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Wind Power and the Cost of Local Compensation Schemes: A Swedish Revenue Sharing Policy Simulation

Erik Lundin

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

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Erik Lundin [†]

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Abstract

Local resistance towards wind power is a central challenge for the energy transition, implying that legally imposed compensation schemes for nearby residents may become more prevalent in the near future. In this study, I use GIS-coded data on detached residential buildings in Sweden to simulate a variety of revenue sharing schemes applied to every present and planned commercial scale wind power project, with a focus on documenting the impact on investor costs. I compare models that entitle compensation for distance between six and ten times the tip height of the closest turbine, imposing schemes that are both constant within the eligible distance, as well as declining with distance from the turbine. An important conclusion is that costs vary considerably depending on the model chosen. When compensations are awarded for residents as far away as ten times the turbine height, foregone revenues exceed two percent for a large share of the projects, potentially necessitating the inclusion of a regulated cap on compensation costs.

Keywords: Wind power; negative externalities; local acceptance; energy transition; NIMBYism

JEL: H23; D62; D4; P18; P48

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

1 Introduction

Albeit a cornerstone of the energy transition, wind power is also associated with negative local externalities in the form of visual and acoustic disturbances for local residents and worsened conditions for wildlife (Zerrahn, 2017). Concordantly, almost every published European study examining the effect of wind power on property values find a statistically and economically significant negative effect (Parsons and Heintzelman, 2022). A growing literature also demonstrates that the presence of nearby wind turbines reduces 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 socially sustainable wind power expansion could therefore be facilitated by financial compensation mechanisms for nearby residents, thereby mitigating local opposition due to Not In My Back Yard (NIMBY)-ism. Such mechanisms rarely arise through voluntary negotiations between developers and nearby residents, for several reasons. First, approval decisions are in most countries the responsibility of the local or county government and not the residents themselves. Thus, "negotiations" between residents and developers necessitate engagement with local planning authorities who typically lack the mandate to both design and introduce such mechanisms. Second, even under the assumption that nearby residents were responsible for approval decisions, negotiations would have to involve a large number of residents with limited means of coordination and information about the expected future impact of the project, leading to substantial transaction costs. Therefore, the prerequisites for achieving socially efficient bargaining outcomes are not met (Coase, 1960), suggesting that a legally imposed compensation scheme could serve to internalize these negative externalities. Consistent with this argument, a recent study on wind power applications in the UK finds that inefficiencies in the approval process (i.e., approving projects that should have been rejected and vice versa) have most likely resulted in a substantial misallocation of investments due to a lack of internalization of negative externalities (Jarvis, 2022). Irrespective of the static welfare effects in terms of direct investment misallocation, local acceptance is also a prerequisite for a distributionally equitable and socially sustainable wind power expansion with broad public support. It should also be noted that the revenue sharing mechanisms reviewed in the present study consider exclusively *distributional* justice. A growing literature shows that also *procedural* justice (i.e, the institutional framework around which decisions on wind power locationing are made) is crucial for local acceptance. The policies presented in the present paper should therefore be regarded as complements rather than substitutes to policies aimed at increasing procedural justice.

A steadily growing literature examines the drivers of local acceptance of wind power: Bessette and Crawford (2022) reviews more than 100 articles in the US and Canada; and Segreto et al. (2020) provides a review of around 40 articles from a European perspective. A common lesson is that financial incentives matter for local acceptance, whether it is in the form of e.g. revenue sharing or lower electricity tariffs for nearby residents. Several studies find that free electricity for the most affected households could serve as a guideline for the level of compensation that would be sufficient to achieve local acceptance. Financial participation is also noted as a key driver of local acceptance by a policy project conducted under the EU Horizon 2020 research and innovation program (WindWind, 2020), suggesting for example the removal of legal barriers for electricity sharing and other financial arrangements. It is also worth emphasizing that the financial incentive schemes proposed are not substitutes for independent rigorous legal environmental assessments on the impacts on nearby residents, birds, and wildlife, but are rather aimed at increasing local acceptance for projects that fulfill basic legal environmental requirements.

While previous studies provide rigorous evaluations of the effectiveness of financial compensation schemes from the viewpoint of the residents, less is known about the effect on investors' revenues given that such compensation schemes would be implemented on a wider scale. The aim of the present study is to fill this gap by performing a diagnostic assessment of the impact on investor revenues following two hypothetical "generic" compensation schemes imposed on the stock of current and planned wind power projects in Sweden. Common to both models is that nearby residents are entitled a share of the revenue generated by nearby turbines. None of the models incorporate topographic characteristics determining turbine visibility, although previous studies demonstrate that these are crucial determinants for quantifying disamenities and effects on property values (Jarvis, 2022). Such models would demand much more extensive data collection, severely limiting model tractability and transparency.

Naturally, an international generalization of the results is not straight forward since the density of buildings around wind turbines is likely lower in Sweden than in most other European countries. This holds especially for northern Sweden, where projects are usually located in sparsely populated areas. In the southern part, settlement density is more similar to that in the rest of Europe. However, the main take-away of the simulation is to highlight how results vary with the type of compensation scheme employed, rather than to provide an exact international generalization of absolute levels.

In the first, “constant”, model, every house within a distance of a given factor X of the tip height H of a turbine (“XH”) is entitled to the spot market value of a predefined share of turbine output, and the payout remains unchanged for all distances until the threshold is reached. Investor costs are simulated for distances between 6H-10H. 6H is a natural lower bound since very few turbines are allowed at closer distances. In the case of a typical turbine with a height of 180 meters, this suggests a distance of approximately 1 kilometer. 10H is a natural upper bound since most research on wind power and property values indicate a statistically significant negative effect up to 2 km (i.e. somewhat above 10H given a tip height of 180 m), while the effect for longer distances is limited and diminishes quickly (Parsons and Heintzelman, 2022). 10H is also the reference point for several recent laws and policy proposals in e.g. Sweden; Bavaria; and Poland (Swedish Government, 2023; Bayern Innovative, 2022; International Trade Administration, 2023). In the Swedish case, 10H marks the cutoff for a scheme proposed to compensate nearby residents. In Bavaria and Poland, previous legislation have imposed 10H-minimum distances below which no turbines have been allowed, although these rules have recently been relaxed in the wake of the recent energy crisis.

In the second, “linear”, model, payout structures mirror those of the constant model for distances up to 6H, and then declines linearly down to zero at a certain distance, reflecting the fact that disamenities subside with distance. Also in the linear model, I simulate thresholds ranging between 6H-10H. Additionally, compensations could have varied also within distances 0H-6H, but given that a turbine passes environmental legislation at these distances, topographic characteristics usually limit the visual impact considerably, limiting the value of differentiating the compensation further.

In both models, each household is entitled to compensation for the two turbines that generate the highest individual compensation. The choice to limit compensation to two turbines relies on the assumption that the marginal disamenities from additional turbines likely diminish rapidly, and that a more accurate mechanism would lead to a lower degree of tractability and transparency.

Only detached houses are included in the model simulation. Potentially, also multi-family homes and commercial buildings could be regarded as eligible for some type of compensation. However, more than 95 percent of all buildings within 10H are classified as detached houses. Therefore, other buildings are excluded for the sake of tractability and transparency.

In principle, the constant model resembles the Danish compensation scheme *VE-bonusordningen*, which gives residents within 8H of a turbine the right to the spot market value corresponding to the electricity produced by 6.5 kW of the installed capacity of a nearby wind farm (Energistyrelsen, 2023), conditional on that the total project cost does not exceed 1.5 percent of total capacity. If this cap is reached, the compensation for nearby residents is scaled down accordingly. To the best of my knowledge, no current official standardized compensation mechanism resembles the linearly declining structure presented in the present study.

I present simulation results in two steps. First, I demonstrate how the relative investor cost varies with each model, in terms of the total share of project output that is lost due to the revenue sharing mechanism. To achieve this, I begin by applying the constant 6H-model to all wind power projects in the sample and normalize total investor costs for each wind power project to unity. I then apply each of the remaining sub-models, expressing the total cost of these models as a factor of the cost of the 6H-model. I then compare the distribution of these figures, finding that the constant 10H-model increases total costs approximately fivefold relative to the 6H-model, compared to about threefold for the linear 10H-model, although results vary somewhat depending on region. Further, I find that costs under the linear 10H- and constant 8H-models are approximately equal.

Second, I compute the absolute cost of each model (also expressed as a share of total project output), by imposing a base-level of compensation for eligible households. It is not evident how to determine a sufficient level of compensation that is likely to compensate for the disamenities and thereby increase local acceptance. I here borrow from previous studies finding that free electricity for the most affected households would suffice to achieve local acceptance, and parameterize the model accordingly. Although it is beyond the scope of this study to speculate around the deeper psychological mechanisms behind this preference, it’s worth noting that this type of compensation underscores the value creation from wind power in the form of electricity, as opposed to directly counterbalancing the disamenities and their subsequent effects on property values. Although I adjust the revenue sharing parameter specifically to match the retail cost of electricity for a representative detached house in Sweden (including taxes), the basic principle should also be applicable also for other countries. Under the 6H-model, results show that two percent of revenues are sufficient to finance the scheme for the vast majority of all projects. However, under the constant 8H and linear 10H-models, costs exceed two percent for about one third of all projects in the southern region, suggesting that policymakers may want to introduce some type of cost cap if the scheme should not jeopardize wind power profitability.

Last, it should also be emphasized that investors usually spend substantial time and effort on bargaining with local policy makers, residents, and other stakeholders. Given that a compensation scheme would reduce the costs associated with this negotiation, and in addition increase the probability of approval, a compensation scheme could also lead to increased investor profits, although a quantification of such an effect is beyond the scope of this study.

2 Institutional background and data

2.1 Wind power in Sweden

Before the turn of the century, large scale wind power plants were virtually non-existent in Sweden. A green electricity certificates system was introduced in 2003, after which wind power investments grew rapidly with a sharp increase from 2007 and onward. Wind power is still expanding steadily, with the rate of increase being approximately constant during the last decade.

Applications for wind power have to be approved by the local government, which means that the possibilities of approval depend on the policy preferences of the local government. Except for local approval, the project is also subject to an environmental evaluation conducted by non-political officials to ensure that impacts on nearby residents, birds, wildlife, and nature are in line with the legal environmental requirements. For a more detailed account of the application process, see Appendix B.

There are two distinct rationales behind wind power investments. First, there are commercial projects that involve multiple turbines. These projects are often investor-owned, although they may also be owned by smaller firms or local consumer-owned economic associations. These projects usually comprise five turbines or more, with the purpose of generating profit. Second, individuals and consumer-owned economic associations sometimes initiate small scale wind power projects, with the combined purpose of generating electricity for its members and an intrinsic preference for carbon-neutral electricity. As the interest of the present study lies in large, commercially viable projects, I restrict the study to projects with five or more turbines.

In 2022, the Swedish government appointed an inquiry to develop a compensation mechanism for those affected by wind power. The proposed mechanism roughly corresponds the linear 10H-model presented here. Specifically, it entitles every detached house within 1 km of a turbine a share of the estimated spot market revenue of the turbine's output. The level of the share is determined based on the presumption that households closer than 1 km from at least two representative turbines should be (approximately) fully compensated for their cost of electricity (excluding network charges), and amounts to 0.25 percent of turbine output. This figure is employed also in the models proposed in the present study. For a detailed account of how I map electricity expenses to the 0.25 percent sharing rule, see Appendix C. For distances between 1 km and 10H, the compensation declines linearly until it reaches zero at 10H. Similar to the Danish model, an upper bound is applied at two percent of project output, after which every compensation is scaled down accordingly. Some key figures on the supposed consequences of this scheme are presented by the Swedish Government (2023)[p.335-343] and were originally compiled for the inquiry by the author of the present study.

Although the main benchmark for determining compensation levels is the cost of electricity, it is also relevant to assess whether the proposed compensation would be sufficient to compensate for losses in property values: If current residents would prefer to move further away from the site, would the Net Present Value (NPV) of the compensation make up for the loss in property values? In Appendix D, I briefly address this question using back-of-the-envelope-computations. Results show that the NPV of the compensation received by the households eligible for the highest compensation corresponds to about 20 percent of the mean property value for permanent housing, which is in line with the upper bound of the effects for properties within 2 km of a site found in the previous studies reviewed by Parsons and Heintzelman (2022). Hence, it appears likely that the proposed compensation would also compensate for losses i property values, although this figure should be interpreted with great care.

2.2 Data

Wind turbines

Data on wind turbines are from “Vindbrukskollen”, a publicly available database managed by the Energy Agency (2023). These data contain information about the coordinates, tip height, capacity, owner, and construction year of each turbine. It also includes information on approved turbines that are currently in the planning phase, as well as data on applications for turbines where approval decisions are pending. Data on constructed turbines are more complete than application data, and some of the projects that are still in the planning phase have therefore been dropped from the analysis.

Buildings

Data on the distance between turbines and detached houses were originally compiled for the government inquiry discussed above (Swedish Government, 2023) and are now publicly available (Lundin, 2023).

House prices

Data on house prices are on municipality level, and are publicly available through Statistics Sweden (2023).

2.3 Descriptive statistics

Table 1 summarizes the variables used in the analysis, by region (north/south). Regions are approximately equal in size. The unit of observation is project, and house counts are based on all turbines in the project. The first set of variables describe the number of houses within various multiples of the tip height. The first variable counts the number of houses within three times the tip height of at least one turbine, which is around 0.5 for both the northern and southern regions. For the following variables, house density is notably greater in the south, with approximately three times as many houses for every distance band. The next set of variables describe the number of houses based on number of kilometers. Here, the difference between regions is even larger than when comparing the tip height based metrics, since turbine height is lower in the south. The following set of variables describe project characteristics, highlighting that projects in the north contain both more and higher turbines than in the south, implying a mean capacity that is more than twice as large compared to the southern projects. The last set of variables contain mean prices for permanent and holiday houses in the municipality where the project is located. As expected, prices of permanent houses are higher than holiday houses. Further, prices in the south are almost twice of the prices in the south. Several previous international studies have highlighted that house prices nearby wind power projects are on average lower than in surrounding areas not only due to the causal impact of wind turbines, but also since wind power is usually located in less attractive areas. Wilhelmsson and Westlund (2023)[Figure 3, p. 19] demonstrate that this relationship holds also for Sweden, with approximately 15 percent lower prices in neighborhoods nearby wind power already ten years before construction.

Table 1: Summary statistics of main variables

	North		***South***		***Diff***
	Mean	Sd	Mean	Sd	
House counts based on tip height					
nr. houses $<$ 3H	0.50	1.28	0.51	1.18	-0.01
nr. houses $<$ 4H	1.04	3.12	2.10	3.99	-1.06**
nr. houses $<$ 5H	2.08	5.89	6.11	9.53	-4.03***
nr. houses $<$ 6H	4.23	10.92	12.55	17.06	-8.32***
nr. houses $<$ 7H	6.90	16.08	21.71	28.09	-14.81***
nr. houses $<$ 8H	10.64	23.88	33.34	44.34	-22.71***
nr. houses $<$ 9H	14.89	30.49	47.20	59.96	-32.31***
nr. houses $<$ 10H	19.45	38.27	63.20	79.75	-43.75***
House counts based on km					
nr. houses $<$ 1 km	1.92	3.20	13.44	26.38	-11.52***
nr. houses $<$ 2 km	25.53	63.17	103.79	158.23	-78.26***
nr. houses $<$ 3 km	63.99	137.29	292.50	451.41	-228.51***
Project characteristics					
Capacity	85.79	135.67	27.91	33.61	57.88***
Nr. of turbines	29.40	31.40	10.86	7.64	18.54***
Tip height	189.31	46.10	169.37	48.88	19.94***
House price in municipality					
Houseprice (permanent)	1150.96	661.13	2140.90	950.73	-989.94***
Houseprice (holiday)	933.95	542.20	1799.70	949.21	-865.75***
Observations	148		187		335

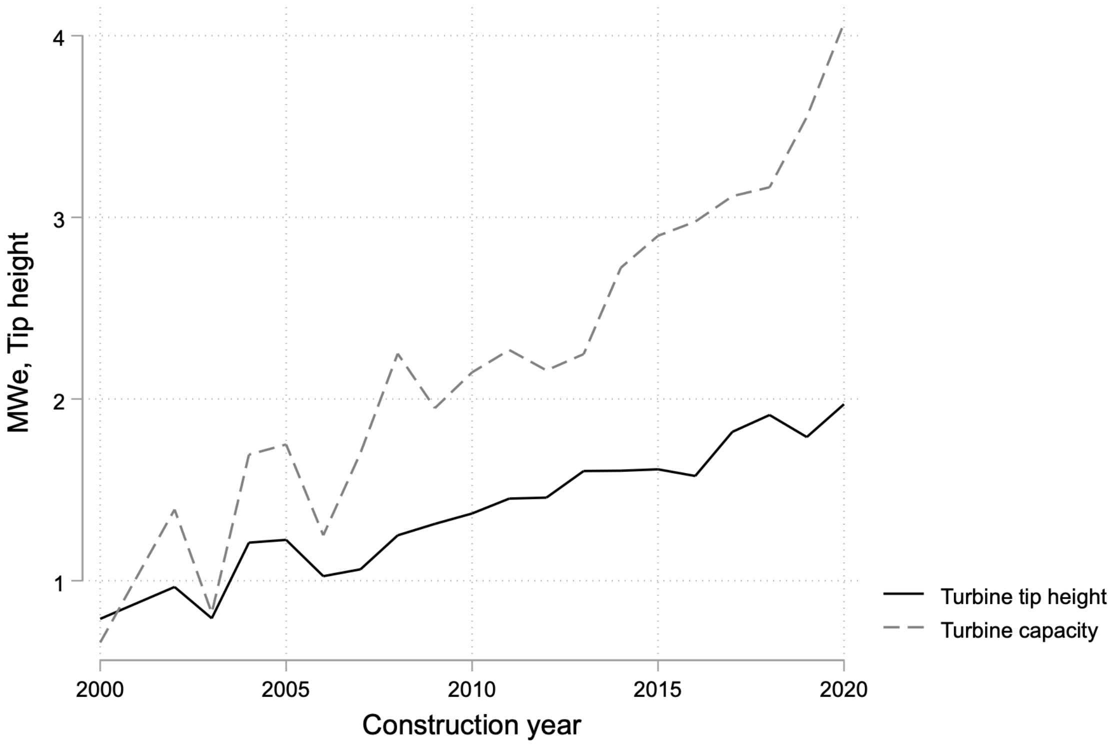
* $p < .10$, ** $p < 0.05$, *** $p < 0.01$

Note: Summary statistics of the main variables. Each project is a separate observation. The left (right) column contains applications in the northern (southern) region. Only projects involving five or more turbines are included. Capacity in MWe. Houseprices in KSEK. A *t-test* is used to test for differences in means across groups (north-south).

While Table 1 includes all projects, Table A1 contains only projects that are either planned or pending (i.e., still in the process for a final decision), revealing that these turbines are notably higher than the existing ones, with a mean turbine height of 220 meters as compared to 170 meters for the existing ones. Also for these projects, there is a clear difference across regions, with the northern projects comprising a greater number of turbines than those in the south.

Figure 1 demonstrates that tip height for constructed turbines has approximately doubled between 2005 and 2020. Also depicted is turbine capacity, revealing an approximately fourfold increase during the same period. This is partly since rotor blade length increases approximately proportionally with turbine height, causing the rotor swept area to increase exponentially (since rotor swept area is $\pi \times \text{bladelength}^2$).

Figure 1: Trends in turbine height and capacity



Note: Trends in turbine height (solid black) and capacity (dashed gray) of installed wind power turbines. Tip height in hundreds of meter. Capacity in MWe.

The rotor swept area is in turn proportional to the power output of a turbine [1].

Figure 2 depicts the locations of present (green), planned (yellow) and pending (orange) projects,

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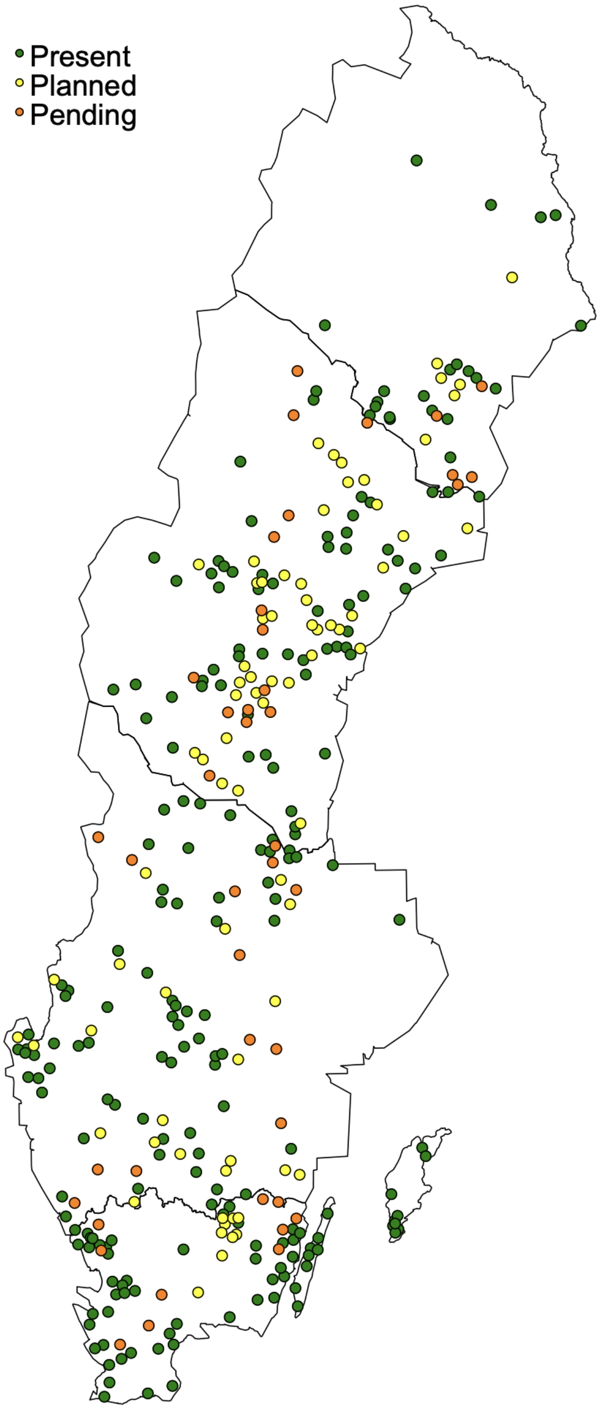
[1] Specifically, Power output of a turbine = rotor swept area × air density × wind speed^3 × power coefficient × $\frac{1}{2}$

demonstrating that each subgroup of projects is relatively evenly distributed across the country.

Figure 2: Present, planned, and pending projects



Note: Locations for present (green), planned (yellow), and pending (orange) wind power projects. Only projects with five turbines or more are included. Black lines are price area borders. The two top areas (SE1 and SE2) comprise the northern region, and the two bottom areas (SE3 and SE4) comprise the southern region.

3 Model simulation

3.1 Description of the models

Below I describe in detail the simulated models.

Constant model: A house within a multiple of X times the tip height of a turbine ("XH") is entitled to a compensation corresponding to the spot market value of 0.25 percent of the output from that turbine. Distance is measured based on the centroid of the house and the turbine respectively. Compensation is awarded for at most two turbines. If more than two turbines are located within the relevant distance, compensation is awarded for the two turbines that generate the highest compensation. Simulations are conducted for discrete distances ranging between 6H-10H.

Linear model: For distances up to 6H, the compensation is computed according to the constant model described above. For distances between 6H up to a factor X, the compensation in terms of MWh is computed according to:

$$Compensation^{MWh} = \sum_{i=1}^{2} turbine_i^{MWh} \times 0.25\ \% \times (1 - \frac{distance_i - 6H}{XH - 6H}) \tag{1}$$

Where subscript i refers to turbines 1 and 2 respectively, and $turbine_i^{MWh}$ is the output of turbine i. Tip height and distances are measured in meter. To compute the compensation in monetary terms, the compensation in terms of MWh is then multiplied by the corresponding hourly spot market price. Simulations are conducted for discrete distances ranging between 6H-10H.

3.2 Simulation results

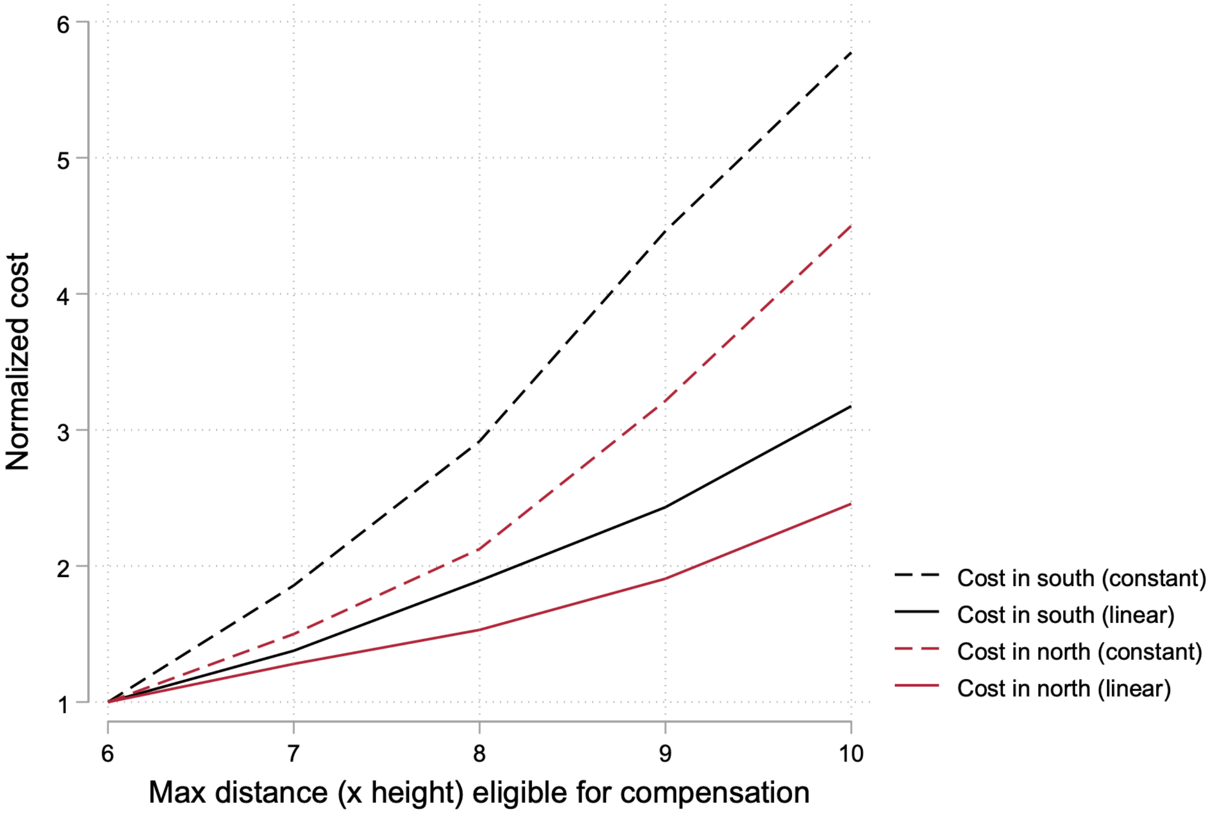
Normalizing the cost of the constant 6H-model to unity

For each project, I begin by normalizing total investor costs of the constant 6H-model to unity for each project. I then simulate all other sub-models, and express total costs as a factor of the 6H-model. Figure 3 depicts these figures for the median project in the south (black lines) and north (red lines) respectively.

In the more densely populated southern region, total costs under the constant model increase almost sixfold when moving from the 6H- to the 10H-model. This increase is approximately constant, although somewhat steeper within the 8H-10H range. Under the linear model, costs instead only increase threefold when moving from the 6H to the 10H-model. In the less populated northern region, costs instead increase by a factor of 4.5 when moving from 6H to 10H under the constant model, and the corresponding figure for the linear model is 2.5.

Common to both regions is that costs are approximately equal under the constant 8H and linear 10H models respectively. For shorter distances, differences are less pronounced: Under the constant 8H-model, costs are approximately equal to the linear 7H-model in both regions.

Figure 3: Normalized cost, by region

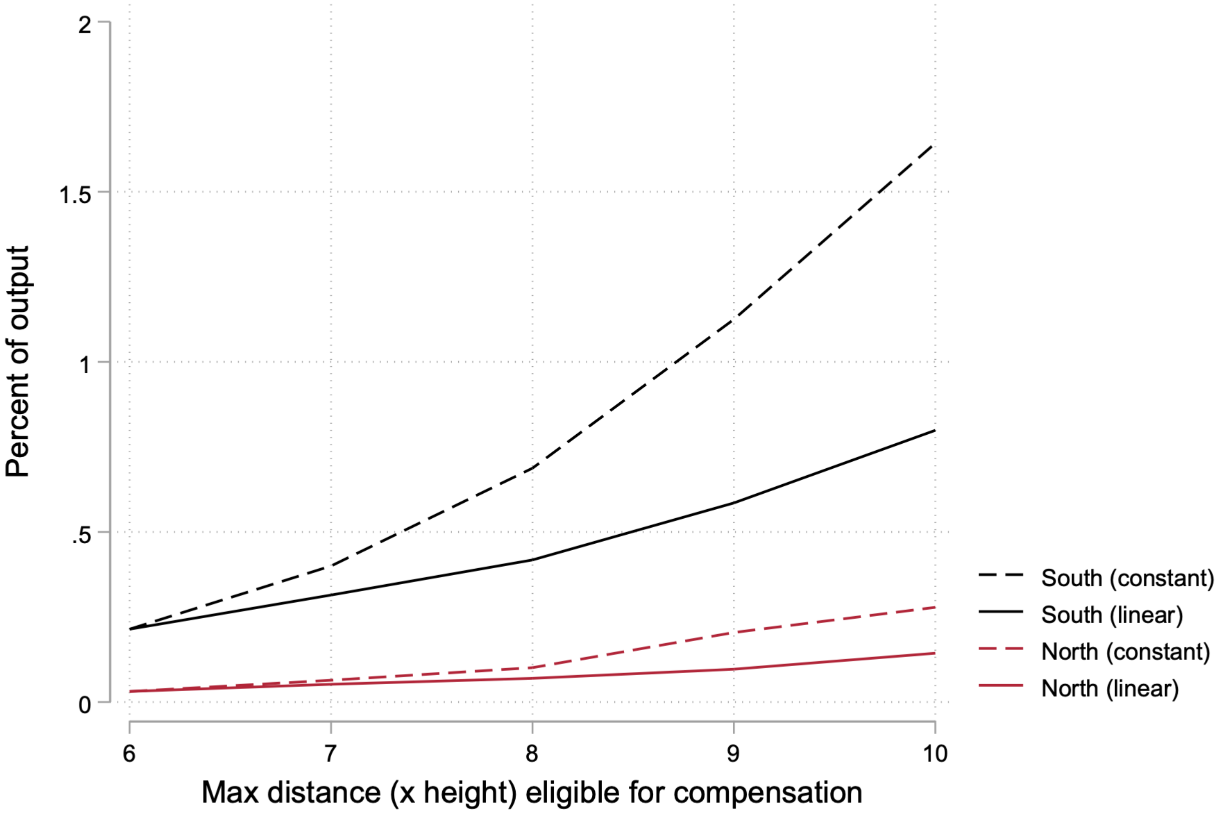


Note: Median investor cost of each simulated model, expressed as a factor of the constant 6H-model. Results are presented by region, where black (red) lines represent projects in the south (north).

Expressing costs in terms of fraction of output

Figure 4 instead depicts median costs under each model expressed as a fraction of project output. Descriptive statistics are provided in Table 2. Costs in the south are notably higher than in the north: In the north, median costs fall well below 0.5 percent for all variations of the models. However, in the south, the median costs exceed 0.5 percent already in the constant 8H and linear 9H-models respectively.

Figure 4: Median costs in percent of output, by region



Note: Median investor cost of each simulated model, expressed as a share of project output. Results are differentiated with respect to region, where black (red) lines represent projects in the south (north)

Table 2: Simulation summary statistics

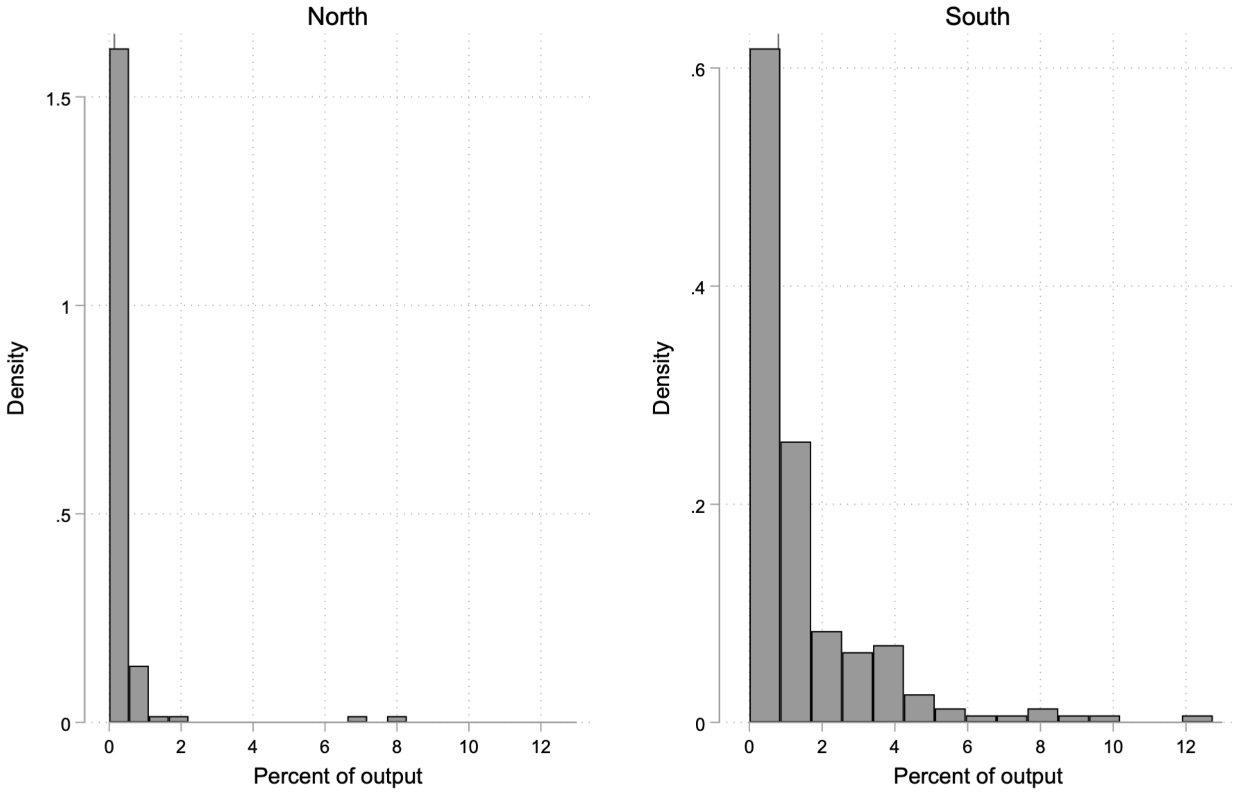
	North				***South***			
	Mean	Sd	Min	Max	Mean	Sd	Min	Max
Constant model								
6H	0.09	0.23	0.00	2.21	0.46	0.62	0.00	3.08
7H	0.17	0.44	0.00	4.38	0.84	1.01	0.00	5.41
8H	0.31	0.90	0.00	7.21	1.39	1.81	0.00	12.05
9H	0.49	1.60	0.00	14.35	2.08	2.80	0.00	18.60
10H	0.71	2.49	0.00	24.70	2.93	4.23	0.03	30.95
Linear model								
6H	0.09	0.23	0.00	2.21	0.46	0.62	0.00	3.08
7H	0.13	0.34	0.00	3.29	0.63	0.79	0.00	3.89
8H	0.18	0.46	0.00	4.47	0.87	1.07	0.00	5.74
9H	0.25	0.68	0.00	5.86	1.15	1.44	0.00	8.72
10H	0.34	1.01	0.00	8.28	1.49	1.93	0.00	12.74
Observations	120				183			

* $p < .10$, ** $p < 0.05$, *** $p < 0.01$
Note: Summary statistics of the cost of each compensation model, by region. Costs are expressed as a fraction of total project output.

The model of most interest to policy makers is likely the 10H linear model, as it resembles most closely the model suggested by the government inquiry discussed above (Swedish Government, 2023). This model should also be of greatest interest internationally, due to the number of recent legislative debates related to the 10H threshold in e.g. Bavaria, Poland, and Ireland. Further, the linear version reflects the fact that disamenities decrease with distance, and should therefore be most efficient in providing sufficient compensations to achieve local acceptance while at the same time keeping investor costs at a reasonable level. In the following, I present a number of figures describing the cost of this model in greater detail, while also documenting the corresponding figures for the constant 8H-model, which exhibits very similar figures across all metrics.

Figure 5 depicts histograms (by region) for the the total cost under the linear 10H-model, expressed as a share of output. In the northern region, the cost exceeds one percent only for five percent of all projects, while the corresponding figure for the south is 40 percent, highlighting that conditions vary greatly across regions. As a reference, Figure A1 depicts the corresponding figures for the 8H constant model, exhibiting a very similar distribution.

Figure 5: Compensation cost under the linear 10H-model



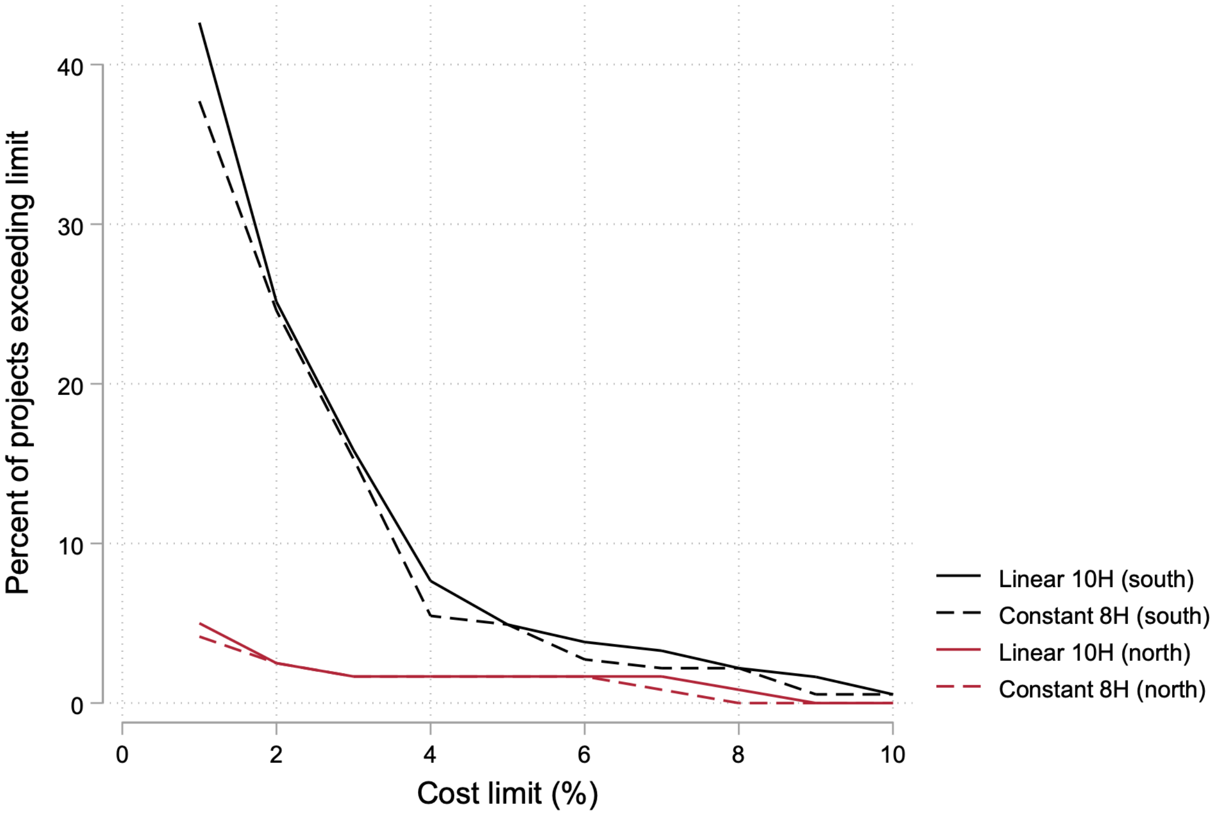
Note: Histograms of the cost of the linear 10H-model, by region. Costs are expressed as a fraction of total project output.

Figure by 6 depicts the share of projects exceeding cost limits in the range of 1 to 10 percent of output, by region. Although it is beyond the scope of this study to evaluate what cost level is reasonable without jeopardizing investor interest, it is reasonable to assume that policy makers would like to impose some type of upper cost bound.

As noted above, in the northern region, only a small share of projects even reach the 0.5 percent limit. However, in the southern region, around 25 percent of all projects reach the two percent limit. It is only at the 4 percent limit that the threshold is exceeded for less than 10 percent of all projects.

Except for heterogeneity with respect to region, another question is how costs differ depending on if the project has already been constructed or if it still in the planning or application phase. Here, on the other hand, there is no notable differences across groups, as depicted in Figure A2.

Figure 6: Percent of projects exceeding various cost thresholds, by region



Note: Percent of projects exceeding various cost thresholds, where thresholds are in percent of project output. Southern projects in black, northern projects in red.

4 Conclusion

I simulate the cost of various wind power revenue sharing schemes using data from Sweden, allowing both for constant and linearly decreasing compensation levels for distances between six and ten times turbine tip height. An important conclusion is that costs vary considerably depending on the model chosen. When compensations are awarded for residents as far away as ten times turbine height, foregone revenues exceed two percent for a comparatively large share of the projects, potentially necessitating the inclusion of a regulated cap on compensation costs.

A distinctive feature of all schemes is that compensation levels are deterministic when expressed as a fraction of foregone revenues. This could be interpreted as allocating risk concerning the future spot price of electricity to nearby residents. However, since residents' expenses are positively correlated with the price of electricity, the scheme should instead be characterized as a legally imposed long term contract between producers and consumers, providing price hedging for both parties, which should generally be an attractive feature of the scheme.

Future studies could discuss democratic considerations for policy makers set to evaluate pros and cons of the different types of models considered. For example, investors and policy makers may want to achieve local acceptance for as many residents as possible using a limited amount of resources. Then, a comparatively low compensation level with a longer distance eligibility threshold may be appear attractive, while possibly at the expense of not achieving acceptance among the comparatively few households located most closely to the turbines.

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Appendix A: Additional tables and figures

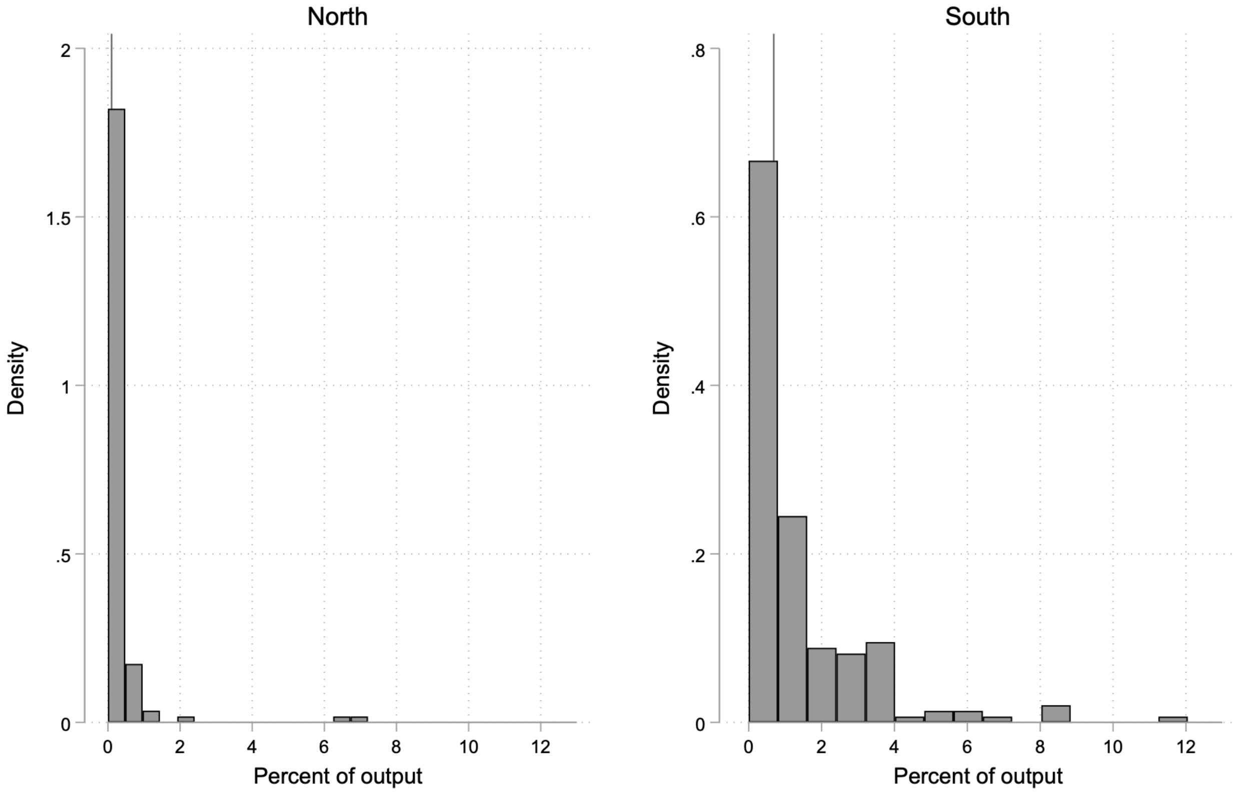
Table A1: Summary statistics, planned and pending projects

	North		***South***		***Diff***
	Mean	Sd	Mean	Sd	
House counts based on tip height					
nr. houses < 3H	0.55	1.36	0.85	1.45	-0.30
nr. houses < 4H	1.25	4.25	4.45	5.86	-3.21**
nr. houses < 5H	2.72	8.13	10.87	12.86	-8.14***
nr. houses < 6H	5.89	14.84	20.26	21.14	-14.37***
nr. houses < 7H	8.97	21.33	33.58	34.12	-24.62***
nr. houses < 8H	13.00	31.25	48.92	53.06	-35.92***
nr. houses < 9H	16.65	35.96	66.91	68.41	-50.26***
nr. houses < 10H	20.58	38.99	89.75	91.53	-69.17***
House counts based on km					
nr. houses < 1 km	1.80	3.43	7.85	9.37	-6.05***
nr. houses < 2 km	16.68	26.12	68.43	75.39	-51.76***
nr. houses < 3 km	40.28	49.53	191.60	181.80	-151.33***
Project characteristics					
Capacity	84.70	173.90	30.52	44.79	54.18*
Nr. of turbines	33.57	36.44	13.87	9.56	19.70***
Tip height	220.89	41.26	220.64	38.72	0.25
House price in municipality					
Houseprice (permanent)	1027.29	540.00	1917.60	891.57	-890.31***
Houseprice (holiday)	838.20	506.28	1565.36	788.08	-727.16***
Observations	65		53		118

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

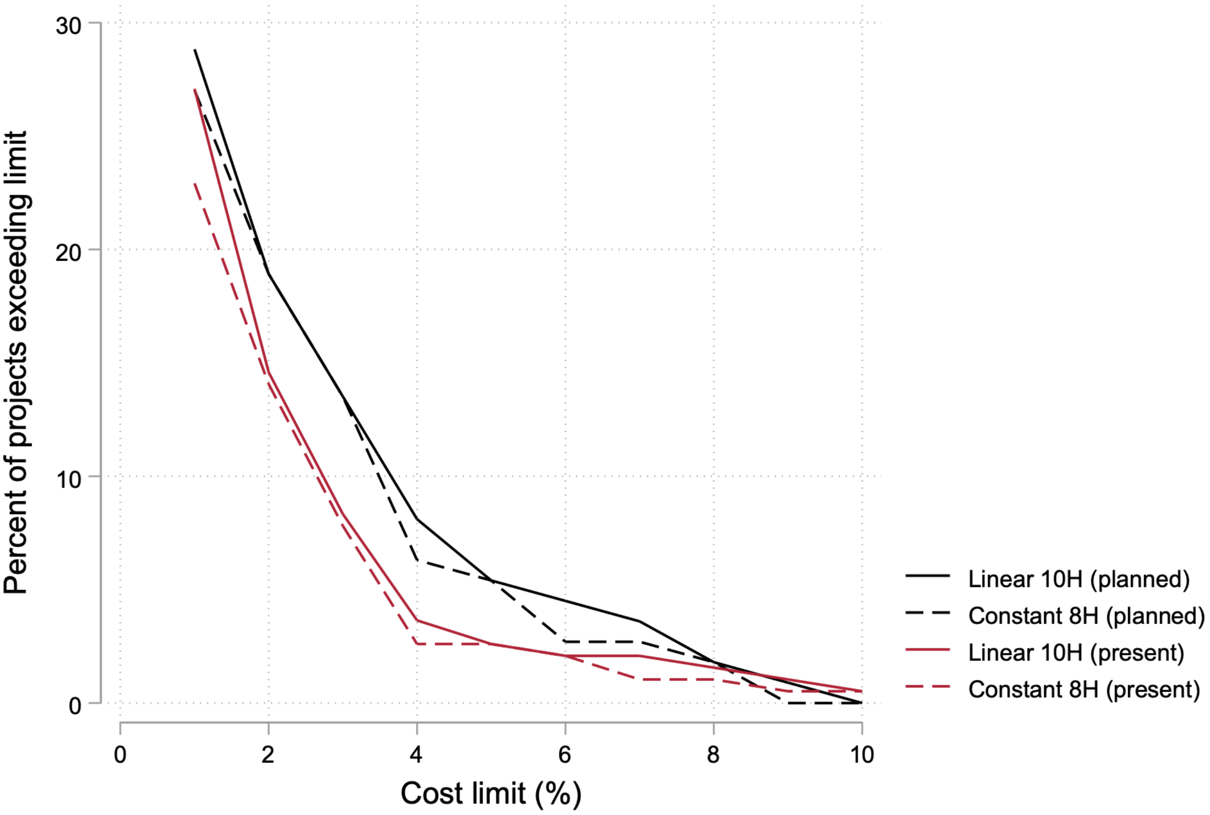
Note: Summary statistics of the main variables, where distances are measured in km instead of tip height. Each project is a separate observation. The left (right) column contains applications in the northern (southern) region. Only projects involving five or more turbines are included. Capacity in MWe. Housprices in KSEK. A *t-test* is used to test for differences in means across groups.

Figure A1: Compensation cost under the constant 8H-model



Note: Histograms of the cost of the constant 8H-model, by region. Costs are expressed as a fraction of total project output.

Figure A2: Percent of projects exceeding various cost thresholds, by planned/present



Note: Percent of projects exceeding various cost thresholds, where thresholds are in percent of project output. Planned projects (both approved and pending applications) in black, present projects in red.

Appendix B: Application process

Below I describe the application process for a representative project in chronological order.

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*) and 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 comprises several hundred pages.

If the project spans several municipalities, each municipality need 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, there may be differences within each project.

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*).

Appendix C: Mapping household electricity expenses to the sharing rule

I largely follow Swedish Government (2023)[p.338] and employ the following assumptions:

1. The consumer cost of electricity equals the unweighted average price on the day-ahead market plus a retailer margin of 5 %, plus VAT of 25% on the price paid to the retailer.
2. Energy tax (including VAT) per kWh equals the day-ahead price excluding VAT. For 2023, the tax amounted to 49 öre/kWh (approx 0.043 EUR/kWh) which will supposedly be somewhat lower than the unweighted mean day-ahead price, but is sufficient as an approximation.
3. The capture rate of wind power is $\frac{3}{4}$. The capture rate reflects the fact that increased wind power production has a negative effect on the day-ahead price, meaning that the compensation from wind power sold on the spot market will fall below the average spot price.
4. The yearly electricity consumption of an average household in a detached house amounts to 15 000 kWh, where approximately 10 000 kWh is used for heating. This assumes that traditional electric radiators have been replaced by heat pumps (for detached houses with traditional electric radiators, yearly consumption is around 20 000 kWh).
5. The capacity of a representative turbine is 3 MW, with a capacity factor of 35 percent. Given 8760 hours per year, this implies an annual output of $3 \times 0.35 \times 8760 = 9198$ MWh.

Assumptions (1) and (2) imply that:
Consumer cost of electricity including tax $=$ Spot price$[1 + (1.05 \times 1.25)] \approx$ Spot price $\times\, 2\frac{1}{3}$
Combined with assumption (3), this implies that the consumer cost of one kWh of household consumption corresponds to the revenues from $\frac{4}{3} \times 2\frac{1}{3} \approx 3$ kWh of energy from the compensation mechanism. Combined with assumption (4) this means that the yearly compensation, measured in kWh, should amount to $3 \times 15000 = 45000$ kWh$=$ 45 MWh if the full cost of electricity should be covered by the compensation.

Given that two turbines entitle compensation and that these turbines are located within 6H of the house, assumption (5) implies that the compensation should equal $\frac{45}{9198 \times 2} \approx 0.25$ % of total turbine output.

Appendix D: Can the sharing rule compensate for the negative impact on property values?

Even if the answer largely hinges on various parametric assumptions, below I provide a "guesstimate". I apply the following assumptions:

1. In accordance with Appendix C, yearly compensation for households receiving the maximum annual compensation is 45MWh.
2. The mean spot price of electricity received by wind power is 37 EUR/MWh (which was approximately the mean price in Sweden during 2021, times a capture rate of $\frac{3}{4}$).
3. The real discount factor is 5 percent.

4. The mean price for a permanent house in municipalities where wind power is located is approximately 170 KEUR.

Combining assumptions (1)-(3) yields a NPV of $\frac{37\times45}{0.05} \approx 48KEUR$, which combined with assumption (4) corresponds to 20 percent of the mean house value. This is roughly in line with the upper bound of the effects found within the range of 2 km from a project in the studies reviewed by Parsons and Heintzelman (2022). Hence, it is likely that the proposed compensation will compensate for the loss in property values, although this result should be interpreted with great care due to the strong assumptions imposed.