IFN Working Paper No. 1511, 2024

The Socioeconomics of Wind Power Expansion: Evidence from Sweden

Erik Lundin and Jenny von Platten

Research Institute of Industrial Economics
P.O. Box 55665
SE-102 15 Stockholm, Sweden
info@ifn.se
www.ifn.se

The Socioeconomics of Wind Power Expansion: Evidence from Sweden *

Erik Lundin[†] Jenny von Platten [‡]

November 26, 2024

Click here to download the latest version

Abstract

We document the socioeconomics of wind power expansion in Sweden using two metrics. First, we compute the difference in socioeconomic status (SES) between residents exposed to wind power (0-2 km from the closest turbine) and those not exposed. For each site, the metric is computed ten years prior until five years after construction. When the comparison group is other residents within the same municipality, differences for all examined characteristics are either economically or statistically insignificant. However, compared to the national average, exposed residents have 14 percent lower earnings and approximately one year less of education. These differences remain approximately constant during the whole phase. Second, we exploit data on approved and rejected wind power applications to examine the association between the probability of approval and earnings and education of the exposed residents. We find a negative association between the probability of approval and both variables, although the association with education is more robust.

Keywords: Wind power; energy justice; energy inequality; energy transition; NIMBYism

JEL: P48; Q48; Q53; Q58; H23.

*This research was conducted within the framework of the IFN research program "Sustainable Energy Transition". The authors gratefully acknowledge financial support from the Swedish Energy Agency.

†Research Institute of Industrial Economics (IFN). Email: erik.lundin@ifn.se. Website: www.eriklundin.org.

‡The International Institute for Industrial Environmental Economics, Lund University. Email: jenny.von_platten@iiiee.lu.se. Website: https://www.ri.se/en/person/jenny-von-platten.

1 Introduction

Albeit a cornerstone of the energy transition, wind power is also associated with negative local externalities through visual and acoustic disturbances for local residents (Zerrahn, 2017). Concordantly, almost every published European study examining the effect of wind power on property values finds a statistically and economically significant negative effect up to about 2 km from the site (Parsons and Heintzelman, 2022). A growing body of literature also demonstrates that nearby wind turbines reduce residents' willingness to participate in the energy transition in general, for example by lowering the interest in clean energy tariffs and reducing voter support for "green" politicians (Germeshausen et al., 2023).

A theoretical framework for the socioeconomics of wind power expansion is provided by the concept of "energy justice" (Jenkins et al., 2016). It is rooted in three main perspectives: distributive justice, procedural justice, and recognition justice. The focus of the present study is distributive justice. It concerns the distribution of benefits and burdens in transitions, both in terms of financial gains and losses as well as of how other forms of advantages, risks, and externalities are shared (Williams and Doyon, 2019). The distribution of benefits and burdens can be analyzed both geographically and across socioeconomic groups. In the case of wind power expansion, distributive justice is usually determined by households' proximity to wind turbines (Mueller and Brooks, 2020).

Procedural justice is, unlike distributive justice, not concerned with the outcome of transitions, but rather with the process through which transition is achieved (McCauley et al., 2019). This relates to participation and decision-making and having a non-discriminatory inclusion of different stakeholders with varying perspectives on the matter (Walker, 2009). For wind power expansion, this often entails ensuring that locally affected communities participate in the decision-making process and receive sufficient information. In Sweden, such citizen participation is legally demanded, and municipalities have a veto that can always be exercised against new wind turbines. However, it has been suggested that participation often is symbolic and offers limited ability to influence the decision-making process (Larsen and Raitio, 2019; Lawrence and Larsen, 2017).

Finally, recognition justice builds on procedural justice but goes beyond the inclusion of stakeholders to explore who is or is not being recognized as a relevant stakeholder in a certain matter (McCauley et al., 2019). This relates to sustaining a generous process where different views and beliefs are welcome and where alternative futures and transition pathways are recognized and respected (Vasstrøm and Lysgård, 2021).

In this study, we document the distributive justice of wind power expansion in Sweden using two metrics: First, we compute the difference in socioeconomic status (SES) between residents exposed to wind power (0-2 km from the closest turbine) and those not exposed. The metric is computed for every major wind project that was constructed between 2010 and 2015, ten years prior until five years after construction. By following how differences in SES develop over time, we can examine if potential distributive injustices are gradually strengthened or mitigated. A gradual increase in SES differences could occur for two reasons. The most likely is through relocation, where high SES residents gradually move to unexposed areas and potentially also are replaced by low SES residents. The other is through a direct causal effect of wind power expansion on SES, which could happen if e.g. adverse health effects of wind power exposure lead to lower employment rates or education levels for existing residents. When the comparison group is other residents within the same municipality, differences for all examined variables are either economically or statistically insignificant. However, compared to the national average, exposed residents have 14 percent lower earnings and approximately one year less of education. Both differences are statistically significant. These differences remain approximately constant during the whole phase. These results indicate that although wind power expansion has negative distributive effects when evaluated at the national level, differences do not increase over time. Hence, even if there may be adverse health effects associated with wind power expansion, these are not so prominent that they pass through to standard SES indicators. Similar figures are found when examining the same metrics for wind power applications that were rejected, although differences compared to the national mean are somewhat less pronounced.

Second, we exploit data on approved and rejected wind power applications to examine the association between the probability of approval and SES of the exposed residents. We here focus on earnings and education levels. We document a negative association between the probability of approval and both variables, although the association with education level is more robust. This result could potentially also be informative about procedural justice if educated residents are more capable of influencing decision-makers to reject projects. However, since unobserved variables determining wind power suitability may also covary negatively with the SES of the residents, results cannot be interpreted causally, Results from this second metric align with previous research by Liljenfeldt and Pettersson (2017) using a very similar data set, although we test for a larger set of model specifications, including fixed effects by region and decision year.

While our results indicate that wind power disproportionately affects low SES municipalities, this does not mean that the current wind power locations are inefficient. It may very well be that the total value of the negative externalities would increase if turbines were relocated to high SES areas. Nevertheless, our results indicate that some type of financial compensation mechanism could be helpful in mitigating the negative distributional effects of wind power. See Lundin (2024) for a simulation of the costs of a variety of compensation schemes applied to every large-scale wind power project in Sweden.

Except for Liljenfeldt and Pettersson (2017), previous studies on distributional justice and wind power expansion in Sweden are relatively sparse and rely mainly on case studies or survey data. The conflicts around geographical distribution of wind power deployment are documented by Bjärstig et al. (2022). Although these conflicts tend to be complex, reoccurring grievances concern land use conflicts, the urban-rural divide, and violations of indigenous people's rights (Avila, 2018). The lion's share of research focuses on the wind power expansion in or close to Sápmi (Cambou, 2020). Here, a significant injustice lies in Sámi livelihoods being threatened by wind turbines that are of benefit for the majority of Sweden, but not for them (Ramasar et al., 2022). Studies on the general public's attitudes towards wind power are more prevalent, and the most recent study is Niskanen et al. (2024), confirming that local opposition stems from several factors. For example, the study demonstrates how local resistance groups during recent years have adopted a view that could be characterized as "not in anyone's back yard", expressing disbelief in wind power as a source of energy in general, regardless of its local impact.

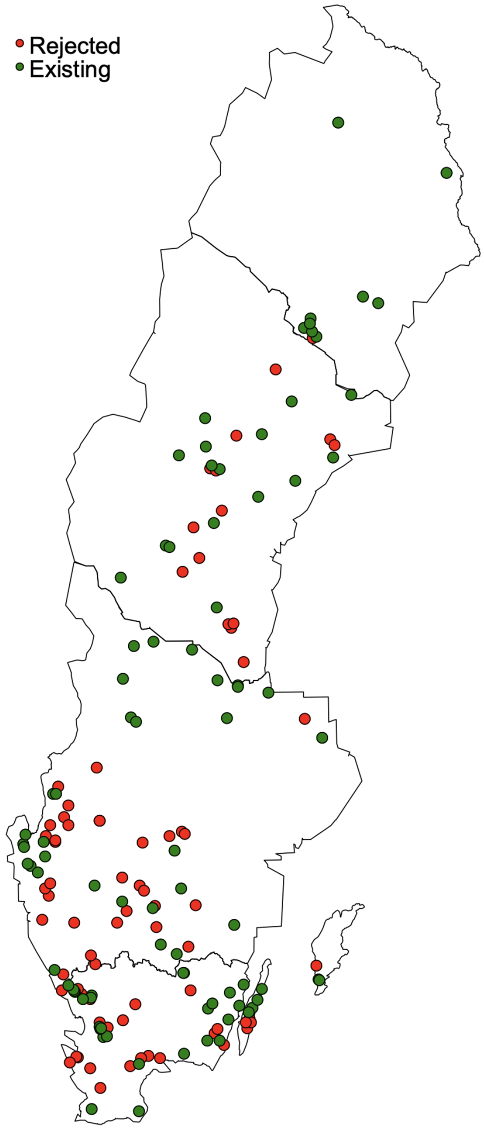
Internationally, studies of the distributional impacts of wind power expansion also largely rely on case studies or survey data. An exception is Mueller and Brooks (2020), finding that residents with lower education levels and labor market participation are disproportionately exposed to wind power expansion in the US. In a case study using examples from Denmark and Germany, (Mundaca et al., 2018) discuss both distributive, procedural, and recognition perspectives of wind power planning but do not examine geocoded socioeconomic data.

2 Wind power in Sweden

Before 2003, large-scale wind power plants were virtually non-existent in Sweden. A green electricity certificate system was then introduced in 2003, which, together with technological progress and cost reductions, spurred investors' interest in wind power. Green certificates were awarded for each MWh produced, and demand was created by a regulation demanding consumers to purchase certificates amounting to a certain share of their consumption. Although investors started submitting applications soon after the introduction of the certificates, due to the long lead times it was not until 2010 that the share of wind power reached 2 percent of total output. Since then, wind power has expanded steadily, and in 2023 the output share was 20 percent. Although the certificate system was important for creating initial investments, certificate prices have been declining steadily in tandem with lowered production costs. The system is currently being phased out, and from 2022 new plants were no longer awarded certificates.

Figure 1 depicts the locations of the projects that constitute the main sample of the analysis. All projects involve three or more turbines. A green dot indicates that the project was constructed at some point between 2010 - 2015. A red dot indicates that the project received its final rejection decision between 2008 - 2013. Since the mean time from the final approval decision until construction is about two years, the two groups should be comparable in terms of timing. In the second part of the analysis, when analyzing the probability of approval, all approval decisions between 2004 and 2015 are included. In 2011 the Swedish wholesale market was divided into four prize zones, running from north to south. Although we do not exploit the difference in prices between the zones, they provide a convenient partition of Sweden into four regions of roughly equal size, which we exploit in the regression analysis. In the map, price zone borders are displayed as black solid lines. For an analysis of how the introduction of these zones affected wind power investment behavior, see Lundin (2022).

Figure 1: Map of wind projects in sample



Note: Locations of existing (green) and rejected (red) wind power projects with three or more turbines. Existing (rejected) projects were constructed (got their rejection decisions) between 2010-2015 (2008-2013). Black solid lines are prize zone borders.

2.1 Application process

Applications for wind power are submitted to the county where the project is intended to be located. All applications have to pass an environmental assessment made by the county. Further, municipalities have the right to reject applications on arbitrary grounds without motivation, which is usually called the municipal "veto right". The rationale behind the veto right is to allow municipalities to maintain decision-making within their own borders while removing the bureaucratic burdens related to the approval process. The veto right was formally introduced in 2009. However, already before its introduction, municipalities also had to approve applications although they had to motivate their decisions on the basis of the project's environmental impact. Below, we describe the application process for a representative project in more detail.

1. Pre-investigation and public hearing. Before an application is submitted, the investor investigates the proposed site and contacts land owners to ensure access to the land. The process is usually comparatively thorough, spanning 1-4 years (Vattenfall, 2023). The investor then organizes at least one public hearing concerning the proposed project, which is obliged by law (chapter 6, the Swedish Environmental Code). The hearing is intended for nearby residents, politicians, and other stakeholders.

2. Application submission and original decision. A formal application is then submitted to the county administration, evaluating the environmental impact of the project regarding birds, wildlife, impact on nearby residents, potential conflicts with military interests, and other related issues. The evaluation is conducted by non-political officials (*Miljöprövningsdelegationen*). There are 21 county administrations across the country. The evaluation is independent, but the investor also needs to submit its own report on the presumed environmental impact of the project. The reports are comparatively extensive and usually comprise several hundred pages.

If the project spans several municipalities, each municipality needs to approve the turbines within its own border. The county administration then notifies the investor about its decision, with separate decisions for each turbine. Usually all turbines get the same decision, but due to e.g. differences in environmental impacts or in the exercise of the veto right across municipalities, decisions may differ.

3. Appeal and final decision. Original decisions may be appealed to the Land and Environmental Court (*Mark- och miljödomstolen*) by both the investor and other stakeholders. More than 40 % of all decisions are appealed. There are six courts locates across the country. Although less common, it is also possible to further appeal the decision to the national Land and Environmental Court of Appeal (*Mark- och miljööverdomstolen*).

3 Data

Registry data on SES are proprietary and provided by Statistics Sweden. All data are anonymized. Observations are by individual-year, between the years 2000-2021, for every individual 16 years and older. Except for SES, data also include residential locations, where Statistics Sweden divides Sweden into a 1x1 km grid and assigns every individual to the relevant square. Although Statistics Sweden also has information on the exact coordinates of each individual's residential building, these data are not revealed since individuals could then be identified. The variables used are the following, where all income metrics are assessed before tax:

- Earnings: yearly labor income
- Capital income: yearly capital income
- Sick pay: Share of yearly labor income from sick pay, i.e., $\frac{\text{Sick pay}}{\text{Sick pay}+\text{ordinary labor earnings}}$
- Employment status: indicator equal to unity if the individual was part- or full time employed on Nov. 1st in the relevant year.
- Education level: Ordinal measure 0-7, where 6 is a university degree and 7 is a PhD.
- Nr. of yearly relocations: Nr. of times that the individual has changed its residential address during the year
- Age: Age on Dec. 31 in the relevant year.

Data on wind turbines have been compiled using the publicly available database *Vindbrukskollen*, which is administered by the Energy Agency. It contains information on almost every application for wind power in Sweden since the early 2000:s. In the analysis, we use the following variables:

- Coordinates of each turbine in the project. In accordance with the LISA-data, every turbine is assigned to a square on the grid.
- Final approval decision (approve of reject)
- Year of the final approval decision
- Year of construction

Using data on turbine coordinates we can also categorize every individual according to the proximity to a wind project. If an individual is coded as exposed to a project, this means that the centroid of the individual's square is located 0-2 km away from the centroid of the square of the closest turbine.

4 Econometric analysis

4.1 Association between SES and proximity to wind turbines

Table 1 presents cross-sectional summary statistics at the year of construction, five years after construction, and ten years prior to construction, for the main outcome variables. Each variable is computed for three groups: Exposed residents, the remaining municipality, and the national average. The two latter variables are expressed as differences in relation to exposed residents. The first four variables are indexed to 100 for the national average. As a reference, Table A1 presents the corresponding figures for rejected projects.

To complement these figures, Figures 2 and 3 depict trends for each outcome variable for the existing projects, evaluated every year during the whole phase. Figures A1 and A2 display the corresponding trends for the rejected projects.

Table 1: Summary statistics, existing projects

	0-2km				Diff Muni	Diff National
	Mean	Sd	Min	Max		
Year of construction						
Earnings (Index)	86.45	28.73	0.00	248.68	2.55	-13.55***
Capital income (Index)	75.49	208.25	-196.54	1280.44	7.99	-24.51
Education level (Index)	88.52	10.32	51.47	113.45	-1.10	-11.48***
Share of income from sick pay (Index)	127.82	157.58	0.00	1170.89	6.82	27.82
Employed	0.60	0.13	0.00	1.00	0.05**	0.03
Age	50.95	5.38	35.17	70.40	0.35	3.39***
Nr. of relocations/year	0.08	0.06	0.00	0.29	-0.04***	-0.06***
Population within 2km from project	273.00	494.40	3.00	2584.00	0.00	0.00
Year of construction +5						
Earnings (Index)	85.91	22.37	21.03	141.09	2.91	-14.09***
Capital income (Index)	69.56	121.77	-34.18	717.29	8.73	-30.44*
Education level (Index)	88.01	10.16	44.97	107.37	-2.10	-11.99***
Share of income from sick pay (Index)	129.29	100.74	0.00	519.59	10.93	29.29*
Employed	0.62	0.11	0.28	0.89	0.06***	0.03**
Age	51.28	4.23	43.86	67.94	0.06	3.29***
Nr. of relocations/year	0.09	0.09	0.00	0.71	-0.04**	-0.06***
Population within 2km from project	282.33	514.69	2.00	2758.00	0.00	0.00
Year of construction -10						
Earnings (Index)	77.81	17.88	27.69	114.87	-5.65*	-22.19***
Capital income (Index)	76.72	427.87	-1084.57	1794.14	-0.15	-23.28
Education level (Index)	83.13	11.53	41.68	128.84	-4.91***	-16.87***
Share of income from sick pay (Index)	141.03	120.42	0.00	691.48	16.01	41.03**
Employed	0.19	0.27	0.00	0.70	-0.02	-0.03
Age	50.70	4.96	35.44	68.39	0.46	2.99***
Nr. of relocations/year	0.07	0.06	0.00	0.22	-0.04***	-0.07***
Population within 2km from project	257.32	466.63	1.00	2550.00	0.00	0.00
Observations	231				490	490

* $p < .10$, ** $p < 0.05$, *** $p < 0.01$

Note: Summary statistics for the main variables. The first four variables are indexed to 100 for the national mean. "Employed" is an indicator equal to unity for individuals who are employed. Only projects with three or more turbines are included. "Diff Muni" computes the difference between the mean of the exposed residents and the municipality mean (excluding the exposed group). "Diff National" computes the difference between the mean of the exposed residents and the national mean. A *t-test* is used to test for differences across groups.

Relation to the municipality mean

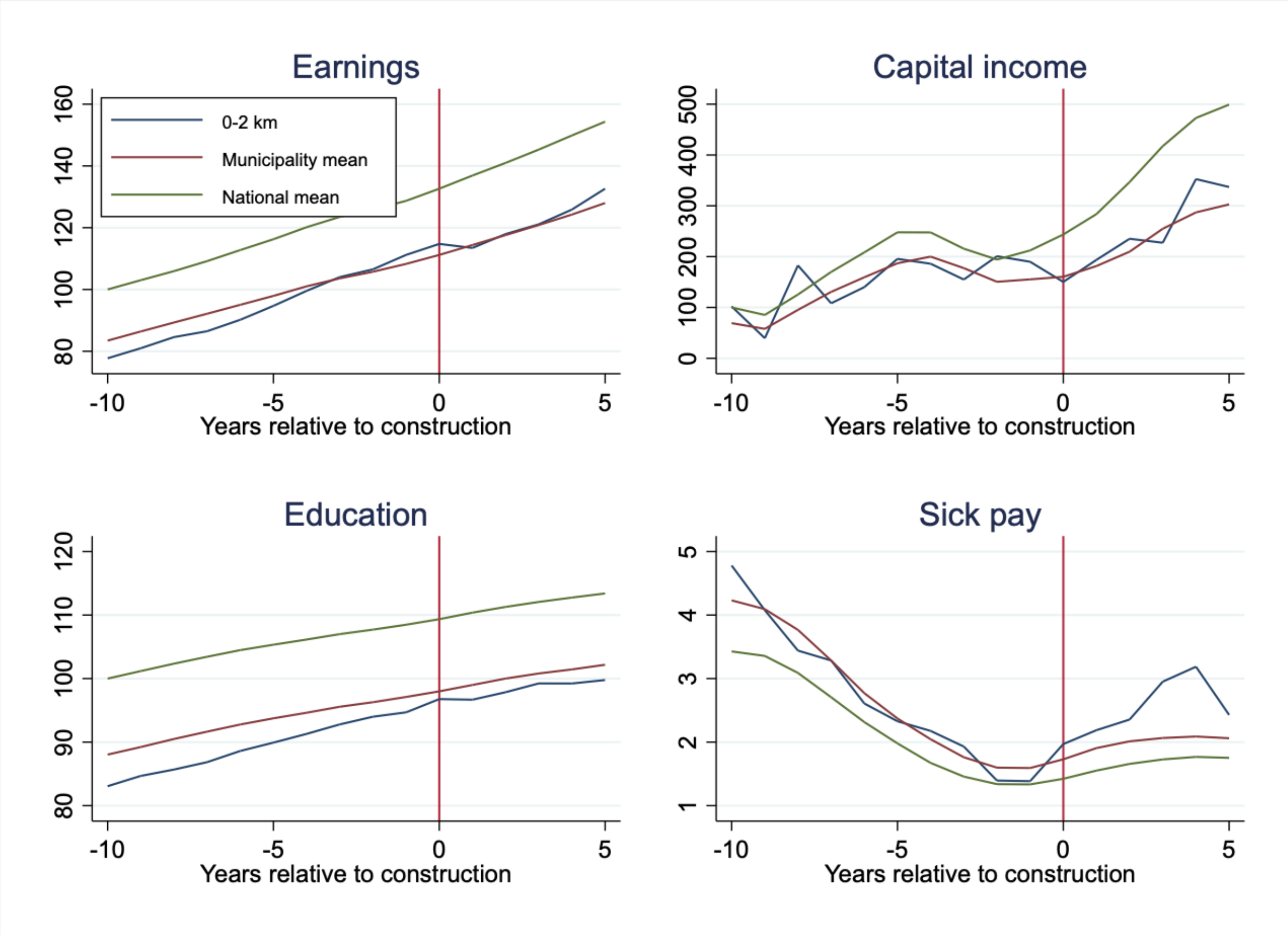
At the year of construction, only employment level and the nr. of relocations/year display any statistically significant difference in relation to the municipality mean. For the exposed group, the employment level is 0.6, compared to $0.6 - 0.05 = 0.55$. When the same variable is evaluated five years after construction, the difference remains at 0.06, which is only trivially different from 0.05. When instead evaluated ten years before construction, the difference is insignificant. When instead computing this metric using rejected projects in Table A1, we see a similar relation, with employment levels being slightly higher at the time of construction, as well as five years after. Hence, the slight relative increase in employment levels should not be interpreted as an indication that wind power creates job opportunities for the exposed residents.

The nr. of yearly relocations is 0.10 for the exposed group at the time of construction, compared to $0.10 + 0.02 = 0.12$ for the remaining municipality. The difference increases to 0.03 five years after construction, and when evaluated ten years prior to construction, it is 0.04. Since the difference is present also ten years before construction, the results give no indication of any causal effect on wind power on relocations. Similar results for the rejected projects are also seen in Table A1.

Five years after construction, there is no statistically significant difference in any of the remaining outcome variables, which is true also for the rejected projects. For the existing projects, earnings and education levels are slightly lower and statistically different for the exposed group when evaluated ten years prior to construction. The same holds for the rejected projects, although the difference in earnings is not statistically significant.

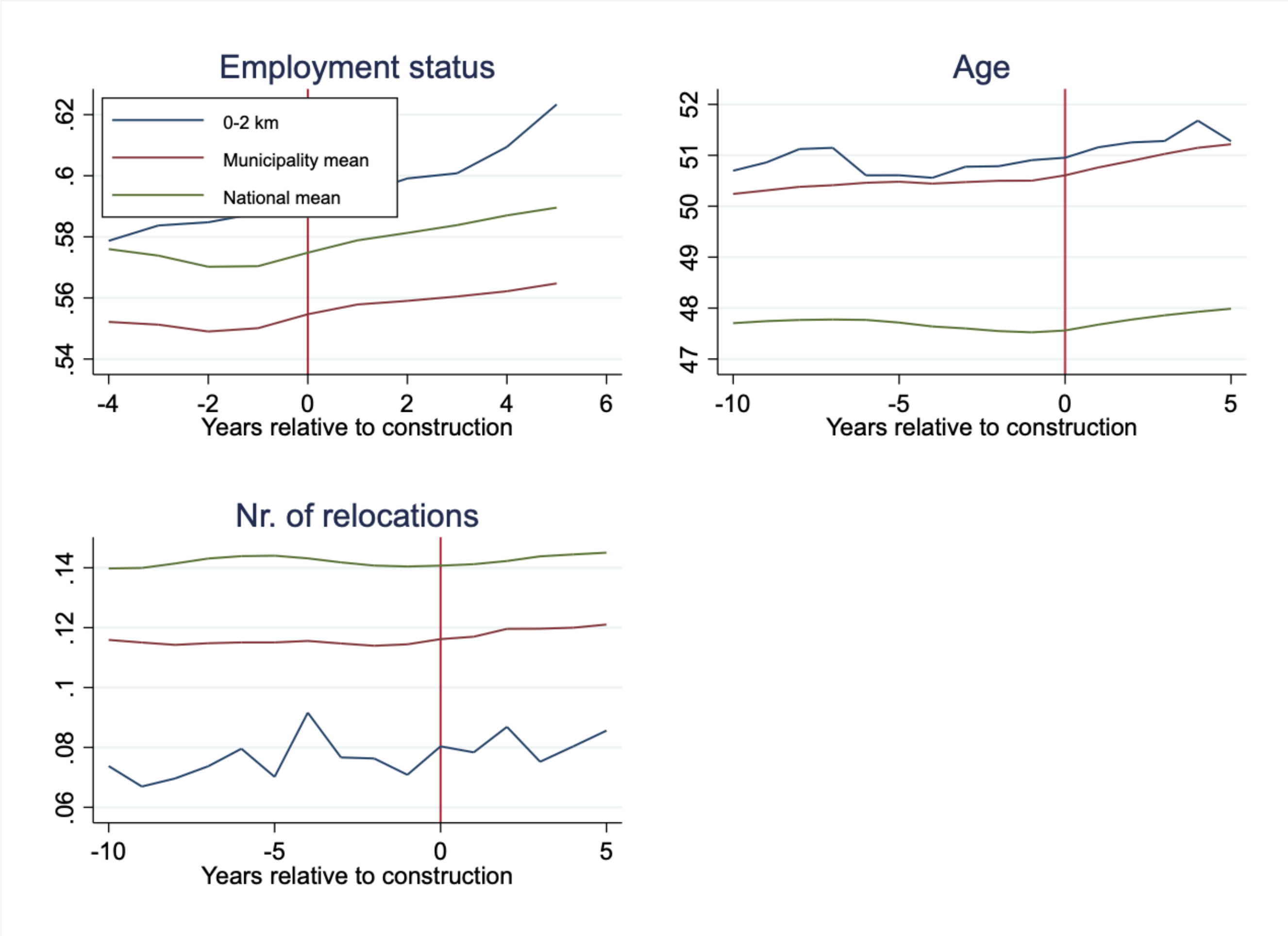
In sum, the differences between the exposed group and the remaining residents in the municipality are either economically or statistically insignificant. Where differences are present, we do not find any indications that wind power developments have had any causal effect on any of the outcomes.

Figure 2: Trends in outcome variables, existing projects



Note: Trends in SES indicators for residents exposed to existing projects, as well as the corresponding municipality and national means.

Figure 3: Trends in outcome variables, existing projects



Note: Trends in SES indicators for residents exposed to existing projects, as well as the corresponding municipality and national means.

Relation to the national mean

For most variables, differences are now more pronounced. In the year of construction, earnings are about 14 percent below the national average. Capital income is 24 percent lower, although the difference is statistically insignificant. This difference may be driven by differences in house prices between rural and urban areas. Also, education levels are about 11 percent lower, which translates to approximately one year of education. Differences in all variables remain approximately similar during the whole construction phase. Similar figures are seen for the rejected projects, although differences are somewhat less pronounced than for the constructed projects.

In sum, results indicate that both earnings and education levels for those exposed to wind power are lower than the national average. Other differences are either economically or statistically insignificant (or both).

4.2 Association between approval and SES indicators

Econometric model

Using a very similar data set to ours, Liljenfeldt and Pettersson (2017) find a negative association between the probability of approval and both earnings and education. Using an estimation strategy similar to theirs, we employ a logistic regression analysis to estimate the following model:

$$Y_{pt} = \alpha + \beta_1 earnings_{pt} + \beta_2 education_{pt} + \beta_3 age_{pt} + \beta_4 pop_{pt} + \beta_5 turbines_{pt} + \lambda_t + \omega_z + \varepsilon_{pt} \tag{1}$$

Where:

- Y_{pt} is an indicator variable where approval of application p in year t is coded as unity. The reference year is the year of the final decision of the application. If a project has been approved, it is only included in the sample if it also has been constructed at some point. Since every turbine receives an individual decision, we code an application as approved if more than half of all turbines in the application are approved. In this analysis, we use all applications that received their final decision between 2004 and 2015.

- $Earnings_{pt}$ is mean yearly earnings for residents living 0-2 km from the project in year t, and $Education_{pt}$ is the corresponding mean education level. Both variables are standardized.

- Further, pop_{pt} is the number of exposed residents, age_{pt} is the mean age of the exposed residents, and $turbines_{pt}$ is the number of turbines in the project application. All three variables are log-transformed.

- Last, λ_t and ω_z are year- and price zone fixed effects (for ease of exposition, no coefficient vectors are included). There are four prize zones, that are comparable in terms of area, although zone four (the most southern zone) is somewhat smaller than the remaining areas (see Figure 1). By including price zone fixed effects, all identifying source of variation comes from within each price zone. Thereby, any unobserved factors that are common within each price are controlled for. Last, ε_{pt} is the error term that we assume is clustered within municipality.

Since the outcome variable is binary, we employ a logit estimator for our main specification. As a robustness test, we also estimate the model using OLS.

Results

The logit results are presented in Table 2. Since education and earnings are highly positively correlated, which may cause problems with multicollinearity, we begin by estimating the model by including each variable separately. Instead of logit coefficients, we display the marginal effects evaluated at the sample mean of all variables.

In specifications (1)-(3), only earnings are included. In the first specification, no time fixed effects are included, and only population and age are included as controls. The coefficient associated with earnings is here -0.15 and precisely estimated. The interpretation is that a one standard deviation increase in earnings is associated with a 15 percentage point reduction in the probability of approval. As a reference, the mean approval rate across the whole sample is 0.65. In specification (2) we also include yearly fixed effects, which is important since the approval rate declined during the sample period. The coefficient then drops to -0.061 and is less precisely estimated. In our preferred specification (3), we also include the number of turbines as a control variable and include price zone fixed effects. The coefficient then drops to -0.046 and turns insignificant. Turning to the control variables, the coefficient associated with population is negative in all specifications, and statistically significant in the first two specifications. A negative sign is expected since it should be more difficult to get approved when more residents are exposed. The coefficient on age is also negative and statistically significant in specifications (1) and (3). Since there is no direct reason why the age of the exposed residents would have a direct negative effect on the probability of approval, it is likely that this variable is also correlated with some unobserved confounders. Last, the coefficient associated with the number of turbines is positive and precisely estimated. This is likely also a result of unobserved confounders since more turbines are associated with greater disturbance, *ceteris paribus*. For example, it may be that larger projects are in general better planned than smaller projects, since larger project are associated with higher financial risks for the investors.

In specifications (3)-(6) we instead include education as the main explanatory variable. By contrast to the coefficient on earnings, both the magnitude and precision of the coefficient remain precisely estimated throughout all specifications. In the preferred specification (3), the coefficient is -0.096. The interpretation is that one standard deviation increase in the education level (corresponding to approximately one year of education) is associated with a 9.6 percentage point reduction in the probability of approval. In terms of the coefficients on the control variables, these are only trivially different from those in specifications (1)-(3).

In specifications (7)-(8) we include both earnings and education in the same regressions. The preferred specification is (8), which also includes price zone fixed effects. The magnitude and precision for the coefficients on both earnings and education are now very similar to those in specifications (3) and (6), confirming that the association is driven by the level of education and not earnings.

In sum, results indicate that the probability of approval is negatively associated with both earnings and education level. However, the association with education level is more robust than for earnings. Even if we interpret these results mainly in terms of distributional justice, we cannot rule out that the association is in fact causal. In that case, results should also be interpreted in terms of procedural justice, in that highly educated residents are more able to influence decision-makers to reject applications in their neighborhoods.

As a robustness test, Table A2 presents results from the same specifications estimated using OLS. The magnitude of the coefficients are largely in line with the logit specification, albeit somewhat smaller. Further, coefficients are somewhat less precisely estimated than in the logit specification, confirming that the logit specification is likely more appropriate.

Table 2: Logit estimation with approval as the dependent variable.

	Include earnigns			Include education			Include both	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Earnings (0-2km)	-0.15***	-0.061*	-0.046				-0.000086	0.0095
	(0.032)	(0.035)	(0.031)				(0.041)	(0.040)
Education (0-2km)				-0.13***	-0.094**	-0.096**	-0.086*	-0.10**
				(0.039)	(0.043)	(0.043)	(0.051)	(0.051)
Age of residents	-1.57***	-0.77	-0.85**	-1.32**	-0.86	-1.06**	-1.16**	-1.02**
	(0.48)	(0.50)	(0.40)	(0.55)	(0.57)	(0.45)	(0.48)	(0.41)
Population	-0.057**	-0.050*	-0.010	-0.055**	-0.054*	-0.019	-0.039	-0.019
	(0.025)	(0.027)	(0.025)	(0.026)	(0.029)	(0.026)	(0.026)	(0.026)
Turbines in project			0.18***			0.19***	0.21***	0.19***
			(0.053)			(0.056)	(0.057)	(0.057)
Time FE	No	Yes	Yes	No	Yes	Yes	Yes	Yes
Price zone FE	No	No	Yes	No	No	Yes	No	Yes
N	211	202	202	211	202	202	202	202

* $p < .10$, ** $p < 0.05$, *** $p < 0.01$
Note: Results from the logit specification in Eq. (1). Coefficients have been transformed to marginal effects evaluated at the sample mean of all control variables. Earnings and education are standardized. Population, age, and the nr. of turbines are log transformed. Standard errors (in parentheses) are clustered by municipality.

5 Conclusion

We document the socioeconomics of wind power expansion in Sweden using two metrics. First, we demonstrate that individuals exposed to wind power earn about 14 percent less and have roughly one year less of education compared to the national average. However, compared to the municipality average, differences are either economically or statistically insignificant (or both). By computing SES metrics ten years prior up to five years after construction, we conclude that the differences are comparatively constant over time, providing no evidence of a causal effect of wind power on SES. Similar results are found when computing the same metrics for wind power applications that were rejected. Since no intra-municipal differences in SES are detected, the findings suggest that the differences in SES appear on a larger geographical scale, highlighting how rural municipalities are disproportionately affected by wind power compared to urban municipalities. The finding that groups with lower SES are disproportionately exposed to wind power projects invites further analyses of the externalities, risks and negative effects of wind turbine proximity.

Second, we exploit data on approved and rejected wind power applications to examine the association between the probability of approval and the SES of the exposed residents. Although we cannot interpret the association causally due to potential unobserved heterogeneity, we find a negative association between the probability of approval and both earnings and education levels. The association with education is more robust, indicating that one additional year of education is associated with about 9-10 percent lower probability of approval (from a mean approval rate of 65 percent). Future studies could develop empirical strategies to disentangle the causal effect of education on the possibility of influencing decision-makers to reject wind power, which would shed light on potential procedural injustices related to wind power locationing.

References

Avila, Sofia, "Environmental justice and the expanding geography of wind power conflicts," *Sustainability Science*, 2018, *13* (3), 599–616.

Bjärstig, Therese, Irina Mancheva, Anna Zachrisson, Wiebke Neumann, and Johan Svensson, "Is large-scale wind power a problem, solution, or victim? A frame analysis of the debate in Swedish media," *Energy Research & Social Science*, 2022, *83*, 102337.

Cambou, Dorothée, "Uncovering injustices in the Green Transition," *Arctic Review on Law and Politics*, 2020, *11*, 310–333.

Germeshausen, Robert, Sven Heim, and Ulrich J. Wagner, "Support for renewable energy: The case of wind power," Technical Report 2023.

Jenkins, Kirsten, Darren McCauley, Raphael Heffron, Hannes Stephan, and Robert Rehner, "Energy justice: A conceptual review," *Energy Research & Social Science*, 2016, *11*, 174–182.

Larsen, Rasmus Kløcker and Kaisa Raitio, "Implementing the state duty to consult in land and resource decisions," *Arctic Review on Law and Politics*, 2019, *10*, 4–23.

Lawrence, Rebecca and Rasmus Kløcker Larsen, "The politics of planning: assessing the impacts of mining on Sami lands," *Third World Quarterly*, 2017, *38* (5), 1164–1180.

Liljenfeldt, Johanna and Örjan Pettersson, "Distributional justice in Swedish wind power development – An odds ratio analysis of windmill localization and local residents' socio-economic characteristics," *Energy Policy*, 2017, *105*, 648–657.

Lundin, Erik, "Geographic price granularity and investments in wind power: Evidence from a Swedish electricity market splitting reform," *Energy Economics*, 2022, *113*, 106208.

_ , "Wind power and the cost of local compensation schemes: A Swedish revenue sharing policy simulation," *Energy Economics*, 2024, *135*, 107632.

McCauley, Darren, Vasna Ramasar, Raphael J Heffron, Benjamin K Sovacool, Desta Mebratu, and Luis Mundaca, "Energy justice in the transition to low carbon energy systems: Exploring key themes in interdisciplinary research," 2019.

Mueller, J Tom and Matthew M Brooks, "Burdened by renewable energy? A multi-scalar analysis of distributional justice and wind energy in the United States," *Energy Research & Social Science*, 2020, *63*, 101406.

Mundaca, Luis, Henner Busch, and Sophie Schwer, "'Successful'low-carbon energy transitions at the community level? An energy justice perspective," *Applied Energy*, 2018, *218*, 292–303.

Niskanen, Johan, Jonas Anshelm, and Simon Haikola, "A multi-level discourse analysis of Swedish wind power resistance, 2009–2022," *Political Geography*, 2024, *108*, 103017.

Parsons, George and Martin D. Heintzelman, "The Effect of Wind Power Projects on Property Values: A Decade (2011–2021) of Hedonic Price Analysis," *International Review of Environmental and Resource Economics*, 2022, *16* (1), 93–170.

Ramasar, Vasna, Henner Busch, Eric Brandstedt, and Krisjanis Rudus, "When energy justice is contested: A systematic review of a decade of research on Sweden's conflicted energy landscape," *Energy Research & Social Science*, 2022, *94*, 102862.

Vasstrøm, Mikaela and Hans Kjetil Lysgård, "What shapes Norwegian wind power policy? Analysing the constructing forces of policymaking and emerging questions of energy justice," *Energy Research & Social Science*, 2021, *77*, 102089.

Vattenfall, "Hur fungerar tillståndsprocessen för en vindkraftpark på land?," , website 2023. https://group.vattenfall.com/se/var-verksamhet/vindprojekt/faq-vindkraft/hur-fungerar-tillstandsprocessen-for-en-vindkraftpark-pa-land.

Walker, Gordon, "Beyond distribution and proximity: exploring the multiple spatialities of environmental justice," *Antipode*, 2009, *41* (4), 614–636.

Williams, Stephen and Andréanne Doyon, "Justice in energy transitions," *Environmental Innovation and Societal Transitions*, 2019, *31*, 144–153.

Zerrahn, Alexander, "Wind Power and Externalities," *Ecological Economics*, 2017, *141*, 245–260.

Appendix A: Additional Tables and Figures

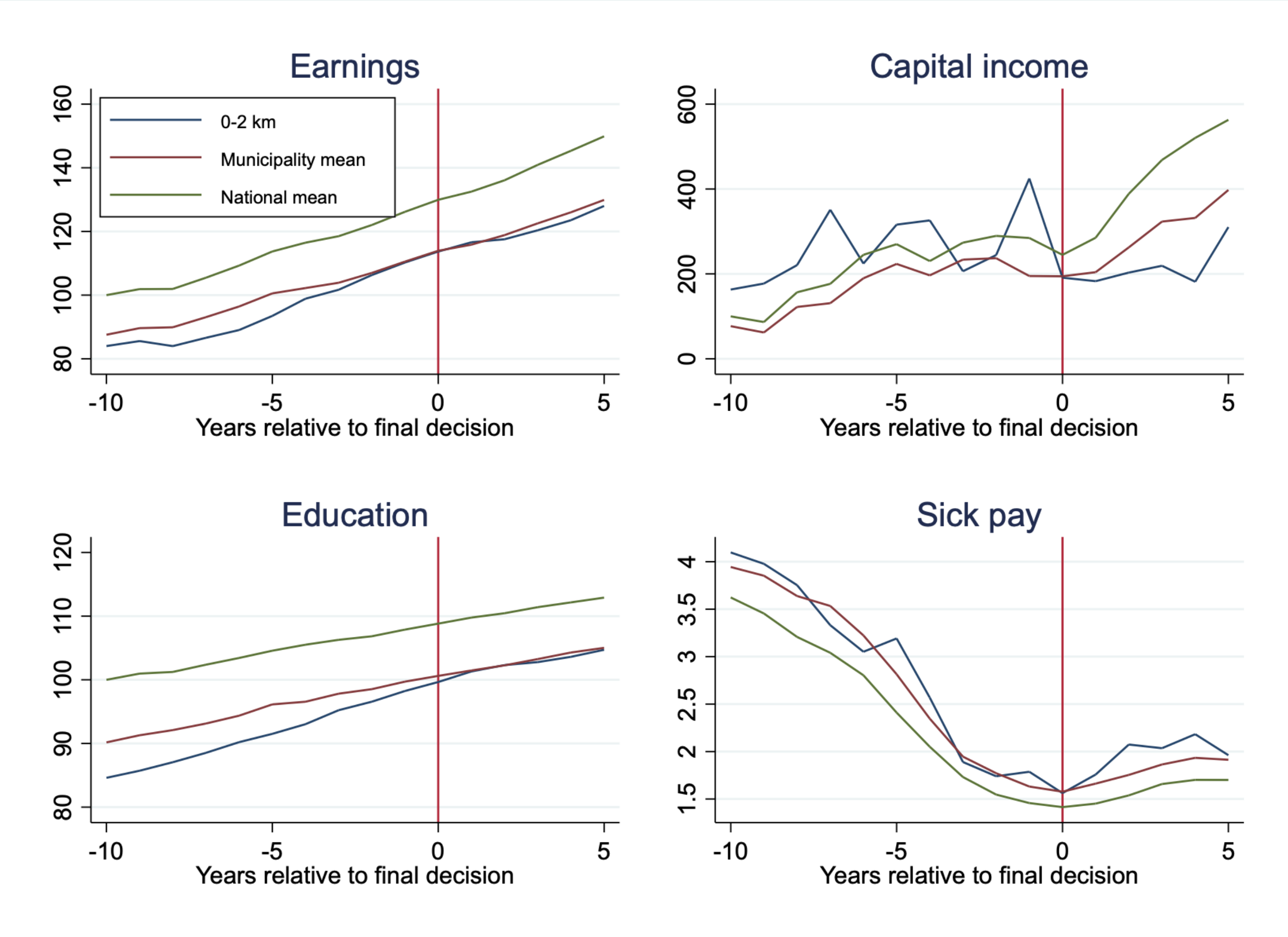
Table A1: Summary statistics, rejected projects

	0-2km				Diff Muni	Diff National
	Mean	Sd	Min	Max		
Year of construction						
Earnings (Index)	87.60	18.32	53.89	158.55	-0.10	-12.40***
Capital income (Index)	81.60	154.98	-451.18	448.47	1.46	-18.40
Education level (Index)	91.64	10.33	72.91	134.39	-0.84	-8.36***
Share of income from sick pay (Index)	115.00	67.95	0.00	336.76	3.55	15.00
Employed	0.59	0.06	0.44	0.71	0.03**	0.02*
Age	50.99	3.29	44.55	58.24	0.86	3.42***
Nr. of relocations/year	0.10	0.05	0.00	0.20	-0.02**	-0.05***
Population within 2km from project	500.31	1658.11	4.00	11201.00	0.00	0.00
Year of construction +5						
Earnings (Index)	85.89	19.61	50.86	167.09	-0.83	-14.11***
Capital income (Index)	57.47	96.76	-290.16	402.02	-10.94	-42.53**
Education level (Index)	92.83	8.24	80.99	121.57	-0.21	-7.17***
Share of income from sick pay (Index)	119.88	72.68	0.00	396.86	7.04	19.88
Employed	0.61	0.07	0.43	0.77	0.04***	0.02
Age	51.70	3.70	43.65	62.95	0.95	3.80***
Nr. of relocations/year	0.09	0.04	0.00	0.17	-0.03***	-0.06***
Population within 2km from project	561.14	1843.92	7.00	12214.00	0.00	0.00
Year of construction -10						
Earnings (Index)	83.81	15.79	60.80	125.98	-3.73	-16.19***
Capital income (Index)	267.86	531.61	-517.01	2401.08	180.68	167.86
Education level (Index)	84.62	7.06	69.54	98.95	-5.56***	-15.38***
Share of income from sick pay (Index)	115.68	59.64	0.00	269.64	6.42	15.68
Employed	0.17	0.28	0.00	0.68	0.01	0.01
Age	50.82	3.04	46.57	57.67	1.33*	3.13***
Nr. of relocations/year	0.08	0.04	0.00	0.18	-0.04***	-0.06***
Population within 2km from project	513.55	1437.82	6.00	8327.00	0.00	0.00
Observations	121				244	244

* $p < .10$, ** $p < 0.05$, *** $p < 0.01$

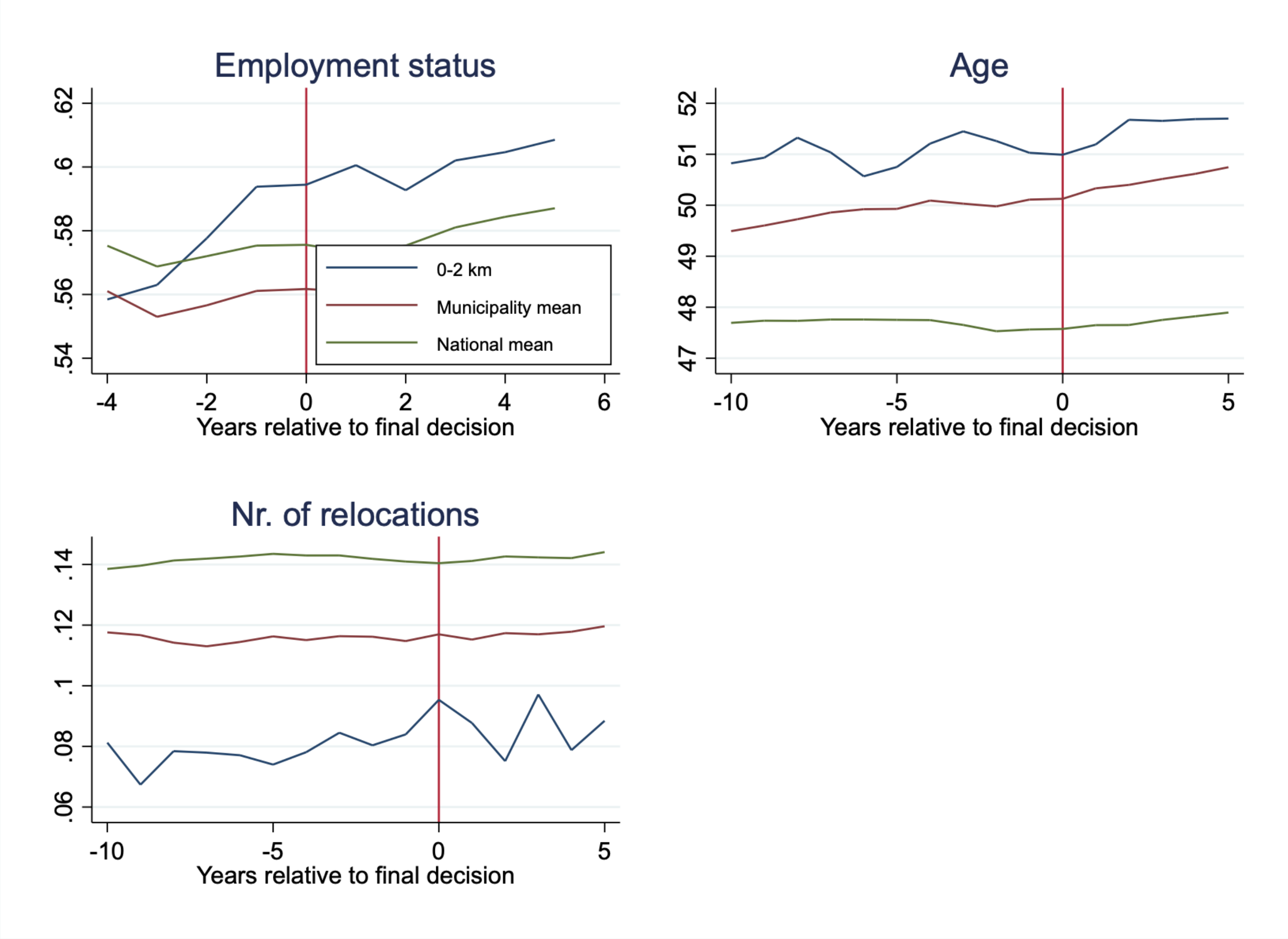
Note: Summary statistics for the main variables. The first four variables are indexed to 100 for the national mean. "Employed" is an indicator equal to unity for individuals who are employed. Only projects with three or more turbines are included. "Diff Muni" computes the difference between the mean of the exposed residents and the municipality mean (excluding the exposed group). "Diff National" computes the difference between the mean of the exposed residents and the national mean. A *t-test* is used to test for differences across groups.

Figure A1: Trends in outcome variables, rejected projects



Note: Trends in SES indicators for residents exposed to rejected applications, as well as the corresponding municipality and national means.

Figure A2: Trends in outcome variables, rejected projects



Note: Trends in SES indicators for residents exposed to rejected applications, as well as the corresponding municipality and national means.

Table A2: OLS estimation with approval as the dependent variable.

	Include earnigns			Include education			Include both	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Earnings (0-2km)	-0.14***	-0.055	-0.039				-0.0076	-0.0076
	(0.031)	(0.035)	(0.031)				(0.041)	(0.041)
Education (0-2km)				-0.12***	-0.077*	-0.065*	-0.062	-0.062
				(0.037)	(0.040)	(0.037)	(0.045)	(0.045)
Age of residents	-1.40***	-0.60	-0.78**	-1.08**	-0.60	-0.81*	-0.84**	-0.84**
	(0.39)	(0.42)	(0.39)	(0.43)	(0.47)	(0.43)	(0.41)	(0.41)
Population	-0.049**	-0.043*	-0.027	-0.046*	-0.041	-0.026	-0.026	-0.026
	(0.023)	(0.025)	(0.024)	(0.024)	(0.025)	(0.025)	(0.025)	(0.025)
Turbines in project			0.17***			0.16***	0.16***	0.16***
			(0.043)			(0.043)	(0.043)	(0.043)
Time FE	No	Yes	Yes	No	Yes	Yes	Yes	Yes
Price zone FE	No	No	No	No	No	No	No	No
N	211	211	211	211	211	211	211	211

* $p < .10$, ** $p < 0.05$, *** $p < 0.01$

Note: Results from the OLS specification in Eq. (1). Earnings and education are standardized. Population, age, and the nr. of turbines are log transformed. Standard errors (in parentheses) are clustered by municipality.