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The impact of wind farm visibility on property values: A spatial difference-in-differences analysis

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ABSTRACT

Today's investment decisions in large-scale onshore wind projects in Germany are no longer determined only by the investment's economic benefit, but also by concerns associated to social acceptance. Despite a mostly positive attitude towards the expansion of wind power, local public concerns often stem from the belief that the proximity to large-scale wind farms may lead to a decrease in property prices. In particular, the change in landscape caused by the construction of a wind farm may have an adverse impact on the view from some properties, and thus may negatively affect their price. To investigate the potential devaluation of properties in Germany due to wind farms, we use a quasi-experimental technique and apply a spatial difference-in-differences approach to various wind farm sites in the federal state of North Rhine-Westphalia. We adopt a quantitative visual impact assessment approach to account for the adverse environmental effects caused by the wind turbines. To properly account for spatial dependence and unobserved variables biases, we apply augmented spatial econometric models. The estimates indicate that the asking price for properties whose view was strongly affected by the construction of wind turbines decreased by about 9–14%. In contrast, properties with a minor or marginal view on the wind turbines experienced no devaluation.

1. Introduction

Over the last two decades, fostered by strong financial incentives, wind power in Germany has seen a rapid market diffusion. Guaranteed feed-in tariffs for renewable energies such as wind power often rewarded investors in these technologies with substantial economic returns. However, today's investment decisions in large-scale onshore wind power projects in Germany primarily are no longer determined by the investment's economic benefit, but also by the mitigation of public concerns and thereby the increase of social acceptance. Despite a mostly positive attitude towards the expansion of wind power, local public concerns often stem from the belief that the proximity to wind turbines diminishes property prices.

The proximity to a wind farm site may lead to various types of locally adverse effects, such as noise, sound pressure, electromagnetic interference, shadow flicker, as well as visual and scenic intrusion (Manwell et al., 2002). While noise, sound pressure, electromagnetic inference, and shadow flicker effects only occur in the immediate proximity to the wind farm (mainly within the first few hundred meters to the site), visual and scenic effects can have strong influences over considerable distances. Generally speaking, among the various locally adverse effects caused by wind farms, landscape and visual effects are considered to be the most dominant and relevant factors triggering public concerns (Andolina et al., 1998; Benson, 2005; Gipe, 2002; Manwell et al., 2002; Miller et al., 2005; van Beek et al., 1998). Wind farms, sited in predominantly rural areas, are usually visible from considerable distances, as these constructions are often significantly taller than any other object in the existing landscape (Miller et al., 2005). In addition, the average hub height and rotor diameter of wind turbines have increased tremendously over the last years, causing further changes in the landscape of the affected regions. The current trend of repowering (i.e. substituting older facilities by newer, larger, and more efficient ones) will continue to foster this development.

The visual impact threshold distance, i.e. the maximum distance from which a wind farm is visible, can be up to about 30 to 40 km, depending on the terrain characteristics, landscape background, and weather conditions (Bishop, 2002; Sullivan et al., 2012). However, regarding the determination of thresholds of potential visual wind farm impacts, it is important to note that visibility cannot be regarded as a binary factor (i.e. only indicating if a wind farm is visible or not), but that the significance of the visual impact can vary within a spectrum

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that ranges from uninformed detection of the wind farm to strong visual disturbance (Bishop, 2002).[2] Therefore, in order to estimate the visual impact of a wind farm for different locations in a specific region, visibility has to be treated as a function of wind farm size and shape in relation to the observer's distance, the view angle to the object, the object's contrast in relation to its background, and atmospheric scattering (Benson, 2005; Bishop, 2002; Bishop and Miller, 2007; Hurtado et al., 2004; Manchado et al., 2013; Molina-Ruiz et al., 2011; Möller, 2006). Even if wind turbines are visible from distances of up to 30 or 40 km under certain circumstances, usually the significance of a visual impact can be expected to drop substantially beyond distances in excess of two to three kilometers (Bishop, 2002; Sullivan et al., 2012). Hence, visual impacts tend to be extremely complex and difficult to estimate quantitatively (Möller, 2006). Nonetheless, the literature on visual impact assessment of wind turbines provides a few studies that focus on the development and application of quantitative measures of visual impacts (Hurtado et al., 2004; Kokologos et al., 2014; Manchado et al., 2013; Möller, 2006; Torres-Sibille et al., 2009).

As location is one of the most important determinants of a property's value, the proximity to environmental amenities and disamenities in the surroundings, and hence the associated preferences of the consumers, are supposed to be indirectly reflected in its value. The assessment and quantification of changes in the locational attributes of a given property (e.g. due to the construction of a wind farm in the proximity) can be implemented by means of the hedonic pricing method, which allows for the extraction of the implicit price of one attribute from the overall price of the property (Parmeter and Pope, 2013; Rosen, 1974). Applied to the case where the change in the locational attributes of a property is caused by the construction of a wind farm, the extraction of the attributes' implicit price demands for a suitable and differentiated representation of the wind farms' influence on the location of the property. As the impact on landscape and view can be considered as the most dominant wind farm effect, studies aiming at a precise and reliable estimation of potential local impacts of wind farms on property values in the surroundings should rely on an explicit incorporation of visibility effects. Still, most studies only apply simple distance measures as proxies for all kinds of local wind farm effects, and do not account for more sophisticated measurements of actual visibility changes.

The aim of this study is to investigate local visual impacts of wind farms on the development of property prices by explicitly implementing direct visibility estimates in the analysis. Four large-scale wind farm sites located in the immediate vicinity of three medium-sized cities in the federal state of North Rhine-Westphalia (NRW), Germany, are investigated. Within the framework of the hedonic pricing method, we apply a spatial difference-in-differences (DID) model that allows for a comparison of the observed changes in the values of the treated properties against the values of a control group. Applied to the case of wind farm construction, the treatment and control groups are defined according to various wind farm visibility criteria (see Section 2). To assess the visual impacts of wind farms, we partially adapt the quantitative visual impact measurement approach proposed by Hurtado et al. (2004) and develop a criteria-based 'Visual Impact Level' (*VIL*) ranking incorporating the magnitude of visibility (i.e. the number of visible turbines), the distance to the wind farm, and the view angle from the center of the property.[3] Thanks to the implementation of a quantitative criteria-based approach considering the relation of distance, magnitude of visibility, and view angle, we improve the current common practice of applying qualitative-subjective evaluations of visual impacts in hedonic pricing analysis. More specifically, the impact of the different visibility levels on the property values is estimated by means of a Spatial Fixed Effects model, a Spatial Auto-Regressive Lag Model with an Auto-Regressive Error Term (SAC/SARAR),[4] and a Spatial Durbin Error Model (SDEM).

In order to control for endogenous influences and omitted variable bias (Parmeter and Pope, 2013), the DID approach has been used in various hedonic pricing applications, such as transportation (Dubé et al., 2014), urban amenities (Gibbons and Machin, 2008; Branas et al., 2011; Heckert and Mennis, 2012), and recently also energy-related issues (Hoen et al., 2013). In recent years, the literature also provided a few examples of how spatial dependence can effectively be incorporated in DID model frameworks. Particularly, Dubé and Legros (2011, 2013a) provided various application examples, where the DID framework was specified in a way "(…) to deal with the omission of a latent constant spatial structure uncorrelated with the independent variables and generating spatial autocorrelation among residuals" (Dubé et al., 2014, p. 25). In a similar way, the present study follows those methodological developments and applies a DID model coupled to spatial econometric techniques (for details on the model specification, see Section 3).

To date, the number of publications that investigate the impact of wind farms on property values by means of hedonic pricing methods is still limited. Despite the scarcity of publications, however, there is considerable variety of approaches regarding the selection of suitable variables (particularly with respect to the choice of the most appropriate proxy for wind farm impacts) and estimation techniques (mainly with regard to possible omitted variable biases and spatial dependence).

Being among the earliest published studies on this topic, Sims and Dent (2007) as well as Sims et al. (2008) investigate the impacts of wind farms on house prices in Cornwall, UK. Sims and Dent (2007) apply a simplistic regression approach that does not control for any spatial effects in the data. Various distance zone dummies are used as proxies for wind farm impacts. Furthermore, the authors consider only property sales that took place after the construction of the wind farm, which is by far the most problematic issue. Sims et al. (2008), in contrast, consider the problem of spatial relationships in the data by using spatial fixed effects. Furthermore, they incorporate some dummy variables indicating visibility. They do so, however, without considering any actual relation to distance or extent of visibility. The data base is again rather small (199 property sales), though it considers transactions over a longer time interval. Overall, both Sims and Dent (2007) and Sims et al. (2008) could not obtain any significant evidence of the effects investigated, though this outcome might have been strongly influenced by the limitations in the analysis carried out.

Hoen et al. (2009, 2011) and Hoen et al. (2013) analyze wind farm impacts on various sites in the US and provide by far the most comprehensive studies currently available in the literature. In an article distilled from their project report (Hoen et al., 2009), Hoen et al. (2011) investigate about 7,500 single-family house sales in the proximity of 24 large-scale wind farm sites spread across nine US states. In their study, they explicitly focus on visibility effects and develop an ordered qualitative visual impact ranking system that incorporates distance to the turbines, the number of turbines visible, as well as the view angle. Within a standard hedonic framework, different model specifications were applied, also accounting for spatial autocorrelation via spatial fixed effects and nearest neighbor weights. According to the results obtained, no evidence was found for visual impacts or other wind farm-related effects in the considered study areas. Hoen et al. (2013) further improved the two aforementioned studies by applying a DID framework with spatial econometric methods in order to control for spatial

[2] Bishop (2002) defines four visibility categories: uninformed detection, uninformed recognition, informed recognition, and informed visual impact. For further information on visual thresholds for detection, recognition, and visual impact, see also Shang and Bishop (2000).

[3] Due to limited data availability and computational issues, accounting for weather conditions, atmospheric scattering, and background contrasting is beyond the scope of this analysis.

[4] In the literature, the spatial auto-regressive lag model with an auto-regressive error term is typically labeled either as SAC (LeSage and Pace, 2009) or SARAR (Kelejian and Prucha, 1998).