Another difference between the two waves is the shorter duration of the construction phase.

[58]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.

so much to the maintenance. The local unemployment effect per million euros invested reaches -0.10 and -0.08 during the construction and maintenance phases, respectively, for the plants that opened from 2019 onward. In contrast, during the first wave, these multipliers were -0.05 during the construction phase and positive during the maintenance phase (0.139).

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 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 before. Thus, the first wave now includes the entire 2018. Error bands depict the 95% confidence interval.

TABLE 12

LOCAL EMPLOYMENT AND UNEMPLOYMENT EFFECTS FOR SOLAR

	Employment		Unemployment	
	Pre-opening (1)	Post-opening (2)	Pre-opening (3)	Post-opening (4)
Until 2018	2.420***	1.450***	-0.153*	0.123
	(0.470)	(0.361)	(0.079)	(0.130)
Since 2019	0.488***	0.087*	-0.057***	-0.032***
	(0.110)	(0.047)	(0.015)	(0.008)
# Obs.	538409	538409	454536	454536
# Municipalities	3,214	3,214	3,251	3,251

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 before. Thus, the first wave now includes the entire 2018.

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). 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.

Using our second-wave employment multipliers (Table 12), solar investments will allow creating 3,657 new local jobs on average per year during the current decade.[59] In particular, 1,337 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 1,248 in 2021 to 3,399 in 2030 as the cumulative capacity increases. Also, on average, local unemployment will decrease by 1,010 persons annually, from 615 in 2021 to 1,404 in 2030.

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.

[59] 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.

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 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 municipalities where the investments occur.[60] 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),[61] reducing the electricity prices for local residents, increasing the local taxes paid by the renewable investors, reserving quotas for local projects in the renewable auctions ran at the national level or prioritizing grid access to those projects that promise to provide greater local benefits.[62] 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 market benefits of investing in renewable energies.

[60]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.

[61]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.

[62]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.

References

Alloza, Mario, Jesús Gonzalo, and Carlos Sanz, 2021, Dynamic effects of persistent shocks, Working paper.

Alloza, Mario, and Carlos Sanz, 2021, Jobs multipliers: Evidence from a large fiscal stimulus in spain, *Scandinavian Journal of Economics* 123, 751–779.

Auerbach, Alan, and Yuriyi Gorodnichenko, 2012, Fiscal multipliers in recession and expansion, in Alberto Alesina, and Francesco Giavazzi, ed.: *Fiscal Policy after the Financial Crisis* (University of Chicago Press).

Baringa, 2022, A market study including an assessment of potential financial instruments to support renewable energy commercial power purchase agreements, Discussion paper prepared for the European Investment Bank.

Bartik, Alexander W., Janet Currie, Michael Greenstone, and Christopher R. Knittel, 2019, The local economic and welfare consequences of hydraulic fracturing, *American Economic Journal: Applied Economics* 11, 105–55.

Batini, Nicoletta, Mario Di Serio, Matteo Fragetta, Giovanni Melina, and Anthony Waldron, 2022, Building back better: How big are green spending multipliers?, *Ecological Economics* 193, 107305.

Black, Dan, Terra McKinnish, and Seth Sanders, 2005, The Economic Impact Of The Coal Boom And Bust, *Economic Journal* 115, 449–476.

Borusyak, Kirill, Xavier Jaravel, and Jann Spiess, 2022, Revisiting event study designs: Robust and efficient estimation, Working Paper.

Brown, Jason P., John Pender, Ryan Wiser, Eric Lantz, and Ben Hoen, 2012, Ex post analysis of economic impacts from wind power development in u.s. counties, *Energy Economics* 34, 1743–1754.

Callaway, Brantly, and Pedro H.C. Sant'Anna, 2021, Difference-in-differences with multiple time periods, *Journal of Econometrics* 225, 200–230 Themed Issue: Treatment Effect 1.

Caramizaru, E., and A. Uihlein, 2020, Energy communities: an overview of energy and social innovation, .

Chodorow-Reich, Gabriel, 2019, Geographic cross-sectional fiscal spending multipliers: What have we learned?, *American Economic Journal: Economic Policy* 11, 1–34.

Costa, Helia, and Linda Veiga, 2021, Local labor impact of wind energy investment: An analysis of portuguese municipalities, *Energy Economics* 94.

Curtis, E. Mark, and Ioana Marinescu, 2022, Green energy jobs in the us: What are they, and where are they?, Working Paper 30332 National Bureau of Economic Research.

de Chaisemartin, Clément, and Xavier d'Haultfoeuille, 2022, Difference-in-differences estimators of intertemporal treatment effects, .

de Chaisemartin, Clément, and Xavier D'Haultfoeuille, 2022, Two-way fixed effects and differences-in-differences with heterogeneous treatment effects: A survey, .

de Chaisemartin, Clément, Xavier d'Haultfoeuille, Félix Pasquier, and Gonzalo Vazquez-Bare, 2022, Difference-in-differences estimators for treatments continuously distributed at every period, Working paper.

de Chaisemartin, Clément, and Xavier D'Haultfœuille, 2020, Two-way fixed effects estimators with heterogeneous treatment effects, *American Economic Review* 110, 2964–96.

Dröes, Martijn I., and Hans R.A. Koster, 2021, Wind turbines, solar farms, and house prices, *Energy Policy* 155.

Dube, Arindrajit, Daniele Girardi, Òscar Jordà, and Alan. M. Taylor, 2022, A local projection approach to difference-in-difference event studies, NBER Working Paper, SI 2022 Forecasting Empirical Methods.

Fabra, Natalia, and Juan Pablo Montero, 2022, Technology-Neutral vs. Technology-Specific Procurement, .

Feyrer, James, Erin Mansur, and Bruce Sacerdote, 2020, Geographic Dispersion of Economic Shocks: Evidence from the Fracking Revolution: Reply, *American Economic Review* 110, 1914–1920.

Feyrer, James, Erin T. Mansur, and Bruce Sacerdote, 2017, Geographic dispersion of economic shocks: Evidence from the fracking revolution, *American Economic Review* 107, 1313–34.

Feyrer, James, and Bruce Sacerdote, 2011, Did the stimulus stimulate? real time estimates of the effects of the american recovery and reinvestment act, Working Paper 16759 National Bureau of Economic Research.

Germeshausen, Robert, Sven Heim, and Ulrich J. Wagner, 2021, Support for renewable energy: The case of wind power, Discussion paper.

Gibbons, Stephen, 2015, Gone with the wind: Valuing the visual impacts of wind turbines through house prices, *Journal of Environmental Economics and Management* 72, 177–196.

Goodman-Bacon, Andrew, 2021, Difference-in-differences with variation in treatment timing, *Journal of Econometrics* pp. 254–277.

Haan, Peter, and Martin Simmler, 2018, Wind electricity subsidies — a windfall for landowners? evidence from a feed-in tariff in germany, *Journal of Public Economics* 159, 16–32.

Hartley, Peter R., Kenneth B. Medlock, Ted Temzelides, and Xinya Zhang, 2015, Local employment impact from competing energy sources: Shale gas versus wind generation in texas, *Energy Economics* 49, 610–619.

IRENA, 2017a, Renewable energy benefits: Leveraging local capacity for solar pv, .

——— , 2017b, Renewable energy benefits: Leveraging local capacity for onshore wind, *Discussion paper*.

——— , 2022a, Renewable Energy and Jobs - Annual Review 2021, *Discussion paper*.

——— , 2022b, Renewable Power Generation Costs in 2020, Discussion paper.

——— , 2022c, Trends in Renewable Energy, Discussion paper.

James, Alexander G., and Brock Smith, 2020, Geographic dispersion of economic shocks: Evidence from the fracking revolution: Comment, *American Economic Review* 110, 1905–13.

Jarvis, Stephen, 2021, The economic costs of nimbyism - evidence from renewable energy projects, Crc tr 224 discussion paper series University of Bonn and University of Mannheim, Germany.

Jordà, Oscar, 2005, Estimation and inference of impulse responses by local projections, *American Economic Review* 95.

Kahn, Matthew, and Erin Mansur, 2013, Do local energy prices and regulation affect the geographic concentration of employment?, *Journal of Public Economics* 101, 105–114.

Kline, Patrick, and Enrico Moretti, 2014, Local Economic Development, Agglomeration Economies, and the Big Push: 100 Years of Evidence from the Tennessee Valley Authority, *The Quarterly Journal of Economics* 129, 275–331.

Krekel, Christian, Julia Rechlitz, Johannes Rode, and Alexander Zerrahn, 2021, Quantifying the externalities of renewable energy plants using wellbeing data: The case of biogas, SOEPpapers on Multidisciplinary Panel Data Research 1116 DIW Berlin, The German Socio-Economic Panel (SOEP).

Leduc, Sylvain, and Daniel Wilson, 2013, Roads to prosperity or bridges to nowhere? theory and evidence on the impact of public infrastructure investment, *NBER Macroeconomics Annual* 27, 89–142.

Marin, Giovanni, and Francesco Vona, 2021, The impact of energy prices on socioeconomic and environmental performance: Evidence from French manufacturing establishments, 1997–2015, *European Economic Review* 135.

Metcalf, Gilbert E., and James H. Stock, 2020, Measuring the macroeconomic impact of carbon taxes, *AEA Papers and Proceedings* 110, 101–06.

MITECO, 2020, Impacto economico, de empleo, social y sobre la salud publica del plan nacional integrado de energia y clima 2021-2030, .

Moretti, Enrico, 2010, Local multipliers, *American Economic Review* 100, 373–77.

Morgenstern, Richard D., William A. Pizer, and Jhih-Shyang Shih, 2002, Jobs Versus the Environment: An Industry-Level Perspective, *Journal of Environmental Economics and Management* 43, 412–436.

Nakamura, Emi, and Jón Steinsson, 2018, Identification in macroeconomics, *Journal of Economic Perspectives* 32, 59–86.

Popp, David, Francesco Vona, Giovanni Marin, and Ziqiao Chen, 2022, The employment impact of green fiscal push: Evidence from the american recovery act: Evidence from the american recovery act, *Brookings Papers on Economic Activity*.

Ramey, V.A., 2016, Chapter 2 - macroeconomic shocks and their propagation, , vol. 2 of *Handbook of Macroeconomics* . pp. 71–162 (Elsevier).

Ramey, Valerie A., and Sarah Zubairy, 2018, Government spending multipliers in good times and in bad: Evidence from us historical data, *Journal of Political Economy* 126, 850–901.

Rand, Joseph, and Ben Hoen, 2017, Thirty years of north american wind energy acceptance research: What have we learned?, *Energy Research Social Science* 29, 135–148.

REE, 2021, Informe del Sistema Eléctrico Español 2020, Discussion paper.

Schmidheiny, K., and S Siegloch, 2020, On event studies and distributed-lags in two way fixed effects models: Identification, equivalence and generalization, CEPR Discussion Paper 13477.

Sun, Liyang, and Sarah Abraham, 2021, Estimating dynamic treatment effects in event studies with heterogeneous treatment effects, *Journal of Econometrics* 225, 175–199 Themed Issue: Treatment Effect 1.

Sunak, Yasin, and Reinhard Madlener, 2016, The impact of wind farm visibility on property values: A spatial difference-in-differences analysis, *Energy Economics* 55, 79–91.

The White House, 2022, President biden's state of the union address, .

Vona, Francesco, Giovanni Marin, and Davide Consoli, 2018, Measures, drivers and effects of green employment: evidence from US local labor markets, 2006–2014, *Journal of Economic Geography* 19, 1021–1048.

Wilson, Daniel J., 2012, Fiscal spending jobs multipliers: Evidence from the 2009 american recovery and reinvestment act, *American Economic Journal: Economic Policy* 4, 251–82.

World Bank, 2021, Inclusive growth at a crossroads. part one of strengthening inclusion and facilitating the green transition, *EU Regular Economic Report* 7.

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). 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 ($\beta_{\tau-24} = 0$).[63, 64]

Figures A.1 and A.2 show the employment and unemployment results, respectively, for both monthly and 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 very 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

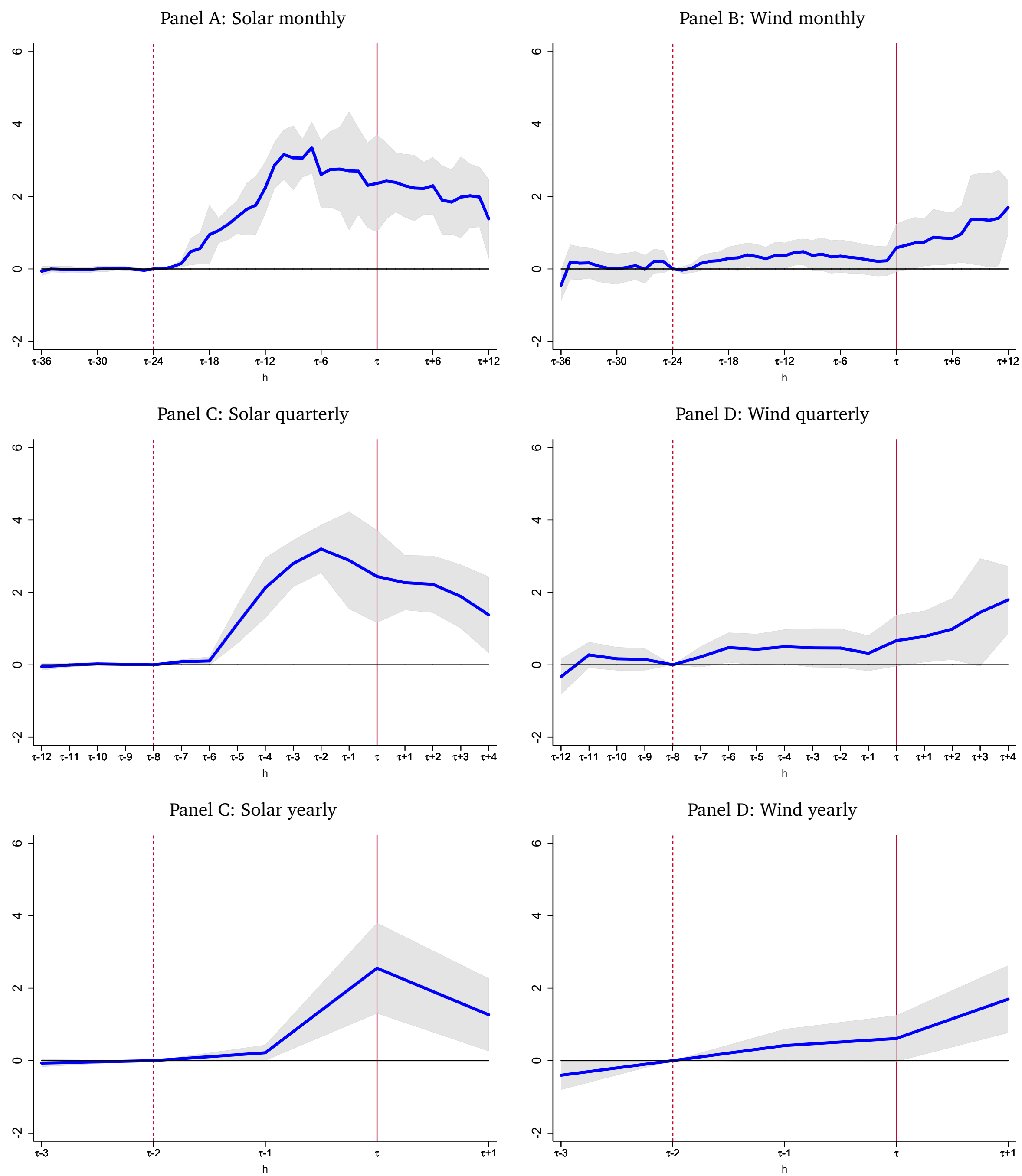
	Employment		Unemployment	
	Pre-opening (1)	Post-opening (2)	Pre-opening (3)	Post-opening (4)
Solar Multiplier (Jobs/MW)	2.796***	2.163***	-0.085	0.231
	(0.375)	(0.424)	(0.110)	(0.145)
Wind Multiplier (Jobs/MW)	0.337*	0.977**	-0.111**	-0.132**
	(0.196)	(0.426)	(0.056)	(0.067)
Obs.	583,414	583,414	500,102	500,102
Municipalities	3,214	3,214	3,251	3,251

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.

[63] 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 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 controls, 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.

[64] As Schmidheiny and Siegloch (2020) show, the specification of equation (7) is equivalent to a distributed-lag model of the following form: $y_{i,t} = \sum_{h=-35}^{24} \gamma_{\tau+h} K_{i,t-h} + \alpha_i + \lambda_t + \epsilon_{i,t}$, where the $\beta_{\tau+h}$'s can be recovered from a combination of the $\gamma_{\tau+h}$'s.

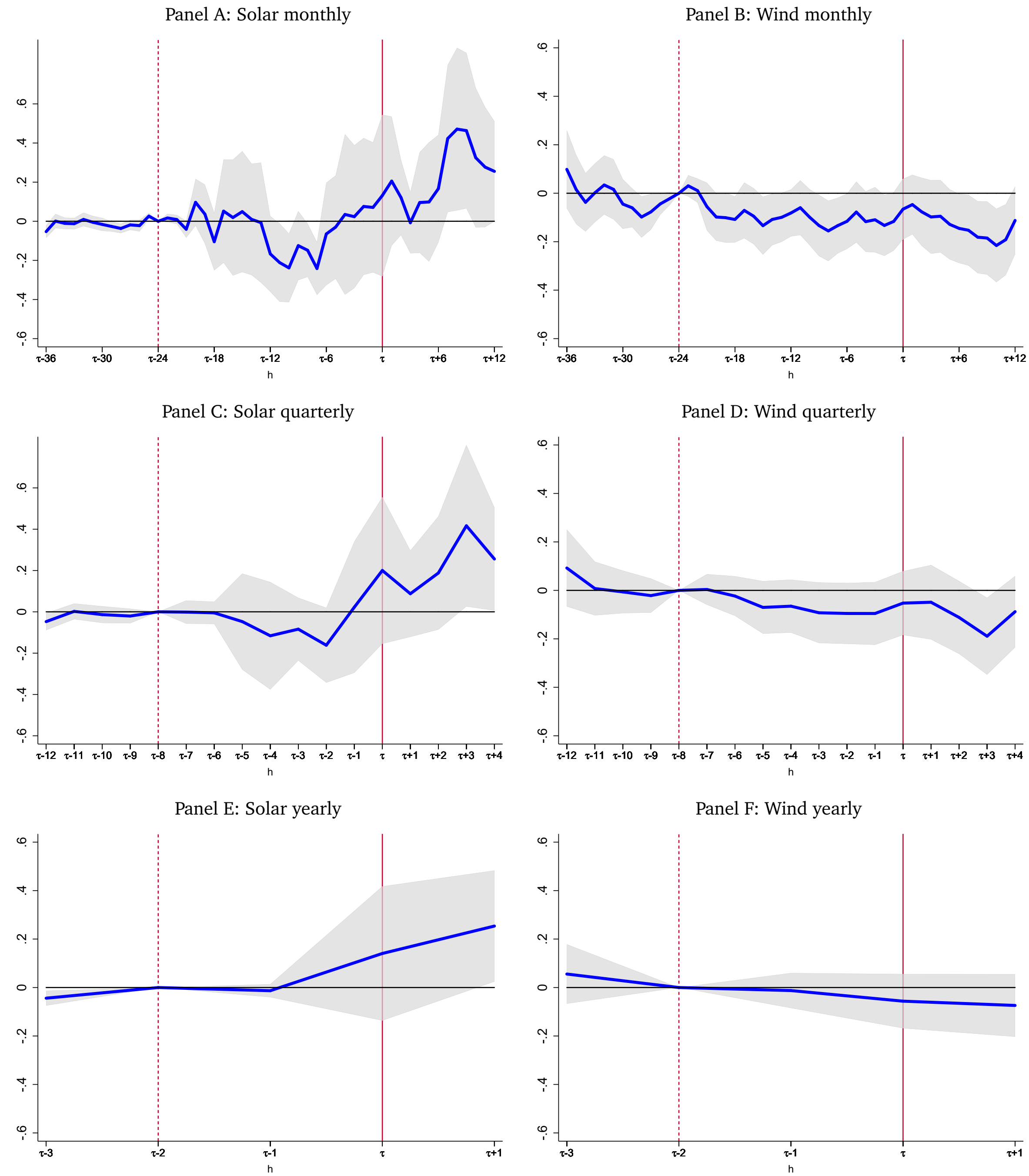
FIGURE A.1
LOCAL EMPLOYMENT EFFECTS - EVENT STUDY ESTIMATES



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 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 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)	2,210	168
All (2019-2020)	105	30
Rural (2006-2018)	1,482	117
Urban (2006-2018)	728	51
Size of shocks (2006-2018, MW)		
Mean	0.528	18.723
Percentile 25	0.016	4.000
Percentile 50	0.050	14.400
Percentile 75	0.110	28.000
Size of shocks (2019-2020, MW)		
Mean	27.525	27.388
Percentile 25	0.085	9.61
Percentile 50	0.700	24.000
Percentile 75	39.983	34.650

Notes: This table shows descriptive statistics of the municipalities included in the sample.

B.1 Results at the county level

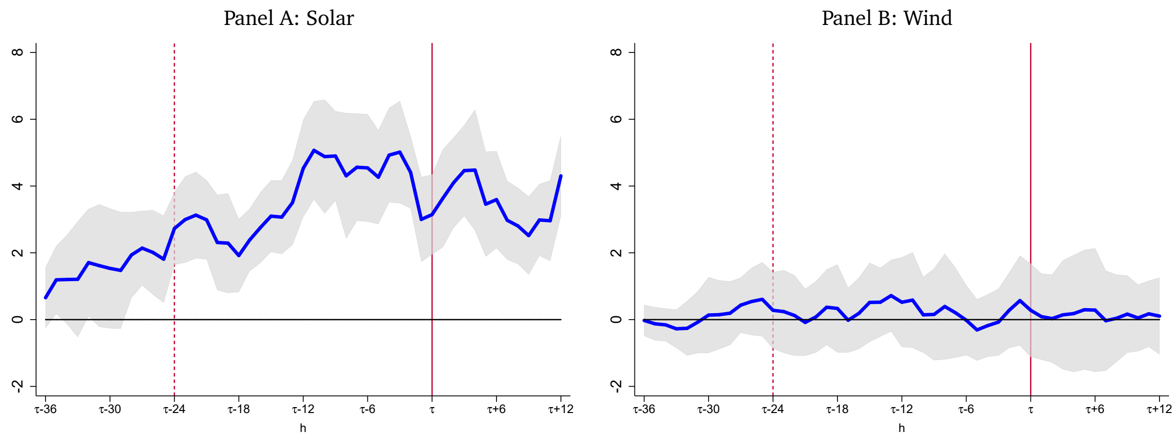
TABLE B.3
EMPLOYMENT AND UNEMPLOYMENT EFFECTS AT THE COUNTY LEVEL

	Employment		Unemployment	
	Pre-opening (1)	Post-opening (2)	Pre-opening (3)	Post-opening (4)
Solar Multiplier (Jobs/MW)	4.552***	3.484***	-1.089**	-0.349
	(0.458)	(0.528)	(0.545)	(0.592)
Wind Multiplier (Jobs/MW)	0.196	0.134	-0.069	-0.256*
	(0.623)	(0.719)	(0.250)	(0.144)
# Obs.	45,967	45,967	38,033	38,033
# Counties	320	320	318	318

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

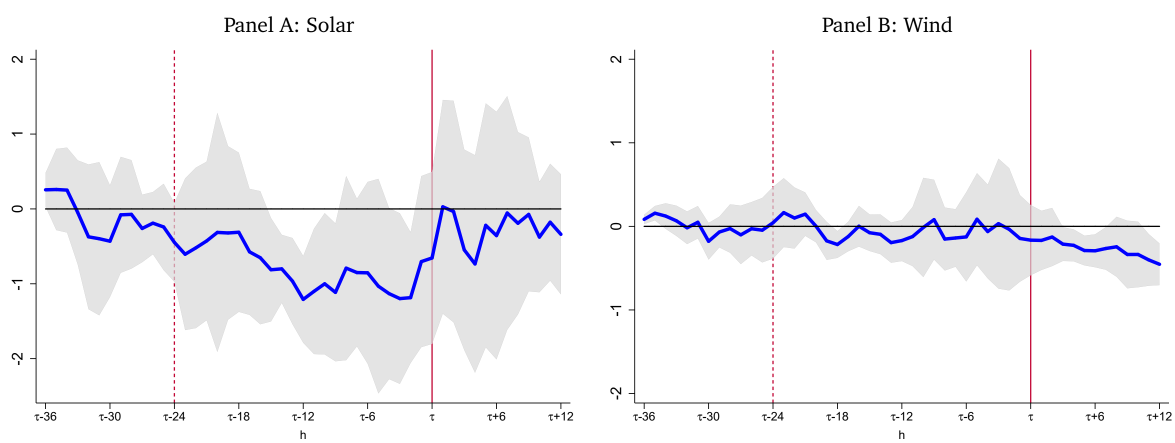
EMPLOYMENT EFFECTS - COUNTY LEVEL



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 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

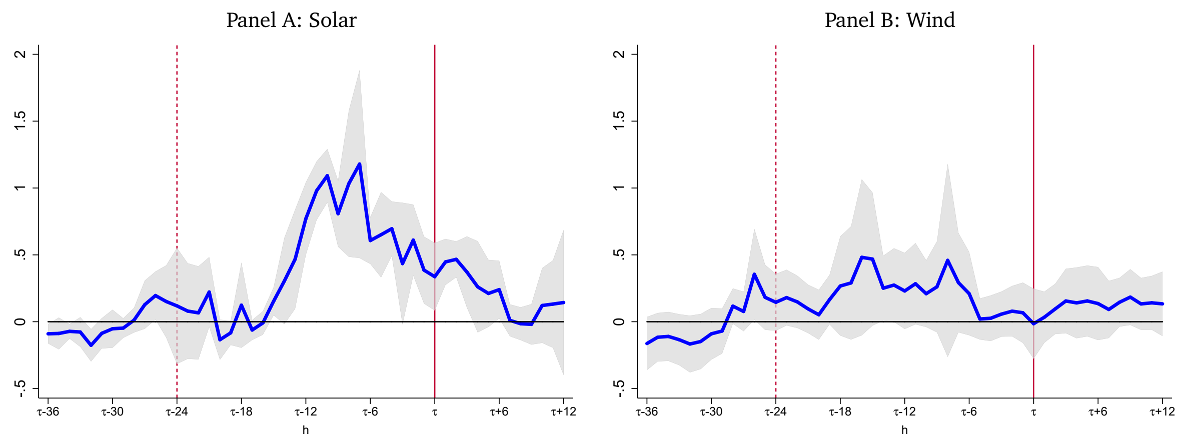
UNEMPLOYMENT EFFECTS. COUNTY LEVEL



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 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 per million euros invested

FIGURE B.5
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 2011-January 2018, h periods before or after the start-up date (marked with a vertical 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. In addition, this specification controls for solar and wind installed capacity between t-12 and t-1, as costs data is only available since 2010.

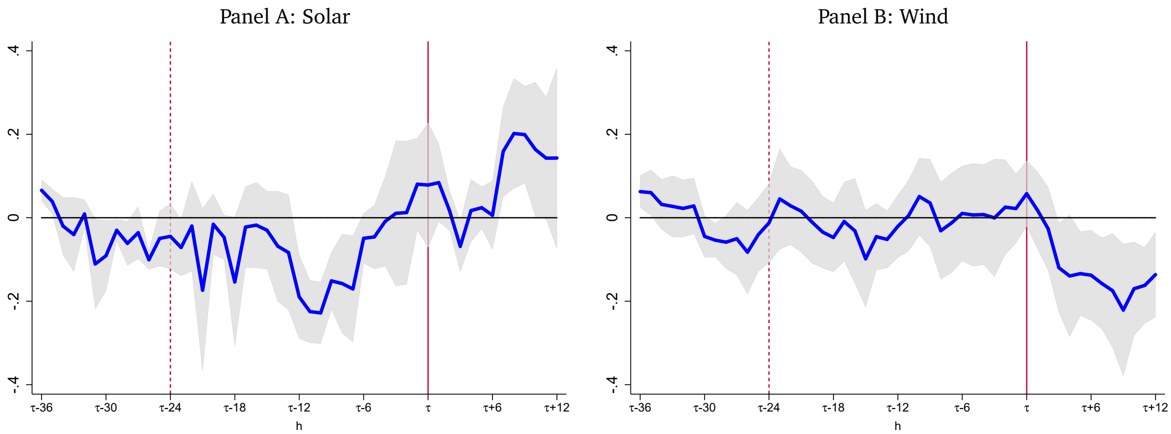
TABLE B.4
EMPLOYMENT AND UNEMPLOYMENT EFFECTS PER 1 MILLION EUROS

	Employment		Unemployment	
	Pre-opening (1)	Post-opening (2)	Pre-opening (3)	Post-opening (4)
Solar Multiplier (Jobs/million euros)	0.771^{***}	0.214^{***}	-0.094^{***}	0.085^{**}
	(0.050)	(0.062)	(0.031)	(0.035)
Wind Multiplier (Jobs/million euros)	0.183	0.116	0.008	-0.114^{**}
	(0.124)	(0.103)	(0.049)	(0.052)
# Obs.	271,886	271,886	275,452	275,452
# Municipalities	3,211	3,211	3,249	3,249

Notes: This table reports the results of estimating the local employment and unemployment effects at the municipality level for the period January 2011-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. In addition, this specification controls for solar and wind installed capacity between t-12 and t-1, as costs data is only available since 2010.

FIGURE B.6

UNEMPLOYMENT EFFECTS PER ONE MILLION EUROS

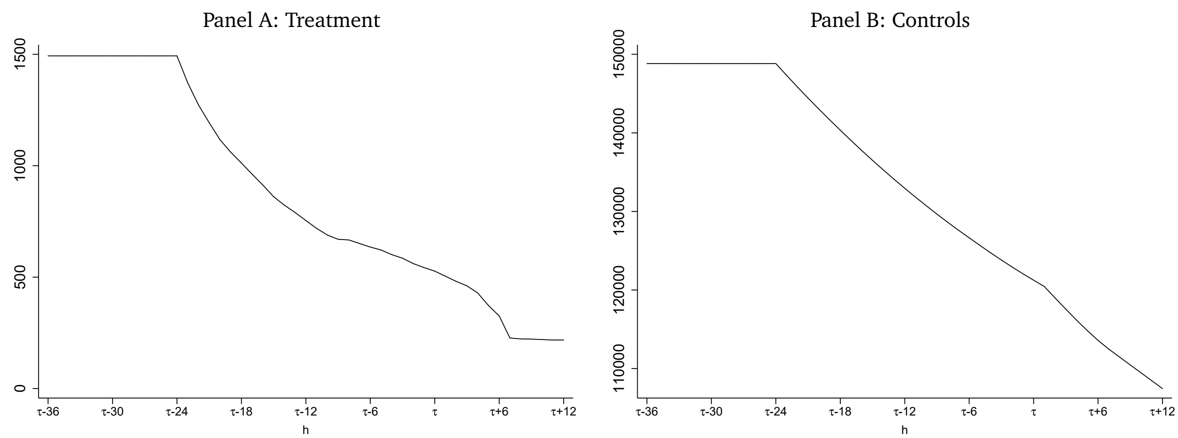


Notes: These figures show the effects of investing one million euros on unemployment by residents in the municipality where the investment occurs in the period January 2011-January 2018, h periods before or after the start-up date (marked with a vertical red line). Panel (a) shows the results for solar investments, and panel (b) for wind investments. Error bands depict the 95% confidence interval. Standard errors are clustered at the municipality level. In addition, this specification controls for solar and wind installed capacity between t-12 and t-1, as costs data is only available since 2010.

B.3 Number of Observations under the clean control condition

FIGURE B.7

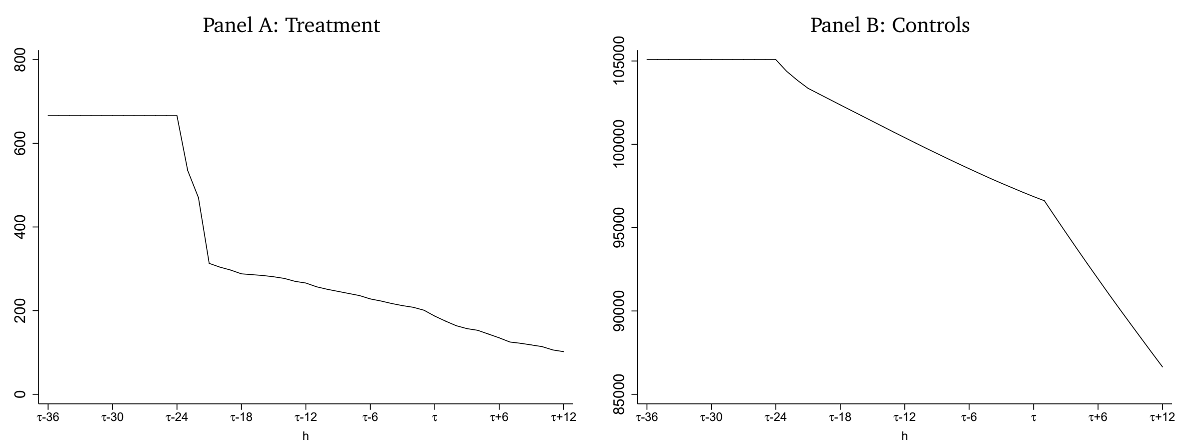
EMPLOYMENT EFFECTS - CLEAN CONTROL - TREATED AND CONTROL OBSERVATIONS



Notes:

FIGURE B.8

UNEMPLOYMENT EFFECTS - CLEAN CONTROL - TREATED AND CONTROL OBSERVATIONS

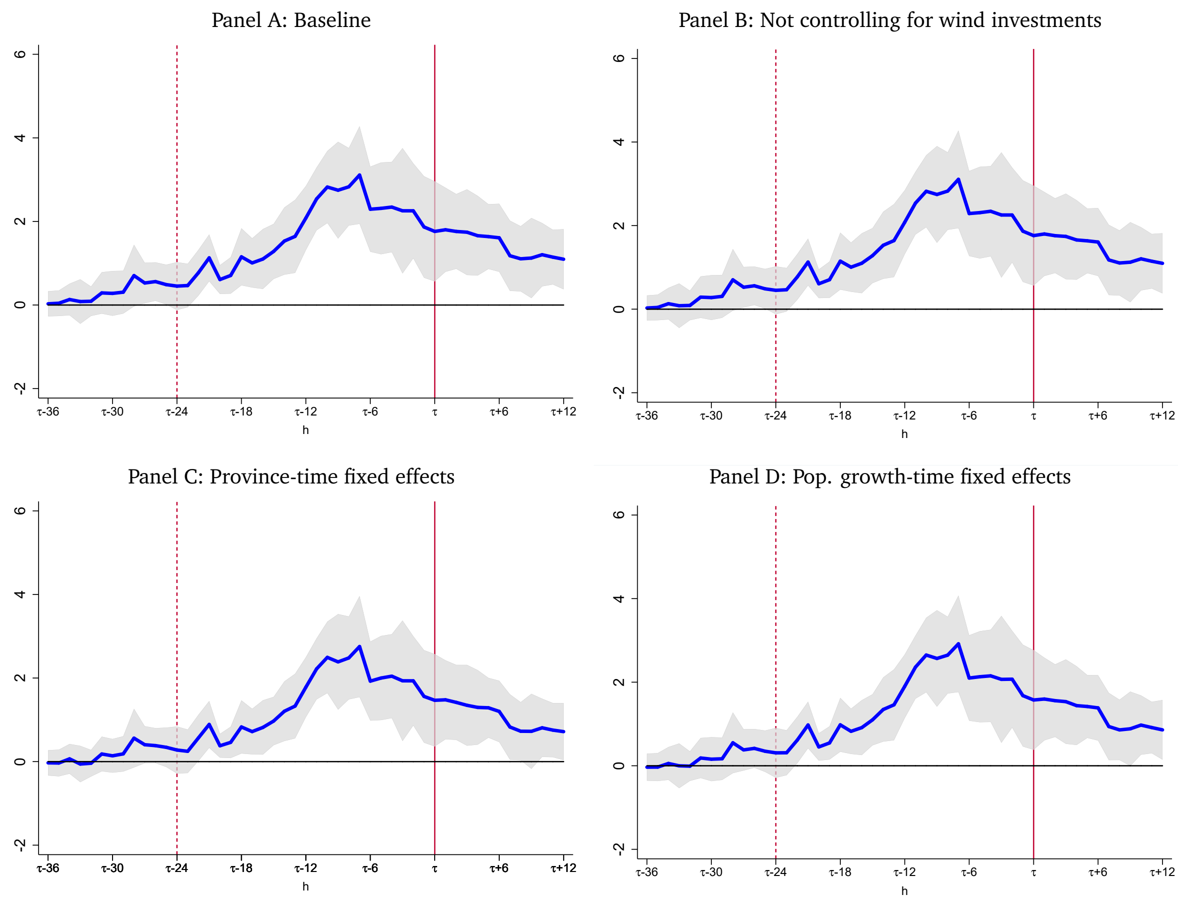


Notes:

B.4 Robustness Results

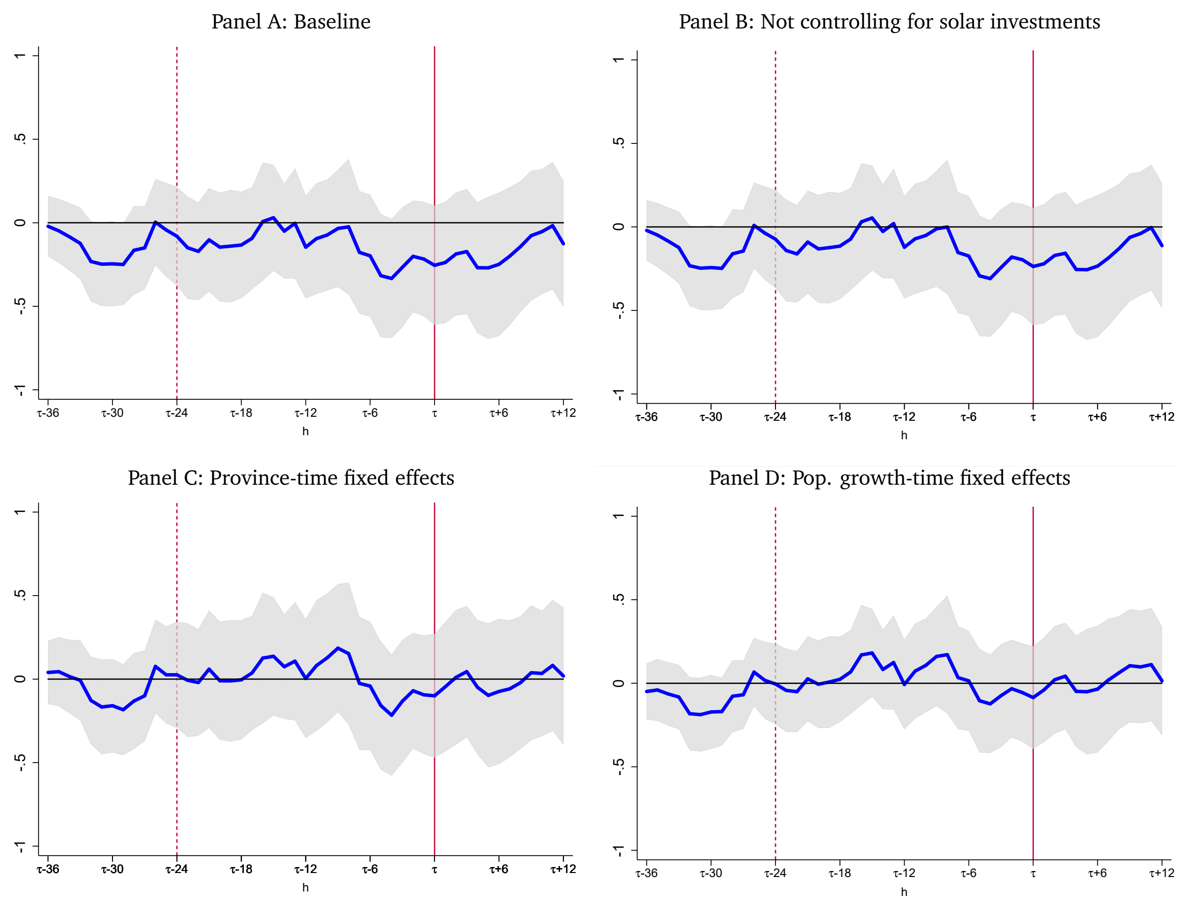
FIGURE B.9

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.10
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.5
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)	2.468***	2.466***		2.130***	2.280***
	(0.450)	(0.449)		(0.428)	(0.453)
Wind Multiplier (Jobs/MW)	-0.186		-0.163	-0.031	0.012
	(0.167)		(0.164)	(0.180)	(0.137)
Post-opening					
Solar Multiplier (Jobs/MW)	1.471***	1.470***		1.104***	1.249***
	(0.411)	(0.410)		(0.380)	(0.395)
Wind Multiplier (Jobs/MW)	-0.183		-0.168	-0.025	0.018
	(0.191)		(0.188)	(0.195)	(0.165)

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.

Table B.6

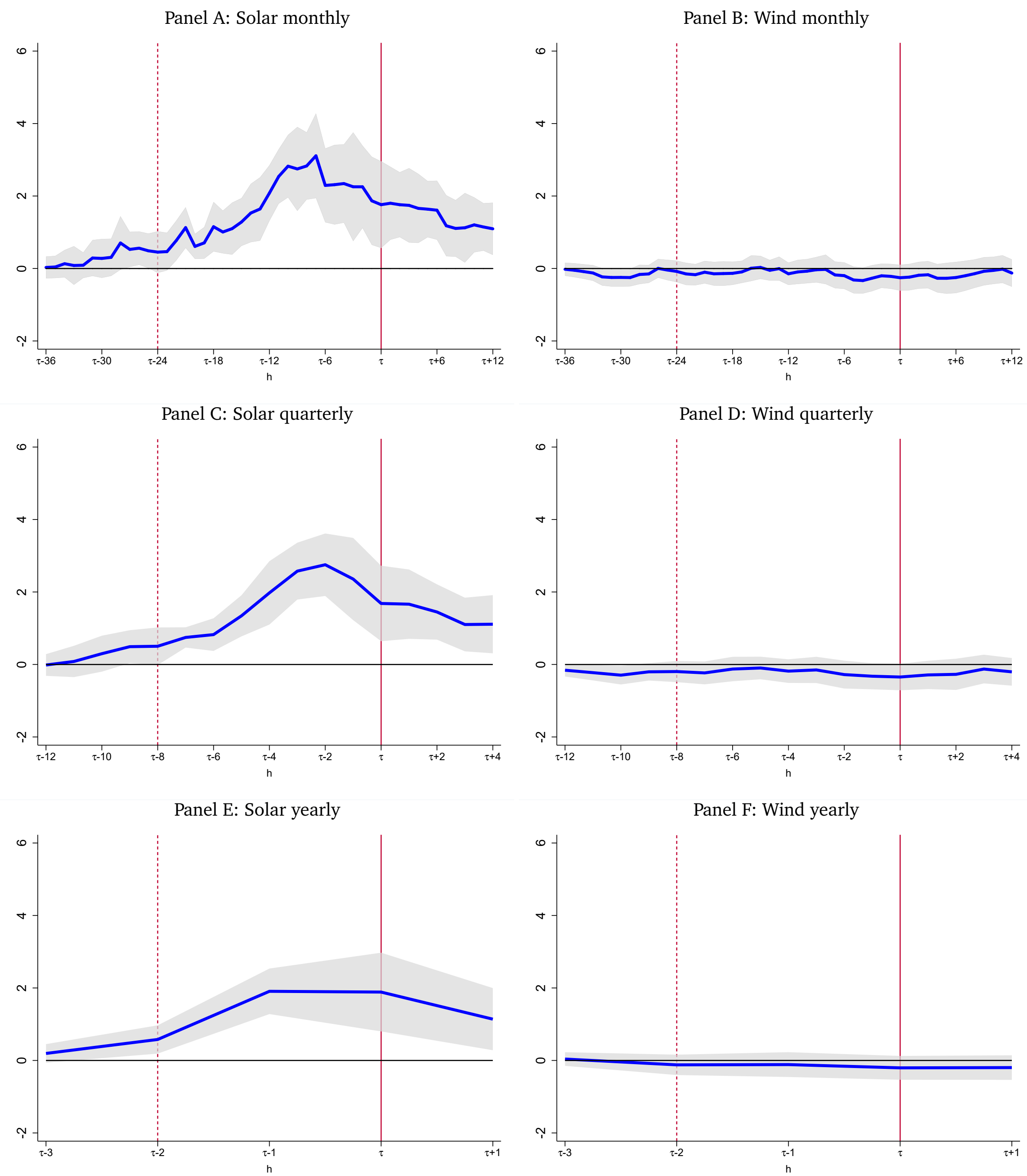
Local employment effects - alternative standard errors

	Municipality		County	
	Pre-opening (1)	Post-opening (2)	Pre-opening (3)	Post-opening (4)
Solar				
Multiplier (Jobs/MW)	2.468	1.471	4.552	3.484
Standard errors				
Baseline	0.450***	0.411***	0.458***	0.528***
Two-way clustering	0.504***	0.475***	0.664***	0.835***
HAC	0.665***	0.569***	0.918***	0.958***
Driscoll and Kraay	0.693***	0.611**	0.977***	1.161***
Wind				
Multiplier (Jobs/MW)	-0.186	-0.183	0.196	0.134
Standard errors				
Baseline	0.167	0.191	0.623	0.719
Two-way clustering	0.225	0.282	0.790	0.872
HAC	0.148	0.165	0.619	0.650
Driscoll and Kraay	0.163	0.183	0.645	0.709
# Obs.	460,645	460,645	45,967	45,967
# Municipalities/counties	3,213	3,213	320	320

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.11

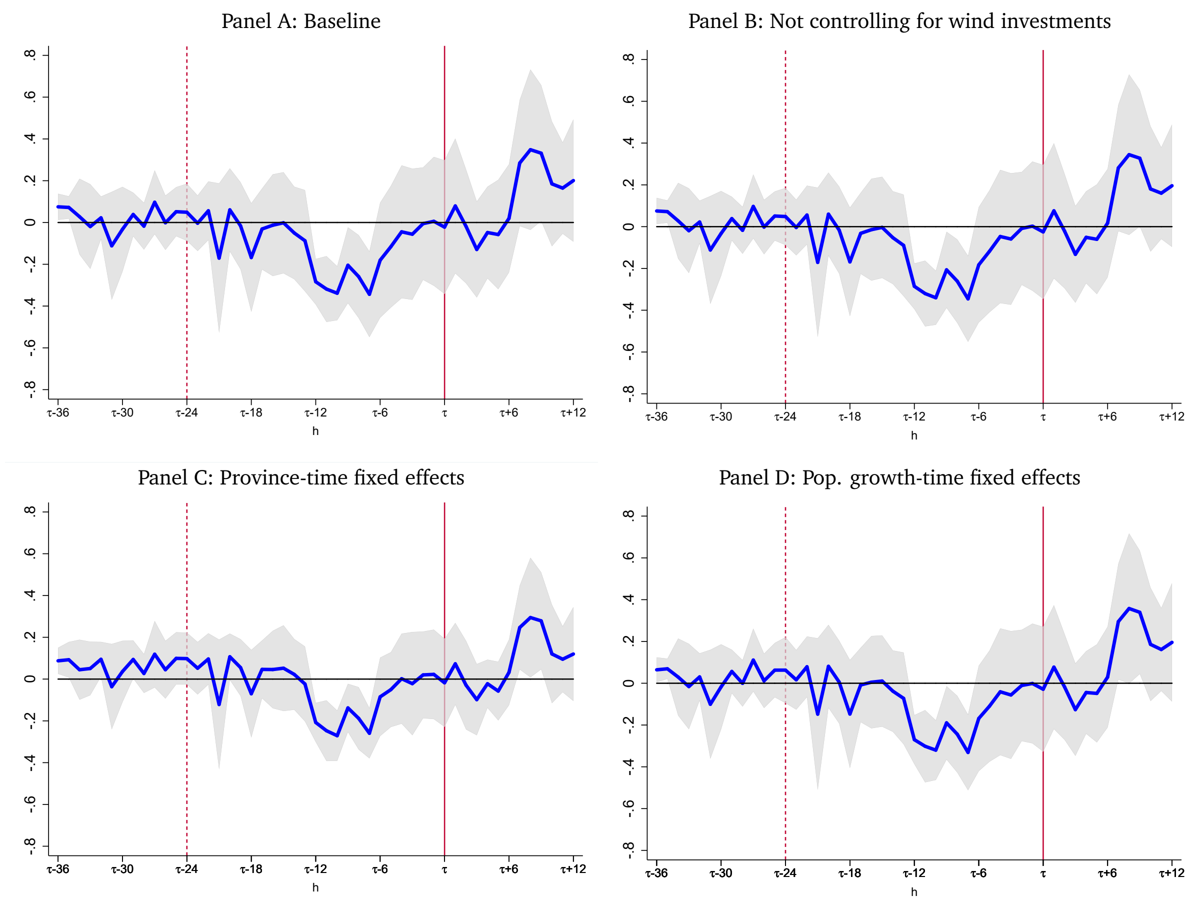
LOCAL EMPLOYMENT EFFECTS - MONTHLY, QUARTERLY AND YEARLY DATA



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 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.

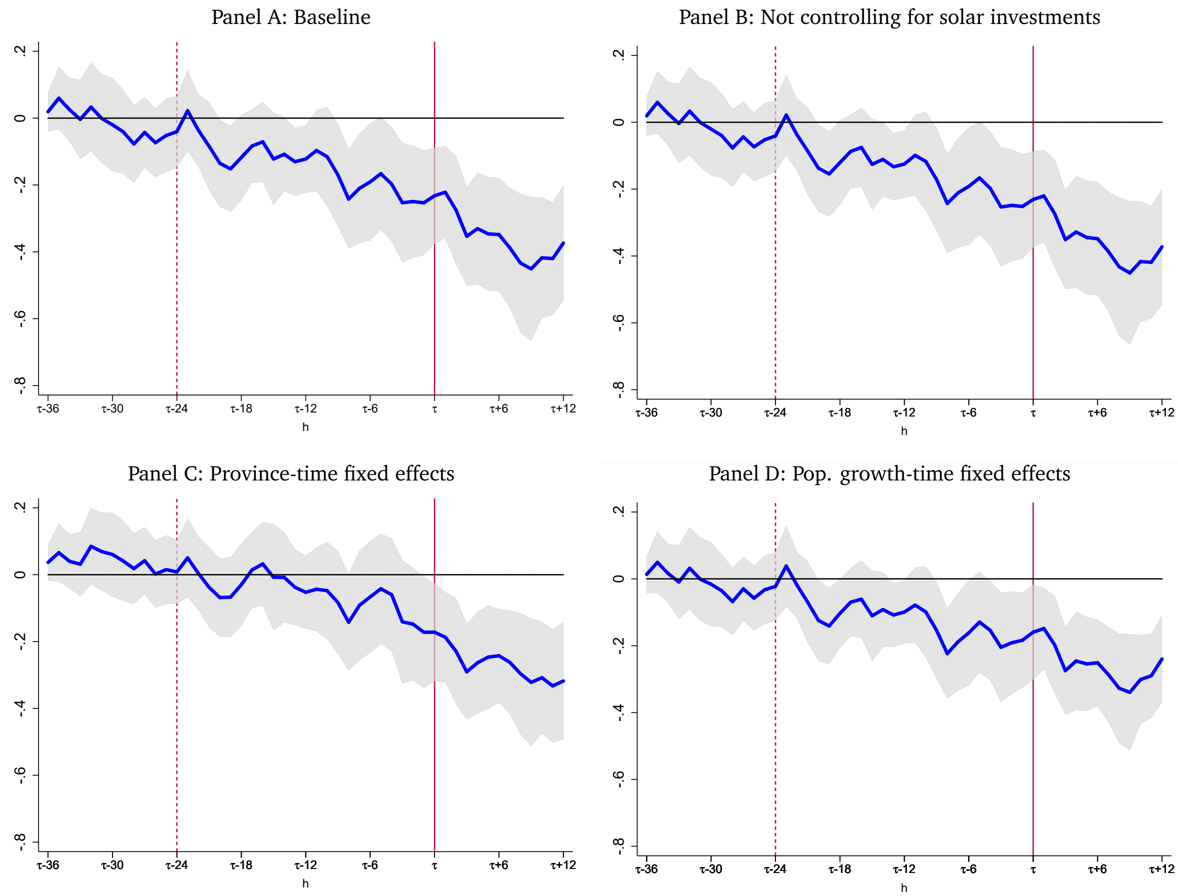
FIGURE B.12

UNEMPLOYMENT EFFECTS OF SOLAR ENERGY - ROBUSTNESS



Notes: These figures report the results of conducting the same robustness tests as in figure B.9, but now for the impact of solar investments on unemployment at the municipality level. All results remain similar to the baseline.

FIGURE B.13
UNEMPLOYMENT EFFECTS OF WIND ENERGY - ROBUSTNESS



Notes: These figures report the results of conducting the same robustness tests as in figure B.9, but now for the impact of wind investments on unemployment at the municipality level. All results remain similar to the baseline.

TABLE B.7
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)	-0.182*	-0.184*		-0.115**	-0.171**
	(0.095)	(0.096)		(0.051)	(0.087)
Wind Multiplier (Jobs/MW)	-0.192***		-0.193***	-0.094	-0.156**
	(0.072)		(0.071)	(0.072)	(0.063)
Post-opening					
Solar Multiplier (Jobs/MW)	0.096	0.092		0.079	0.099
	(0.121)	(0.122)		(0.072)	(0.107)
Wind Multiplier (Jobs/MW)	-0.352***		-0.351***	-0.264***	-0.256***
	(0.076)		(0.076)	(0.070)	(0.058)

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.

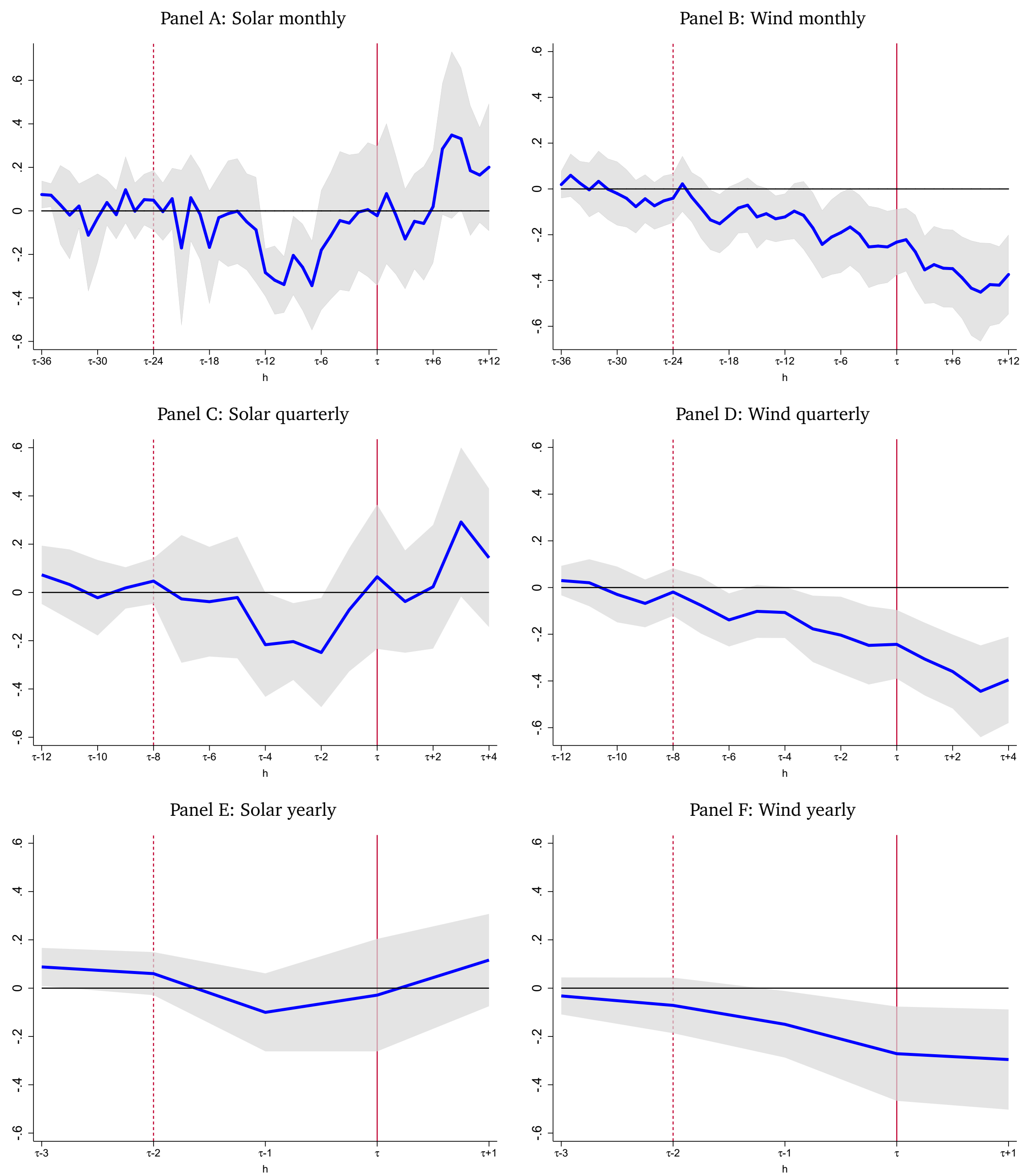
Table B.8
Local unemployment effects - alternative standard errors

	Municipality		County	
	Pre-opening (1)	Post-opening (2)	Pre-opening (3)	Post-opening (4)
Solar				
Multiplier (Jobs/MW)	-0.182	0.096	-1.089	-0.349
Standard errors				
Baseline	0.095*	0.121	0.545**	0.592
Two-way clustering	0.110	0.138	0.615*	0.664
HAC	0.072**	0.086	0.435**	0.544
Driscoll and Kraay	0.083**	0.109	0.529**	0.622
Wind				
Multiplier (Jobs/MW)	-0.192	-0.352	-0.069	-0.256
Standard errors				
Baseline	0.072***	0.076***	0.250	0.144*
Two-way clustering	0.085**	0.090***	0.350	0.212
HAC	0.062***	0.059***	0.279	0.158
Driscoll and Kraay	0.059***	0.064***	0.278	0.160
# Obs.	375,861	375,861	38,033	38,033
# Municipalities/counties	3,251	3,251	318	318

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.14

LOCAL UNEMPLOYMENT EFFECTS - MONTHLY, QUARTERLY AND YEARLY DATA



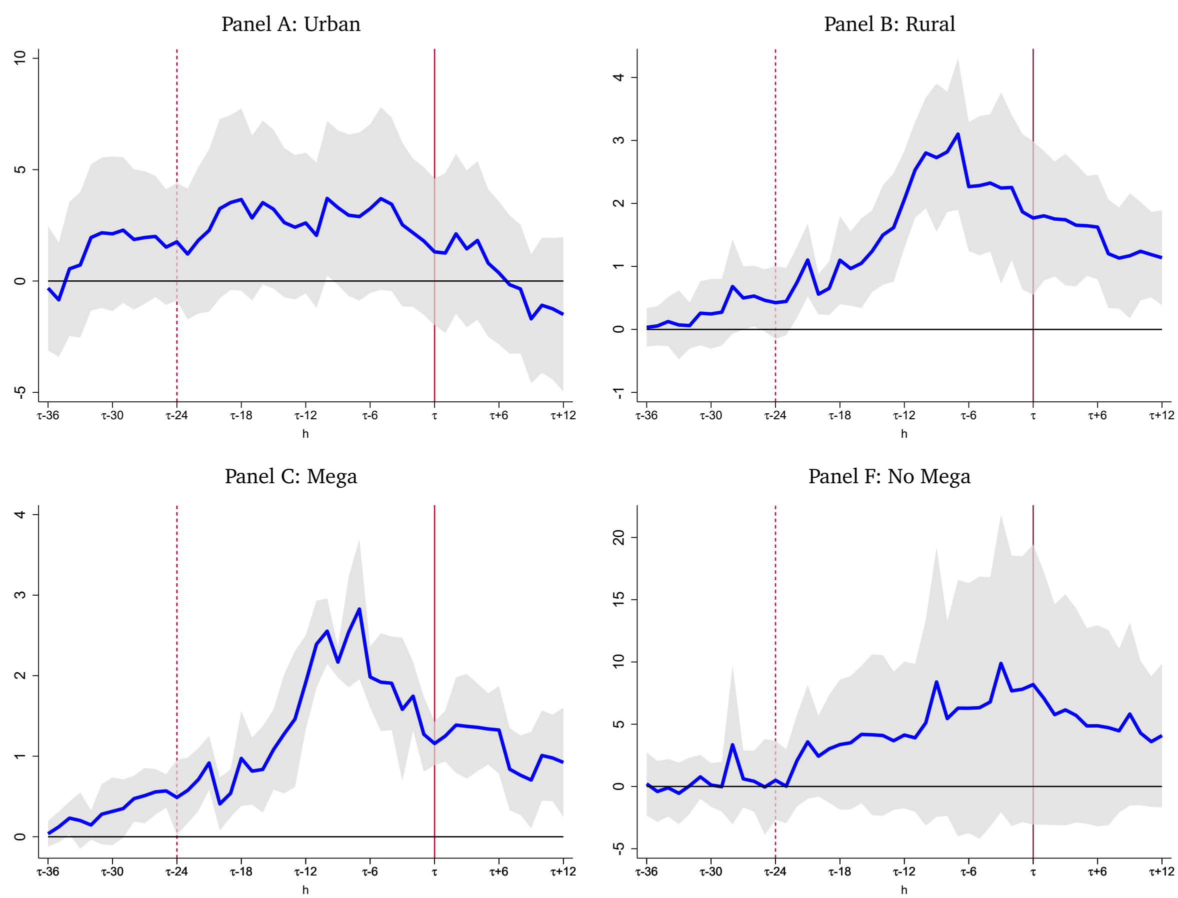
Notes: These figures show the effects of investing 1 MW on unemployment by residents in the municipality where the investment occurs, h periods (months, quarters or years) before or after the start-up date (marked with a vertical red line). Panels (a) and (b) show the results for solar and wind investments 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.5 Additional Results

B.5.1 Heterogeneous effects for solar investments

FIGURE B.15

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 (with less or more than 10,000 inhabitants), and between large and small projects (above or below 49MW). Results depicted h periods before or after the start-up date (marked with a vertical red line). Panel (a) shows the results for urban municipalities, panel (b) for rural municipalities, panel (c) for large projects, and panel (d) for small projects.

FIGURE B.16

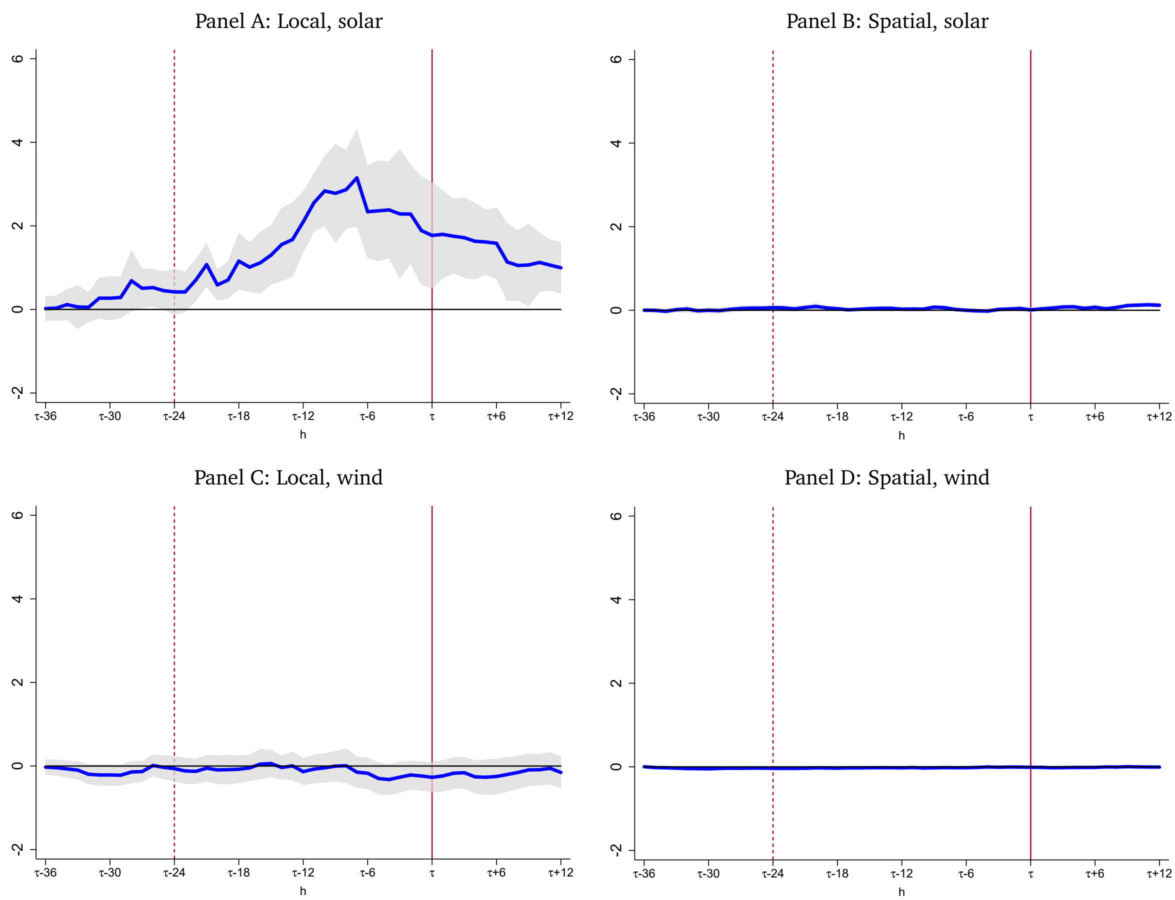
UNEMPLOYMENT EFFECTS - HETEROGENEITY

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 (with less or more than 10,000 inhabitants), and large and small projects (above or below 49MW). Results depicted h periods before or after the start-up date (marked with a vertical red line). Panel (a) shows the results for urban municipalities, panel (b) for rural municipalities, panel (c) for large projects, and panel (d) for small projects.

B.6 Spatial Effects

FIGURE B.17

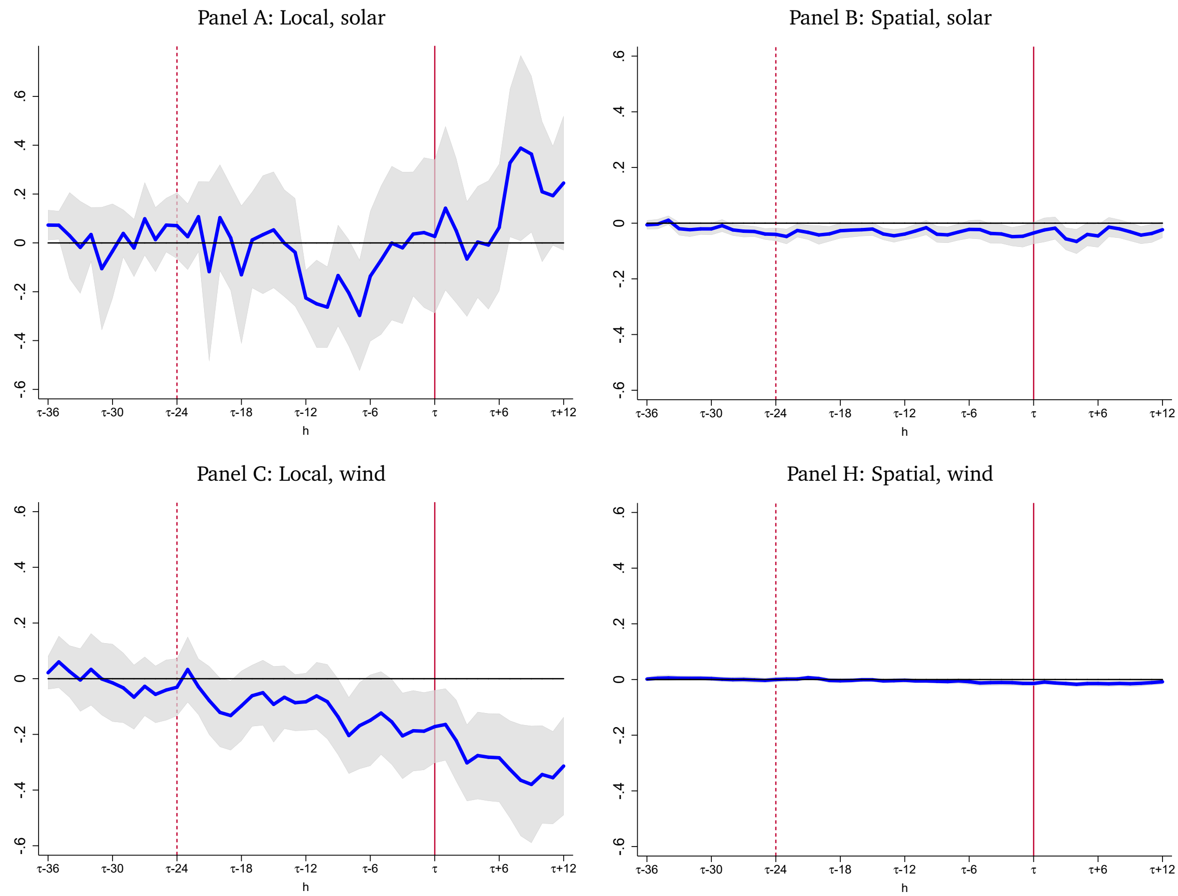
EMPLOYMENT LOCAL AND SPATIAL EFFECTS (30 KM)



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 30 kilometers. Results depicted h periods before or after the start-up date (marked with a vertical 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.18

UNEMPLOYMENT LOCAL AND SPATIAL EFFECTS (30 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 30 kilometers. Results depicted h periods before or after the start-up date (marked with a vertical 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.7 Solar Investments during the Second Wave

TABLE B.9

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	0.772***	0.191**	-0.053*	0.139***
	(0.056)	(0.091)	(0.031)	(0.040)
Since 2019	0.671***	0.052	-0.103***	-0.077***
	(0.176)	(0.067)	(0.028)	(0.009)
Observations	349652	349652	354129	354129
# Municipalities	3,214	3,214	3,251	3,251

Notes: This table reports the results of estimating the local employment and unemployment effects of solar investments during the period January 2011-January 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-12 and t-1, as costs data is only available since 2010.