SPATIAL ANALYSIS OF FINANCIAL PARTICIPATION SCHEMES TO OFFSET PROPERTY VALUE LOSSES NEAR WIND TURBINES

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Overview

Wind turbines play a key role in the renewable energy transition but can negatively impact local property values (Schütt, 2024). As wind turbine deployment is spatially heterogeneous, the associated externalities and benefits are unevenly distributed and highly localized. To address these externalities and improve local acceptance, financial participation schemes are frequently discussed and adopted. In Germany, for example, various schemes have been implemented at both the national level (Renewable Energy Act (EEG): €0.002 per kWh paid to hosting municipalities) and the state level (e.g., Brandenburg: €10,000 per turbine; Saxony-Anhalt: €6 per kW paid to hosting municipalities). However, the uniform nature of these schemes may overlook regional disparities in externalities (e.g., property value losses), limiting their cost-effectiveness.

Against this background, this study evaluates the cost-effectiveness of financial participation schemes designed to offset property value losses near wind turbines. Using causal forests and Generalized Additive Models (GAMs), we first estimate the heterogeneous impacts of wind power deployment on property values across Germany (Heuer & Sommer, 2024). Subsequently, we assess the extent and cost of offsetting these impacts under different designs of financial participation schemes. The findings provide insights to guide policymakers in developing more cost-effective compensation strategies.

Methods

We used causal forest to to quantify turbine-induced property value losses, a method integrating random forest algorithms with causal inference frameworks (Athey & Imbens, 2016). Property values were modeled based on data from ImmobilienScout24 (2000–2022) and wind turbine data from the Core Energy Market Data Register (CEMDR). Property values are modeled as a function of proximity to turbines, grouped into distance bands (0–1 km, 1–2 km, and 2–3 km) (Munday et al., 2011), alongside socio-demographic variables such as income and population density. The cleaned dataset of 682,576 observations was analyzed to estimate Conditional Average Treatment Effects (CATEs). Generalized Additive Models (GAMs) extrapolated these effects to unobserved areas, providing spatially comprehensive property value loss estimates.

Compensation schemes analyzed included payments per kWh, per kW, and per turbine, distributed either by area or the number of houses within a 3 km radius. Payment ranges spanned €0.0 to €0.2 (kWh), €0.0 to €20 (kW) and €0 to €1,000,000 (per turbine). Net Present Value calculations used a 3% discount rate and a 20-year turbine lifespan, consistent with industry standards (Lind et al., 2011; IRENA, 2021). A comparative analysis of six scenarios (three tariffs × two distribution strategies) assessed their effectiveness in mitigating spatial disparities and their cost-effectiveness in offsetting property value losses.

Results

We find that wind turbines reduce on average property values by 3.6% within 1 km, 2.4% at 1–2 km, and 0.9% at 2–3 km. GAM-based extrapolation revealed regional disparities: while most areas report minimal losses, extreme cases range from -€27.66 million to €4.33 million per 1 km². Total simulated property value losses related to current wind power deployment in Germany amount to €21.9 billion.

This evaluation compares three financial participation models—per-kWh, per-kW, and per-turbine payments—under two distribution strategies (area-based and household-based), with a focus on achieving at least 50% compensation of the total damage (€21.9 billion).

The most cost-effective scheme is the household-based per-turbine payment (€29.09 billion at €55,000 per turbine), followed by household-based per-kW tariffs (€33.54 billion at €3.1/kW) and area-based per-kW schemes (€37.30 billion at €4.2/kW), which better align with localized property losses than energy production-based models. Per-kWh schemes involve the highest transfers and overcompensation, particularly under area-based distributions (€39.81 billion at €0.018/kWh). Household-based per-kWh models (€35.29 billion at €0.013/kWh) slightly reduce overcompensation. All schemes exhibit substantial targeting errors, overcompensating some communities while undercompensating others.

Conclusions

This study highlights the challenges of designing effective compensation schemes for externalities (e.g. property value losses) from wind turbines. Our results also evaluate current financial participation schemes in Germany. At the national level, the Renewable Energy Act (EEG) provides €0.002 per kWh, covering only 14.6% of total damages. At the state level, Brandenburg's €10,000 per turbine payment covers 15.1%, and Saxony-Anhalt's €6 per kW tariff covers 57.3%. These policies inadequately address regional disparities in turbine-induced property losses. In conclusion, our analysis demonstrates that financial participation can help to offset a substantial part of the property value losses produced by wind power deployment. However, fully compensating losses is financially impractical with existing models due to significant overpayment. Consequently, a combination of refined financial schemes, localized benefits (e.g., community ownership), and procedural participation is essential for fostering public acceptance.

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