

A Service of

ZBW

Leibniz-Informationszentrum Wirtschaft Leibniz Information Centre for Economics

Serra-Sala, Claudia

Working Paper Harnessing the Wind: The Impact of Wind Farm Development on Municipal Finances

CESifo Working Paper, No. 11283

Provided in Cooperation with: Ifo Institute – Leibniz Institute for Economic Research at the University of Munich

Suggested Citation: Serra-Sala, Claudia (2024) : Harnessing the Wind: The Impact of Wind Farm Development on Municipal Finances, CESifo Working Paper, No. 11283, CESifo GmbH, Munich

This Version is available at: https://hdl.handle.net/10419/305525

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



WWW.ECONSTOR.EU



Harnessing the Wind: The Impact of Wind Farm Development on Municipal Finances

Claudia Serra-Sala



Impressum:

CESifo Working Papers ISSN 2364-1428 (electronic version) Publisher and distributor: Munich Society for the Promotion of Economic Research - CESifo GmbH The international platform of Ludwigs-Maximilians University's Center for Economic Studies and the ifo Institute Poschingerstr. 5, 81679 Munich, Germany Telephone +49 (0)89 2180-2740, Telefax +49 (0)89 2180-17845, email office@cesifo.de Editor: Clemens Fuest https://www.cesifo.org/en/wp An electronic version of the paper may be downloaded • from the SSRN website: www.SSRN.com

- from the RePEc website: <u>www.RePEc.org</u>
- from the CESifo website: <u>https://www.cesifo.org/en/wp</u>

Harnessing the Wind: The Impact of Wind Farm Development on Municipal Finances

Abstract

Wind farm development, despite offering global benefits, often encounters local opposition fostered by local negative externalities and uncertain benefits. This study investigates the financial impact of wind farm development on host municipalities using Spanish municipality-level budget data from 1994 to 2022. Results from two-way fixed effect difference-in-difference and event study models show an average 45 percent increase in municipal revenue per capita, funding real investments and current expenditures. This revenue increase, driven by a tax base expansion, is complemented by a rise in capital income and local tax responses in the form of higher tax rates associated with this infrastructure.

JEL-Codes: H200, R100, Q400.

Keywords: energy transition, local public finance, wind power.

Claudia Serra-Sala Barcelona School of Economics Campus Bellaterra, UAB Spain - 08193, Bellaterra claudia.serra@bse.eu.

July 2024

I gratefully acknowledge the support and encouragement from my advisors, Pilar Sorribas and Dirk Foremny. I would also like to thank comments and support from Andreu Arenas, Daniel Montolio, Jordi Jofre-Monseny, Judit Vall, Mariana Lopes da Fonseca, Nadine Riedel, and Mar Reguant. I acknowledge comments from participants at the CESifo Area Conference on Energy and Climate Economics 2024, the Spanish Economic Association Meeting, the European Public Choice Society Conference, the Meeting of the Catalan Economic Society, and the seminar series of the Barcelona School of Economics Energy Research Group. This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (grant agreement No 101001732-ENECML) and from PID2021-126517NB-I00/ Ministerio de Ciencia, Innovación y Universidades. I am also a CESifo research affiliate, and a IEB associate researcher.

1 Introduction

Renewable energy production technologies play a central role in the transition towards a decarbonized paradigm, offering global benefits by offsetting the greenhouse gas emissions associated with conventional technologies.¹ Among these renewable sources, wind power is of particular interest as it is recognized as one of the most environmentally friendly sources of energy generation.² However, while wind infrastructure holds significant potential for clean energy generation, its development can also create negative local externalities. Consequently, new infrastructure initiatives often encounter opposition and conflict with local residents, resulting in a misallocation of renewable energy investment and higher deployment costs (Jarvis, 2024).

From a socioeconomic perspective, the development of this type of infrastructure, often located in rural areas, has been frequently presented as an opportunity for economic activity and employment creation in those regions. However, the realization of these benefits for host communities is not immediate. In addition to the visual and noise impacts associated with wind infrastructure, the displacement of potential alternative land uses and the perception of wind as a common good contribute to the formation of "Not In My Backyard" attitudes and the demand from local communities for compensation (Ejdemo and Söderholm, 2015; Lehmann, Reutter, and Tafarte, 2023). Moreover, the perception of inequality and fairness in the distribution of benefits from wind energy projects are found to prompt local opposition to the installation of wind farms (Clausen and Rudolph, 2020; Wolsink, 2007; Vuichard et al., 2022; Hübner et al., 2023).

In this paper, I study the local impact of large renewable energy projects on municipal finances and local tax responses. To do so, I focus on the development of wind farms in Spain, a country that experienced a rapid growth in its wind energy sector between 2000 and 2013, leading to its position as the second-largest European country in terms of installed wind capacity. I use difference-in-differences and event-study methodologies which exploit spatial and temporal variations in the development of wind energy production installations to provide a clear causal identification of their local effects.

By exploiting the Spanish setting, this analysis contributes to understanding the impact wind investments have on host municipalities. This is particularly relevant in the absence of specific compensation mechanisms to offset the costs associated with such infrastructure. The lack of significant local employment effects (Fabra et al., 2023) suggests that,

¹Cullen (2013) quantifies the emissions offset by wind power, and Novan (2015) quantifies the marginal external benefit of wind turbines and solar panels on pollution.

²See Rahman, Farrok, and Haque (2022) or Schiermeier et al. (2008) for a review of the environmental impact of electrical power plants based on renewable energy sources.

at the local level, the impact of such investments can take place mainly through income flows accumulating to landowners, local ownership stakes in the plant, or through an improvement in municipal finances (Mauritzen, 2020). In this context, understanding to what extent host municipalities can financially benefit from wind farm development is of primary interest. Resources generated from this type of infrastructure can be used to indirectly compensate local communities via increases in public expenditure and reductions in citizens' fiscal pressure.

More specifically, I use data from 1994 to 2022 for local budgets to investigate how municipal revenue is affected by the development of a wind farms in their territory. I link this data to the development of wind farms by using information from the Spanish Register of Energy Producers, which provides the timing, location, and capacity of the universe of wind power plants in Spain. Baseline results show that, on average, wind farm development leads to a 45 percent increase in municipal revenue per capita. This effect, which first appears during the construction of a new installation, is persistent and stable during the operations and maintenance phase.

The magnitude of the effect, though seemingly large, should be contextualized based on baseline budget values of affected municipalities. While tax liabilities from wind energy projects, determined by cadastral valuations and installation costs, are independent of municipal characteristics, municipal budgets are strongly influenced by their size and population. Excluding other potential financial impacts, a typical wind farm of 33 MW incurs about 1.4 million euros in construction tax and approximately 55,000 euros annually in property taxes. Considering these figures in relation to the average total budget of municipalities with population of 20,000 or less, which is roughly 1 million euros, the potential effect is notably significant.³

These results are consistent with the strand of literature analyzing natural-resource windfalls.⁴ Although positive effects on local revenue are present in either case, analyzing the effect of wind installations is especially relevant due to their substantial differences in project durability, local employment, and wage effects. While the impact of wind farms on the local labor market is rather limited, fossil fuel booms and busts often come with large effects (Komarek, 2016; Allcott and Keniston, 2018; Feyrer, Mansur, and Sacerdote, 2017). In terms of project durability, shocks associated to fossil fuels often decrease as

³Ballpark estimates based on 2022 installation cost from the USA National Renewable Energy Laboratory, cadastral valuations from the Spanish Treasury, and average municipal tax rates. With a mean population of 2,500 inhabitants, 87 percent of the affected municipalities have populations of 10,000 or less, resulting in substantially lower baseline total budgets.

 $^{^{4}}$ See for example Bartik et al. (2019) or Newell and Raimi (2015) for analysis focused on the shale oil and gas booms.

the natural resource is exhausted. This is not the case for wind installations. In the case of wind turbines, the effects may be more permanent due to the nature of the resource, allowing for continued investment through re-powering in locations with high winds and existing installations (Mauritzen, 2020).

After identifying the aggregate effect on revenue, I decompose the results among the different revenue instruments that could potentially be affected by the construction of wind farms. Results show that the positive effect on municipal revenue is driven by different channels along the lifetime of the infrastructure.⁵ During the construction phase, the increase in total revenue is mainly driven by a larger yield from the construction tax. However, once the operations and maintenance phase starts, the effect takes place through increases in revenue generated from direct taxes and capital income.

Next, I investigate whether municipalities react to the broadening of the tax base derived from the development of wind farms to indirectly compensate inhabitants by modifying the tax rates under their discretion to decrease fiscal pressure on local inhabitants. To do so, I focus on the property tax, which is the main source of municipalities' own revenue, amounting to an average of 23 percent of total municipal revenue in 2019. More precisely, I analyze the tax rates associated with the different property tax categories by exploiting municipal tax rate data obtained from the Spanish Tax Agency. I find that receiving municipalities react to wind energy developments by increasing tax rates associated with this type of infrastructure (i.e., the special category property tax) close to maximum levels while decreasing tax rates associated with urban and rural property. The change in property tax rates implies that the effect on revenue is not only mechanical due to a broadening of the tax base but is complemented by local tax responses.

These results complement previous literature analyzing reactions to large capital-intensive projects through local tax responses. Langenmayr and Simmler (2021) exploit the development of the German wind energy sector and identify increases in municipal corporate taxes after the development of this type of non-mobile capital investment. By analyzing the different categories of the property tax, I show that local tax responses take place both through increases in the tax rates directly targeting capital-intensive projects as well as by alleviating the fiscal pressure associated to other property categories.

Last, I investigate municipalities' use of this new revenue to identify whether it is channeled toward policies directly benefiting local residents. Benefits to receiving communities can extend beyond the creation of employment opportunities if additional resources de-

⁵The IEC 61400[1] standard sets the design lifetime of a turbine in 20 years. This can be extended depending on environmental factors and the correct maintenance procedures being followed. See Ziegler et al. (2018) for a review on the lifetime extension of onshore wind turbines.

rived from the development of this type of infrastructure are used to redistribute income to hosting communities through improvements in the provision of public goods and services. The results show that, in aggregate terms, municipalities used this new source of revenue to increase total expenditure per capita by 30 percent. By decomposing the increase in expenditure into its different categories, I show that these resources were mainly used to increase current expenditure and real investment. The extent to which host communities benefit from these developments is dependent on the specific programs financed by these resources and limited by restrictions in the capacity of municipalities to modify tax rates.

This paper contributes to the ongoing debate on the local impact of wind farms by providing a country-wide analysis of their effect on local finances. Although a developing body of literature has started exploring the effect of wind farms on local public finances, previous research has mainly centered on housing values and employment.⁶ Studies focusing on European countries tend to point toward negative housing value effects (Dröes and Koster, 2021; Jarvis, 2024), yet consensus in the strand of literature analyzing employment effects is limited. Results on employment effects are mild and tend to differ conditional on the empirical methodology used and the level of analysis.⁷ Focusing on the months surrounding the opening of wind farms in Spain, Fabra et al. (2023) find no increases in employment at the municipality level. In the case of Portugal, Costa and Veiga (2021) find short-term employment effects during the construction phase and a very small and sustained impact during the operations and maintenance phase.

The body of literature documenting increases in the local tax base and local revenues derived from wind farm development mostly focuses on specific regions or projects in the U.S. (see for example 2022; 2022; 2016).⁸ Brunner and Schwegman (2022) examine how county governments respond to increases in the local tax base generated by the universe of U.S. wind farm installations. My results are consistent with their findings that wind farms led to large increases in county revenue. Nevertheless, they document increases in property values that are inconsistent with findings in European countries. In the U.S. setting, counties' provision of public goods and services includes spending on

⁶For studies focusing on housing values see for example Dröes and Koster (2021); Jarvis (2024); Jensen et al. (2018); Sunak and Madlener (2016); Gibbons (2015). For studies focusing on employment effects, see, for example, Hartley et al. (2015); Brown et al. (2012); Allan et al. (2020); Fabra et al. (2023); Costa and Veiga (2021).

⁷See for example Slattery, Lantz, and Johnson (2011); Lehr, Lutz, and Edler (2012) for input-output approaches; Ejdemo and Söderholm (2015) for analysis based on a specific project; Copena and Simón (2018) for analysis based on participatory qualitative research; or Shoeib, Renski, and Infield (2022) for a matching approach.

⁸In the European context, Costa and Veiga (2021) report both short and long-term positive impacts of wind energy investment on total revenues of Portuguese municipalities where a special tax on 2.5 percent of total wind revenue has to be paid to receiving municipalities.

infrastructure such as highways or hospitals, which can lead to increases in housing prices due to citizens' valuation of locally provided public goods and sorting into counties with higher provisions. In the Spanish case, this type of public spending is assigned to higher administrative levels, and municipal competencies are limited to infrastructure such as sports facilities, public parks, or civic centers.

My results have important policy implications and contribute to the ongoing debate on the local impact of wind farms by showing that host municipalities financially benefit from their development. The revenue windfalls generated by this type of infrastructure, which are partially driven by increases in the tax base, are complemented by local tax responses as municipalities use their normative capacity to maximize the revenue generated from this type of energy installation. By analyzing the use that municipalities make of these extra financial resources, I show that it is targeted toward compensating host communities through increases in real investment and decreases in fiscal pressure. Yet, municipalities' competencies in terms of fiscal autonomy and public expenditure capacity are limited, and conflicts around planned investments are still present. The results presented in this paper point to the need to design mechanisms that can help compensate for local costs, mitigate local objections, and minimize conflicts around planned investments with the goal of moving toward a more optimal energy transition.

The rest of the paper is structured as follows. Section 2 describes the development and characteristics of the Spanish wind energy sector. Section 3 presents the data. Section 4 discusses the empirical strategy. Section 5 presents the baseline results, the analysis of local tax responses, and the decomposition of the revenue and expenditure effects. Section 6 concludes.

2 Institutional Context

2.1 Wind Energy in Spain

Wind power installation in Spain has witnessed significant growth over the past two decades, positioning the country as the second-largest in Europe in terms of installed wind capacity. The largest share of the installed capacity occurred between 1998 and 2012 and picked up again in 2018, resulting in a total of 30 gigawatts installed by 2022. The discontinuation of support schemes and incentives for renewable investments marked the end of the first installation wave in 2012. Starting in 2018, a new set of regulations revitalized wind power development. The updated legal framework incorporates an auction system that ensures remuneration to cover production costs and guarantees a reasonable yield for renewable installations. Within this new framework, the development of re-

newable energies is projected to continue expanding in the forthcoming years, aiming to achieve the target of 50 gigawatts of installed wind power by 2030, as established by the Spanish National Integrated Energy and Climate Plan.

Administrative permits to develop new wind power plants are granted by the Regional Government of the Autonomous Community where the plant has to be located.⁹ The issuance of administrative authorizations is contingent upon obtaining positive impact statements. These reports evaluate the integration of environmental, landscape, or urban aspects of the project and determines the conditions to be established for the adequate protection of the environment and natural resources during the facility's execution and operation. Concerning land occupation, developers can reach bilateral agreements with landowners or apply for the public utility declaration of the project. While the public utility status enables the expropriation of the necessary land to develop the project, bilateral agreements with landowners generally offer a more cost-efficient approach.

Figure 1: Geographical distribution of wind farm installations

- (a) First year of installation
- (b) Total power per capita (kW)



Notes: Panel (a) shows the first year a wind farm was installed in each treated municipality. Panel (b) reports the wind power per capita installed in each municipality in 2022. Data from the Spanish Registry of Energy Producers (Electra).

As of 2022, the 1,240 wind power plants installed in Spanish territory were concentrated

⁹Administrative permits for wind farms with an installed power exceeding 50 megawatts or those that affect the territory of more than one region are granted by the Central Government. Wind farms with installed capacity below 50 megawatts can be registered as a special category energy producer, entitling them to receive the favorable treatment associated with this category. The current data set does not include any wind farm with an installed capacity above 50 megawatts.

	(a) With Wind Power Plant (N=543)		(b) V Wind F (N=	Without Power Plant =7,565)		
Municipal Area (km2)	Mean	St. Dev.	Mean	St. Dev.	t-test	(p-value)
Full Sample <20,000 inhabitants	125.79 106.81	149.21 99.99	$57.36 \\ 54.15$	84.57 70.69	-17.048 -15.673	$0.000 \\ 0.000$
Land Use $(\%)$						
Artifical surface	1.03	3.50	2.26	7.19	3.969	0.000
Agricultural land	50.22	27.85	54.84	30.78	3.395	0.001
Forest	17.59	17.59	18.13	20.64	0.586	0.558
Bushes and/or herbaceous	28.86	20.79	22.70	21.25	-6.541	0.000
Open spaces with scarce vegetation	1.99	7.97	1.85	7.96	-0.402	0.688
Wetland	0.23	1.94	0.13	1.49	-1.430	0.153
Water bodies	0.45	1.55	0.47	1.97	0.261	0.794
Wind Potential						
IEC1	30.69	6.80	21.79	6.71	-29.851	0.000
IEC3	37.45	7.51	27.38	7.81	-29.115	0.000
Wind density (100m)	$41,\!051$	$13,\!526$	$28,\!489$	$14,\!172$	-20.010	0.000
Installed Wind Capacity (MW)						
Total power (first installation)	33.05	27.46	-	-	-	-
Total power (end of period)	51.83	56.97	-	-	-	-
Power per capita (first installation)	0.10	0.19	-	-	-	-
Power per capita (end of period)	0.14	0.26	-	-	-	-
Demographic						
Population (full sample)	8,147	36.279	4,720	45,192	-1.723	0.085
Population (<20,000)	2,560	3,612	1,774	3,094	-5.450	0.000
Population density (full sample)	57.79	265.41	145.69	816.23	2.493	0.013
Population density (<20,000)	28.25	60.29	79.79	415.80	2.781	0.005
Ideology (% of municipalities)						
Left	41.26	49.28	42.05	49.37	0.357	0.721
Center	14.13	34.86	17.14	37.69	1.799	0.072
Right	34.94	47.72	31.53	46.47	-1.643	0.100
Independent Party	9.67	29.58	9.28	29.02	-0.296	0.767

Table 1: Summary statistics: Municipal characteristics

Notes: Summary statistics of municipal characteristics prior to the development of a wind farm. Treated municipalities include those where a wind farm was developed after 1997. Measures of land use shares, population density, demographic characteristics, and political parties correspond to 1994. Measures of final installed capacity and wind potential correspond to the year 2022.

in 547 municipalities.¹⁰ Figure 1 illustrates the spatial distribution of wind farms across

¹⁰Notice that the data provided by the Spanish Register of Energy Producers facilitates only one municipality name per installation. The current dataset indicates that 547 municipalities are affected by, at least, one wind farm. However, this number could be larger if installations also affect neighboring municipalities.

the territory. Panel (a) documents the first year a wind farm was installed in each affected municipality. Panel (b) documents each municipality's accumulated wind power per capita in 2020. Besides the expected concentration of this type of infrastructure in areas with higher wind potential, Figure 1 does not show evidence of specific geographical patterns in the development of the sector.

Table 1 presents summary statistics on municipal characteristics prior to the development of a wind farm. In population terms, the affected municipalities are predominantly small. Out of the 543 municipalities affected, 489 have less than 10,000 inhabitants, and 259 have less than 1,000. Additionally, these municipalities exhibit significantly larger areas and lower population densities. Regarding land use, the municipalities where wind farms are developed have lower proportions of artificial surface and agricultural land, and higher proportions of bushes or herbaceous vegetation. While a smaller proportion of municipalities affected by a wind farm have a center-right party in power, the summary statistics do not indicate substantial differences in the distribution of political power.

2.2 Municipal Organization and Tax Instruments

Spain comprises 8,131 municipalities, the basic local entity within the state's organizational structure. The range of basic services that a municipality must provide depends on its population size. While all municipalities are obliged to provide services such as street lighting, waste collection, sewage management, or public road maintenance, the extent of these services increases with the municipality's population.¹¹ The main sources of municipal financial resources are constituted by locally managed tax instruments and inter-governmental grants. Locally managed taxes consist of three direct and two indirect taxes. Direct taxes, which are to be paid annually, are composed of the property tax, serving as one of the main sources of municipal revenue, the tax on economic activities, and the tax on motor vehicles. The two indirect taxes managed at the municipal level are composed of the construction and building works tax, as well as the tax on the appreciation of urban land value.¹²

¹¹The Law 7/1985 establishes the foundation of the local regime and outlines the responsibilities of municipalities based on their population size. Municipalities with more than 5,000 inhabitants are obliged to provide public parks, libraries, markets, and waste treatment services. In addition to these provisions, municipalities with over 20,000 inhabitants must also provide civil protection, social services, fire prevention and extinction, sports facilities for public use, and a slaughterhouse. Furthermore, municipalities surpassing 50,000 inhabitants are further required to provide urban collective passenger transport and environmental protection services.

¹²Municipal financial resources further comprises revenue generated from the entity's assets, subsidies, public prices, credit operations, fines, and penalties. Additionally, municipalities that are a regional capital or those with more than 75,000 inhabitants can participate in central and regional government taxes. Inter-governmental grants are allocated based on a formula considering population size, with

Apart from bi-lateral agreements with developers, municipalities can primarily financially benefit from the development of wind farms in their territory through two direct taxes, the Special Category Property Tax (IBICE) and the Economic Activity Tax (IAE), as well as an indirect tax, the Construction and Building Works Tax (ICIO). Moreover, developers must pay a fee for the granting of urban planning licenses at the time of obtaining the building permit. The national-level regulations governing these tax instruments define their key characteristics, including the tax base, minimum and maximum tax rates, and administrative processes. While municipalities cannot modify the fundamental aspects of each tax instrument, they retain a certain degree of autonomy in setting the tax rates applied within their territory. Table 2 provides summary statistics for the main tax instruments, which are described below.

	Mean	s.d.	Min	Max
Property Tax				
Rural	0.620	0.198	0.3	1.2
Urban	0.584	0.139	0.3	1.2
Special	0.873	0.332	0.4	1.3
Economic Activity Tax				
Minimum Coefficient	1.123	0.481	0.4	3.8
Maximum Coefficient	1.302	0.727	0.4	3.8
Construction, Installation and Building Works Tax	2.431	1.054	0.0	4.0

Table 2: Municipal tax instruments: Tax rates, 2022

Notes: Summary statistics of the main municipal tax instruments and their categories. The data corresponds to the year 2022 and includes the 7,606 municipalities part of the common tax regime.

Property Tax. The Property Tax is a direct tax on property value to be paid annually. Properties are categorized into three types: rural, urban, and special characteristics. Special characteristics properties include installations related to energy production, dams, roads and highways, ports, and airports. Although the tax base definition, minimum and maximum tax rates are determined at the central level, municipalities can set the tax rate for each property category within their jurisdiction. Urban property can be taxed at rates ranging from 0.3 and 1.10 percent, rural property can be taxed between 0.3 and 0.9 percent, and special characteristics' property can be taxed at a rate ranging from 0.4 to 1.3 percent.¹³

increasing weights applied at thresholds of 5,000, 20,000, and 50,000 inhabitants.

¹³Municipalities have the flexibility to adjust the urban and rural property tax rates beyond the specified ranges in specific cases such as being a provincial or autonomous community capital, when provide more services than legally required, or in the case of having large shares of rural land. Additionally, municipalities can introduce certain tax credits and reduce the urban and rural rates when new cadastral values are established.

The tax base for rural and urban properties is based on the cadastral value. However, for properties of special characteristics, the cadastral value considers not only the value of the land but also the value of the installation itself. For this type of property, the tax assessment comprises all the elements necessary for their operation, including land, buildings, and installations. After a Supreme Court ruling on the year 2007, wind farms with an installed power of less than 50 megawatts were reclassified and included in the special category of property. This inclusion resulted in a significant increase in the tax base, as the machinery integrated within wind farms began to be considered part of the special characteristics tax base.

Economic Activity Tax. The Economic Activity tax is a direct tax levied on the mere exercise of entrepreneurial, professional, or artistic activities in the municipal territory. For wind farms, the tax rate is determined by the Central Government at 0.721215 euros per generated kilowatt. While local councils do not have the authority to modify the tax rate, they can establish a coefficient scale that considers the physical location of the premises within the municipality. This coefficient, regulated by the municipal by-laws, has to range from 0.4 to 3.8 and is applied to the tax liability calculated based on the central government tax rate.

Construction, Installation and Building Works Tax. This tax is levied on every construction project that requires a construction permit within a municipality. The tax is calculated based on the actual and effective cost of the construction, which serves as the tax base. The local council determines the tax rate, ranging from 0 to 4 percent. The payment of this tax is required at the time of obtaining the building permit. Upon completion of the construction, the tax liability is adjusted according to the project's actual cost, and a final settlement is made to reconcile any differences.

3 Data

This paper employs a panel dataset at the municipality level covering the period from 1994 to 2022. The dataset combines information on the universe of Spanish wind energy installations, along with data on municipal revenue and expenditure, municipal-level tax rates, and sociodemographic characteristics. Table 3 provides summary statistics for the main variables of interest, disaggregated by municipalities based on the presence of a wind energy installation.

The Spanish Register of Energy Producers provides information on the municipality name,

installed power, and registration date for all wind energy installations across Spain.¹⁴ To construct a comprehensive municipality-level panel dataset representing the evolution of total installed capacity, I aggregate the power installed in each wind farm by municipality and year. I then merge this dataset with data on municipal finances and local tax rates sourced from the Spanish Ministry of Finance.

The Spanish Ministry of Finance provides data on revenue and expenditure at the municipal level starting in 1994. This database contains information on the total budget and the different chapters and subchapters categorized within the economic classification. Before 2000, this dataset covers a range from 4,617 to 6,170 out of the 8,131 Spanish municipalities. The coverage expands to include over 7,970 municipalities after 2000. Data on local tax rates covers municipalities part of the common tax regime. Although the data starts from 2000, information on the special characteristics property tax is accessible from 2004 onwards.

Table 3 reports summary statistics of the budget variables and local tax rates for the base year.¹⁵ The primary sources of municipal revenue correspond to current and capital transfers, and direct taxes. The most significant categories of expenditure correspond to real investments, current goods and services, and personnel expenses. Compared to control municipalities, treated municipalities show slightly lower levels of revenue and expenditure per capita. Yet, the summary statistics show that significant differences only take place in terms of lower revenue from public prices and fees and indirect taxes, and lower levels of current expenditure and real investment. Regarding local tax rates, treated municipalities report slightly lower urban property tax rates, a lower minimum economic activity tax coefficient, and a higher construction tax.¹⁶

To account for municipal geographic and sociodemographic characteristics, I collect information on electoral results, population, wind potential, and land uses. More specifically, I obtain electoral data from the Spanish Ministry of Territorial Policy. I use data from the Spanish National Institute of Statistics (INE) for socio-demographic characteristics. The Global Wind Atlas provides data at a 250 meters grid resolution on the wind speed, wind density, and IEC Capacity Factors. To observe municipality land use, I use data from the CORINE land cover project and aggregate it at the municipal level.

¹⁴The Spanish Register of Energy Producers consolidates the registers of each Autonomous Community. Although data released by Autonomous Communities shows that wind farms are likely to affect more than one municipality, the data released by the Spanish registry only provides one municipality name for each wind farm.

¹⁵See Appendix A.2 for a brief description of each concept.

¹⁶In Appendix A.1, Table A1 reports summary statistics of municipalities divided into terciles of installed wind power. While municipalities with smaller installations show slightly larger populations, there are no significant differences in municipal revenue per capita.

	(a) With Wind Power Plant (N=491)		(b) V Wind P (N=	Vithout ower Plant =7,098)		
Municipal Budget: Revenue per capita	Mean	St. Dev.	Mean	St. Dev.	t-test	(p-value)
Direct Taxes	104.81	116.45	112.92	104.37	1.314	0.189
Indirect Taxes	8.94	12.72	11.84	23.96	2.115	0.034
Public Prices and Fees	65.05	48.72	80.90	104.73	2.652	0.008
Current Transfers	141.26	71.90	137.91	95.78	-0.604	0.546
Capital Income	38.87	73.08	42.32	92.79	0.642	0.521
Real Investments	4.81	18.47	5.73	27.80	0.579	0.563
Capital Transfers	97.56	162.22	118.08	225.31	1.579	0.114
Financial Assets	0.89	6.69	1.19	21.74	0.238	0.812
Financial Liabilities	21.69	49.41	21.83	62.32	0.038	0.970
Financial Assets and Liabilities	22.58	51.77	23.01	65.99	0.113	0.910
Total Revenue	483.87	297.77	532.73	377.68	2.234	0.026
Municipal Budget: Expenditure per capita						
Personnel Expenses	112.72	68.34	114.34	78.87	0.353	0.724
Current Goods and Services	129.43	66.78	149.61	100.92	3.476	0.001
Financial Expenses	12.58	16.12	10.89	19.62	-1.488	0.137
Current Transfers	22.69	30.33	20.83	32.50	-0.984	0.325
Real Investment	150.32	183.51	179.35	258.00	1.951	0.051
Capital Transfers	11.97	32.29	9.26	38.94	-1.197	0.231
Financial Assets	1.41	12.13	0.64	11.13	-1.171	0.242
Financial Liabilities	19.28	39.75	17.24	35.40	-0.976	0.329
Financial Assets and Liabilities	20.69	44.14	17.87	37.30	-1.269	0.205
Total Expenditure	460.40	267.76	502.15	360.16	2.006	0.045
Tax Instruments						
Property Tax: Rural	0.58	0.20	0.58	0.19	0.096	0.924
Property Tax: Urban	0.54	0.14	0.57	0.15	4.252	0.000
Property Tax: Special	0.71	0.26	0.69	0.23	-1.025	0.305
Economic Activity Tax: Min	1.01	0.32	1.05	0.35	2.241	0.025
Economic Activity Tax: Max	1.14	0.47	1.16	0.51	0.800	0.424
Construction Tax	2.09	0.92	1.92	1.04	-3.033	0.002

Table 3: Summary statistics: Dependent variables

Notes: Summary statistics for the main variables of interest, distinguishing between treated (Panel a) and control (Panel b) municipalities. Subset of municipalities part of the common tax regime, excluded those treated before 1998. Summary statistics on municipal revenue and expenditure correspond to 1996 data. Information on tax instruments corresponds to year 2004 and excludes municipalities treated before this year. Monetary values are expressed in per capita terms.

4 Empirical Strategy

I employ a difference-in-difference identification strategy to estimate the effect of wind farm installation on municipal revenue, expenditure, and local tax responses.¹⁷ The baseline approach is to estimate a standard difference-in-difference model, where municipalities are considered to be treated when the construction of the first wind farm in their territory begins. Specifically, the model is formulated as follows:

 $^{^{17}\}mathrm{See}~2022$ and ~2022 for other studies using this methodology to analyze the local impact of wind farm development.

$$Y_{i,t} = \alpha + \beta D_{i,t} + \gamma X_{i,t} + \theta_i + \zeta_t + \epsilon_{i,t} \tag{1}$$

where $Y_{i,t}$ denotes the outcome of interest in municipality *i* and year *t*; $D_{i,t}$ is an indicator variable taking the value of one if municipality *i* had a wind farm installed in year *t*; $X_{i,t}$ is a vector of controls at the municipality-year level, including land use shares and the ideology of the mayors' political party; θ_i and ζ_t denote municipality and year fixed effects, respectively; and $\epsilon_{i,t}$ is a random disturbance term. Standard errors are clustered at the municipality level to account for the variation in treatment at the municipality-year level. The main coefficient of interest, β , represents the difference-in-difference estimate of the effect of the first wind farm development on the outcome variable. This estimate is interpreted as the average yearly effect from the beginning of the construction phase onward.

To capture the effects occurring during the construction phase, I define a municipality as starting to be treated three years prior to the registration of the first wind farm in their territory in the Energy Producers Register, which occurs once the installation is already constructed.¹⁸ To control for potential effects from subsequent wind energy installations, I include a control variable defined as the cumulative wind power installed in each municipality and year minus the power installed in the first deployment.¹⁹ The model specification incorporates municipality and year fixed effects to ensure that the estimates are identified within year and municipality variation in exposure to wind farm installations.

To examine the temporal dynamics of the effect and assess the validity of the paralleltrend assumption, I complement the difference-in-difference specification with an eventstudy model. Estimating an even-study model allows to observe how the effect evolves

¹⁸By adopting a three-year pre-treatment assignment, I follow a similar approach to studies such as Fabra et al. (2023) and Costa and Veiga (2021). Fabra et al. (2023) consider the construction phase of a wind power plant to take between 20 and 24 months, and Costa and Veiga (2021) consider the construction phase of a wind power plant to take an average of two years. I extend the construction phase one extra year to capture, on the one hand, the effects of installations with longer construction duration and, on the other, potential financial interactions with municipalities taking place before the construction of the wind farm starts. In the Appendix, Figure A2a shows the distribution of municipalities based on the first year a wind farm was deployed in its territory.

¹⁹In the Appendix, Figure A2b illustrates the distribution of treated municipalities based on the share of total wind power installed on the first treatment year. This figure shows that treated municipalities are likely to be exposed to multiple wind energy developments over time. Around 40 percent of the municipalities experience additional wind energy deployments after the installation of the first wind farm.

over time and provides further evidence on the robustness of the difference-in-difference results. Observing the temporal dynamics is especially relevant as the increase in municipal revenue can stem from various sources throughout the lifespan of the wind farm. The model is specified as follows:

$$Y_{i,t} = \beta_0 + \sum_{k=-5}^{k=-1} \beta_k^{lead} D_{i,t}^k + \sum_{k=1}^{k=14} \beta_k^{lag} D_{i,t}^k + \gamma X_{i,t} + \theta_i + \zeta_t + \epsilon_{i,t}$$
(2)

where $Y_{i,t}$ corresponds to the outcome of interest in municipality *i* and year *t*. The number of years before or after the beginning of the construction phase of a wind farm is represented by $k \in [-5, 14]$. The term $D_{i,t}^k$ is a dummy variable that takes a value of one if municipality *i* in year *t* is *k* periods before or after the installation of the first wind farm. The regression includes municipality, θ_i , and year, ζ_t , fixed effects, and a set of control variables $X_{i,t}$. Standard errors, $\epsilon_{i,t}$, are clustered at the municipality level.

To capture the effects during the construction phase, $D_{i,t}^1$ equals one three years before the year of inscription in the energy producers register. The omitted category, $D_{i,t}^0$, represents the year before the construction phase starts. I include indicator variables for the five years before a municipality starts being treated $(D_{i,t}^{-5} \text{ to } D_{i,t}^{-1})$ and up to 10 years after the wind farms becomes operational $(D_{i,t}^1 \text{ to } D_{i,t}^{14})$. To aggregate effects in periods outside this temporal window, $D_{i,t}^{-5}$ and $D_{i,t}^{14}$ take a value of one for all years that are more than five years before the beginning of the construction phase, or 14 years after.

The main coefficients of interest in Equation (2) are the set of β_k^{lead} and β_k^{lag} . The estimation of β_k^{lead} helps validate the pre-trends assumption, as it estimates differences between treated and control municipalities prior to the development of a wind farm. β_k^{lag} estimates the effect of wind energy installations on the outcomes of interest. Estimating these treatment indicators allows the coefficients to evolve over time in a non-parametric way and provides information on the temporal dynamics of the effect. All other terms are defined as in Equation (1).

The growing body of literature on two-way fixed effects models with staggered treatment timing points to potential sources of bias in cases of heterogeneous treatment effects (Callaway and Sant'Anna, 2021; De Chaisemartin and d'Haultfoeuille, 2023; Goodman-Bacon, 2021). A potential source of bias derives from comparisons in which earlier treated units are used as controls for later treated units. To address these concerns, I employ two strategies. First, I exclude from the analysis municipalities that had a wind farm deployed before 1998. By doing so, I eliminate potential bias derived from "always treated" municipalities as I ensure that all treated units are observed at least at the base period. Second, I follow the approach of Cengiz et al. (2019) and estimate all my models using stacked regressions where each treated unit is matched to "clean" controls.

More specifically, I create a stacked sample where each municipality is assigned to a specific cohort based on the year a wind farm was first developed. For each cohort, I construct a panel dataset that includes all yearly observations for that cohort of treated municipalities and all control municipalities. I then create the stacked sample by appending all the panels. To ensure that comparisons are made between treated and control units within the same cohort, I interact the year and municipality fixed effects with a cohort indicator. By doing so, I address potential concerns derived from bad controls as I ensure that no comparisons are made across different cohorts of treated municipalities. In Appendix B.1, I show that both the magnitude of the estimated effect and its temporal dynamics remain consistent when using the newly developed difference-in-difference estimators proposed by Callaway and Sant'Anna (2021), De Chaisemartin and d'Haultfoeuille (2024), Sun and Abraham (2021), and Borusyak, Jaravel, and Spiess (2024).

In the empirical work that follows, I start by analyzing the effect of wind farms on municipal non-financial revenue and expenditure. I identify the specific channels through which wind energy installations affect municipality revenue and the types of expenditure financed by them by decomposing the effects on revenue and expenditure into their respective categories. To ensure comparability across municipalities of different sizes, I normalize all monetary variables by population.For a consistent analysis of the impact of wind farm development on host municipalities, I exclude from the dataset the 523 municipalities outside the common tax regime and the 17 municipalities that received a wind farm before 1998. The final dataset encompasses 7,589 municipalities, with 491 of them hosting at least one wind farm.

To ensure cleaner comparison groups, I implement two sample restrictions. First, I restrict the analysis to municipalities with less than 20,000 inhabitants. This restriction responds to the fact that financial resources and spending obligations attributed to municipalities increase with their population size. By excluding larger municipalities, I ensure that the estimated effects are based on a more homogeneous sample of municipalities in terms of spending needs and financial capacities. This restriction results in the exclusion of 41 treated municipalities and 347 controls from the analysis. Second, I further exclude control municipalities geographically adjacent to treated municipalities. By doing so, I obtain a cleaner control group and rule out any bias resulting from potential spillover effects. Although the Spanish Register of Energy Producers provides information only for the main municipality where a wind farm is installed, data by some autonomous communities indicate that neighboring municipalities are also likely to be affected.

5 Results

I first present the baseline results, which show the aggregate effect of wind farm development on municipal revenue, expenditure, and local tax responses. These baseline results provide a comprehensive overview of the impact of wind energy installations on hosting municipalities. Next, I decompose these aggregate effects to identify the revenue sources through which they take place and the use that municipalities make of this new revenue source. To do so, I estimate the effect for each revenue and expenditure category. This analysis provides insights into the specific mechanisms driving the aggregate effect.

5.1 Aggregate Municipal Revenue and Expenditure

I start the analysis by evaluating the average treatment effect of wind farm development on municipal revenue and expenditure. I estimate Equations 1 and 2 on the baseline sample of municipalities from 1994 to 2022. Tables 4 and 5 summarize the results from estimating the difference-in-difference model defined by Equation 1. Positive and statistically significant coefficients in Table 4 indicate that the first wind farm development led to a 45 percent average yearly increase in municipal non-financial revenue per capita. Results in Table 5 indicate that municipalities used this new revenue to increase non-financial expenditure per capita by 30 percent.

To isolate the monetary effect from population changes, I keep population constant at the beginning of the period. In Tables 4 and 5, Panel (a) summarizes the results for the specification in which the dependent variable is expressed in per capita terms based on each municipality-year population. Panel (b) reports the results for the specification in which the population is kept constant in 1994. The magnitude of the effect is substantially lower when the monetary effect is isolated from population changes. This difference in magnitude indicates different population dynamics in affected municipalities. Appendix A.4 shows that treated municipalities follow decreasing population trends.

The estimated effect and its magnitude are consistent with the inclusion of controls and the restriction of the sample to more comparable municipalities. Column (1) reports the point estimates for the base specification, including municipality-cohort and year-cohort fixed effects. Column (2) includes, as controls for municipality-year characteristics, the share of land uses and the ideology of the political party to which the mayor belongs. Adding the mayors' ideology as a control helps to isolate confounding effects derived from differences in policies depending on the political alignment of the city council. Column (3) further

	(1)	(2)	(3)	(4)	(5)				
	(a) C	bserved Popu	lation						
First Installation	509.472^{***} (60.867)	$489.410^{***} \\ (60.470)$	447.731^{***} (60.033)	508.656^{***} (64.093)	523.620^{***} (64.203)				
	$786.796 \\ 0.203$	$786.818 \\ 0.206$	$786.818 \\ 0.206$	$800.898 \\ 0.207$					
(b) Constant Population									
First Installation	308.031^{***} (60.564)	333.570^{***} (60.720)	311.926^{***} (61.835)	354.302^{***} (66.940)	343.853^{***} (66.986)				
$\begin{array}{l} \text{Mean (treated=1, t=0)} \\ \text{R-squared} \end{array}$	$\begin{array}{c} 747.118 \\ 0.122 \end{array}$	$\begin{array}{c} 747.129 \\ 0.127 \end{array}$	$\begin{array}{c} 747.129 \\ 0.127 \end{array}$	$750.790 \\ 0.123$	$\begin{array}{c} 750.790 \\ 0.118 \end{array}$				
N Municipalities	7,504	7,504	7,504	7,256	5,772				
RFE and TFE Mun Charact Installed Power Excluded Municipalities Excluded Neighbors	Yes No No No	Yes Yes No No No	Yes Yes No No	Yes Yes >20,000 No	Yes Yes >20,000 Yes				

Table 4: Effect of wind farm development on non-financial revenue (euros per capita)

Notes: Results from estimating the difference-in-difference model described by Equation 1 where the dependent variable is municipal non-financial revenue in euros per capita. Per capita values in terms of observed population (Panel a) and 1994 population (Panel b). Mean indicates the mean value of the outcome variable for treated municipalities before a wind farm has been developed. Controls for municipal characteristics include land use shares and the ideology of the mayor's political party. "Installed power" controls for subsequent wind power installations accumulated at the municipality-year level. The first treatment year is set at the beginning of the construction phase. The construction phase is considered to start three years before the electricity producers registration date. Standard errors are clustered at the municipality-cohort level. * p < 0.10, ** p < 0.05, *** p < 0.01.

includes as a control the accumulated amount of wind power installed in each municipality in subsequent years after the first wind farm development. By controlling for further wind power installations, I isolate potential confounding effects from subsequent developments and provide a more precise identification of the impact of the first installation.

Defining the control group as the full set of non-treated municipalities can result in the inclusion of non-representative controls in the analysis. Large municipalities are obliged to provide a broader set of public services and are entitled to a larger amount of resources per inhabitant. Furthermore, the development of a wind farm is likely to affect municipalities neighboring treated units. To eliminate bias driven by large municipalities and potentially affected control units, Columns (4) and (5) restrict the sample to municipalities of less than 20,000 inhabitants and control units not neighboring treated municipalities. Column (4) summarizes the results for the sample restricted to small municipalities. Column (5), the preferred specification, excludes non-treated neighboring municipalities.

The results presented in Table 4 indicate that the development of a wind farm has a significant positive impact on municipal resources.²⁰ The estimates reported in Panel (a) indicate an increase in non-financial revenue of 523.6 euros per capita, representing a 65 percent increase relative to the mean value of treated municipalities before the beginning of the construction phase. However, the results in Panel (b) suggest that a portion of this effect can be attributed to declining population trends. When the population is held constant at the beginning of the analysis period, the increase in non-financial revenue is estimated to be 343.8 euros per capita, representing a 45.8 percent increase compared to the pre-treatment period. Evaluating these results relative to the mean power of Spanish wind farms, which is of 33.05 MW (see Table 1), the effect represents an increase of 10.4 euros per capita per MW installed.²¹

Results in Table 5 indicate that municipalities use the extra revenue generated by wind farms to increase municipal expenditure. However, the magnitude of the effect is smaller than the effect on revenue.²² Consistent with the findings on revenue, the effect on expenditure is attenuated when population is held constant at the beginning of the period of analysis. In the preferred specification, presented in Column (5) of Panel (b), results indicate that municipalities increase non-financial expenditure by 215.54 euros per capita, representing a 29.4 percent increase relative to the mean expenditure per capita in the pre-treatment period.²³

After quantifying the aggregate effect on non-financial revenue and expenditure, Figure 2 plots the β_k coefficients and associated 95 percent confidence intervals from estimating the event study model defined by Equation 2. These results correspond to the specification which includes municipality-cohort and year-cohort fixed effects, controls for municipal characteristics and subsequent wind power installations, and uses the sample restricted to municipalities of less than 20,000 inhabitants and control units not neighboring affected municipalities. Non-statistically significant β_k^{lead} coefficients close to zero show no evidence of a pre-trend in municipal revenue (triangular coefficients, in red) or expenditure

²⁰Financial resources are not expected to be affected by wind farms. Thus, the baseline analysis focuses on non-financial revenue. Appendix B.2 shows that these results are consistent to the inclusion of financial revenue.

²¹Although these amounts might seem substantially large, they align with ballpark estimates of typical wind farm tax liabilities and municipal budgets. Based on installation cost estimates from the USA National Renewable Energy Laboratory, cadastral valuations from the Spanish Treasury, and average municipal tax rates, a 33 MW wind farm incurs construction tax liabilities of approximately 1.4 million euros and annual property taxes of about 55,000 euros. These figures should be considered in the context of the average budget of municipalities with populations of 20,000 or less, which is around 1 million euros.

²²Spending of public administrations is legally limited by the budget stability, public debt, and expenditure rules. The expenditure rule prevents the spending of public administrations from exceeding the medium-term GDP growth rate of the Spanish economy.

²³Appendix B.2 shows that these results are consistent to inclusion of financial information.

	(1)	(2)	(3)	(4)	(5)				
	(a) C	Observed Popu	lation						
First Installation	369.583^{***} (47.714)	$351.440^{***} \\ (47.329)$	310.819^{***} (46.867)	357.577^{***} (49.857)	369.625^{***} (49.954)				
	$767.437 \\ 0.235$	$767.506 \\ 0.239$	$767.506 \\ 0.239$	$781.455 \\ 0.239$	$781.455 \\ 0.235$				
(b) Constant Population									
First Installation	$194.841^{***} \\ (44.091)$	$217.876^{***} \\ (44.191)$	$195.262^{***} \\ (44.189)$	$227.128^{***} \\ (47.624)$	215.538^{***} (47.663)				
$\begin{array}{l} \text{Mean (treated=1, t=0)} \\ \text{R-squared} \end{array}$	$\begin{array}{c} 729.544 \\ 0.155 \end{array}$	$\begin{array}{c} 729.603 \\ 0.161 \end{array}$	$\begin{array}{c} 729.603 \\ 0.161 \end{array}$	$\begin{array}{c} 733.654 \\ 0.157 \end{array}$	$733.654 \\ 0.147$				
N Municipalities	7,504	7,504	7,504	7,256	5,772				
RFE and TFE Mun Charact Installed Power Excluded Municipalities Excluded Neighbors	Yes No No No	Yes Yes No No	Yes Yes No No	Yes Yes >20,000 No	Yes Yes >20,000 Yes				

Table 5: Effect of wind farm development on non-financial expenditure (euros per capita)

Notes: Results from estimating the difference-in-difference model described by Equation 1 where the dependent variable is municipal non-financial expenditure in euros per capita. Per capita values in terms of observed population (Panel a) and 1994 population (Panel b). Mean indicates the mean value of the outcome variable for treated municipalities before a wind farm has been developed. Controls for municipal characteristics include land use shares and the ideology of the mayor's political party. "Installed power" controls for subsequent wind power installations accumulated at the municipality-year level. The first treatment year is set at the beginning of the construction phase. The construction phase is considered to start three years before the electricity producers registration date. Standard errors are clustered at the municipality-cohort level. * p < 0.10, ** p < 0.05, *** p < 0.01.

(diamond coefficients in blue) prior to the development of the first wind farm.

In Figure 2, the estimated β_k^{lead} coefficients describe the temporal dynamics of the effect. Positive and statistically significant coefficients indicate an increase in the outcome of interest k periods after the beginning of the construction phase, relative to the base period t = 0. The triangular coefficients in red correspond to the estimated effect on municipal non-financial revenue. These results indicate that wind farm development significantly and consistently impacts municipal non-financial revenue. The largest increase in municipal revenue appears during the construction phase and stabilizes once the wind farm enters its operation and maintenance phase.

The blue diamond coefficients, representing the estimated effect on municipal non-financial expenditure, indicate that the additional resources generated by the wind farm development translate into a sustained increase in municipal spending. This effect follows a smoother evolution during the construction phase, and stabilizes once the wind farm be-

Figure 2: Dynamic effect of wind farm development on municipal finances: Non-financial revenue and expenditure (euros per capita)



Notes: Results from estimating the event study model defined by Equation 2. The dependent variables are municipal nonfinancial revenue (coefficients in red represented by a triangle) and non-financial expenditure (coefficients in blue represented by a diamond). The magnitudes are expressed in euros per capita relative to the 1994 population. These results correspond to the specification including municipality-cohort and year-cohort fixed effects, and controls for municipal characteristics, and subsequent wind power installations. The sample is restricted to municipalities of less than 20,000 inhabitants and control units not neighboring affected municipalities. The reference year (represented by the dashed line) is set at the year before the beginning of the construction phase. The construction phase is considered to start three years before the energy producers register (dotted line). Standard errors are clustered at the municipality-cohort level. Confidence intervals at the 95 percent level.

comes operational. These findings indicate that, on average, the increase in municipal expenditure is lower than the increase in revenue. However, after the construction phase, the point estimates are not statistically different, and both variables follow a similar trend over time. Appendix B demonstrates that these results are consistent and stable across alternative difference-in-difference estimators, the inclusion of financial information, and alternative sample definitions.²⁴

5.2 Local Tax Responses

I study local tax responses to wind farm development by analyzing changes in the different categories of property tax. The results reported in Table 6 and Figure 3 show that municipalities react to the development of wind farms by increasing tax rates associated with this type of infrastructure, while decreasing the fiscal pressure associated with urban and rural land. These results indicate that the increase in municipal revenue derived from wind energy development is not only driven by a mechanical effect due to a broadening of

²⁴In Appendix B.1, Figure A6 shows that these results are consistent with difference-in-difference estimators proposed by Callaway and Sant'Anna (2021), De Chaisemartin and d'Haultfoeuille (2024), Sun and Abraham (2021), and Borusyak, Jaravel, and Spiess (2024). Appendix B.2 shows that the results are consistent and stable when including financial information. Appendix B.3 shows that the results remain consistent when including municipalities outside the common tax regime and when restricting the analysis period to 2008 onward.

the tax base, but is complemented by municipal responses in the form of increases in tax rates associated with this type of non-mobile capital investment close to maximum levels.

The data on municipal tax rates, sourced from the Spanish Tax Agency, includes information on urban and rural property tax rates from year 2000 and on special characteristics tax rates from year 2004. To prevent bias resulting from including always treated units in the analysis, these results focus on municipalities that received a wind farm during this time period. Thus, the findings on urban and rural tax rates are derived from the subset of municipalities that received their first wind farm from 2004 onwards. The results for the special tax rate are based on the subset of municipalities that received their first wind farm starting in 2008.²⁵

Table 6 summarizes the results from estimating Equation (1) on the logarithm of the tax rate for each category of property tax. Panel (a) summarizes the results for the special tax rate. The results reported in Column (5) indicate that, in aggregate terms, municipalities respond to the development of the first wind farm in their territory by increasing the tax rates targeted at this type of infrastructure by 22.7 percent. Panels (b) and (c) report the results for the urban and rustic tax rates. These results show that local tax responses not only occur by substantially increasing the tax burden of wind farms but are complemented by decreasing the fiscal pressure associated with other tax categories. Specifically, the results in Column (5) indicate that, following the development of the first wind farm, municipalities reduce the urban property tax rate by 2.7 percent (Panel b) and the rural property tax rate by 3.9 percent (Panel c).

These results are consistent across different specifications adding regional and time-fixed effects (Column 1); controlling for municipal characteristics (Column 2); controlling for further wind power installations (Column 3); restricting the sample to municipalities of less than 20,000 inhabitants (Column 4), and excluding control units that border treated municipalities (Column 5).

Figure 3 plots the β_k coefficients of estimating Equation 2 for each of the three property tax categories. Panel (a) shows the results for the special category property tax. Starting at the construction phase, municipalities respond to the construction of a wind farm by progressively increasing the fiscal pressure on this type of investment. The increase in the

²⁵These restrictions reduce the number of treated municipalities from 477 to 353 for the urban and rural tax rates, and to 192 for the special category tax rate. In 2007, a Supreme Court ruling included the machinery used for producing electric energy as part of the special category property tax base. By restricting the sample of treated municipalities to those who received their first wind farm starting in 2008, I further ensure that the results are not influenced by reactions to this tax base expansion. Appendix B.3.2 shows that both baseline results and local tax responses remain consistent when the analysis is restricted to municipalities that received the first wind farm starting in 2008.





(a) Special category property tax



Notes: Results from estimating the event study model defined by Equation 2. The dependent variables are the logarithm of the special property tax rate (Panel a), the logarithm of the urban tax rate (red coefficients represented by a triangle in Panel b), and the rural property tax rate (blue coefficients represented by a diamond in Panel b). Results correspond to the specification which includes municipality-cohort and year-cohort fixed effects, controls for municipal characteristics and subsequent wind power installations, and restricts the analysis to municipalities of less than 20,000 inhabitants and control units not neighboring treated municipalities. Results in Panel (a) correspond to the subset of municipalities that received the first wind farm installation starting in 2008. Results in Panel (b) correspond to the subset of municipalities that received the first wind farm installation starting in 2004. The reference year (represented by the dashed line) is set at the year before the beginning of the construction phase. The construction phase is considered to start three years before the energy producer registration (dotted line). Standard errors are clustered at the municipality-cohort level. Confidence intervals at the 95 percent level.

	(1)	(2)	(3)	(4)	(5)				
	(a) Sp	ecial Propert	y Tax						
First Installation	0.230^{***} (0.020)	0.230^{***} (0.020)	0.211^{***} (0.020)	$\begin{array}{c} 0.214^{***} \\ (0.020) \end{array}$	0.227^{***} (0.020)				
Mean (treated=1, t=0) R-squared N Municipalities	$0.776 \\ 0.125 \\ 7,228$	$0.776 \\ 0.126 \\ 7,228$	$0.776 \\ 0.126 \\ 7,228$	$0.765 \\ 0.123 \\ 6,952$	$0.765 \\ 0.107 \\ 5,478$				
(b) Urban Property Tax									
First Installation	-0.038*** (0.010)	-0.041^{***} (0.010)	-0.034^{***} (0.010)	-0.029^{***} (0.010)	-0.027^{***} (0.010)				
Mean (treated=1, t=0) R-squared N Municipalities	$0.540 \\ 0.122 \\ 7,389$	$0.540 \\ 0.128 \\ 7,389$	$0.540 \\ 0.128 \\ 7,389$	$0.533 \\ 0.136 \\ 7,131$	$0.533 \\ 0.131 \\ 5,649$				
	(b) R	ural Property	r Tax						
First Installation	-0.037^{***} (0.009)	-0.037^{***} (0.009)	-0.035^{***} (0.008)	-0.038^{***} (0.009)	-0.039^{***} (0.009)				
Mean (treated=1, t=0) R-squared N Municipalities	$0.598 \\ 0.095 \\ 7,389$	$0.598 \\ 0.097 \\ 7,389$	$0.598 \\ 0.097 \\ 7,389$	$0.596 \\ 0.100 \\ 7,130$	$0.596 \\ 0.102 \\ 5,648$				
RFE and TFE Mun Charact Installed Power Excluded Municipalities Excluded Neighbors	Yes No No No No	Yes Yes No No No	Yes Yes Yes No No	Yes Yes Yes >20,000 No	Yes Yes Yes >20,000 Yes				

Table 6: Local Tax Responses to Wind Farm Development: Property Tax Rates

Notes: Results from estimating the difference-in-difference model described by Equation 1. The dependent variables are the logarithm of the special property tax rate (Panel a), the logarithm of the urban property tax rate (Panel b), and the logarithm of the rural property tax rate (Panel c). Mean indicates the mean tax rate in treated municipalities during the period before the development of a wind farm. Controls for municipal characteristics include land use shares and the ideology of the mayor's political party. "Installed power" controls for subsequent wind power installations accumulated at the municipality-year level. The first treatment year is set at three years before the energy producer registration date. Standard errors are clustered at the municipality-cohort level. * p < 0.10, ** p < 0.05, *** p < 0.01.

special category tax rate stabilizes four years after the wind farm becomes operational, reaching near to maximum levels.²⁶ These results show no evidence of pre-trends, as coefficients prior to the beginning of the construction phase are non-significant and close to zero. Furthermore, in Appendix B.1, Figure A7 shows that the results are consistent to alternative difference-in-difference estimators.

While municipalities react to the development of a wind farm by increasing tax rates targeted at them, they modestly decrease the fiscal pressure associated with the rest of the property tax categories. In Figure 3, Panel b shows the results for the urban and

²⁶In Appendix A.3, Figure A3c illustrates the temporal evolution of the special category tax rate for treated and control municipalities. This figure shows that treated municipalities react to the development of a wind farm by increasing the fiscal pressure on this type of investment close to maximum levels.

rural tax rates. Although the temporal dynamic is the same for all three categories, the decrease in tax rates associated with urban and rural land is significantly smaller. For the urban property tax, the largest effect occurs during the periods around the beginning of the operations phase and stabilizes once the wind farm is fully operative. Turning to the tax on rural land, results indicate a progressive decrease in its fiscal pressure. Non-statistically significant coefficients close to zero prior to the beginning of the construction phase show no evidence of pre-trends.²⁷

5.3 Identification of Revenue Sources

To identify the main channels through which wind farms affect municipal resources, I decompose the aggregate revenue effect into its different categories.²⁸ In addition to the local tax responses documented above, the development of a wind farm is expected to increase revenue generated from direct and indirect taxes as it mechanically increases its tax bases. Furthermore, municipalities can increase their capital income through royalty payments or property rents. Table 7 summarizes the results from estimating the difference-in-difference model defined by Equation (1) for each revenue category. These results show that, in aggregate terms, the most significant increase in municipal revenue occurs through an increase in revenue generated from direct and indirect taxes, followed by an increase in revenue generated from capital income.

More specifically, Table 7 shows that, beyond increases in revenue generated from direct and indirect taxes, revenue from capital income accounts for 26 percent of the increase in aggregated municipal revenue. Columns (1), (2), and (5) show that a wind farm development increases the revenue generated from direct taxes by 85 percent, multiplies by 1.8 capital income, and by six the revenue generated from the construction tax. In this context, the increase in capital income is especially relevant. This revenue category, which includes concepts such as income from rents, concessions, or dividends and profit shares, indicates that municipalities can benefit from the development of this type of renewable energy investment through channels beyond fiscal tools.²⁹

In Table 7, Columns (8) and (9) analyze changes in municipalities' financial behavior.

²⁷In Appendix A.3, Figure A3 plots the temporal evolution of the urban and rural tax rates in treated and control municipalities. This figure illustrates that, although the extent of the change is minor, control municipalities experience a modest increase in tax rates associated with urban and rural property, whereas treated municipalities maintain their tax rates stable for urban land and marginally decrease them for rural land.

 $^{^{28}}$ See Appendix A.2 for the definition of each revenue category.

²⁹Municipalities of less than a thousand inhabitants are only obliged to report budget information disaggregated at the chapter level. At this level of aggregation, this analysis cannot identify the specific sources through which the increase in capital income takes place.

	(1) Direct Taxes	(2) Indirect Taxes	(3) Public Prices and Fees	(4) Current Transfers	(5) Capital Income	(6) Real Investments	(7) Capital Transfers	(8) Financial Assets	(9) Financial Liabilities
Fist Installation	$\begin{array}{c} 130.175^{***} \\ (30.563) \end{array}$	$\begin{array}{c} 126.265^{***} \\ (33.464) \end{array}$	15.797^{*} (8.234)	-23.111^{**} (11.119)	90.476^{***} (13.800)	-3.986 (3.527)	8.238 (13.175)	0.580^{*} (0.302)	-5.228^{**} (2.206)
N Municipalities Mean (treated=1, t=0)	5,772 152.758	5,772 19.412	5,772 97.701	5,772 207.907	5,772 50.314	5,772 15.161	5,772 207.537	5,772 0.287	5,772 27.161
R-squared	0.151	0.007	0.027	0.182	0.011	0.002	0.072	0.000	0.019
RFE and TFE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mun Charact	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Installed Power	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Excluded Municipalities	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000
Excluded Neighbors	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 7: Effect of Wind Farm Development on Municipal Revenue: Decomposition by Revenue Source

Notes: Results from estimating the difference-in-difference model described by Equation (1). The dependent variables are each revenue source expressed in euros per capita relative to 1994 population. Mean indicates the mean value of the outcome variable for treated municipalities in the period of time before the development of a wind farm. Controls for municipal characteristics include land use shares and the ideology of the mayor's political party. "Installed power" controls for subsequent wind power installations accumulated at the municipality-year level. The first treatment year is set at the beginning of the construction phase. The construction phase is considered to start three years before the electricity producers registration date. Standard errors are clustered at the municipality-cohort level. * p < 0.10, ** p < 0.05, *** p < 0.01.

Negative coefficients associated with financial liabilities (i.e., loans and credits) show that municipalities react to wind farm development by decreasing their indebtedness. Results in Column (4) represent a small decrease in resources derived from current transfers.³⁰ This exercise further provides evidence of the validity of the results by showing null impacts on the revenue sources not expected to be affected by wind energy installations.

To document the temporal evolution of the estimated effect and evaluate the existence of pre-trends, Figure 4 plots the β_k 's and associated 95 percent confidence intervals from estimating Equation (2). These results show no evidence of pre-trends and indicate that the channels through which wind farm development increases municipal resources change along the lifetime of the infrastructure. Panel (a) shows the point estimates for Direct (triangles) and Indirect (diamonds) taxes. These results indicate that during the construction phase the increase in resources is generated through an expansion in the revenue generated from indirect taxes. Yet, once the operation phase starts, the effect on indirect taxes decreases and is compensated by an increase in resources generated from direct taxes and capital income (Panel c). The null impact on the remaining categories further validates the robustness of this analysis.

The estimation of the temporal dynamics of different revenue sources provides a more

³⁰As shown in Appendix A.4, treated municipalities show decreasing population trends. Thus, revenue from current taxes, which is dependent on population, is expected to be reduced over the period of analysis.

Figure 4: Dynamic Effect of Wind Farms Development on Municipal Revenue: Decomposition by Revenue Category



(a) Direct and Indirect Taxes

(b) Public Prices and Current Transfers



(c) Capital Income and Real Investments

Euros per capita

(d) Capital Transfers and Financial Revenue



Notes: Results from estimating the event study model defined by Equation (2). The dependent variables are municipal revenue in euros per capita from direct taxes and indirect taxes (Panel a); public prices and current transfers (Panel b); capital income and real investments (Panel c); and capital transfers and financial revenue (Panel d). Per capita measures in terms of 1994 population. Results correspond to the specification reported in Table 7 which includes municipality-cohort and year-cohort fixed effects, controls for municipality characteristics and subsequent wind power installations, and restricts the sample to municipalities of less than 20,000 inhabitants not bordering treated units. The reference year (dashed line) is set a the year before the beginning of the construction phase. The construction phase is considered to start three years before the preliminary register to the energy producers register (dotted line). Standard errors are clustered at the municipality-cohort level. Confidence intervals are shown at the 95 percent level.

complete picture of the financial impact of large-scale renewable infrastructure on hosting municipalities. While aggregate effects on revenue categories highlight the main channels through which municipalities benefit from wind farm investment, the dynamic analysis reveals that this revenue effect is not confined to a specific point in time but is consistent over the lifetime of the infrastructure. During the construction phase, municipalities mainly benefit from revenue generated from the construction tax. However, once the wind farm becomes operational and the increase in revenue from indirect taxes dissipates, this effect is replaced by a substantial and sustained increase in revenue generated from direct taxes and capital income.

5.4 Decomposition of the Effect on Expenditure

To provide a general picture of the use that municipalities make of the revenue windfall from large-scale renewable infrastructure, I decompose the expenditure effect into each of its categories.³¹ Table 8 summarizes the results from estimating the difference-in-difference model defined by Equation (1). These results indicate that municipalities mainly use these new resources to finance increases in current expenditure and real investments. Municipality's current expenditure is primarily utilized to finance its day-to-day activity, encompassing a range of expenses such as supplies, purchases or services rendered. On the other hand, real investment refers to expenses that are typically more visible in nature and are aimed at increasing the provision of long-lasting public investments within the municipality.

Table 8:	Effect of	of Wind	Farm 1	Development	of Municipal	Expenditure:	Decomposi	tion by
Expendi	iture Ca	tegory						

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Personnel	Current	Financial	Current	Real	Capital	Financial	Financial
	Expenses	Expenditure	Expenses	Transfers	Investments	Transfers	Assets	Liabilities
Fist Installation	-1.368 (9.344)	$50.758^{***} \\ (14.560)$	-1.136^{**} (0.516)	$\frac{12.411^{**}}{(5.780)}$	$152.768^{***} \\ (27.441)$	2.105 (2.249)	1.294^{*} (0.695)	-4.122^{**} (2.076)
N Municipalities	5,772	5,772	5,772	5,772	5,772	5,772	5,772	5,772
Mean (treated=1, t=0)	163.232	211.305	7.266	38.113	300.324	13.414	0.350	21.052
R-squared	0.266	0.187	0.021	0.032	0.058	0.004	0.000	0.015
RFE and TFE Mun Charact Installed Power Excluded Municipalities	Yes Yes >20,000	Yes Yes Yes >20,000	Yes Yes >20,000	Yes Yes >20,000	Yes Yes Yes >20,000	Yes Yes Yes >20,000	Yes Yes Yes >20,000	Yes Yes >20,000

Notes: Results from estimating the difference-in-difference model described by Equation (1). The dependent variables are each expenditure category expressed in euros per capita relative to the 1994 population. Mean indicates the mean value of the outcome variable for treated municipalities in the period before the development of a wind farm. Controls for municipal characteristics include land use shares and the ideology of the mayor's political party. "Installed power" controls for subsequent wind power installations accumulated at the municipality-year level. The reference period (dashed line) is set at the year before the beginning of the construction phase. The construction phase is considered to start three years before the energy producers register. Standard errors are clustered at the municipality-cohort level. * p < 0.10, ** p < 0.05, *** p < 0.01.

More specifically, Table 8 shows that 70 percent of the increase in municipal expenditure is directed towards real investments. Compared to the use of resources before the development of a wind farm, these results indicate that municipalities increased current expenditure by 23 percent (Column 2), and real investments by 50 percent (Column 5). I complement this analysis by estimating the effect on financial assets (Column 7) and liabilities (Column 8). Negative coefficients associated with financial liabilities indicate a

³¹See Appendix A.2 for the definition of each expenditure category.

decrease in financial resources allocated towards paying off public debt, suggesting that revenue windfalls allow municipalities to reduce their debt burden.

Figure 5: Dynamic Effect of Wind Farm Development on Municipal Expenditure: Decomposition by Expenditure Category



Notes: Results from estimating the event study model defined by Equation 2. The dependent variables are personnel and current expenditures (Panel a); financial expenditure and current transfers (Panel b); real investments and capital transfers (Panel c); and financial assets and liabilities (Panel d). Magnitudes are expressed in per capita terms relative to the 1994 population. The results correspond to the specification that includes municipality-cohort and year-cohort fixed effects, controls for municipality characteristics and subsequent wind power installations, and restricts the sample to municipalities with less than 20,000 inhabitants and control units not neighboring treated municipalities. Reference year (represented by the dashed line) is set at the beginning of the construction phase. The construction phase is considered to start three years before the inscription to the energy producers register (dotted line). Standard errors are clustered at the municipality-cohort level.

Figure 5 plots the β_k coefficients and associated 95 percent confidence intervals from estimating Equation (2) for each expenditure category. The results show no evidence of pre-trends, as point estimates before the development of a wind farm are close to zero and statistically insignificant. While the temporal dynamics of municipal revenue reveal differential effects over the lifetime of the infrastructure, the allocation of resources to municipal expenditure shows a more consistent pattern over time. The increase in resources allocated to current expenditure and real investments begins during the construction phase and stabilizes during the operations phase. Small and statistically insignificant coefficients associated with the remaining expenditure categories further demonstrate the robustness of the results, proving that they do not stem from identifying a systematic change.

6 Concluding Remarks

Understanding whether local communities benefit from the development of renewable energy infrastructure in their territory is a necessary step to design and implement, if needed, compensation mechanisms aiming at mitigating the local costs associated to the energy transition and improve the efficiency in the development of renewable energies. This paper contributes to this debate by clearly identifying the effect of wind farm development on municipal finances and local tax responses. To do so, I combine data on the development of wind farms in Spain with a panel dataset on municipal budgets and tax rates from 1994 and 2022. To causally identify the effect of a wind farm, I use difference-indifferences and event-study methodologies, which exploit spatial and temporal variation of their development.

The results show that, at mean levels, the development of a wind farm has a long-lasting positive effect on municipal revenue per capita. This effect is partially driven by an expansion of the tax base and complemented by local tax responses in the form of increases close to the maximum tax rates associated with this type of infrastructure. By decomposing the effect on revenue into its different categories, I show that the channels through which municipalities benefit from their development change along the lifetime of the infrastructure. Although during the construction phase, the increase in revenue occurs through a larger yield from indirect taxes, the long-lasting effect on municipal revenue is generated by increased capital income and direct taxes. The increase in property tax rates associated with wind farms indicates that the effect on revenue generated from direct taxes is not only driven by expansions of the tax base but complemented by local reactions aimed at maximizing the revenue generated from this type of infrastructure.

After quantifying the revenue effect, I analyze whether municipalities use these new resources to indirectly compensate the local community. I find that the revenue generated by wind farms is channeled toward increases in current expenses and real investment. The largest share of the newly generated income is allocated to real investments indicating that municipalities use the revenue generated by wind farms to indirectly compensate hosting communities by increasing investment in infrastructure and durable goods. The increase in expenditure is complemented by decreases in fiscal pressure associated with urban and rural property.

This study makes several contributions. First, I add to the literature analyzing the local

impact of renewable energy projects by examining the nationwide effects of wind farm development on municipal financial resources in a context in which specific compensation mechanisms are absent. Second, I contribute to the literature analyzing reactions to large capital-intensive projects through local taxation responses. The results shown in this paper provide evidence that hosting municipalities increase tax rates levied on wind farms close to the maximum level while decreasing fiscal pressure associated with other tax categories. Last, the literature analyzing the effect of natural resource windfalls has mainly focused on the impact of shale oil and gas booms. This paper adds to this body of literature by analyzing the effect of wind exploitation, a natural resource with substantially different effects in terms of local employment and project durability.

The results of this analysis have important policy implications. Although they show that municipalities financially benefit from the development of wind farms in their territory, local opposition to new developments is still present and existing research shows that citizens living in proximity to wind energy projects electorally punish the government responsible for the policy (Stokes, 2016). The results of this analysis point to different avenues for future research.

First, the use of municipalities' financial resources is limited by their competencies. Exploring whether opposition to wind farm development reacts differently to implementing more direct compensation mechanisms, such as in-kind transfers, subsidized access to electricity, or wind farm ownership, could help design tools to mitigate the locallyconcentrated negative externalities associated with this type of infrastructure.

Second, the provision of public goods and services can be affected by the capacity of the city council's to identify the needs of its inhabitants and the access to infrastructure to develop the necessary investment. Exploring differences in the utilization of financial resources based on characteristics of municipalities' city councils, such as political ideology, background knowledge, or access to consulting and advisory services, can provide further insight into the mechanisms determining optimal provision of public goods.

Last, the visual and noise impacts of wind farms extend beyond the geographical territory of a municipality. If the revenue shock is concentrated in the municipality where a wind farm is developed, opposition from neighboring municipalities is likely to rise. The results presented in this paper point to the need to design comprehensive mechanisms helping to compensate for local costs, mitigate local objections, and minimize conflicts around planned investments to move toward a more efficient and socially inclusive energy transition.

References

- Allan, Grant, David Comerford, Kevin Connolly, Peter McGregor, and Andrew G Ross (2020). "The economic and environmental impacts of UK offshore wind development: The importance of local content". *Energy* 199, p. 117436.
- Allcott, Hunt and Daniel Keniston (2018). "Dutch disease or agglomeration? The local economic effects of natural resource booms in modern America". The Review of Economic Studies 85.2, pp. 695–731.
- 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 11.4, pp. 105–55.
- Borusyak, Kirill, Xavier Jaravel, and Jann Spiess (2024). "Revisiting event-study designs: robust and efficient estimation". *Review of Economic Studies*, rdae007.
- Brown, Jason P, John Pender, Ryan Wiser, Eric Lantz, and Ben Hoen (2012). "Ex post analysis of economic impacts from wind power development in US counties". *Energy Economics* 34.6, pp. 1743–1754.
- Brunner, Eric, Ben Hoen, and Joshua Hyman (2022). "School district revenue shocks, resource allocations, and student achievement: Evidence from the universe of US wind energy installations". *Journal of Public Economics* 206, p. 104586.
- Brunner, Eric J and David J Schwegman (2022). "Windfall revenues from windfarms: How do county governments respond to increases in the local tax base induced by wind energy installations?" *Public Budgeting & Finance* 42.3, pp. 93–113.
- Callaway, Brantly and Pedro HC Sant'Anna (2021). "Difference-in-differences with multiple time periods". *Journal of Econometrics* 225.2, pp. 200–230.
- Cengiz, Doruk, Arindrajit Dube, Attila Lindner, and Ben Zipperer (2019). "The effect of minimum wages on low-wage jobs". *The Quarterly Journal of Economics* 134.3, pp. 1405–1454.
- Clausen, Laura Tolnov and David Rudolph (2020). "Renewable energy for sustainable rural development: Synergies and mismatches". *Energy Policy* 138, p. 111289.
- Copena, Damián and Xavier Simón (2018). "Wind farms and payments to landowners: Opportunities for rural development for the case of Galicia". *Renewable and Sustainable Energy Reviews* 95, pp. 38–47.
- Costa, Hélia and Linda Veiga (2021). "Local labor impact of wind energy investment: An analysis of Portuguese municipalities". *Energy Economics* 94, p. 105055.
- Cullen, Joseph (2013). "Measuring the environmental benefits of wind-generated electricity". American Economic Journal: Economic Policy 5.4, pp. 107–133.
- De Chaisemartin, Clément and Xavier d'Haultfoeuille (2024). "Difference-in-differences estimators of intertemporal treatment effects". *Review of Economics and Statistics*, pp. 1–45.
- De Chaisemartin, Clément and Xavier d'Haultfoeuille (2023). "Two-way fixed effects and differences-in-differences with heterogeneous treatment effects: A survey". *The Econometrics Journal* 26.3, pp. C1–C30.
- De Silva, Dakshina G, Robert P McComb, and Anita R Schiller (2016). "What blows in with the wind?" *Southern Economic Journal* 82.3, pp. 826–858.
- Dröes, Martijn I and Hans RA Koster (2021). "Wind turbines, solar farms, and house prices". *Energy Policy* 155, p. 112327.

- Ejdemo, Thomas and Patrik Söderholm (2015). "Wind power, regional development and benefit-sharing: The case of Northern Sweden". *Renewable and Sustainable Energy Re*views 47, pp. 476–485.
- Fabra, Natalia, Eduardo Gutierrez, Aitor Lacuesta, and Roberto Ramos (2023). "Do Renewables Create Local Jobs?" *CEPR Discussion Paper* 17206.
- Feyrer, James, Erin T Mansur, and Bruce Sacerdote (2017). "Geographic dispersion of economic shocks: Evidence from the fracking revolution". American Economic Review 107.4, pp. 1313–1334.
- Gibbons, Stephen (2015). "Gone with the wind: Valuing the visual impacts of wind turbines through house prices". Journal of Environmental Economics and Management 72, pp. 177–196.
- Goodman-Bacon, Andrew (2021). "Difference-in-differences with variation in treatment timing". Journal of Econometrics 225.2, pp. 254–277.
- Hartley, Peter R, Kenneth B Medlock III, Ted Temzelides, and Xinya Zhang (2015). "Local employment impact from competing energy sources: Shale gas versus wind generation in Texas". *Energy economics* 49, pp. 610–619.
- Hübner, Gundula, Valentin Leschinger, Florian JY Müller, and Johannes Pohl (2023).
 "Broadening the social acceptance of wind energy-An Integrated Acceptance Model". *Energy policy* 173, p. 113360.
- Jarvis, Stephen (2024). "The economic costs of NIMBYism: Evidence from renewable energy projects". Journal of the Association of Environmental and Resource Economists (Accepted).
- Jensen, Cathrine Ulla, Toke Emil Panduro, Thomas Hedemark Lundhede, Anne Sofie Elberg Nielsen, Mette Dalsgaard, and Bo Jellesmark Thorsen (2018). "The impact of on-shore and off-shore wind turbine farms on property prices". *Energy policy* 116, pp. 50–59.
- Komarek, Timothy M (2016). "Labor market dynamics and the unconventional natural gas boom: Evidence from the Marcellus region". *Resource and Energy Economics* 45, pp. 1–17.
- Langenmayr, Dominika and Martin Simmler (2021). "Firm mobility and jurisdictions' tax rate choices: Evidence from immobile firm entry". *Journal of Public Economics* 204, p. 104530.
- Lehmann, Paul, Felix Reutter, and Philip Tafarte (2023). "Optimal siting of onshore wind turbines: Local disamenities matter". *Resource and Energy Economics* 74, p. 101386.
- Lehr, Ulrike, Christian Lutz, and Dietmar Edler (2012). "Green jobs? Economic impacts of renewable energy in Germany". *Energy Policy* 47, pp. 358–364.
- Mauritzen, Johannes (2020). "Will the locals benefit?: The effect of wind power investments on rural wages". *Energy policy* 142, p. 111489.
- Newell, Richard G and Daniel Raimi (2015). "Oil and gas revenue allocation to local governments in eight states". Working Paper 21615.
- Novan, Kevin (2015). "Valuing the wind: renewable energy policies and air pollution avoided". American Economic Journal: Economic Policy 7.3, pp. 291–326.
- Rahman, Abidur, Omar Farrok, and Md Mejbaul Haque (2022). "Environmental impact of renewable energy source based electrical power plants: Solar, wind, hydroelectric, biomass, geothermal, tidal, ocean, and osmotic". *Renewable and Sustainable Energy Reviews* 161, p. 112279.

- Schiermeier, Quirin, Jeff Tollefson, Tony Scully, Alexandra Witze, and Oliver Morton (2008). "Electricity without carbon". *Nature* 454.7206, pp. 816–824.
- Shoeib, Eman Ahmed Hamed, Henry C Renski, and Elisabeth Hamin Infield (2022). "Who benefits from Renewable Electricity? The differential effect of wind power development on rural counties in the United States". *Energy Research & Social Science* 85, p. 102398.
- Slattery, Michael C, Eric Lantz, and Becky L Johnson (2011). "State and local economic impacts from wind energy projects: Texas case study". *Energy Policy* 39.12, pp. 7930– 7940.
- Stokes, Leah C (2016). "Electoral backlash against climate policy: A natural experiment on retrospective voting and local resistance to public policy". American Journal of Political Science 60.4, pp. 958–974.
- Sun, Liyang and Sarah Abraham (2021). "Estimating dynamic treatment effects in event studies with heterogeneous treatment effects". *Journal of econometrics* 225.2, pp. 175–199.
- Sunak, Yasin and Reinhard Madlener (2016). "The impact of wind farm visibility on property values: A spatial difference-in-differences analysis". *Energy Economics* 55, pp. 79– 91.
- Vuichard, Pascal, Anna Broughel, Rolf Wüstenhagen, Andrea Tabi, and Jakob Knauf (2022). "Keep it local and bird-friendly: Exploring the social acceptance of wind energy in Switzerland, Estonia, and Ukraine". Energy research & social science 88, p. 102508.
- Wolsink, Maarten (2007). "Planning of renewables schemes: Deliberative and fair decisionmaking on landscape issues instead of reproachful accusations of non-cooperation". *Energy policy* 35.5, pp. 2692–2704.
- Ziegler, Lisa, Elena Gonzalez, Tim Rubert, Ursula Smolka, and Julio J Melero (2018). "Lifetime extension of onshore wind turbines: A review covering Germany, Spain, Denmark, and the UK". *Renewable and Sustainable Energy Reviews* 82, pp. 1261–1271.

A Additional Material

A.1 Supplementary Descriptive Information

Figure A1: Evolution of installed wind power at the national level (Spain)



Notes: Evolution of wind power installation in Spain from 1990 to 2022. The bars correspond to the left y-axis and represent yearly installations measured in Gigawatts. The line corresponds to the right y-axis and represents yearly accumulated wind power measured in Gigawatts. Data sourced from Eurostat.



Figure A2: Distribution of treated municipalities

Notes: Panel (a) shows the distribution of municipalities based on the first year a wind farm was deployed. Panel (b) shows the distribution of municipalities based on the share of power installed in the first treatment year over the total power installed at the end of the analysis period. Approximately 60 percent of municipalities had the totality of the wind capacity in their territory installed in the first year a wind power plant was developed. The remaining 40 percent of municipalities underwent further wind power installations after the initial development in their territory.

Table A1: Summary statistics: Municipalities categorized into terciles based on installed wind power

			Te	ercile						
	Lower $(N=162)$			Mic	Middle (N=165)			Higher (N=157)		
	Mean (sd)	Min	Max	Mean (sd)	Min	Max	Mean (sd)	Min	Max	
Inicial power (kW)	9,186.489 6,566.169	4	19,800	30,184.818 5,819.306	20,000	40,000	64,236.885 27,594.803	40,500	198,055	
Inicial power (kW per capita)	43.982 108.615	0.000	582.353	$106.361 \\ 178.416$	0.122	1,235.294	234.745 321.893	0.106	1,612.903	
Population	3,243.347 3,993.117	27	19,030	2,281.974 3,289.648	19	17,212	1,929.466 3,160.947	38	17,566	
Municipal Revenue	460.111 219.099	128.477	1,138.525	521.345 431.739	168.598	3,218.401	455.978 213.637	162.203	1,602.865	

Notes: Summary statistics by terciles of municipalities based on the total power installed in the first wind farm development in within their territory. Municipalities part of the common tax regime, excluded those treated before 1998. Population and municipal revenue figures correspond to 1996 data. Monetary values expressed in per capita terms.

A.2 Budget Decomposition: Definition of Categories

Municipal revenue is composed of the following categories:

- **Direct taxes**: mainly composed by revenue generated from the property and economic activity taxes.
- Indirect taxes: mainly composed by revenue generated from the construction tax.
- **Public prices and fees**: are fees collected for the provision of a service that directly benefits the interested party, such as public land occupation, fees for basic public services provision, or public prices.
- Current transfers: comprise transfers from other government levels, both in the form of participation in state taxes or as subsidies to finance specific activities. Even though transfers from the municipal funding fund are the most important element of this chapter, current transfers can also originate from private companies and entities.
- **Capital income**: generated by property rents, bank deposits, or royalty payments. This income category encompasses concepts such as income from real estate, concessions, special uses, dividends, or profit shares.
- Real investments: composed by revenue from sales of land and other properties
- **Capital transfers**: formed by payments from other administrations or private entities, earmarked to finance investments and constructions
- **Financial assets**: includes the income derived from the reimbursement of financial assets, such as stocks, shares, bonds, or granted loans
- **Financial liabilities**: includes income derived from financial operations, predominantly loans and credits

Municipal expenditure is composed of the following categories:

- Personnel expenses: consists of City Council and civil servants' wages
- Current goods and services: comprise expenses incurred from the operation of the city, encompassing rents, maintenance, repair activities, utilities, and materials
- Financial expenses: related to the payment of interest on loans or credits
- Current transfers: grants and subsidies granted to citizens and other entities
- **Real investments**: includes investments in infrastructure, encompassing maintenance, repairs, as well as new provisions, intangible investments, or investments in property and communal assets

- **Capital transfers**: formed by payments to other administrations or private entities to finance their projects
- **Financial assets**: includes expenses related to the acquisition of financial assets, such as stocks, shares, bonds, or loans granted
- Financial liabilities: includes expenses derived from financial operations, primarily loans, and credits

A.3 Local Tax Responses: Descriptive Evidence



Figure A3: Evolution of property tax rates

Notes: Evolution of tax rates in treated and control municipalities. Mean values and standard errors. Reference year (represented by the dashed line) is set at the year before the beginning of the construction phase. The construction phase is considered to start three years before the energy producers registration (dotted line). The solid y-line represents the maximum rate for each property tax category. The dashed y-line represents the minimum rate for each property tax category. Subset of municipalities of less than 20,000 inhabitants and control units not neighboring treated municipalities. Municipalities where a wind farm was installed before 2004 are excluded from panels (a) and (b). Municipalities where a wind farm was installed from panel (c).

A.4 Population Dynamics

Figure A4: Population dynamics



Notes: Results from estimating the event study model defined by Equation 2. The dependent variable is the logarithm of the yearly municipal population. Results correspond to the specification which includes municipality-cohort and year-cohort fixed effects, and restricts the analysis to municipalities of less than 20,000 inhabitants not neighboring affected units. The reference year (represented by the dashed line) is set at the beginning of the construction phase. The construction phase is considered to start three years before registration to the energy producers register (dotted line). Standard errors are clustered at the municipality-cohort level. Confidence intervals at the 95 percent level.

Figure A5: Effect of wind farm development on municipal finances: Exclusion of population dynamics



Notes: Results from estimating the event study model defined by Equation 2. The dependent variables are non-financial revenue (Panel a) and non-financial expenditure (Panel b). Magnitudes are expressed in per capita terms relative to the yearly municipal population (triangular coefficients, in red) and to the 1994 population (diamond coefficients, in blue). Results correspond to the specification which includes municipality-cohort and year-cohort fixed effects, controls for municipal characteristics and subsequent wind power installations, and uses the sample restricted to municipalities of less than 20,000 inhabitants not neighboring affected units. The reference year (represented by the dashed line) is set at the year before the beginning of the construction phase. The construction phase is considered to start three years before registration to the energy producers register (dotted line). Standard errors are clustered at the municipality-cohort level. Confidence intervals at the 95 percent level.

B Robustness Checks

B.1 Alternative DID Estimators

Figure A6: Effect of Wind Farm Development on Municipal Finances: Alternative Difference-in-Difference Estimators

(a) Non-financial Revenue (euros per capita - observed population)



(c) Non-financial Expenditure (euros per capita - observed population) (b) Non-financial Revenue (euros per capita - 1994 population)



(d) Non-financial Expenditure (euros per capita - 1994 population)



Notes: Results from estimating Equation 2 using alternative difference-in-difference estimators. Panels (a) and (c) correspond to magnitudes expressed in per capita terms relative to the observed population. Panels (b) and (d) correspond to magnitudes expressed in per capita terms relative to the 1994 population. These results are estimated using the sample restricted to municipalities of less than 20,000 inhabitants and control units not neighboring treated municipalities. The reference year (dashed line) is set at three years before the beginning of the construction phase. The construction phase is considered to start three years before the energy producers registration (dotted line). Standard errors are clustered at the municipality level. Confidence intervals at the 95 percent level.

Figure A7: Local Tax Responses to Wind Farm Development: Alternative Difference-in-Difference Estimators



Notes: Results from estimating Equation 2 using alternative difference-in-difference estimators. Magnitudes are expressed in logarithms. These results are estimated using the sample restricted to municipalities of less than 20,000 inhabitants and control units not neighboring affected municipalities. The reference year (dashed line) is set at three years before the beginning of the construction phase. The construction phase is considered to start three years before the energy producers registration (dotted line). Standard errors are clustered at the municipality-cohort level. Confidence intervals at the 95 percent level.

B.2 Incorporation of Financial Information

Table A2: Effect of wind farm development on municipal finances: Financial and non-financial revenue (euros per capita)

	(1)	(2)	(3)	(4)	(5)				
	(a) No	on-Financial R	levenue						
First Installation	308.031^{***} (60.564)	333.570^{***} (60.720)	311.926^{***} (61.835)	354.302^{***} (66.940)	343.853^{***} (66.986)				
$\begin{array}{l} \text{Mean (treated=1, t=0)} \\ \text{R-squared} \end{array}$	$\begin{array}{c} 747.118 \\ 0.122 \end{array}$	$\begin{array}{c} 747.129 \\ 0.127 \end{array}$	$\begin{array}{c} 747.129 \\ 0.127 \end{array}$	$750.790 \\ 0.123$	$750.790 \\ 0.118$				
(b) Total Revenue									
First Installation	303.492^{***} (60.922)	330.456^{***} (61.079)	309.068^{***} (62.248)	350.322^{***} (67.378)	339.205^{***} (67.428)				
$\begin{array}{l} \text{Mean (treated=1, t=0)} \\ \text{R-squared} \end{array}$	$778.447 \\ 0.119$	$778.467 \\ 0.125$	$778.467 \\ 0.125$	$778.238 \\ 0.121$	$\begin{array}{c} 778.238 \\ 0.116 \end{array}$				
N Municipalities	7,504	7,504	7,504	7,256	5,772				
RFE and TFE Mun Charact Installed Power Evoluded Municipalities	Yes No No	Yes Yes No	Yes Yes Yes	Yes Yes Yes	Yes Yes Yes				
Excluded Neighbors	No	No	No	≥20,000 No	>20,000 Yes				

Notes: Results from estimating the difference-in-difference model described by Equation 1. The dependent variables are municipal non-financial revenue (Panel a) and total municipal revenue (Panel b). The magnitudes are expressed in per capita terms relative to the 1994 population. Mean indicates the mean value of the outcome variable for treated municipalities in the period before the development of a wind farm. Controls for municipal characteristics include land use shares and the ideology of the mayor's political party. Installed power controls for subsequent wind power installations accumulated at the municipality-year level. The first treatment year is set at three years before the registration date. Standard errors are clustered at the municipality-cohort level. * p < 0.10, ** p < 0.05, *** p < 0.01.

	(1)	(2)	(3)	(4)	(5)				
	(a) Non-	-Financial Exp	penditure						
First Installation	$194.841^{***} \\ (44.091)$	$217.876^{***} \\ (44.191)$	$195.262^{***} \\ (44.189)$	$227.128^{***} \\ (47.624)$	$215.538^{***} \\ (47.663)$				
	$\begin{array}{c} 729.544 \\ 0.155 \end{array}$	$\begin{array}{c} 729.603 \\ 0.161 \end{array}$	$\begin{array}{c} 729.603 \\ 0.161 \end{array}$	$733.654 \\ 0.157$	$733.654 \\ 0.147$				
(b) Total Expenditure									
First Installation	$190.165^{***} \\ (44.388)$	$214.804^{***} \\ (44.469)$	$193.043^{***} \\ (44.479)$	$225.202^{***} \\ (47.930)$	$212.710^{***} \\ (47.971)$				
	$754.015 \\ 0.156$	$754.075 \\ 0.163$	$754.075 \\ 0.163$	$755.056 \\ 0.158$	$\begin{array}{c} 755.056 \\ 0.148 \end{array}$				
N Municipalities	7,504	7,504	7,504	7,256	5,772				
RFE and TFE Mun Charact Installed Power Excluded Municipalities Excluded Neighbors	Yes No No No	Yes Yes No No No	Yes Yes No No	Yes Yes >20,000 No	Yes Yes >20,000 Yes				

Table A3: Effect of wind farm development on municipal finances: Financial and non-financial expenditure (euros per capita)

Notes: Results from estimating the difference-in-difference model described by Equation 1 where the dependent variables are municipal non-financial expenditure (Panel a) and total municipal expenditure (Panel b). The magnitudes expressed in per capita terms relative to the 1994 population. Mean indicates the mean value of the outcome variable for treated municipalities in the period of time before the development of a wind farm. Controls for municipal characteristics include land use shares and the ideology of the mayor's political party. Installed power controls for subsequent wind power installations accumulated at the municipality-year level. The first treatment year is set at three years before the registration date. Standard errors are clustered at the municipality-cohort level. * p < 0.10, ** p < 0.05, *** p < 0.01.

Figure A8: Effect of wind farm development on municipal finances: Incorporation of financial information



Notes: Results from estimating the event study model defined by Equation 2. Panel (a) shows the results for municipal revenue. Panel (b) shows the results for municipal expenditure. The results from estimating the model with the variables defined without financial information are represented by red triangular coefficients. The point estimates from estimating the model with the variables defined including financial information are represented by blue diamond coefficients. The magnitudes are expressed in per capita terms relative to the 1994 population. These results correspond to the specification which includes municipality-cohort and year-cohort fixed effects, controls for municipal characteristics and subsequent wind power installations, and uses the sample restricted to municipalities of less than 20,000 inhabitants and control units not neighboring treated municipalities. The reference year (represented by the dashed line) is set at the year before the beginning of the construction phase. The construction phase is considered to start three years before the energy producers registration date (dotted line). Standard errors are clustered at the municipality-cohort level. Confidence intervals at the 95 percent level.

B.3 Alternative Samples

B.3.1 Inclusion of Municipalities Outside the Common Tax Regime

Figure A9: Effect of wind farm development on municipal finances: Inclusion of municipalities outside the common tax regime



Notes: Results from estimating the event study model defined by Equation 2. The dependent variables are non-financial revenue (Panel a) and non-financial expenditure (Panel b). Magnitudes are expressed in per capita terms relative to 1994 population. Coefficients represented by gray triangles correspond to the baseline results, which include only municipalities part of the common tax regime. Coefficients represented by blue diamonds correspond to the results which include the set of municipalities outside the common tax regime. Results correspond to the specification which includes municipality-cohort and year-cohort fixed effects, controls for municipal characteristics and subsequent wind power installations, and uses the sample restricted to municipalities of less than 20,000 inhabitants and control units not neighboring affected municipalities. The reference year (represented by the dashed line) is set at the year before the beginning of the construction phase. The construction phase is considered to start three years before the energy producers registration (dotted line). Standard errors are clustered at the municipality-cohort level. Confidence intervals at the 95 percent level.

B.3.2 Reduction of the Temporal Framework

Figure A10: Dynamic effect of wind farm development on municipal finances (2008-2022)



Notes: Results from estimating the event study model defined by Equation 2. The dependent variables are non-financial revenue (Panel a) and non-financial expenditure (Panel b). The magnitudes are expressed in euros per capita relative to the 1994 population. Coefficients represented by gray triangles correspond to the baseline results reported in section 5.1. Coefficients represented by blue diamonds correspond to the subset of municipalities part of the common tax regime that received the first wind farm development starting in 2008. Results correspond to the specification including municipality-cohort and year-cohort fixed effects, controls for municipal characteristics and subsequent wind power installations, and restricts the sample to municipalities of less than 20,000 inhabitants and control units not neighboring affected municipalities. The reference year (represented by the dashed line) is set at the year before the beginning of the construction phase. The construction phase is considered to start three years before the energy producers registration date (dotted line). Standard errors are clustered at the municipality-cohort level. Confidence intervals at the 95 percent level.

	(1)	(2)	(3)	(4)	(5)				
(a) Non-financial revenue									
First Installation	591.052^{***} (136.838)	$593.842^{***} \\ (137.116)$	586.579^{***} (139.302)	631.293^{***} (149.632)	627.871^{***} (149.661)				
Mean (treated=1, t=0) R-squared	$1,156.084 \\ 0.037$	$1,\!156.084 \\ 0.037$	$1,156.084 \\ 0.037$	$1,155.186 \\ 0.036$	$1,\!155.186 \\ 0.036$				
(b) Non-financial expenditure									
First Installation	362.976^{***} (82.240)	363.116^{***} (82.544)	343.239^{***} (80.462)	376.717^{***} (86.302)	373.928^{***} (86.355)				
$\begin{array}{l} Mean \ (treated=1, \ t=0) \\ R-squared \end{array}$	$1,109.565 \\ 0.071$	$1,109.565 \\ 0.071$	$1,109.565 \\ 0.072$	$\substack{1,109.131\\0.070}$	$\substack{1,109.131\\0.066}$				
N Municipalities	7,217	7,217	7,217	6,941	5,468				
RFE and TFE Mun Charact Installed Power Excluded Municipalities Excluded Neighbors	Yes No No No	Yes Yes No No No	Yes Yes Yes No No	Yes Yes Yes >20,000 No	Yes Yes Yes >20,000 Yes				

Table A4: Effect of wind farm development on municipal finances: Non-financial revenue and expenditure (2008-2022, euros per capita)

Notes: Results from estimating the difference-in-difference model described by Equation 1. The dependent variables are non-financial revenue (Panel a) and non-financial expenditure (Panel b). The magnitudes are expressed in euros per capita relative to the 1994 population. The analysis is restricted to municipalities part of the common-tax regime that received a first wind farm starting in year 2008. Mean indicates the mean value of the outcome variable for treated municipalities in the period prior to the wind farm development. Controls for municipal characteristics include land use shares and the ideology of the mayor's political party. Installed power controls for subsequent wind power installations accumulated at the municipality-year level. The first treatment year is set at three years before the energy producer registration date. Standard errors are clustered at the municipality-cohort level. * p < 0.10, ** p < 0.05, *** p < 0.01.

Figure A11: Dynamic local tax responses to wind farm development: Property tax rates (2008-2022)



Notes: Results from estimating the event study model defined by Equation 2. The dependent variables are the logarithm of the urban (Panel a) and rural (Panel b) tax rates. Coefficients represented by gray triangles (blue diamonds) correspond to the baseline results estimated on the subset of municipalities that received the first wind farm from 2004 (2008) onward. These results correspond to the specification which includes municipality-cohort and year-cohort fixed effects, controls for municipal characteristics and subsequent wind power installations, and restricts the analysis to municipalities of less than 20,000 inhabitants and control units not neighboring affected municipalities. The reference year (represented by the dashed line) is set at the year before the beginning of the construction phase. The construction phase is considered to start three years before the energy producers registration date (dotted line). Standard errors are clustered at the municipality-cohort level. Confidence intervals at the 95 percent level.

	(1)	(2)	(3)	(4)	(5)				
(a) Urban Property Tax									
First Installation	-0.027^{**} (0.014)	-0.030^{**} (0.014)	-0.026^{*} (0.014)	-0.023^{*} (0.013)	-0.020 (0.013)				
$\begin{array}{l} \text{Mean (treated=1, t=0)} \\ \text{R-squared} \end{array}$	$\begin{array}{c} 0.567 \\ 0.086 \end{array}$	$0.567 \\ 0.092$	$\begin{array}{c} 0.567 \\ 0.092 \end{array}$	$\begin{array}{c} 0.562 \\ 0.099 \end{array}$	$\begin{array}{c} 0.562 \\ 0.094 \end{array}$				
(b) Rural Property Tax									
First Installation	-0.026^{**} (0.010)	-0.027^{***} (0.010)	-0.024^{**} (0.010)	-0.025^{**} (0.011)	-0.026^{**} (0.011)				
$\begin{array}{l} \text{Mean (treated=1, t=0)} \\ \text{R-squared} \end{array}$	$\begin{array}{c} 0.632\\ 0.042\end{array}$	$\begin{array}{c} 0.632 \\ 0.044 \end{array}$	$\begin{array}{c} 0.632 \\ 0.044 \end{array}$	$\begin{array}{c} 0.634 \\ 0.046 \end{array}$	$\begin{array}{c} 0.634 \\ 0.046 \end{array}$				
N Municipalities	7,228	7,228	7,228	$6,\!952$	$5,\!478$				
RFE and TFE Mun Charact Installed Power Excluded Municipalities Excluded Neighbors	Yes No No No	Yes Yes No No	Yes Yes No No	Yes Yes >20,000 No	Yes Yes Yes >20,000 Yes				

Table A5: Local tax responses to wind farm development: Property tax rates (2008-2022)

Notes: Results from estimating the difference-in-difference model described by Equation 1. The dependent variables are the logarithm of the urban tax rate (Panel a) and of the rural tax rate (Panel b). The analysis is restricted to municipalities part of the common-tax regime that received a first wind farm starting in year 2008. Mean indicates the mean marginal tax rate for treated municipalities in the period before the wind farm development. Controls for municipal characteristics include land use shares and the ideology of the mayor's political party. "Installed power" controls for subsequent wind power installations accumulated at the municipality-year level. The treatment year is set at the beginning of the construction phase. The construction phase is considered to start three years before the energy producer registration date. Standard errors are clustered at the municipality-cohort level. * p < 0.10, ** p < 0.05, *** p < 0.01.