Work in Progress

Blowing in the Wind: Revenue Windfalls and Local Responses from Wind Farm Development

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Abstract

The development of wind energy infrastructure encompasses global benefits and can offer opportunities for rural areas. Yet, its development can also generate local negative externalities, and its benefits to host communities are not automatic. This study investigates whether the development of wind farms causes revenue windfalls as the base of existing tax instruments increases, and hence benefits financially receiving municipalities. To do so, I use Spanish municipality-level budget data from 1994 to 2020 and exploit the timing of wind project development. Results based on a two-way fixed effect difference-in-difference and event study models show that the development of a wind farm results in an average 30 percent increase in municipal revenue per capita. These additional funds are primarily allocated toward financing real investments and current expenditures. I show that these revenue windfalls, partially driven by an increase in the tax base, are complemented by local tax responses. Municipalities react to the development of a wind farm by increasing tax rates associated with this type of non-mobile capital investment close to maximum levels, while decreasing the fiscal pressure associated with other property tax categories.

Keywords: Energy Transition, Local Public Finance, Wind Power

JEL: H23, R10, Q50

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1 Introduction

Renewable energy production technologies play a central role in the transition towards a decarbonized paradigm, offering global benefits by offsetting 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 et al., 2021).

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 automatic. 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 demand from local communities for compensation (Ejdemo and Söderholm, 2015). 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).

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., 2022) suggests that,

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

[2] See Rahman et al. (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 2020 for local budgets to investigate how municipal revenue is affected by the development of 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 30 percent increase in municipal revenue per capita. This effect, which already appears during the construction of a new installation, is persistent over time and follows an increasing trend once the new infrastructure is under operation.

These results are consistent with the strand of literature analyzing natural-resource windfalls.[3] 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 and 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 (Marchand and Weber, 2020; Komarek, 2016; Weber et al., 2016; Brown et al., 2014). In terms of project durability, shocks associated to fossil fuels often decrease as 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 their nature, 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 between 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 wind farm.[4] During the construction phase, the increase in total revenue is mainly driven by a larger yield from the construction tax.

[3]See for example Bartik et al. (2019) or Newell and Raimi (2015) for analysis focused on the shale oil and gas booms.

[4]The 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.

However, once the operations and maintenance phase starts, the effect takes place through increases in revenue generated by 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 derived 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 14 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.

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.[5] Studies focusing on European countries tend to point toward negative housing value effects (Dröes and Koster, 2021; Jarvis et al., 2021), 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.[6] Focusing on the months surrounding the opening of wind farms in Spain, Fabra et al. (2022) 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 Shoeib et al., 2022; Brunner and Schwegman, 2022; De Silva et al., 2016).[7] 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 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

[5]For studies focusing on housing values see for example Dröes and Koster (2021); Jarvis et al. (2021); 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. (2022); Costa and Veiga (2021).

[6]See for example Slattery et al. (2011); Lehr et al. (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 et al. (2022) for a matching approach.

[7]In 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.

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 effect between revenue and expenditure categories. Section 6 concludes.

2 Institutional Context

2.1 Wind Farm Development

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 27 gigawatts by 2020. 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 renewable 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.[8] The

[8] Administrative 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

issuance of administrative authorizations is contingent upon obtaining a positive environmental impact statement. This report evaluates the integration of environmental 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.

As of 2020, the 1,201 wind power plants installed in Spanish territory were concentrated in 505 municipalities.[9] Figure 1 illustrates the spatial distribution of wind farms across 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 establishment of wind farms. In population terms, the affected municipalities are predominantly small. Out of the 505 municipalities affected, 468 have less than 10,000 inhabitants, and 237 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 an independent party in power, the summary statistics do not indicate substantial differences in the distribution of political power.

2.2 Municipal Organization and Tax Instruments

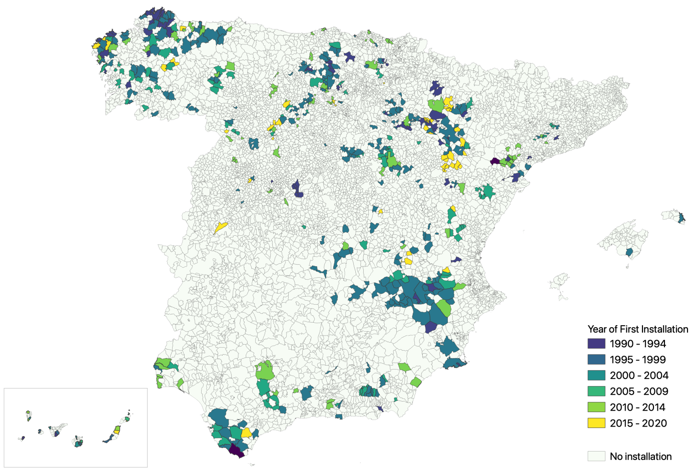
Spain comprises 8,131 municipalities, the basic local entity within the state's organizational structure. The range of basic services that a municipality must provide depends on its population size. While all municipalities are obliged to provide services such as street lighting, waste collection, sewage management, or public road maintenance, the

include any wind farm with an installed capacity above 50 Megawatts.

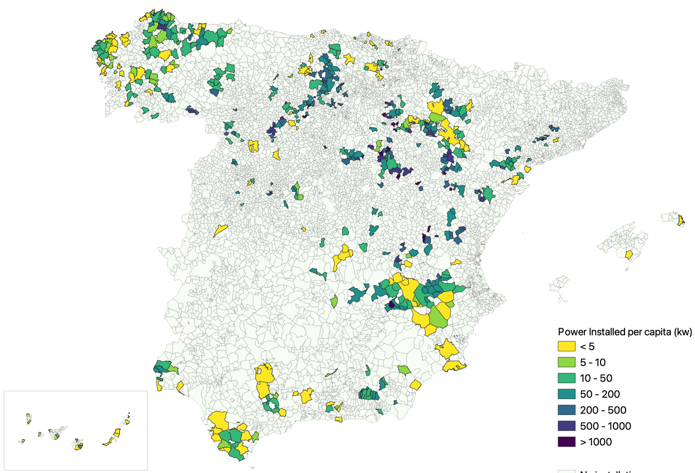
[9]Notice that the data provided by the Spanish Register of Energy Producers facilitates only one municipality name per installation. The current dataset indicates that 505 municipalities are affected by a wind farm. However, this number could be larger if installations affect neighboring municipalities.

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 affected municipality. Panel (b) reports the wind power per capita installed in each municipality in 2020. Data from the Spanish Registry of Energy Producers (Electra).

extent of these services increases with the municipality's population.[10] The main sources

[10]The 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 slaughterhouse. Furthermore, municipalities surpassing 50,000 inhabitants are further required to provide urban collective passenger transport and environmental protection services.

Table 1: Summary Statistics: Municipal Characteristics

	(a) With Wind Power Plant (N=505)		(b) Without Wind Power Plant (N=7624)			
Municipal Area (km2)	Mean	St. Dev.	Mean	St. Dev.	t-test	(p-value)
Full Sample	129.358	149.220	57.636	85.088	-17.267	0.000
<20,000 inhabitants	111.393	101.938	54.168	70.647	-16.500	0.000
Land Use (%)						
Atrifical Surface	1.110	3.689	2.251	7.169	3.537	0.000
Agricultural land	48.799	27.564	54.858	30.764	4.301	0.000
Forest	17.731	17.150	18.124	20.649	0.417	0.677
Bushes and/or herbaceous	29.665	20.800	22.697	21.233	-7.131	0.000
Open spaces with scarce vegetation	2.342	9.107	1.841	7.936	-1.357	0.175
Wetland	0.248	2.018	0.130	1.489	-1.678	0.093
Water bodies	0.481	1.608	0.472	1.966	-0.094	0.925
Wind potential						
IEC1	30.436	6.808	21.896	6.823	-27.166	0.000
IEC3	37.173	7.543	27.501	7.926	-26.561	0.000
Wind density (100m)	40,840.716	13,511.188	28,634.748	14,271.687	-18.621	0.000
Installed Wind Capacity (kW)						
Total Power (end of period)	52,032.384	52,151.228	-	-	-	-
Total Power (first installation)	31,338.962	27,363.653	-	-	-	-
Power per capita (end of period)	188.267	385.678	-	-	-	-
Power per capita (first installation)	134.989	270.260	-	-	-	-
Demographic						
Population density (full sample)	60.524	265.795	146.083	817.554	2.343	0.019
Population density (<20,000)	28.249	61.753	82.702	465.799	2.533	0.011
Population (full sample)	8,525.685	37,532.297	4,692.330	44,910.925	-1.870	0.062
Population (<20,000)	2,643.415	3,660.046	1,768.766	3088.927	-5.870	0.000
Population younger than 15 (%)	12.113	4.994	11.964	5.231	-0.602	0.547
Population older than 64 (%)	26.136	10.049	26.361	10.773	0.444	0.657
Ideology (% of municipalities)						
Extreme Left	2.020	14.083	2.912	16.815	1.154	0.249
Left	40.404	49.120	38.772	48.726	-0.722	0.471
Center-Left	1.010	10.010	0.459	6.760	-1.697	0.090
Center-Right	13.939	34.671	16.448	37.074	1.464	0.143
Right	35.152	47.793	31.217	46.341	-1.827	0.068
Independent Party	6.263	24.253	9.470	29.282	2.384	0.017

Notes: Summary statistics of municipal characteristics prior to the development of a wind farm. Measures of land use shares, population density, demographic characteristics, and political parties correspond to 1996. Measures of final installed capacity and wind potential correspond to the year 2020.

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.[11]

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 tax instruments described below.

Table 2: Municipal Tax Instruments: Tax rates, 2020

	Mean	s.d.	Min	Max
Property Tax				
Rural	0.619	0.197	0.3	1.2
Urban	0.588	0.138	0.3	1.2
Special	0.859	0.329	0.4	1.3
Economic Activity Tax				
Minimum Coefficient	1.119	0.475	0.4	3.8
Maximum Coefficient	1.296	0.719	0.4	3.8
Construction, Installation and Building Works Tax	2.379	1.060	0.0	4.0

Notes: Summary statistics of the main municipal tax instruments and their categories. Data corresponding to the year 2020. The data 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.

[11] Municipal financial resources further comprises revenue generated from the entity's assets, subsidies, public prices, credit operations, fines, and penalties. Additionally, municipalities that are 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 increasing weights applied at thresholds of 5,000, 20,000, and 50,000 inhabitants (Local Treasury Regulatory Law 39/1988 and Royal Legislative Decree 2/2004).

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 considers 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. 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.[12]

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 and has to range from 0.4 to 3.8, 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.

[12]Municipalities have the flexibility to adjust the urban and rural property tax rates beyond the specified ranges if they are a provincial or autonomous community capital, provide public transportation services or more services than legally required, or in the case of having rural land comprising over 80 percent of the total municipal area. When a new cadastral value is established through general collective valuation, the urban and rural tax rates can be reduced to a maximum of 0.1 and 0.075 percent for six years. Additionally, municipalities can introduce a tax credit of up to 90 percent for special characteristics properties.

3 Data

This paper employs a panel dataset at the municipality level covering the period from 1994 to 2020. 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. 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.[13] 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 sub-chapters categorized within the economic classification. Before 2000, this dataset covers a range of 4,619 to 4,990 out of the 8,122 Spanish municipalities. The coverage expands to include over 8,105 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 1 reports summary statistics of municipal geographic and socio-demographic characteristics. 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.

Table 3 reports summary statistics of the budget variables and local tax rates for the base year.[14] The primary sources of municipal revenue correspond to current and capital

[13]The Spanish Register of Energy Producers consolidates the registers of each Autonomous Community. One main limitation of the data made public by the Spanish Register appears when cross-checking with the data released by some of the Autonomous Communities. Autonomous Communities data shows that wind farms are likely to affect more than one municipality. Nevertheless, the data released by the Spanish registry only provides one municipality name for each wind farm.

[14]See Appendix A.2 for a brief description of each concept.

Table 3: Summary Statistics: Dependent Variables

	(a) With Wind Power Plant (N=505)		(b) Without Wind Power Plant (N=7624)			
Tax Instruments	Mean	St. Dev.	Mean	St. Dev.	t-test	(p-value)
Property Tax: Rural	0,552	0,190	0,555	0,176	0,392	0,695
Property Tax: Urban	0,509	0,137	0,539	0,154	3,807	0,000
Property Tax: Special	0,699	0,245	0,694	0,234	-0,316	0,752
Economic Activity Tax: Min	0,933	0,177	0,967	0,158	4,199	0,000
Economic Activity Tax: Max	1,052	0,245	1,044	0,224	-0,647	0,517
Construction Tax	1,777	0,946	1,702	0,987	-1,468	0,142
Municipal Budget: Revenue per capita						
Direct Taxes	122,356	112,086	136,133	140,259	1,637	0,102
Indirect Taxes	17,695	31,054	21,676	65,589	1,025	0,306
Public Prices and Fees	82,673	65,714	99,049	129,569	2,131	0,033
Current Transfers	172,267	95,446	174,949	131,534	0,341	0,733
Capital Income	38,553	73,311	48,065	109,730	1,453	0,146
Real Investments	10,710	44,244	12,766	51,680	0,661	0,509
Capital Transfers	140,444	210,872	163,847	291,375	1,343	0,179
Financial Assets and Liabilities	36,006	93,384	31,327	75,210	-1,009	0,313
Total Revenue	620,704	380,769	687,813	494,555	2,265	0,024
Municipal Budget: Expenditure per capita						
Personnel Expenses	136,201	74,021	139,206	92,804	0,540	0,589
Current Goods and Services	159,523	90,291	180,742	123,152	2,880	0,004
Financial	9,034	11,500	8,138	12,538	-1,184	0,236
Current Transfers	31,623	35,880	31,230	47,956	-0,137	0,891
Real Investment	224,512	257,942	268,031	342,157	2,124	0,034
Capital Transfers	12,053	35,003	11,051	37,884	-0,438	0,661
Financial Assets and Liabilities	36,006	93,384	31,327	75,210	-1,009	0,313
Total Expenditure	595,462	351,681	661,584	474,938	2,327	0,020

Notes: Summary statistics for the key variables of interest, distinguishing between treated (Panel a) and control (Panel b) municipalities. The data on municipal revenue and expenditure pertains to the year 1998. Data on local tax rates corresponds to the year 2000, except for the special property tax rate, which is available from 2004. Monetary values are expressed in per capita terms.

transfers and direct taxes. The most significant categories of expenditure correspond to real investments, current goods and services, and personnel expenses. While, compared to control municipalities, treated municipalities show slightly lower levels of revenue and expenditure per capita, the summary statistics show that significant differences only take place in terms of lower revenue from public prices and fees, as well as lower levels of expenditure in current goods and services and real investment. Regarding local tax rates, treated municipalities report slightly lower urban property tax rates and lower minimum economic activity tax coefficient values.[15]

[15] In Appendix A.1, Table A1 reports summary statistics of municipalities divided into terciles of installed wind power. Treated municipalities do not exhibit important differences in either population in terms of municipal revenue.

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.[16] 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:

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

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 political party ideology of the mayor; 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 of interest. This estimate is interpreted as the average yearly effect on the outcome of interest from the beginning of the construction phase onward.

To capture the effects occurring during the construction phase, I consider a municipality to be treated three years prior to its preliminary inscription in the Energy Producers Register. The preliminary inscription takes place once the installation is already constructed and serves as a prerequisite to start the testing phase.[17] To control for potential effects from subsequent wind energy installations, I include a control variable representing the cumulative wind power installed in each municipality and year. This variable is defined as the accumulated wind power installed in each municipality and year minus the power

[16] This methodology has also been used to analyze the local impact of wind farm development by Brunner, Hoen, et al., 2022 and Brunner and Schwegman, 2022.

[17] By adopting a three-year pre-treatment assignment, I follow a similar approach to previous studies such as Fabra et al. (2022) and Costa and Veiga (2021). Fabra et al. (2022) 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 started to be constructed in its territory.

installed in the treatment year.[18] The model specification incorporates municipality and year-fixed effects to ensure that the estimates are identified within year and municipality variation in wind farm installation exposure.

To ensure cleaner comparison groups, I implement two sample restrictions. First, I restrict the analysis to municipalities with less than 20,000 inhabitants. 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 44 treated municipalities and 370 controls from the analysis. Second, I 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 from autonomous communities indicate that neighboring municipalities are also likely to be affected. After excluding neighboring municipalities, the final sample includes 6,829 municipalities, of which 461 have at least one wind farm within their territory.

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

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

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

[18] In the Appendix, Figure A2b illustrates the distribution of treated municipalities based on the share of 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 developments after the installation of the first wind farm.

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, $D^1_{i,t}$ equals one three years before the year of preliminary inscription in the energy producers register. The omitted category, $D^0_{i,t}$, represents the year before the construction phase starts. I include indicator variables for the five years before a municipality starts being treated ($D^{-5}_{i,t}$ to $D^{-1}_{i,t}$) and up to 10 years after the wind farms becomes operational ($D^1_{i,t}$ to $D^{14}_{i,t}$). To aggregate effects in periods outside this temporal window, $D^{-5}_{i,t}$ and $D^{14}_{i,t}$ 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^{lead}_k and β^{lag}_k. The estimation of β^{lead}_k helps validate the pre-trends assumption as estimates differences between treated and control municipalities prior to the development of a wind farm. β^{lag}_k 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, 2022b; 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 final sample all municipalities that were treated before 1998. By doing so, I ensure that all treated units are observed at least at the base period, and I eliminate potential bias derived from "always treated" municipalities. 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 (2022a), and Borusyak et al. (2021).

In the empirical work that follows, I start by analyzing the effect of wind farms on municipal non-financial revenue and expenditure. To identify the specific channels through which wind energy installations affect municipality revenue and the types of expenditure financed by them, I decompose the effects on revenue and expenditure into their respective chapters. To ensure comparability across municipalities of different sizes, I normalize all monetary variables by population.To address potential bias from always-treated units, I exclude the 44 municipalities that received a wind farm before 1998 from the base sample. To analyze local tax responses, I focus on the 7,606 municipalities part of the common tax regime.[19]

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 receiving municipalities. Next, I decompose the aggregate effect to identify the revenue sources through which the effect takes 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 2020.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 an average yearly increase in municipal non-financial revenue of 274.2 euros per capita. Results in Table 5 indicate that municipalities used this new revenue to increase non-financial expenditure by 123.5 euros per capita.

To isolate the monetary effect from population changes, I keep population constant at

[19]Appendix B.3 shows that results are robust regardless of including non-common tax regime municipalities.

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.

Table 4: Effect of Wind Farm Development on Non-financial Revenue (euros per capita)

	(1)	(2)	(3)	(4)	(5)
(a) Observed Population					
First Installation	423.900***	407.500***	348.900***	402.600***	409.500***
	(58.030)	(57.710)	(56.710)	(61.370)	(61.390)
Mean (treated=1, t=0)	875.830	875.867	875.867	882.772	882.956
R-squared	0.203	0.207	0.207	0.207	0.208
(b) Constant Population					
First Installation	248.100***	270.500***	239.300***	276.900***	274.200***
	(57.520)	(57.780)	(58.800)	(64.500)	(64.510)
Mean (treated=1, t=0)	915.462	915.504	915.504	916.826	924.494
R-squared	0.127	0.132	0.132	0.128	0.123
N Municipalities	8,040	8,040	8,040	7,761	6,865
RFE and TFE	Yes	Yes	Yes	Yes	Yes
Mun Charact	No	Yes	Yes	Yes	Yes
Installed Power	No	No	Yes	Yes	Yes
Excluded Municipalities	No	No	No	>20,000	>20,000
Excluded Neighbors	No	No	No	Yes	Yes

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 three years before the preliminary registration date. Standard errors are clustered at the municipality-cohort level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

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) includes as 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 wind farm installation.

Columns (4) and (5) restrict the sample to small and non-neighboring municipalities to eliminate bias driven by larger municipalities and potentially affected control units. Column (4) summarizes the results for the sample restricted to municipalities of less than 20,000 inhabitants. Column (5), the preferred specification, excludes non-treated neighboring municipalities from the sample. By limiting the analysis to smaller municipalities and excluding neighboring units from the regression, this specification eliminates potential attenuation biases derived from the introduction of treated units as controls.

The results presented in Table 4 suggest that the development of wind farms has a significant positive impact on municipal resources. Specifically, I focus on non-financial revenue as financial revenue is expected to remain unaffected by wind farms.[20] The estimates in Panel (a) indicate an increase in non-financial revenue of 409.5 euros per capita, representing a 46 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 population changes. When the population is held constant at the beginning of the analysis period, the increase in non-financial revenue is estimated to be 274.2 euros per capita, representing a 29.7 percent increase compared to the pre-treatment period.

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.[21] 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 123.5 euros per capita, representing a 13.8 percent increase relative to the mean expenditure per capita in the pre-treatment period.[22]

[20] Appendix B.2 shows that these results are consistent to the inclusion of financial revenue.

[21] The Organic Law on Budgetary Stability and Financial Sustainability approved in 2012 limits the spending of public administrations with three financial rules: budget stability, public debt, and expenditure rule. The expenditure rule prevents the spending of public administrations from exceeding the medium-term GDP growth rate of the Spanish economy.

[22] Appendix B.2 shows that these results are consistent with the specification including financial expenditure.

Table 5: Effect of Wind Farm Development on Non-financial Expenditure (euros per capita)

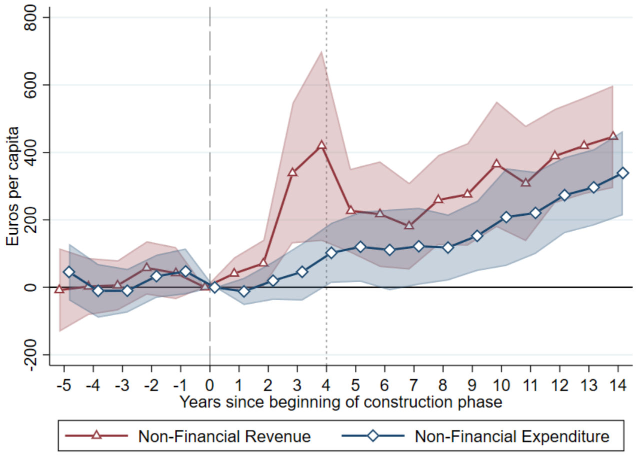
	(1)	(2)	(3)	(4)	(5)
(a) Observed Population					
First Installation	250.600***	236.000***	191.900***	229.300***	235.700***
	(42.110)	(41.820)	(41.490)	(44.610)	(44.620)
Mean (treated=1, t=0)	850.754	850.811	850.811	857.637	857.977
R-squared	0.222	0.226	0.226	0.226	0.226
(b) Constant Population					
First Installation	103.800***	124.200***	99.960***	126.000***	123.500***
	(36.520)	(36.700)	(36.990)	(40.280)	(40.290)
Mean (treated=1, t=0)	887.629	887.686	887.686	889.037	896.283
R-squared	0.166	0.172	0.172	0.169	0.164
N municipalities	8,040	8,040	8,040	7,761	6,865
RFE and TFE	Yes	Yes	Yes	Yes	Yes
Mun Charact	No	Yes	Yes	Yes	Yes
Installed Power	No	No	Yes	Yes	Yes
Excluded Municipalities	No	No	No	>20,000	>20,000
Excluded Neighbors	No	No	No	No	Yes

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 three years before the preliminary registration date. Standard errors are clustered at the municipality-cohort level. * p < 0.10, ** p < 0.05, *** p < 0.01.

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 not neighboring affected units. β_k^{lead} coefficients close to zero and non-statistically significant show no evidence of a pre-trend in municipal revenue (triangular coefficients in red) or expenditure (rhombus-shaped coefficients in blue).

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

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 non-financial revenue (coefficients in red represented by a triangle) and non-financial expenditure (coefficients in blue represented by a rhombus). 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, controls for municipal characteristics, and subsequent wind power installations. The sample is 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 the preliminary register to the energy producers register (dotted line). Standard errors are clustered at the municipality-cohort level. Confidence intervals at the 95 percent level.

non-financial revenue. These results indicate that wind farm development significantly and consistently impacts municipal non-financial revenue. This effect is substantial during the construction phase. After the construction phase, the increase in revenue slightly decreases in magnitude, and it gradually increases again during the wind farm's lifetime. The rhombus-shaped coefficients correspond to the estimated effect on municipal non-financial expenditure. The effect for municipal expenditure follows an increasing trend and shows a smoother evolution than in the case of revenue. These results indicate that, on average, the increase in municipal expenditure is lower than the increase in revenue. However, the point estimates are not statistically different, and both variables follow a similar trend over time. These results indicate that extra resources generated by wind farms translate into a sustained increase in municipal expenditure.[23]

[23]In Appendix B.1, Figure A7 shows that these results are consistent to alternative difference-in-difference estimators. Appendix B.2 shows that the results are consistent and stable to including financial information.

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 a mechanical effect driven by a broadening of the tax base. The broadening of the tax base 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 results reported in this section correspond to the sub-sample of municipalities part of the common tax regime.[24] The sample of municipalities that can be analyzed is limited by the data provided by the Spanish Tax Agency. This data contains information on municipal tax rates starting in year 2000 for the urban in rural property tax rates and in year 2004 for the special characteristics tax rate. To prevent bias in the results from including always treated units in the analysis, the results presented in this section exclude municipalities that received a wind farm before the beginning of the analysis period. The results from the analysis of urban and rural tax rates is based on the sample of municipalities that received the first wind farm starting in 2004. The results from the special tax rate are based on the sample restricted to municipalities that received the first wind farm starting in 2008.[25]

Table 6 summarizes the results from estimating equation (1) on the tax rate logarithm of each category of property tax. Panel (a) summarizes the results of the special tax rate. The results reported in Column (5) indicate that, in aggregate terms, municipalities react to the development of the first wind farm in their territory by increasing by 20 percent

[24] The regions of Euskadi and Navarra are not part of this analysis as they belong to a special tax regime and municipalities are subject to different tax regulations. The data provided by the Spanish Tax Agency only contains information for municipalities belonging to the common tax regime.

[25] 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 the first wind farm starting in 2008, I further ensure that reactions to this tax base expansion are not driving results. This restriction reduces the number of treated municipalities from 463 to 247 in the case of the urban and rural tax rates, and to 155 in the case of the special category tax rate. Appendix B.3 shows that the results are not significantly different when the analysis is restricted to municipalities that received the first wind farm starting in 2008. Table A4 shows the difference-in-difference results for non-financial revenue and expenditure. Table A5 shows the difference-in-difference results for the urban and rural tax rates. Figure A9 shows the event study results for non-financial revenue (Panel a) and non-financial expenditure (Panel b). Figure A10 shows the results for the urban (Panel a) and rural (Panel b) tax rates.

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

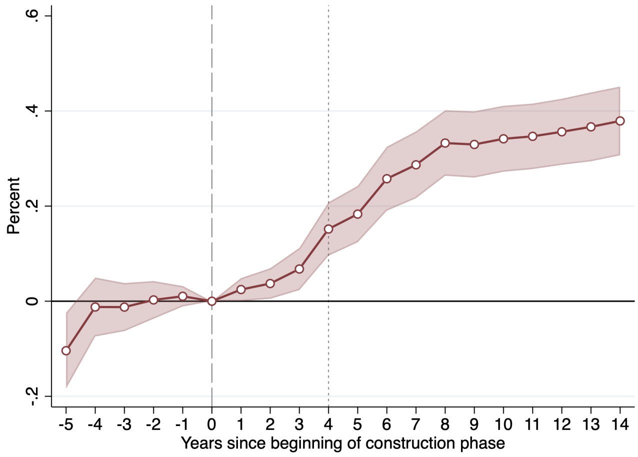
	(1)	(2)	(3)	(4)	(5)
	(a) Special Property Tax				
First Installation	0.206***	0.207***	0.189***	0.194***	0.201***
	(0.022)	(0.022)	(0.021)	(0.022)	(0.022)
Mean (treated=1, t=0)	0.786	0.786	0.786	0.773	0.773
R-squared	0.123	0.124	0.124	0.120	0.111
Municipalities	7,281	7,281	7,281	6,995	6,142
	(b) Urban Property Tax				
First Installation	-0.034***	-0.037***	-0.031***	-0.024**	-0.023**
	(0.012)	(0.012)	(0.012)	(0.011)	(0.012)
Mean (treated=1, t=0)	0.607	0.607	0.607	0.606	0.606
R-squared	0.133	0.139	0.139	0.148	0.146
Municipalities	7,362	7,362	7,362	7,096	6,238
	(c) Rural Property Tax				
First Installation	-0.034***	-0.035***	-0.035***	-0.038***	-0.039***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Mean (treated=1, t=0)	0.592	0.595	0.595	0.587	0.587
R-squared	0.103	0.104	0.104	0.107	0.108
Municipalities	7,362	7,362	7,362	7,095	6,237
RFE and TFE	Yes	Yes	Yes	Yes	Yes
Mun Charact	No	Yes	Yes	Yes	Yes
Installed Power	No	No	Yes	Yes	Yes
Excluded Municipalities	No	No	No	>20,000	>20,000
Excluded Neighbors	No	No	No	No	Yes

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 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 preliminary registration date. Standard errors are clustered at the municipality-cohort level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

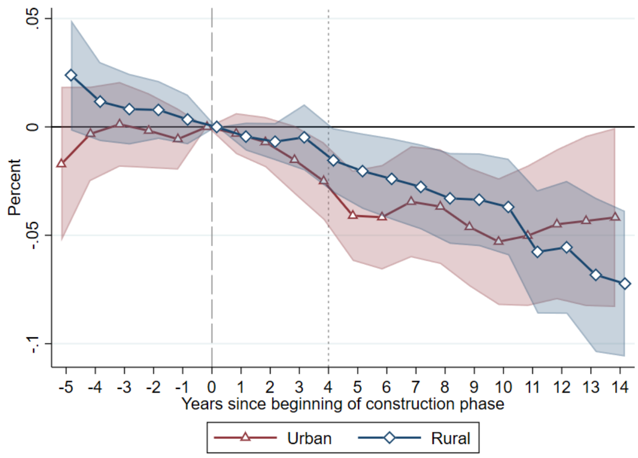
the tax rates targeted to them. Panels (b) and (c) report the urban and rustic tax rate results. These results show that local tax responses not only occur by substantially increasing the tax burden of wind farms but are complemented by decreasing the fiscal pressure associated with the other tax categories. Specifically, the results reported in Column (5) indicate that, after the development of the first wind farm, municipalities reduce the urban property tax rate by 2.3 percent (Panel b) and the rural property tax rate by 3.9 percent (Panel c). These results are consistent with the different specifications adding regional and time-fixed effects (Column 1); controlling for municipal characteristics (Column 2); controlling for further wind power installations (Column 3); and restricting the sample to municipalities of less than 20,000 inhabitants (Column 4) and control units not bordering treated municipalities (Column 5).

Figure 3: Dynamic Local Tax Responses to Wind Farm Development: Property Tax Rates

(a) Special category property tax



(b) Urban and Rural 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 rhombus in Panel b). Results correspond to the specification, including municipality-cohort and year-cohort fixed effects, controls for municipal characteristics, and subsequent wind power installations. Results in Panel (a) correspond to the sample of municipalities of less than 20,000 inhabitants not neighboring affected units part of the common tax regime that received the first wind farm installation after 2008. Results in Panel (a) correspond to the sample of municipalities of less than 20,000 inhabitants not neighboring affected units part of the common tax regime that received the first wind farm installation after 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 preliminary energy producers register (dotted line). Standard errors are clustered at the municipality-cohort level. Confidence intervals at the 95 percent level.

Figure 3 plots the β_k coefficients of estimating Equation 2 for each of the three property tax categories. Panel (a) shows the results corresponding to the special category property tax. Starting at the construction phase, municipalities react to the construction of a wind farm by progressively increasing the fiscal pressure on this type of investment. The special characteristic tax rate increase stabilizes four years after the wind farm becomes operative when it is set close to maximum levels.[26] Results show no evidence of pre-trends as coefficients prior to the beginning of the construction phase are non-significant and close to zero.

Results reported in Figure 3b show that, while municipalities react to the development of a wind farm by increasing tax rates targeted to them, they decrease the fiscal pressure associated with the rest of the property tax categories. 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. In the case of the urban property tax, the largest decrease takes place at the beginning of the construction phase and stabilizes once the wind farm becomes operative. Turning to the fiscal pressure associated with rural land, results show 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

I decompose the aggregate revenue effect into the different revenue sources to identify the main channels through which wind farms affect municipal resources.[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 chapter. These results show that the most significant increase in municipal revenue occurs through an increase in revenue generated from indirect taxes (i.e., the construction tax), followed by an increase in revenue generated from capital income and direct taxes (i.e., property tax and economic

[26]In Appendix A.3, Figure A3c plots the temporal evolution of the special characteristics 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.

[27]In Appendix A.3, Figures A3a and A6c plot the temporal evolution of the urban and rural tax rates in treated and control municipalities. This figure shows that, although the magnitude of the change in trends is small, treated municipalities exhibit a decrease in tax rates associated with urban and rural property once a wind farm is built in their territory.

[28]See Appendix A.2 for the definition of each revenue chapter.

activity tax).

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

	(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
First Installation	98.030***	135.300***	14.000	-18.180*	57.040***	-4.381	-7.599	0.397	-7.735***
	(30.210)	(42.580)	(8.756)	(10.300)	(10.850)	(4.635)	(13.450)	(0.343)	(2.524)
Mean (treated=1, t=0)	185.450	34.742	140.688	242.171	56.510	24.163	240.770	1.540	37.253
N municipalities	6,865	6,865	6,865	6,865	6,865	6,865	6,865	6,865	6,865
R-squared	0.154	0.009	0.031	0.199	0.016	0.002	0.062	0.000	0.018
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

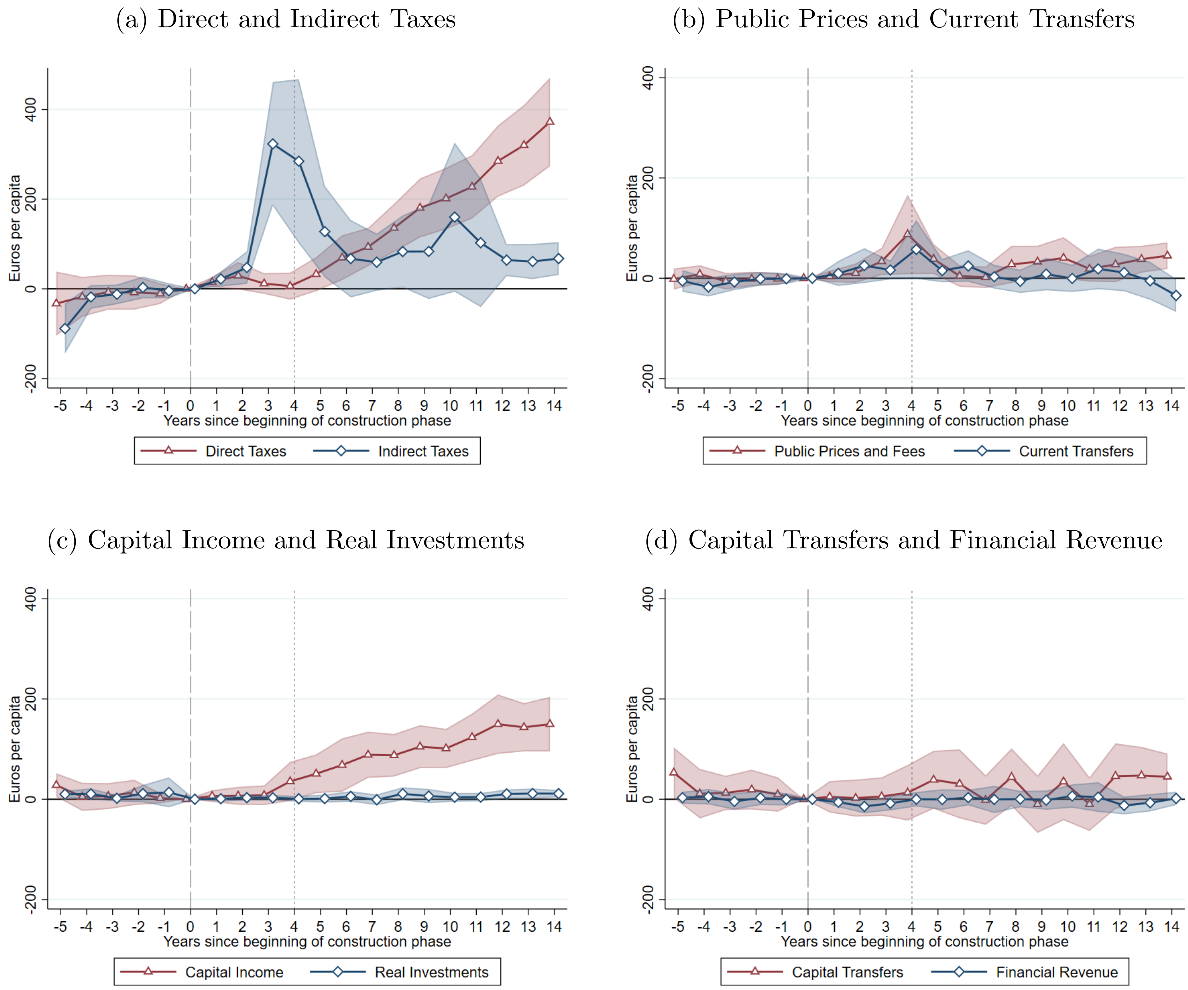
Notes: Results from estimating the difference-in-difference model described by Equation (1). The dependent variables are each revenue source expressed in euros per capita relative to 1994 population. Mean indicates the mean value of the outcome variable for treated municipalities in the period of time 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 preliminary registration date. Standard errors are clustered at the municipality-cohort level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

More specifically, Table 7 shows that increases in capital income explain 20 percent of the increase in municipal revenue. The remaining revenue effect corresponds to increases in revenue generated from direct and indirect taxes. Columns (1), (2), and (5) show that a wind farm development increases the revenue generated from direct taxes by 52 percent, doubles capital income, and multiples by three the revenue generated from the construction tax. The increase in capital income, which includes concepts such as income from rents, concessions, and special uses or dividends and profit shares, is especially relevant in this contest as it represents another form through which municipalities benefit from the development of a wind farm beyond the mechanical increase due to expansions in the tax base.[29]

In Table 7, Columns (8) and (9) analyze changes in municipalities' financial behavior. Negative coefficients associated with financial liabilities (i.e., loans and credits) show that municipalities react to wind farm development by decreasing their indebtedness. Column (4) shows that resources derived from current transfers slightly decrease after the first wind farm. 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.

[29]Municipalities 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.

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



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.

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 (rhombus) 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.

5.4 Decomposition of the Effect on Expenditure

I decompose the increase in expenditure into each of its categories to better understand the use that municipalities make of the extra revenue generated from wind farms.[30] Table 8 summarizes the results from estimating the difference-in-difference model defined by Equation (2). These results indicate that municipalities mainly use these new resources to finance increases in current expenditures 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 Wind Farm Development of Municipal Expenditure: Decomposition by Expenditure Category

	(1) Personnel Expenses	(2) Current Expenditures	(3) Financial Expenses	(4) Current Transfers	(5) Real Investments	(6) Capital Transfers	(7) Financial Assets	(8) Financial Liabilities
First Installation	-3.364	29.040**	-1.642***	8.416	89.640***	1.435	0.345	-4.784**
	(8.325)	(12.99)	(0.555)	(5.556)	(21.590)	(2.272)	(0.532)	(2.142)
Mean	197.759	267.096	8.644	43.276	369.254	10.254	1.537	25.496
N (municipalities)	6,865	6,865	6,865	6,865	6,865	6,865	6,865	6,865
R-squared	0.261	0.202	0.026	0.042	0.068	0.003	0.000	0.017
RFE and TFE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mun Charact	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Installed Power	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
Excluded Neighbors	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Results from estimating the difference-in-difference model described by Equation (1). The dependent variables are each category of expenditure 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 preliminary register to 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 72 percent of the resources allocated to increase municipal expenditure are directed towards real investments. Compared to the use of

[30] See Appendix A.2 for the definition of each expenditure chapter.

resources that municipalities made before the development of a wind farm, Column (2) indicates that municipalities increased current expenditure by 10 percent, and real investments by 24 percent (Column 5). The substantial increase in real investments can be interpreted as a form of indirect compensation to hosting communities with the revenue generated from wind farms. I complement this analysis by estimating the effect on expenditure associated with financial assets (Column 7) and liabilities (Column 8). Negative coefficients associated with financial liabilities indicate a decrease in financial resources allocated towards paying off public debt, suggesting that municipalities used this new financial resource to decrease their debt burden.

Figure 5 plots the β_k coefficients and associated 95 percent confidence intervals from estimating Equation (2) for each category of expenditure. 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. The increase in expenditure follows a smoother upward trend compared to municipal revenue, with increases becoming more prominent during the operation phase. Coefficients corresponding to real investments (Panel c) are less precisely estimated. Yet treated municipalities still demonstrate a significant increase in the allocation of resources towards funding public investment. Small and statistically insignificant coefficients associated with the remaining expenditure categories further demonstrate the robustness of the results and prove that they do not stem from identifying a systematic change.

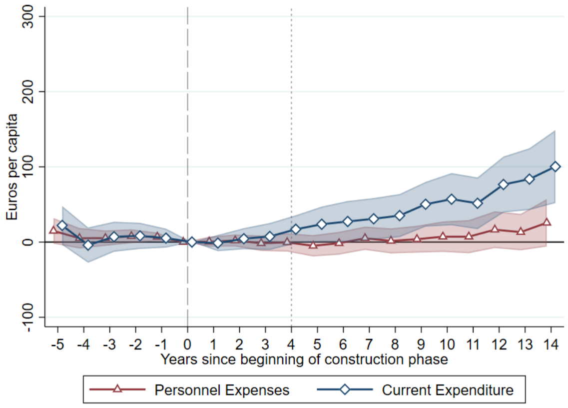
6 Concluding Remarks

Understanding whether local communities benefit from the development of wind farms 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 2020. To causally identify the effect of a wind farm, I use difference-in-differences and event-study methodologies, which exploit spatial and temporal variation of their development.

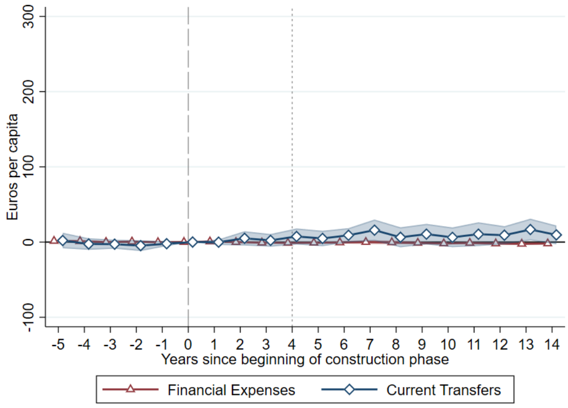
The results show that, at mean levels, the development of a wind farm has a long-lasting positive effect on municipal revenue per capita. This effect is partially driven by an expansion of the tax base and complemented by local tax responses in the form of increases close to the maximum tax rates associated with this type of infrastructure. By decomposing

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

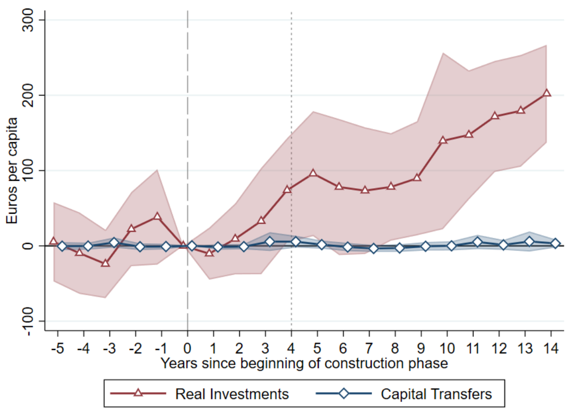
(a) Personnel and Current Expenditure



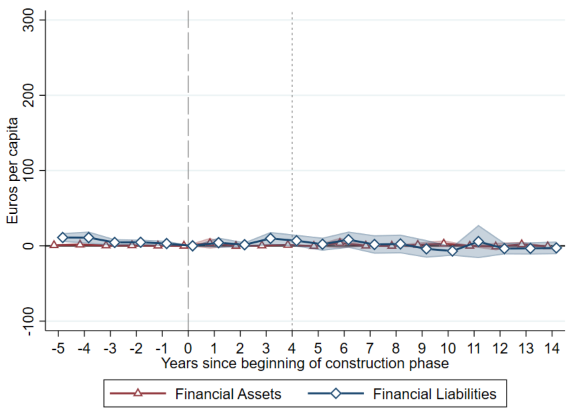
(b) Financial Expenses and Current Transfers



(c) Real Investments and Capital Transfers



(d) Financial Assets and Liabilities



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 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. 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 preliminary inscription 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.

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. The results of this analysis point to different avenues for future research. First, exploring differences in the use of financial resources and local tax responses based on the ideology of municipalities' city councils can bring further insight into the political economy behind the development of renewable energies. Second, 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 locally-concentrated negative externalities associated with this type of infrastructure. 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.

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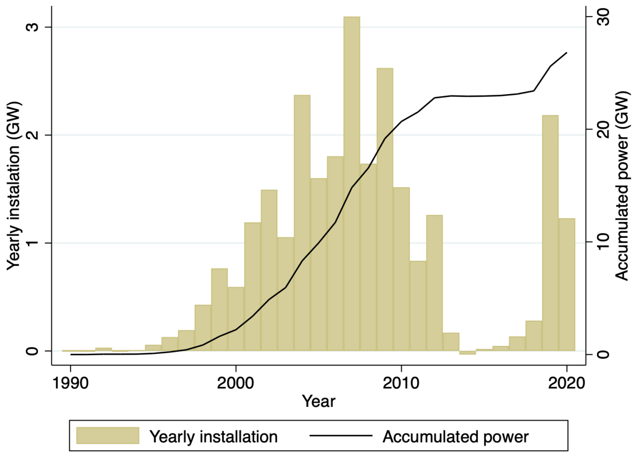
A Additional Material

A.1 Supplementary Descriptive Information

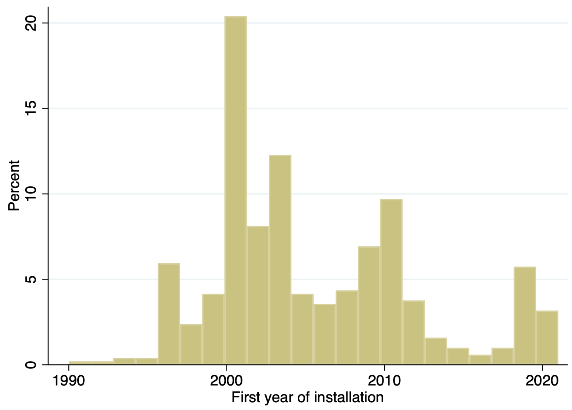
Figure A1: Evolution of Installed Wind Power at the National Level (Spain)



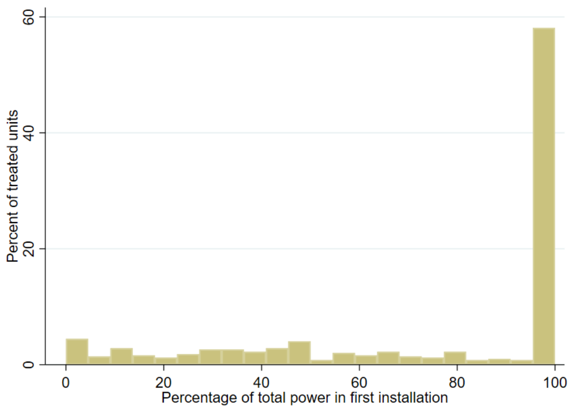
Notes: Evolution of wind power installation in Spain from 1990 to 2020. Bars correspond to the left y-axis and represent yearly installations measured in Gigawatts. The line corresponds to the right y-axis and represents yearly accumulated wind power measured in Gigawatts. Data from Eurostat.

Figure A2: Distribution of Treated Municipalities

(a) First Year of Development



(b) Share of Total Power in First Development



Notes: Panel (a) shows the distribution of municipalities based on the first year a wind farm started to be constructed in each treated municipality. 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. Municipalities correspond to the baseline sample and exclude municipalities with more than 20,000 inhabitants. Roughly 60 percent of municipalities had the total wind capacity in their territory installed in the first year a wind power plant was developed. The remaining 40 percent of municipalities had further wind power installations after the first development in their territory.

Table A1: Summary statistics: Municipalities Categorized in Terciles of Installed Wind Power

	Tercile								
	Lower			Middle			Higher		
	Mean (Sd)	Min	Max	Mean (Sd)	Min	Max	Mean (Sd)	Min	Max
Inicial Pw (kW)	6,671.312	0	17,560	27,144.623	17,850	36,550	61,192.329	36,630	198,055
	(5,944.615)			(5,507.257)			(26,726.952)		
Inicial Pw Pc (kW)	39.263	0.00	733.33	113.921	1.03	1,050.00	277.139	2.27	2,083.33
	(105.110)			(174.728)			(398.721)		
Population	3,298.384	26	19,367	2,381.785	14	17,306	1,878.494	36	16,891
	(4,001.791)			(3,379.187)			(2,976.851)		
Total Revenue (pc94)	595.042	168.087	2,373.442	624.936	179.853	3,339.773	544.606	205.230	2,038.116
	(361.262)			(503.776)			(271.179)		

Notes: Summary statistics by terciles of municipalities defined in terms of total power installed in the first wind farm development in their territory. Population and municipal revenue correspond to values prior to the development of a wind farm. Municipal revenue expressed in per capita values relative to 1994 population.

A.2 Budget Decomposition: Chapters Definition

Municipal revenue is composed of the following chapters:

- **Direct taxes**: are mainly composed by property and economic activity taxes.
- **Indirect taxes**: mainly composed by 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**: composed of transfers from other government levels, both in the 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 come from private companies.
- **Capital income**: generated by property rents, bank deposits, or royalty payments and includes concepts such as income from real estate, from concessions and special uses or dividends and profit shares
- **Real investments**: composed by revenue from sales of land and other properties
- **Capital transfers**: which are formed by payments from other administrations or private entities 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 the income derived from financial operations, mainly loans and credits

Municipal expenditure is composed of the following chapters:

- **Personnel expenses**: which include City Council and civil servants wages
- **Current goods and services**: comprise expenses derived from the operation of the city, including rents, maintenance, and repairs activities as well as utilities and materials
- **Financial expenses**: corresponding to the payment of interest on the loans or credits
- **Current transfers**: grants and subsidies granted to citizens and other entities
- **Real investments**: includes investments in infrastructure, both in maintenance and repairs as well in the new provision, intangible investments or investments in patrimonial and communal assets
- **Capital transfers**: formed by payments to other administrations or private entities to finance their projects

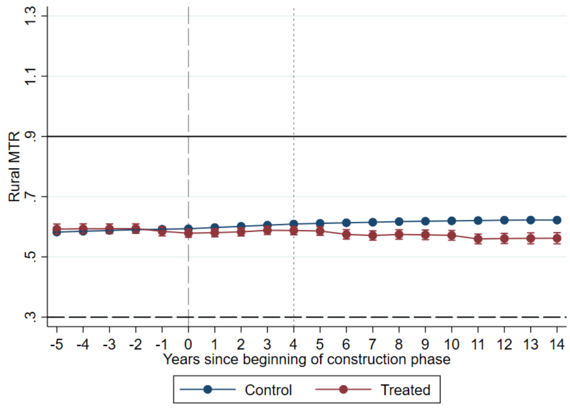
- **Financial assets**: It includes expenses derived from purchasing financial assets, such as stocks, shares, bonds, or granted loans.
- **Financial liabilities**: includes expenses derived from financial operations, mainly loans, and credits

A.3 Local Tax Responses: Descriptive Evidence

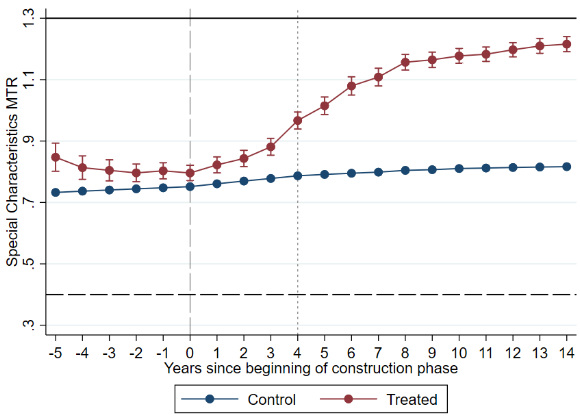
Figure A3: Evolution of Property Tax Rates

(a) Urban tax rate

(b) Rural tax rate



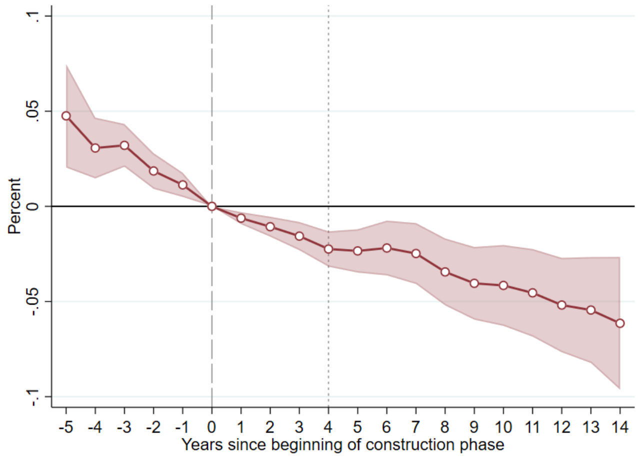
(c) Special tax rate



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 preliminary register to the energy producers register (dotted line). The solid y-line represents the maximum rate for each of the property tax categories. The dashed y-line represents the minimum rate for each of the property tax categories. Baselines sample restricted to municipalities of less than 20,000 inhabitants not neighboring treated municipalities part of the common tax regime. Municipalities where a wind farm was installed before 2004 are excluded from panels (a) and (b). Municipalities where a wind farm was installed before 2008 are excluded from panel (c).

A.4 Population Dynamics

Figure A4: Population Dynamics

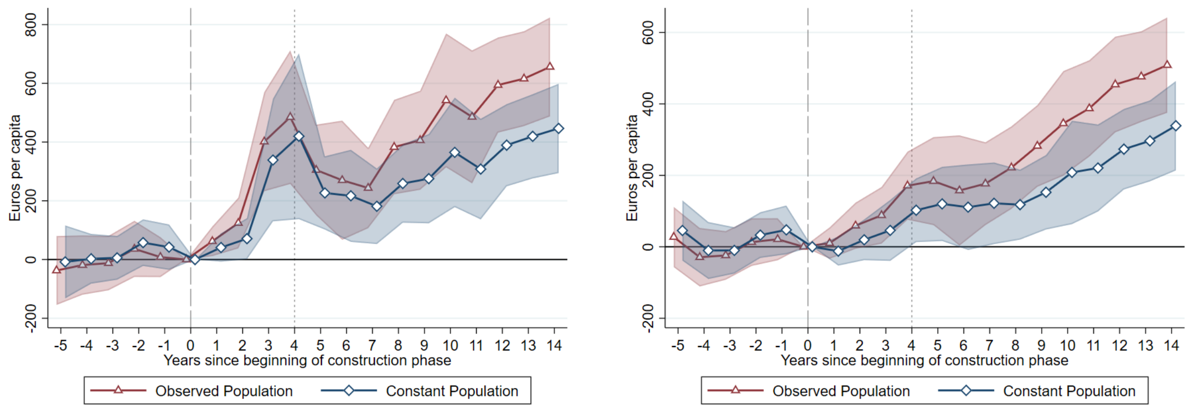


Notes: Results from estimating the event study model defined by Equation 2. The dependent variable is the logarithm of the yearly municipal population. Results correspond to the specification which includes municipality-cohort and year-cohort fixed effects, and uses the sample restricted to municipalities of less than 20,000 inhabitants not neighboring affected units. The reference year (represented by the dashed line) is set at the years 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 at the 95 percent level.

Figure A5: Effect of Wind Farm Development on Municipal Finances: Exclusion of Population Dynamics

(a) Non-financial Revenue

(b) Non-financial Expenditure



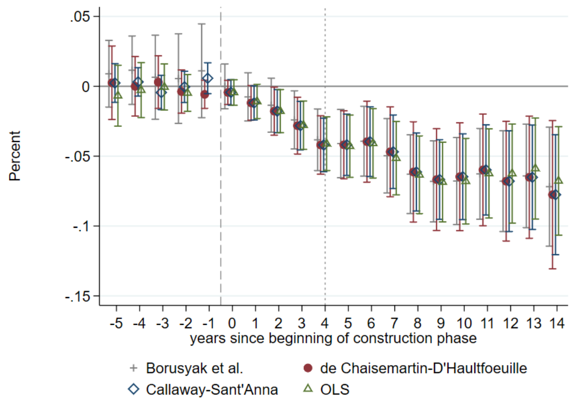
Notes: Results from estimating the event study model defined by Equation 2. The dependent variables are non-financial revenue (Panel a) and non-financial expenditure (Panel b). Magnitudes are expressed in per capita terms relative to the yearly municipal population (triangular coefficients in red) and to the 1994 population (rhombus-shaped 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 the preliminary register 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

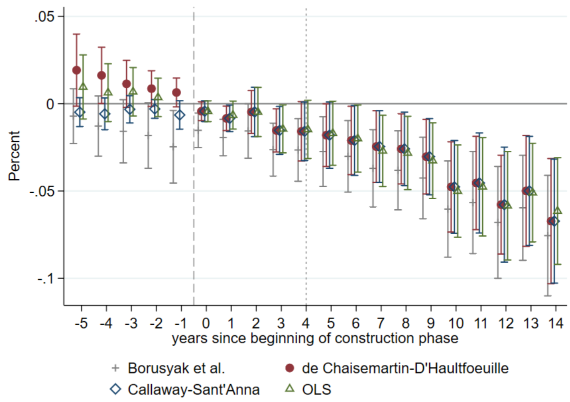
B.1 Alternative DID Estimators

Figure A6: Local Tax Responses to Wind Farm Development: Alternative Difference-in-Difference Estimators

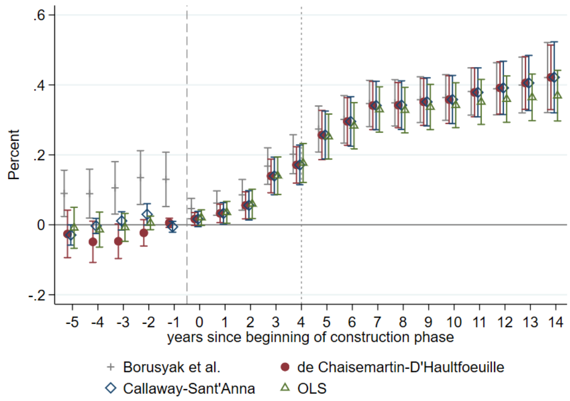
(a) Urban Tax Rate (logs)



(b) Rural Tax Rate (logs)



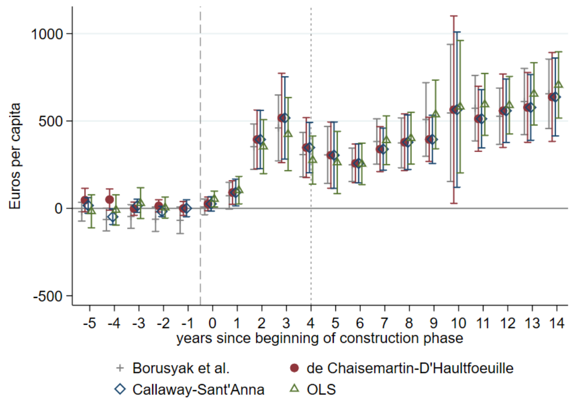
(c) Special Tax Rate (logs)



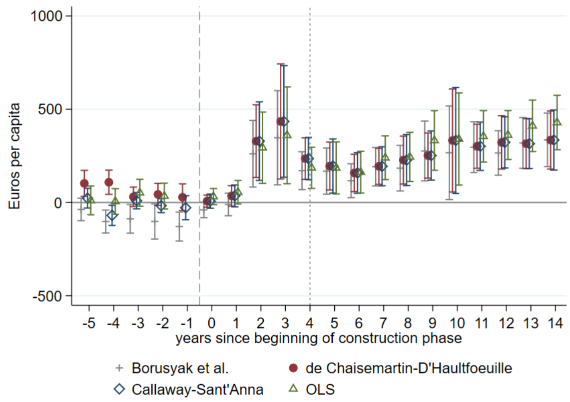
Notes: Results from estimating Equation 2 using alternative difference-in-difference estimators. Magnitudes are expressed in logarithms. These results are estimated using the sample restricted to municipalities of less than 20,000 inhabitants not neighboring affected units part of the common tax regime. 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 preliminary inscription to the energy producers register (dotted line). Standard errors are clustered at the municipality-cohort level. Confidence intervals at the 95 percent level.

Figure A7: Effect of Wind Farm Development on Municipal Finances: Alternative Difference-in-Difference Estimators

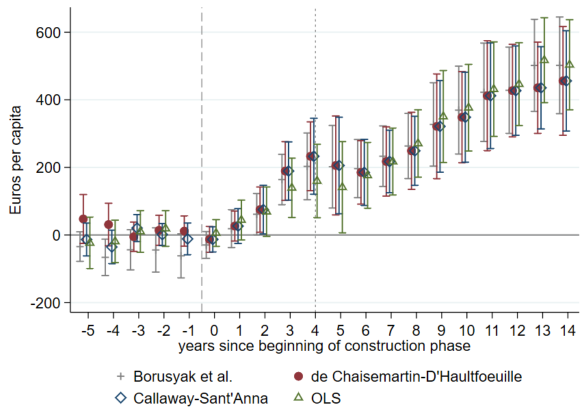
(a) Non-financial Revenue
(euros per capita - observed population)



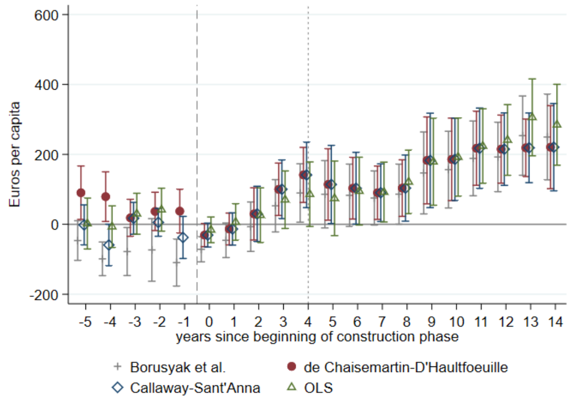
(b) Non-financial Revenue
(euros per capita - 1994 population)



(c) Non-financial Expenditure
(euros per capita - observed 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 not neighboring affected units. 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 preliminary inscription to the energy producers register (dotted line). Standard errors are clustered at the municipality 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) Non-Financial Revenue					
First Installation	248.100***	270.500***	239.300***	276.900***	274.200***
	(57.520)	(57.780)	(58.800)	(64.500)	(64.510)
Mean (treated=1, t=0)	915.462	915.504	915.504	916.826	924.494
R-squared	0.127	0.132	0.132	0.128	0.123
(b) Total Revenue					
First Installation	240.000***	263.500***	231.400***	269.700***	266.900***
	(58.090)	(58.350)	(59.420)	(65.160)	(65.180)
Mean (treated=1, t=0)	955.279	955.327	955.327	954.399	963.287
R-squared	0.125	0.130	0.130	0.127	0.122
N municipalities	8,040	8,040	8,040	7,761	6,865
RFE and TFE	Yes	Yes	Yes	Yes	Yes
Mun Charact	No	Yes	Yes	Yes	Yes
Installed Power	No	No	Yes	Yes	Yes
Excluded Municipalities	No	No	No	>20,000	>20,000
Excluded Neighbors	No	No	No	No	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 preliminary registration date. Standard errors are clustered at the municipality-cohort level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

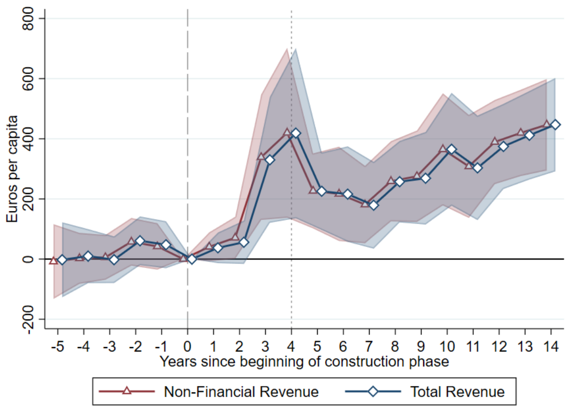
Table A3: Effect of Wind Farm Development on Municipal Finances: Financial and Non-financial Expenditure (euros per capita)

	(1)	(2)	(3)	(4)	(5)
		(a) Non-Financial Expenditure			
First Installation	103.800***	124.200***	99.960***	126.000***	123.500***
	(36.520)	(36.700)	(36.990)	(40.280)	(40.290)
Mean (treated=1, t=0)	887.629	887.686	887.686	889.037	896.283
R-squared	0.166	0.172	0.172	0.169	0.164
		(b) Total Expenditure			
First Installation	97.340***	119.200***	95.630**	122.1***	119.100***
	(36.930)	(37.090)	(37.380)	(40.700)	(40.700)
Mean (treated=1, t=0)	915.589	915.650	915.650	915.302	923.316
R-squared	0.168	0.175	0.175	0.171	0.166
N municipalities	8,040	8,040	8,040	7,761	6,865
RFE and TFE	Yes	Yes	Yes	Yes	Yes
Mun Charact	No	Yes	Yes	Yes	Yes
Installed Power	No	No	Yes	Yes	Yes
Excluded Municipalities	No	No	No	>20,000	>20,000
Excluded Neighbors	No	No	No	No	Yes

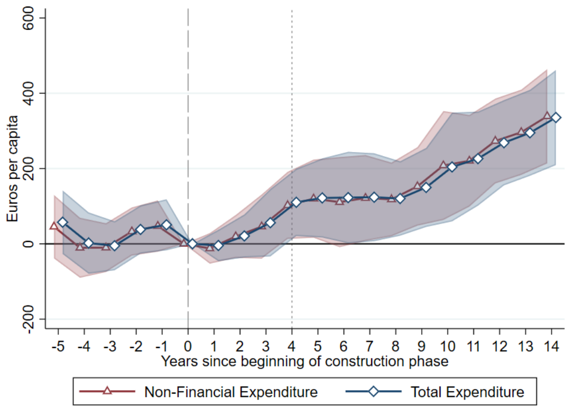
Notes: Results from estimating the difference-in-difference model described by Equation 1 where the dependent variables are municipal non-financial expenditure (Panel a) and total municipal expenditure (Panel b). The magnitudes expressed in per capita terms relative to the 1994 population. Mean indicates 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 preliminary 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

(a) Revenue



(b) Expenditure



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 rhombus-shaped 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 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 the preliminary register to the energy producers register (dotted line). Standard errors are clustered at the municipality-cohort level. Confidence intervals at the 95 percent level.

B.3 Restricted Sample

Table A4: Effect of Wind Farm Development on Municipal Finances: Non-financial Revenue and Expenditure (euros per capita, 2008-2020)

	(1)	(2)	(3)	(4)	(5)
			(a) Non-financial revenue		
First Installation	584.900***	584.900***	577.700***	632.100***	632.100***
	(139.300)	(140.100)	(144.600)	(156.700)	(156.700)
Mean (treated=1, t=0)	1,377.313	1,377.299	1,377.299	1,378.822	1,395.329
Municipalities	7,235	7,235	7,235	6,949	6,103
R-squared	0.025	0.025	0.025	0.025	0.024
			(b) Non-financial expenditure		
First Installation	227.100***	227.300***	213.400***	242.100***	241.100***
	(53.010)	(53.490)	(53.690)	(57.860)	(57.890)
Mean (treated=1, t=0)	1,323.162	1,323.144	1,323.144	1,324.343	1,339.297
Municipalities	7,235	7,235	7,235	6,949	6,103
R-squared	0.059	0.060	0.060	0.059	0.058
RFE and TFE	Yes	Yes	Yes	Yes	Yes
Mun Charact	No	Yes	Yes	Yes	Yes
Installed Power	No	No	Yes	Yes	Yes
Excluded Municipalities	No	No	No	>20,000	>20,000
Excluded Neighbors	No	No	No	No	Yes

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 sample is restricted to municipalities belonging to the common tax regime. Treated municipalities where a wind farm was installed before 2008 are excluded from the sample. Mean indicates the mean marginal tax rate 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 preliminary registration date. Standard errors are clustered at the municipality-cohort level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

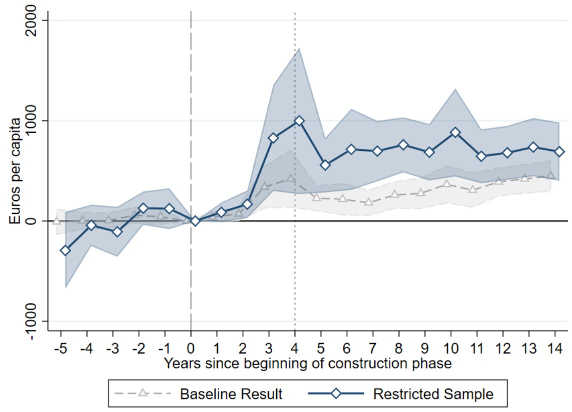
Table A5: Local Tax Responses to Wind Farm Development: Property Tax Rates (2008-2020)

	(1)	(2)	(3)	(4)	(5)
			(a) Urban Property Tax		
First Installation	-0.016	-0.019	-0.017	-0.012	-0.011
	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
Mean (treated=1, t=0)	0.587	0.587	0.587	0.586	0.586
Municipalities	7,281	7,281	7,281	6,995	6,142
R-squared	0.095	0.101	0.101	0.109	0.107
			(b) Rural Property Tax		
First Installation	-0.022**	-0.023**	-0.023**	-0.023**	-0.023**
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
Mean (treated=1, t=0)	0.602	0.602	0.602	0.601	0.601
Municipalities	7,281	7,281	7,281	6,995	6,142
R-squared	0.048	0.049	0.049	0.051	0.051
RFE and TFE	Yes	Yes	Yes	Yes	Yes
Mun Charact	No	Yes	Yes	Yes	Yes
Installed Power	No	No	Yes	Yes	Yes
Excluded Municipalities	No	No	No	>20,000	>20,000
Excluded Neighbors	No	No	No	No	Yes

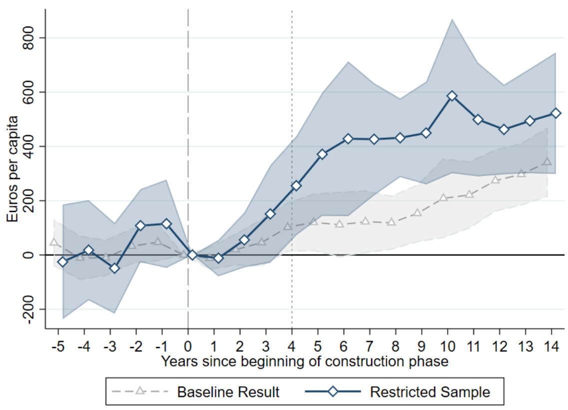
Notes: Results from estimating the difference-in-difference model described by Equation 1. The dependent variables are the logarithm of the urban tax rate (Panel a) and the logarithm of the rural tax rate (Panel b). Analysis restricted to municipalities part of the common-tax regime. Treated municipalities where a wind farm was installed before 2008 are excluded from the sample. Mean indicates the mean marginal tax rate 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 preliminary registration date. Standard errors are clustered at the municipality-cohort level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Figure A9: Dynamic Effect of Wind Farm Development on Municipal Finances (2008-2020)

(a) Non-financial revenue



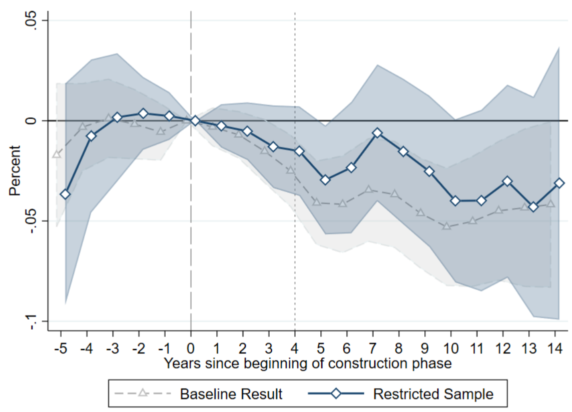
(b) Non-financial expenditure



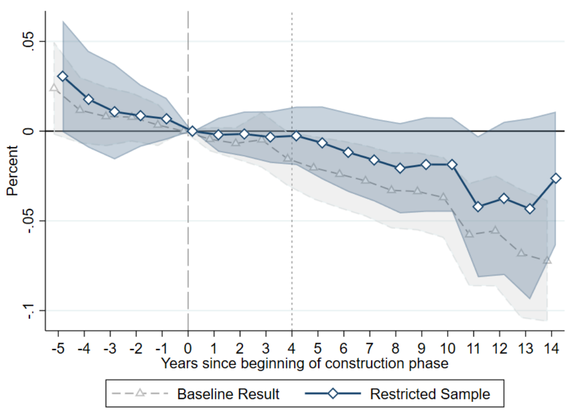
Notes: Results from estimating the event study model defined by Equation 2. The dependent variables are non-financial revenue (Panel a) and non-financial expenditure (Panel b). The magnitudes are expressed in euros per capita relative to the 1994 population. Coefficients represented by triangles in gray correspond to the baseline results estimated on the sample of municipalities of less than 20,000 inhabitants not neighboring affected units. Coefficients represented by rhombus in blue correspond to the sample restricted to municipalities belonging to the common tax regime that received the first wind farm 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. 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 preliminary register to the energy producers register (dotted line). Standard errors are clustered at the municipality-cohort level. Confidence intervals at the 95 percent level.

Figure A10: Dynamic Local Tax Responses to Wind Farm Development: Property Tax Rates (2008-2020)

(a) Urban property tax



(b) Rural property tax



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 triangles in gray correspond to the baseline results estimated on the sample of municipalities part of the common tax regime that received the first wind farm from 2004 onward. Coefficients represented by rhombus in blue correspond to the sample restricted to municipalities belonging to the common tax regime that received the first wind farm starting in 2008. The sample is restricted to municipalities of less than 20,000 inhabitants not neighboring affected units. Results correspond to the specification which includes municipality-cohort and year-cohort fixed effects, controls for municipal characteristics, and subsequent wind power installations. The reference year (represented by the dashed line) is the year before the construction phase starts. 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 at the 95 percent level.