The Effects of Wind Turbines on Property Values in Ontario: Does Public Perception Match Empirical Evidence?

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This research is based, in part, on data provided by the Municipal Property Assessment Corporation. Any opinions, findings, conclusion, or recommendations expressed in this material are those solely of the authors and not necessarily the views of Municipal Property Assessment Corporation.

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ABSTRACT

The increasing development of wind energy in North America has generated concerns from nearby residents regarding potential impacts of wind turbines on property values. Such concerns arose in Melancthon Township (in southern Ontario) following the construction of a large wind farm. Existing literature has not reached a consensus regarding the nature of these impacts. This paper applies a hedonic approach to detailed data on 5,414 rural residential sales and 1,590 farmland sales to estimate the impacts of Melancthon's wind turbines on surrounding property values. These impacts are accounted for through both proximity to turbines and turbine visibility – two factors that may contribute to a disamenity effect. The results of the hedonic models, which are robust to a number of alternate model specifications including a repeat sales analysis, suggest that these wind turbines have not significantly impacted nearby property values. Thus, these results do not corroborate the concerns raised by residents regarding potential negative impacts of turbines on property values.

Key words: Wind turbines; property values; visual disamenity; hedonic approach

INTRODUCTION

Global environmental concerns have led to greater emphasis on generating electricity from renewable resources. Energy sources such as wind have received increasing attention and support from governments wanting to cut carbon emissions and reduce dependence on non-renewable energy sources. As a result, the wind energy industry has become one of the fastest growing industries in the world (Herring 2004). However, in spite of its perceived benefits, a number of issues and challenges have been identified in the economic literature regarding the development of wind energy. These include the intermittency of wind power (e.g., van Kooten 2009), forecast errors for wind power output (e.g., Delarue et al 2009) and challenges with accurate estimation of the economic value of wind power (e.g., Kennedy 2005). Wind energy development has also generated controversy, as concerns have been raised by residents living in close proximity to wind turbines regarding potential negative effects on property values. Such concerns are the focus of this paper.

Previous research on turbines and property values suggests that the primary complaints associated with turbines concern the perceived negative visual effects of turbines on the landscape as well as noise created by the turbines. Most recent studies have focused their analyses on assessing the visual disamenity, which has become the more prominent concern. While earlier literature also examined the issue of noise, the reduced emphasis on the noise disamenity appears to reflect improvements in turbine technology (Moran and Sherrington 2007). As noted by Hoen et al (2009), the impact of proximity to turbines may extend beyond the visual disamenity effect to include nuisance effects such as shadow flicker and health concerns. Each of these effects, whether real or perceived, may also impact property values.

Existing literature on the disamenity effects of wind turbines (see Table 1 for an overview of this literature), which has incorporated a variety of techniques such as surveys, contingent valuation, price comparisons, and hedonic regressions, is inconclusive with respect to effects on property values. Several studies have found evidence of negative impacts, both for onshore turbines (Khatri 2004; Groothuis et al 2008; Heintzelman and Tuttle 2012) as well as offshore turbines (Haughton et al 2004; Ladenburg and Dubgaard 2007; Krueger et al 2011). In some cases, these studies did not examine property values specifically, but instead estimated residents' willingness-to-pay to keep turbines out of their viewshed, their required compensation for these turbines, or costs of landscape impacts. However, these findings are likely linked to anticipated negative property value effects occurring due to this disamenity. The results of other studies found no significant evidence of negative effects on property values (Grover 2002; Sterzinger et al 2003; Poletti 2005; Hoen 2006; Rayner 2007; Sims and Dent 2007; Sims et al 2008; Hoen et al 2009). Thus, consensus has not been reached in the empirical economic literature regarding the expected effects on property values of disamenities associated with wind turbines.

The impacts on property values of other types of disamenities have been well-documented, including impacts of hazardous waste sites (e.g., Kohlhase 1991; Kiel and Williams 2007), landfill sites (e.g., Nelson et al 1992; Hite et al 2001), transmission lines (e.g., Hamilton and Schwann 1995), and oil and natural gas facilities (e.g., Boxall et al 2005). Such disamenities are typically found to negatively impact nearby property values. The purpose of this paper is to estimate the property value impacts of the perceived disamenity associated with a wind farm (a term which refers to a set of wind turbines constructed across multiple properties within a local area) in Melancthon Township in the province of Ontario. This wind farm is one of several that have been constructed across Ontario in the past decade. Concerns about potential negative impacts on property values, as well as related concerns about potential health impacts on residents in close proximity to turbines, have become very prominent in Ontario's public forum in recent years. With the recent growth in Ontario's wind energy industry anticipated to continue as a result of government legislation such as the provincial Green Energy and Green Economy Act (2009), and with an increasing number of grassroots organizations across the province taking a stand against future wind farm developments, further examination of this issue to provide a better understanding of these effects that can inform the escalating controversy is imperative. At a more general level, additional in-depth studies on the property value impacts of wind turbines are needed to address the lack of consensus in the literature.

We apply a hedonic approach to detailed datasets of rural residential[1] sales and farmland sales in the area surrounding Melancthon Township to estimate the effects of the wind turbines on nearby property values. To our knowledge, this is the first hedonic study of the property value effects of wind turbines in Canada. This paper adds to the literature in two key ways. First, these effects are accounted for through both the proximity to the nearest turbine and the level of turbine visibility – i.e., the two factors that contribute to the potential visual disamenity. In addition to using each factor separately, we use an approach that combines proximity and visibility to account for the relationship between these two factors in contributing to the disamenity. Previous studies have tended to use either a distance measure or a visibility measure, which may limit the ability to adequately capture these effects. For example, the disamenity effects for two properties at a similar distance from a turbine may vary with the level of visibility from each property, while disamenity effects for two properties for which the nearest turbine is

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[1] Rural residential properties are located beyond the municipal boundaries of urban areas. These properties tend to be larger than urban residential properties, and are often purchased by landowners that value visual amenities associated with the surrounding 'green' landscape.

fully visible may vary with distance to the turbine. Hence, combining these factors may permit a more accurate representation of disamenity effects associated with turbines.

Second, this paper provides a direct comparison of the effects of wind turbines on two distinct property types: rural residential and agricultural. As indicated in Table 1, the majority of recent studies has focused on the effects on residential properties, while farm properties have received little attention. The property value effects of turbines are anticipated to be greater for rural residential properties as the values of these properties, which are used primarily for residential purposes, may be more sensitive to visual disamenities and other nuisance effects than properties purchased primarily for agricultural use.

The findings of this paper will provide evidence that may help to resolve the controversy that exists in Ontario regarding the impacts of wind turbines on property values. In response to concerns regarding potential impacts, many residents have been calling on the provincial government to delay wind farm developments until these impacts are better understood. This paper will contribute to achieving a better understanding of these impacts, and subsequently will determine whether concerns regarding negative impacts on property values are validated. The results presented in this paper may also inform further policy discussions and developments related to the future direction of wind energy in Ontario. In addition, these results may have applicability for large-scale wind farms constructed in other jurisdictions similar to Melancthon Township, where rural areas are comprised of farms interspersed with rural residential properties for which value is derived from the surrounding viewshed.

BACKGROUND

In 2003, the provincial government of Ontario set a target of achieving 10% of total electricity production from renewable sources by the year 2010. According to Ontario's Ministry of Energy, the province had only 10 wind turbines operating commercially in 2003 but currently there are in excess of 1,000. This growth can be attributed to programs launched by the government to encourage individuals or firms (proponents) to establish wind projects that contribute to the local power grid, whereby the proponent enters into a power purchase agreement with the Ontario Power Authority through which production is guaranteed for twenty years.

Canadian Hydro Developers was one of the earliest successful proponents under this government policy initiative.[2] They proposed to construct a wind farm, in two phases, in Melancthon Township, Dufferin County, about 100 kilometres northwest of Toronto. The first phase consisted of 45 80-metre turbines with a rated capacity of 67.5 megawatts of electricity, while the second phase consisted of 88 turbines with a rated capacity of 132 megawatts.[3] The government of Ontario awarded Canadian Hydro Developers a contract on November 25, 2004.

The development of Phase I began in 2004 with environmental assessments, which were completed in the spring of 2005. Municipal permits and approvals were then obtained, which allowed construction to proceed. The permits identified the specific properties upon which the turbines would be constructed. Service works such as access roads and necessary upgrades were completed by the end of June 2005, which allowed construction to commence in July. Construction of all Phase I turbines was completed by March 2006. For Phase II, some access roads were installed in the fall of 2007, but due to delays in permitting, construction did not occur until the following year, beginning in March and extending to December of 2008. In most

[2] Canadian Hydro Developers has since been acquired by TransAlta Corporation.
[3] Some of the Phase II turbines are situated in neighbouring Amaranth Township.

cases, the land on which turbines were constructed was leased from local property owners, but in some cases properties were bought outright by Canadian Hydro Developers. The leases extend for a period of 20 years, during which time each property owner receives monthly compensation, based on the performance of the turbine(s) located on their property.

Public discussion began after the government of Ontario announced that Canadian Hydro Developers' bid had been accepted for the Melancthon wind farm. Initially, interest in the project was evident from farmers and large property owners who were potential candidates for turbine development on their property. For example, in a letter to the editor of a local newspaper, a Melancthon farmer stated that: "...a wind turbine on a farm is attractive as it might be a source of local power when central power is cut off, and could offset the rising cost of electricity and provide some income..." (*Orangeville Banner*, January 25, 2005).

As the project progressed and details emerged, such as the height of the turbines and their locations, concerns arose from local residents. At a town hall meeting in Melancthon in February 2005, two primary concerns were raised: setbacks and the devaluation of properties. Residents were concerned that the 150-metre proposed setback of a turbine from a residence would not be enough, and that the resulting viewshed would negatively impact the value of properties. Following this meeting, a related article in a local newspaper noted that "...concern was also raised with the impact a wind farm will have on property values, and despite what developers say, residents feel it will have an unfavourable effect." (*Orangeville Banner*, February 18, 2005). The concerns of residents contrasted starkly with the views of the property owners who were expecting a turbine to be constructed on their property. At a township meeting in April 2005, the 23 property owners that accounted for the 45 Phase I turbines presented a petition to council urging them to expedite the process of permit approval.

Despite many public meetings over the course of the planning and development of the wind turbines in Melancthon Township, the debate regarding the distribution of effects of the turbines in this area remained largely unresolved. Since existing literature does not provide conclusive evidence regarding this debate, we conduct an analysis to examine for property value impacts of these turbines.

METHODS

Previous studies on wind turbines have employed a variety of methods to examine for the effects of the disamenities associated with turbines on property values. These methods include hedonic regression analysis (Hoen 2006; Sims and Dent 2007; Sims et al 2008; Hoen et al 2009; Heintzelman and Tuttle 2012), valuation using choice experiments (Ladenburg and Dubgaard 2007; Krueger et al 2011), contingent valuation (Haughton et al 2004; Groothuis et al 2008), and price-trend comparison (Poletti 2005, 2007; Rayner 2007). A number of studies have also used surveys to examine attitudes toward wind turbines and wind energy (Thayer and Freeman 1987; Krohn and Damborg 1999; Sustainable Energy Ireland (SEI) 2003).

The theory behind the possibility of disamenity effects is based on the concept that potential owners value properties on the basis of various property characteristics as well as environmental amenities and disamenities, subject to their budget constraints. Purchase decisions are made based on households' tastes for specific attributes. These tastes are reflected in the values that households place on these attributes. These values can be estimated through a hedonic approach, which decomposes actual transaction prices into components linked to property attributes.

While hedonic models have not been frequently used in studies on the effects of wind turbines, they have seen extensive use in a wide variety of property value studies. This modeling approach is useful for generating the value associated with specific attributes of properties (see Freeman 2003). In this case, a hedonic model is developed for the purpose of determining the impact on property values of turbine proximity and visibility, specified by:

$$P_j = x_{ij}\beta_i + T_j\delta + \varepsilon_j, \qquad (1)$$

where P_j represents the sale price of the *j*th property; x_{ij} is a set of property and location attributes that can impact the sale price; T_j is the variable accounting for the disamenity effects of wind turbines; β_i and δ are parameters to be estimated; and ε_j is the error term.

We estimate six models in our primary analysis, which include three models each for rural residential properties and for farm properties. For both property types, the three models are differentiated based on the approach to accounting for turbine disamenity effects, which is discussed in the following section.

A double-log functional form is used for these models,[4] which is consistent with many hedonic models in the literature (e.g., Irwin 2002; Boxall et al 2005; Deaton and Vyn 2010). Recent literature has suggested that flexible functional forms such as the Box-Cox can outperform simpler forms, particularly in models where spatial fixed effects are used to control for omitted variable bias (Kuminoff et al 2010). However, we did not find any differences in sign or significance of the results for our variables of interest under Box-Cox specifications relative to the double-log form.

As described in previous studies (e.g., Irwin and Bockstael 2001), the identification of hedonic models can be affected by issues such as spatial autocorrelation. This issue can cause

[4] Not all explanatory variables are logarithmically transformed. Decisions about which variables to leave in their original form follow the general rules of thumb outlined in Wooldridge (2006). The variables that have been transformed are indicated in the tables of results (Tables 5 and 6).

inefficient parameter estimates due to omitted explanatory variables that are spatially related or due to spatially weighted price influences of proximate properties. As a result, studies have incorporated a spatial component into hedonic models to address this issue. Likewise, as described in the sensitivity analysis, we use a spatial autoregressive model to determine whether the existence of spatial autocorrelation has affected the parameter estimates. Other identification issues associated with the use of hedonic models include multicollinearity and heteroskedasticity. We address heteroskedasticity by generating robust standard errors, while the issue of multicollinearity is examined in the results section.

DATA

The data used in the hedonic models to estimate the property value effects of the Melancthon wind farm is derived from separate datasets collected by the Municipal Property Assessment Corporation (MPAC) to record sales of rural residential properties and farm properties.[5] These datasets consist of open-market sales (as defined by MPAC) between January 2002 and April 2010[6], inclusive, in Melancthon and ten surrounding townships in the counties of Dufferin, Grey, Simcoe, and Wellington. With the focus of this study on the effects of turbines on nearby properties, sales of properties on which turbines are located are excluded from these datasets.[7] Additionally, we restrict farm properties to those greater than five acres in size, in order to exclude farm properties that may be too small for use in agricultural production.[8]

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[5] MPAC collects this data for the purpose of assessing property values.
[6] The farm sales data extends only to April 2009.
[7] Only three sales of farm properties with turbines were included in the original datasets. This limited number restricts the ability to estimate the effects on the value of properties on which turbines have been constructed; as such, they have been excluded from the analysis.
[8] This restriction, as well as a variation of this restriction (i.e., 20 acre minimum size), does not impact the results.

With wide ranges in sale prices within each dataset, the possibility of outliers exists. Potential outliers are removed by establishing minimum and maximum prices beyond which the distribution of sale prices becomes sparse. Rural residential properties with sale prices below $10,000 and greater than $2,000,000 are removed, while farm properties with sale prices greater than $2,500,000 are removed from the dataset.[9] Following these restrictions, the datasets used for the analysis consist of 5,414 rural residential sales and 1,590 farmland sales.

Both datasets include many properties that sold more than once during the study period. Among the rural residential (farm) sales, 797 (131) properties sold twice, 114 (10) properties sold three times, and 12 (0) properties sold four times. This allows for conducting a repeat sales analysis, which can be an effective method for controlling for omitted variable bias. The results of this analysis can be compared to those of the full sample. Due to the relatively low numbers of properties in close proximity to turbines in the repeat sales sample, we conduct this analysis as a component of the sensitivity analysis rather than as our primary model.

Variables Accounting for Turbine Impacts

The potential visual disamenity associated with turbines is anticipated to arise due to two factors: proximity to the turbine and the level of visibility of the turbine. Each factor is incorporated separately into the hedonic models to account for this disamenity. In addition, as an alternate approach to accounting for this disamenity, a model is specified that combines both factors. Hence, three separate models are estimated for both property types, each with a different approach to accounting for the disamenity effects of turbines.

[9] There were 7 rural residential properties (0.13% of sample) and 5 farm properties (0.31% of sample) with sale prices beyond these constraints. Excluding these sales did not affect the nature of the results.

In the first model, the disamenity effects are accounted for by proximity to turbines, which is measured as the inverse of the distance, in kilometres, from the property to the nearest wind turbine. This approach to accounting for turbine disamenity effects is similar to that of Heintzelman and Tuttle (2012). Geographic information systems (GIS) software was used to calculate the distances from each property in the two datasets to each of the 133 turbines in the Melancthon wind farm, from which the distance to the nearest turbine was determined for each property, and then inverted. While this study focuses to a larger extent on visual disamenities, the use of a proximity variable also accounts for noise disamenities associated with turbines. Due to the distance-decaying nature of the visual and noise disamenities associated with wind turbines, any disamenity effects on property values within the affected area are expected to be relatively higher for properties in closer proximity to turbines. Hence, if such disamenity effects exist, the sign of this proximity variable would be negative. Variation in the magnitude of effects based on distance from the disamenity has been demonstrated in related areas of the literature (Kohlhase 1991; Boxall et al 2005).

In the second model, the disamenity effects are accounted for by the level of visibility, which is measured using a rating system similar to that of Hoen (2006). Under this rating system, a score of one point is assigned if only the top of the blade is visible from the property (e.g., above the treeline), a score of two points is assigned if the hub of the turbine is fully visible, and a score of three points is assigned if the entire vertical span of the blades is visible.[10] The development of this rating system required field visits to each of the properties within 5 kilometres of the wind farm, which was determined based on observations of the study area to be

[10] A rating system of 1, 3, and 5 points for the indicated levels of visibility was also examined, but the results were not found to be sensitive to this alternate rating system.

the extent of the visual impact.[11] Similarly, previous studies have specified distance limits within which the effects are assumed to extend, such as five miles (Sterzinger et al 2003; Hoen 2006) and five kilometres (SEI 2003) from turbines. Both the rural residential and farm datasets include properties up to 50 kilometres from the nearest turbine, which permits the comparison of properties in close proximity to turbines with those from which the turbines are not visible (i.e., a control group). Under the assumption that greater visibility of the turbine increases the disamenity effects on property values, the expected sign of this visibility rating variable is negative.

Since sales data are available both prior to and after the Melancthon wind farm was developed, each of the proximity and visibility measures used in the first two models is multiplied by a categorical variable indicating whether the property was sold in the time period during which disamenity effects are expected to occur, referred to as the post-turbine period. However, the existence of two phases of the wind farm complicates the calculation of these interaction terms. Consideration must be given to the date of sale with respect to the post-turbine period specific to each phase and, subsequently, to the determination of visibility rating of or distance to the nearest turbine in existence at the date of sale. As a result, categorical variables are created to represent the post-turbine period for each phase, while for each property, visibility ratings and distances to the nearest turbine are determined separately for Phase I turbines and for Phase II turbines. To capture appropriately the potential disamenity impacts of the Melancthon wind farm, each disamenity measure is specified for both rural residential and farm properties as the maximum of the Phase I and Phase II measures.

[11] GIS applications can also be used to model the topography of the surrounding landscape and resulting viewshed. Hoen (2006) found that field visits were more accurate for rating turbine visibility than a GIS modeling approach.

The post-turbine periods are specified to account for the time periods in which the potential impacts of the turbines would likely be observed in property transaction prices. Since uncertainty exists in identifying the point in time at which impacts are expected to arise, we use three different specifications of the post-turbine period. In our base model, impacts are assumed to arise upon commencement of turbine construction.[12] While the visual impact of the turbines could not be fully observed at this time, market participants would be aware of the locations of the turbines. Construction began in July 2005 for Phase I turbines and in March 2008 for Phase II turbines. Hence, the post-turbine periods specified for our primary models account for all sales that occurred from these months forward.

Unfortunately, there are relatively few observations in the post-turbine periods that are in close proximity to turbines.[13] Table 2 provides the numbers of post-turbine period observations at various distances from the turbines for the base model and two alternate specifications (which are described below). For example, under the base model specification, there are 23 (8) sales of rural residential (farm) properties within 1 kilometre of the nearest turbine and 103 (40) within 5 kilometres (which represent 1.9% (2.5%) of all sales). The numbers of observations for each visibility rating are provided in Table 3 for each of the post-turbine period specifications. For the base model specification, among the rural residential (farm) properties within 5 kilometres of the nearest turbine, 9 (3) properties have a visibility rating of 1, 19 (13) properties have a visibility rating of 2, and 33 (16) properties have a visibility rating of 3.[14] These relatively low numbers of post-turbine period observations, which may impede the ability to detect significant effects, represent a potential limitation of this study.

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[12] In a survey conducted by Khatri (2004), the majority of chartered surveyors believed that the impacts of turbines began before construction was completed.
[13] This has been a recurring issue in previous hedonic studies on the effects of wind turbines.
[14] The majority of properties within 5 km of the nearest turbine with a visibility rating of 0 are located in the 3-5 km range. The closer the property to the nearest turbine, the more likely that the visibility rating is greater than 0.

To address the uncertainty that exists regarding the point in time that impacts begin to arise, we examine the sensitivity of the base model results to two alternate specifications of the post-turbine periods. The first alternate specification (Pre-Construction) assumes that impacts begin to arise upon project approval (for Phase I) and upon completion of ancillary activities such as access roads (for Phase II), which could provide some indication of where future turbines may be located. These post-turbine periods include sales occurring after November 2004 (Phase I) and after October 2007 (Phase II), of which 30 (9) rural residential (farm) properties are within 1 km and 123 (52) are within 5 km of the nearest turbine (see Table 2). The second alternate specification (Post-Construction) assumes that impacts do not arise until construction is completed (i.e., turbines are fully visible); thus, the post-turbine periods include sales occurring after February 2006 (Phase I) and after November 2008 (Phase II). Among these sales, 18 (6) rural residential (farm) properties are within 1 km and 79 (27) are within 5 km of the nearest turbine.

While both proximity and level of visibility represent plausible measures of the visual disamenity, and have been used accordingly in previous studies, the use of each measure on its own involves potential issues that may impede the ability to appropriately capture the disamenity effects. For example, the impact of turbine visibility is likely to vary spatially – i.e., the disamenity effect of a 3-point visibility rating is assumed to be greater for a turbine at a distance of 1 kilometre than for a turbine 3 kilometres from the property. To address such issues, an additional model is specified that includes both the proximity and visibility variables as well as an interaction term (*Proximity*Visibility*). This represents an approach to accounting for turbine disamenity effects that has not previously been taken in the literature. The interaction term increases with visibility (holding proximity constant) and decreases with distance from the nearest turbine (holding visibility constant); hence, as with each of the proximity and visibility variables, the sign of this variable is anticipated to be negative.

As an alternative to using a continuous distance specification for the proximity variable accounting for the disamenity effects of turbines (Model 1), a set of discrete distance bands is specified based on proximity to the nearest turbine. Distance bands have been used in a number of previous studies (Thayer et al 1992; Mikelbank 2005; Deaton and Vyn 2010). The set of distance bands specified for this study includes the following ranges: 0-1 km, 1-3 km, and 3-5 km. These ranges encompass the visual extent of the wind turbines, which was determined based on observations of the study area to be about 5 km. Since the specification of 1-km bands would result in relatively few observations within some bands, particularly for farm properties, the use of larger bands (i.e., 2-km bands) increases the numbers of observations within each band and reduces the potential for individual properties to have undue influence on the estimated results. An exception is made with the first band (0-1 km) to permit examining for impacts in the area immediately surrounding the turbines where these impacts are anticipated to be greatest, under the assumption of a distance-decaying disamenity effect.[15] For rural residential (farm) properties, there are 23 (8) properties in the 0-1 km band, 28 (11) properties in the 1-3 km band, and 52 (21) properties in the 3-5 km band. Distance band variables are calculated as the maximum of interaction terms specified for each phase between the categorical variable accounting for the existence of the nearest turbine within the specified range and the post-turbine period categorical variable specific to that phase. The results for this model specification are compared to those of the continuous distance specification in the sensitivity analysis.

[15] Alternatively, two successive bands of 2.5 km (i.e., 0-2.5 km; 2.5-5 km) can be specified, which would increase the numbers of observations within the bands. However, this alternate band specification does not change the nature of the results.

We also examine for the effects of turbine density in the sensitivity analysis. With 133 turbines constructed across the Melancthon wind farm, the disamenity effect may depend not only on proximity to and visibility of the nearest turbine but also on the number of turbines within the viewshed. Thus, a turbine density variable is created to account for the existence of multiple turbines in close proximity to properties. To create this variable, the total number of turbines is calculated within a specific radius of each property. Two separate specifications of this variable are created: one with a 2-km radius (*Density 2 km*) and one with a 5-km radius (*Density 5 km*) in which density effects are measured. The maximum number of turbines within 2 (5) kilometres is 24 (91) for rural residential properties and 17 (60) for farm properties. This approach follows that of Boxall et al (2005), which examined the effects of the density of sour gas wells on nearby property values.

Other Hedonic Covariates

In addition to the turbine variables, there are three other categories of variables (i.e., property, location, and time) that are included in the models to account for differences in sale prices across rural residential and farm properties (see Table 4). Many of these variables are consistent with those used in other hedonic property value studies. Due to differences between rural residential properties and farm properties in the importance of various attributes that contribute to value, the sets of variables included in the two models differ to some degree. While the description below covers all variables included in both models, differences between the sets of variables included in the models are evident in Table 4, where summary statistics are provided only for the variables included in each model.

The property variables include attributes of houses that account for differences in property values, such as square footage, the numbers of bathrooms and fireplaces, the existence of features such as a pool and air conditioning, and a house quality index (on a scale of 0-10). Other property variables include the size of the property in acres, the numbers of acres of Class 1 land, Class 2 land, and wooded area, the existence of water and sewer services, and the value of any secondary structures (e.g., barns, sheds, and garages) on the property.

The location variables account for urban and amenity influences in the surrounding area. Amenity variables include a categorical variable that accounts for the abutment of the property to commercial properties. The influence of urban areas on property values are accounted for by the distances to the nearest city with population greater than 10,000 and to the nearest highway interchange, in kilometres. The distance variables were generated using GIS software. Spatial fixed effects, which have received attention in recent hedonic studies as a means of reducing omitted variable bias associated with unobserved local factors (Kuminoff et al 2010), are accounted for through a set of categorical variables for the 11 townships (with one omitted from the models) represented in the datasets.

The time variables account for changes in property values over time as well as for seasonal influences. To capture these influences, sets of year and month categorical variables are included in the models, with the year 2002 and the month of January omitted.

Summary statistics in Table 4 indicate average sale prices of $287,432.20 for rural residential properties and $353,647.40 for farm properties. The average size of farm properties is 78.91 acres, while the average rural residential property size is 6.14 acres.

RESULTS

Three separate hedonic models are analyzed for both rural residential properties and farm properties, the results of which are provided in Table 5 and Table 6, respectively. These models differ in the variable accounting for turbine impacts, with these impacts accounted for by proximity of the property to the nearest turbine in Model 1 (measured as inverse distance), by visibility of the nearest turbine in Model 2 (measured based on a rating scale of 0-3), and by proximity, visibility, and an interaction of these variables in Model 3. With the disamenity effects of turbines assumed to be increasing with visibility rating as well as distance-decaying (hence, increasing with inverse distance), the coefficient for each variable representing turbine impacts is expected to be negative. However, these anticipated outcomes are not observed for either rural residential properties or farm properties, as the estimated coefficients are not statistically significant, and, in many cases, not negative. It may be the case that the relatively low number of observations in close proximity to turbines contributed to the relatively large standard errors and resulting lack of statistical significance. Hence, within the limitations of the data and estimation methods, significant price effects of the wind turbines in Melancthon Township on surrounding properties are not found. To address some of these limitations and their potential influence on the results, the robustness of the results of Model 1 is examined across a number of alternate model specifications, which include the use of alternate post-turbine periods, distance bands, spatial models, repeat sales models, and turbine density variables.[16] Each of these alternate specifications is discussed below, following a brief overview of the results of the property, location, and time variables.

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[16] Only the robustness of the results of Model 1 is described in the sensitivity analysis, as alternate specifications of Models 2 and 3 provide very similar results to those of Model 1.

The results for the remaining variables are consistent across the three models for each property type. The directions of the effects on price for the property and location variables coincide with expectations, with most coefficients being statistically significant. The lack of significance in the remaining coefficients may be due to correlation among variables. The possibility of correlated variables raises the issue of multicollinearity, which may affect the validity of the estimates. An examination of the variance inflation factors (VIFs) for these variables did not indicate any with a VIF greater than 10, which would have been cause for concern (Gujarati 1995).

The results of the fixed effects variables indicate considerable variation in prices across townships for both property types, which may account for the influence of spatially varying omitted variables. The time variables indicate that prices for both property types generally increased from year to year, while seasonal differences are found for rural residential properties where prices in the last few months of the year are significantly higher than prices early in the year.[17]

Sensitivity Analysis

To account for a number of issues and limitations inherent in the approach used in our primary analysis, we examine several alternate model specifications. The results for each specification are compared to those of Model 1 for rural residential properties in Table 7 and for farm properties in Table 8.[18]

[17] In the interest of space, the results for the fixed effects variables and sets of year and month variables are not included in the tables of results. They are available from the authors upon request.
[18] Only the results of the turbine variables are shown in these tables. The results for all other variables are consistent with those of the Model 1.

Given that the assumption imposed regarding the dates that the turbine effects began to arise – July 2005 for Phase I; March 2008 for Phase II – may be somewhat limiting, two alternate post-turbine period specifications are examined. First, pre-construction dates are specified as the points in time at which the effects began to occur: November 2004 for Phase I; October 2007 for Phase II. These dates coincide with project approval (Phase I) and with completion of ancillary activities (Phase II). Second, post-construction dates are specified: February 2006 for Phase I; November 2008 for Phase II. These dates coincide with the completion of turbine construction for the respective phases of the wind farm. The results of the models based on these alternate specifications are displayed in columns 2 (Pre-Construction) and 3 (Post-Construction) of Tables 7 and 8. The results are found to be similar to those of the primary model for both rural residential properties and for farm properties, where no significant effects are observed. This suggests that the lack of significant disamenity effects observed in the primary models is not an artifact of the imposed assumptions for the specifications of the post-turbine periods.

As an alternative to the continuous specification of the proximity variable, a discrete set of distance bands is used to account for the disamenity effects, where variables are specified to account for properties sold in the post-turbine period within bands of 0-1, 1-3, and 3-5 kilometres from the nearest turbine. With the assumed distance-decaying nature of the turbine disamenity effects, the coefficients for the distance band disamenity variables are expected to be negative, with declining magnitudes with distance from the nearest turbine. However, as with the primary models, no significant disamenity effects are observed across the distance bands for either rural residential or farm properties (see column 4 of Tables 7 and 8).

The next component of the sensitivity analysis examines the issue of spatial autocorrelation, which can often arise in hedonic property value models. The results of Moran's *I* tests indicate evidence of spatial autocorrelation in the data for both rural residential sales (I = 0.0723; $p < 0.0001$) and farmland sales (I = 0.0893; $p < 0.0001$). This issue can be accounted for through either a spatial lag model or a spatial error model, depending on the nature of the spatial correlation (see Anselin 1988). Lagrange multiplier (LM) tests can be used to determine which model is most appropriate (Brueckner 1998). Comparisons of the LM statistics for the spatial lag model (rural residential: 1,309.3336; farms: 163.2084) and the spatial error model (rural residential: 393.3383; farms: 95.3762) suggest that the spatial lag model would be more appropriate for addressing this issue for both sets of data.[19] This model is estimated separately for each property type using spatial autoregressive (SAR) models. Building on the hedonic model in equation (1), the SAR model is specified as:

$$P_j = P_j W\rho + x_{ij}\beta_i + T_j\delta + \varepsilon_j, \qquad (2)$$

where ρ is the spatial correlation parameter and W is an n x n spatial weight matrix. This matrix is created based on an inverse distance specification, following a commonly used specification in the spatial econometric literature (Bell and Bockstael 2000), particularly for studies using micro-level data with non-contiguous observations (Bell and Irwin 2002). In this case, a cutoff distance of 5 kilometres is imposed, such that the weight is equal to 1/distance between the two properties if the distance is less than 5 km and zero otherwise.[20]

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[19] However, the results are found to be consistent across both the spatial lag and the spatial error models.

[20] Due to uncertainty that typically exists regarding appropriate specification of the spatial weight matrix, Bell and Dalton (2007) note that sensitivity analyses are often conducted across alternate forms of this matrix. Accordingly, we examined the sensitivity of the results under an alternate spatial weight matrix in which the specification is based on the 10 nearest neighbours (e.g., Pace et al 2000). Further sensitivity analysis was conducted for each specification of *W* by adjusting the cut-off distance and the number of nearest neighbours. In each case, the results were not sensitive to changes in *W*.

The results of the SAR models (column 5 of Tables 7 and 8) are similar to those of the primary models, where no significant effects of turbines are found. Thus, the existence of spatial autocorrelation does not appear to affect the nature of the results. This is not entirely surprising, given the fact that, as noted in Heintzelman and Tuttle (2012), incorporating spatial fixed effects can be analogous to the use of a spatial lag model for addressing issues arising from spatial autocorrelation. Hence, the use of spatial fixed effects in our primary models may reduce the possibility of biased estimates and, subsequently, eliminate the need to account for this bias through a spatial lag model.

The existence of properties in our datasets that sold more than once during the study period permits a repeat sales analysis, from which the estimated disamenity effects can be compared with those of the full sample models. This analysis allows us to implement fixed effects at the parcel level rather than the township level, which may better control for omitted variable bias, and to examine the sensitivity of the results to an alternate geographic scale of fixed effects. The results of the repeat sales models, based on 2,008 sales of rural residential properties (935 properties) and 292 sales of farm properties (141 properties), are similar to those of the full sample models, where no statistically significant effects of turbines on property values are found (see column 6 of Tables 7 and 8).[21] Similarity of results between full sample models and repeat sales models has previously been demonstrated in related hedonic studies on the effects of wind turbines (Hoen et al 2009; Heintzelman and Tuttle 2012). However, while supportive of our primary results, the results of the repeat sales analysis should be viewed with considerable caution, as the lack of significance may be due in part to limited observations in close proximity to turbines. For example, among rural residential (farm) properties, there are 43

[21] These results also hold for repeat sales models based on the other three specifications of the disamenity effects used in the primary analysis. Further, restricting the repeat sales sample to properties that sold both before and after the turbines were constructed (1,150 rural residential sales; 160 farm sales) produces similar results.

(8) properties sold in the post-turbine period within 5 kilometres of the nearest turbine, of which only 10 (2) are within 1 kilometre. Hence, these numbers of observations are likely too few to detect significant effects, which represents a major limitation of this analysis.

While our primary analysis focuses on disamenity effects associated with proximity to or visibility of the nearest wind turbine, this approach ignores the possibility of disamenity effects arising from the existence of multiple turbines. With 133 turbines constructed within a relatively localized area in Melancthon Township, properties in this area may be in close proximity to multiple turbines. To determine whether the number of surrounding turbines affects sale prices, turbine density variables are specified to account for the numbers of turbines within 2 km and within 5 km of each property. These density variables are incorporated into the hedonic models as an alternate approach to the specification of the turbine disamenity – i.e., in place of the proximity and visibility variables. The results of the models for each density specification (columns 7 and 8 of Tables 7 and 8) indicate no significant impacts of turbine density on rural residential or farm property values within either of these distances. Specifically, an increase in the number of turbines in close proximity to a property is not found to negatively impact its value.

In summary, the sensitivity analysis examines the robustness of our primary results across several alternate model specifications. The results across all components of the sensitivity analysis are consistent with those of our primary models, where no significant disamenity effects are found.

CONCLUSION

In response to concerns raised by residents of Melancthon Township regarding potential effects of surrounding wind turbines on property values and to a lack of consensus in the related body of literature, this paper estimates the impacts of the Melancthon wind farm on nearby rural residential and farm property values. This paper adds to the growing body of literature on the effects of wind turbines by utilizing a hedonic approach, which has not been frequently used in related studies (we are aware of only three peer-reviewed studies: Sims and Dent 2007; Sims et al 2008; Heintzelman and Tuttle 2012), to estimate the disamenity effects of turbines on property values using both proximity to turbines and turbine visibility to account for these effects. In addition, this paper permits the comparison of effects across rural residential properties and farm properties, the latter of which has received little attention in the literature.

The analysis discussed above allows us to address our primary research question: Have the wind turbines in Melancthon Township affected surrounding property values? The empirical results generated by the hedonic models, using three different measures to account for disamenity effects, suggest that these turbines have not impacted the value of surrounding properties. Further, the nature of the results, which indicate a lack of significant effects, is similar across both rural residential properties and farm properties. Thus, the anticipated greater effect on rural residential properties – due to the greater amenity value derived from the surrounding landscape – is not found to occur. After conducting extensive sensitivity analysis to test the robustness of the primary model results, these results are found to be consistent across a number of alternate model specifications.

However, while the results indicate a general lack of significantly negative effects across the properties examined in this study, this does not preclude any negative effects from occurring on individual properties. In fact, a recent appraiser's report on the impacts of Melancthon's wind turbines (Lansink 2012) found that the values of five specific properties in close proximity to turbines declined by up to 59%. While the set of properties examined in this study may not be representative of all open-market sales in close proximity to the turbines (the five properties in question were each purchased by Canadian Hydro Developers and resold after turbines had been constructed[22]), it provides evidence that values of specific properties may be negatively impacted, which supports the claims made by a number of local residents.[23] Indeed, the existence of relatively large standard errors for some of the turbine disamenity variables suggests that some properties may have experienced negative impacts from proximity to turbines. Thus, the results of our study cannot refute the claim that values of some nearby properties have been impacted by wind turbines; however, they do suggest that such impacts may not occur to the same degree across all open-market sales of similarly situated properties (although this finding may be limited by the relatively low frequency of such sales). Similarly, Hoen et al (2009) noted that while significant effects were not found across the large set of properties examined, the possibility of negative impacts on individual properties could not be dismissed.

The results discussed above are similar to those of other prior studies on the effects of wind turbines on property values, particularly those utilizing hedonic regressions (Hoen 2006; Sims and Dent 2007; Sims et al 2008). However, these results differ to some degree from those of the recent hedonic study by Heintzelman and Tuttle (2012), which found evidence of significantly negative impacts of turbines on surrounding property values. But the results of this study were mixed, as significantly negative impacts were only observed in two of three counties

[22] Our dataset includes four of these properties but only two of the sales by Canadian Hydro Developers in the post-turbine period (the other sales occurred after the study period of our analysis). However, the presence of these two post-turbine sales of rural residential properties, for which the nearest turbines are 200 and 800 metres away, does not appear to influence our results (i.e., cause estimated impacts to be significantly negative). To provide some context, our rural residential dataset also includes 18 other post-turbine period observations within 800 metres of turbines.

[23] In fact, such appraisal evidence may be used in litigation as the basis for claims of property value loss.

examined, while only limited significance was observed among impacts across a set of distance bands specified based on proximity to turbines. Hence, these results do not differ entirely from our results. Heintzelman and Tuttle (2012) suggested that the variation in their results across counties may have arisen due to heterogeneity in consumer preferences across counties. Similarly, this factor may have contributed to the differences that exist between their results and our results. These differences may also stem from similarities between Melancthon Township and the county in which no significant impacts were found by Heintzelman and Tuttle (2012). For example, the population density of this county, which was lowest among the three counties, is very close to that of Melancthon Township. Perhaps negative impacts are more likely to occur in more densely populated areas, where a relatively greater number of properties may be affected. It may also be the case that impacts of wind farms vary across Ontario in a similar manner to the regional variation observed by Heintzelman and Tuttle (2012). Thus, the possibility remains that significant impacts may be observed in other areas of the province with wind turbines. Future research could explore this possibility.

Based on our results and on those of related studies outlined in Table 1, it is evident that, with the exception of the study by Heintzelman and Tuttle (2012), findings of negative impacts of turbines are more likely to occur for studies using surveys than for studies based on actual sales data. While surveys have indicated that residents often perceive that the existence of wind turbines within their viewshed will reduce the value of their property, such perceptions have not often been corroborated by analyses of sales data, perhaps due in part to data limitations with respect to sales in close proximity to turbines.

The existence of limitations in the analysis undertaken in this paper should not be overlooked. The results generated above are based on values of properties that have been sold.

However, properties for which the value may be negatively impacted by turbines may not have been sold. For example, in the event that a property's value is substantially reduced as a result of disamenities associated with nearby turbines, the owner may be unwilling (or unable) to sell at a loss. On a related note, as previously discussed, the relatively low number of sales of properties in close proximity to turbines and with visibility ratings greater than zero represents another potential limitation, as this may reduce the likelihood of finding significant impacts.

The information that can be derived from the results of this paper is of applied importance given the ongoing expansion of the wind energy industry in North America and corollary concerns raised by local residents regarding disamenity effects. Indeed, a perusal of articles in the popular press over the past few years related to wind turbine development in Ontario indicates significant concerns associated with not only the resulting viewshed but also with health impacts, both of which could impact property values. Thus, the lack of significant effects of the Melancthon wind farm is somewhat surprising, given the public outcry regarding the construction of these turbines.

These results also have application for related issues with municipal property tax assessments, as a number of property owners in close proximity to wind farms in Ontario have appealed their assessment on the basis of claims of negative impacts on the value of their property from surrounding wind turbines. However, a recent decision by Ontario's Assessment Review Board ruled against property owners that had made such an appeal, citing a lack of evidence of adverse impacts on property value.

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Table 1. Overview of selected literature related to wind farms and property value effects

Author (date)	Property type	Extent of effect measured	Method	Findings
Heintzelman and Tuttle (2012)	Residential	0 to 10 miles	Hedonic regression	Negative effects on property values found in two of three areas studied
Hoen et al (2009)	Residential	0 to 10 miles	Hedonic regression	No conclusive evidence of effects
Sims et al (2008)	Residential	0.5 to 1 mile	Hedonic regression	No significant effects observed
Sims and Dent (2007)	Residential	0.5 to 4 miles	Hedonic regression	No impact on property values
Hoen (2006)	Residential	Within 1 mile; within 5 miles	Hedonic regression	Inconclusive
Rayner (2007)	Residential	Pre-construction	Price comparison	No impact on property values
Poletti (2007)	Residential & Agricultural	Target area: turbines visible	Price comparison	No significant effects
Poletti (2005)	Residential	Target area: turbines visible	Price comparison	Inconclusive
Sterzinger et al (2003)	Residential	0 to 5 miles	Price trend comparison	No impact on property values
Krueger et al (2011)	Residential	0.9 to 9 miles	Choice experiments valuation	Costs of visual disamenity decrease with distance of turbines from shore
Ladenburg and Dubgaard (2007)	Residential	8 to 50 km	Choice experiments valuation	Residents willing to pay to site turbines at greater distances from shore
Groothuis et al (2008)	Residential	Turbines within viewshed	Survey; contingent valuation	Majority believe views are harmed; require compensation for turbines in viewshed
Haughton et al (2004)	Residential	Turbines visible offshore	Survey; contingent valuation	Opinion that view is worse; decrease in property values
Khatri (2004)	Residential & Agricultural	Wind farm is visible	Survey of chartered surveyors	Residential values decreased; no impact on farms
Sustainable Energy Ireland (2003)	Residential	Turbines visible; 5 km	Survey of attitudes to local wind farms	Little evidence of a NIMBY effect; majority view wind farms favourably
Grover (2002)	Residential	Variable – 2 miles to 25 miles	Survey of tax assessors	No impact on property assessments
Thayer and Freeman (1987)	Residential	Wind farm is visible	Survey of attitudes and impressions	Neutral or negative reaction to appearance

Table 2. Numbers and percentages of sales in the post-turbine period (3 specifications) within specified distance ranges of turbines

Distance from Nearest Turbine	Rural Residential Properties						Farm Properties					
	Base Model		Pre-Construction		Post-Construction		Base Model		Pre-Construction		Post-Construction	
	#	%	#	%	#	%	#	%	#	%	#	%
0 to 1 km	23	0.42	30	0.55	18	0.33	8	0.50	9	0.57	6	0.38
1 to 2 km	11	0.20	13	0.24	7	0.13	4	0.25	4	0.25	2	0.13
2 to 3 km	17	0.31	19	0.35	10	0.18	7	0.44	11	0.69	4	0.25
3 to 4 km	23	0.42	28	0.52	21	0.39	10	0.63	11	0.69	6	0.38
4 to 5 km	29	0.54	33	0.61	23	0.42	11	0.69	17	1.07	9	0.57
Total	103	1.90	123	2.27	79	1.46	40	2.52	52	3.27	27	1.70

Note: Percentages represent numbers as a proportion of the total sample.

Table 3. Numbers and percentages of sales in the post-turbine period (3 specifications) with each visibility rating

Visibility Rating	Rural Residential Properties						Farm Properties					
	Base Model		Pre-Construction		Post-Construction		Base Model		Pre-Construction		Post-Construction	
	#	%	#	%	#	%	#	%	#	%	#	%
1	9	0.17	12	0.22	10	0.18	3	0.19	4	0.25	4	0.25
2	19	0.35	21	0.39	13	0.24	13	0.82	15	0.94	6	0.38
3	33	0.61	41	0.76	26	0.48	16	1.01	20	1.26	11	0.69

Note: Percentages represent numbers as a proportion of the total sample.

Table 4. Description and summary statistics of variables included in the hedonic models

Variable	Description	Rural Residential Properties		Farm Properties	
		Mean	Std. Dev.	Mean	Std. Dev.
Dependent Variable					
Sale price	Sale price of property ($)	287,432.20	177,151.90	353,647.40	243,045.00
Property Variables					
Lot size	Size of property (acres)	6.1390	15.1026	78.9084	41.7261
Square footage	Total floor area of the house (square feet)	1,690.0160	679.8157	1,429.5930	1,092.5450
Bathrooms	Number of bathrooms	1.7529	0.7501	1.1330	0.9635
Fireplaces	Number of fireplaces	0.4941	0.6526	0.2484	0.5513
Pool	= 1 if pool exists on property	0.0573	0.2324		
Air	= 1 if house is air conditioned	0.2152	0.4110		
Quality	House quality index (0-10)	6.1231	0.7145		
Building value	Value of all secondary buildings on the property ($)	15,112.9700	19,881.0900	31,271.5100	51,229.0200
Water/sewer	= 1 if water and sewer services exist on property			0.7874	0.4093
Class 1 land	Total area of Class 1 land (acres)			12.4418	27.1218
Class 2 land	Total area of Class 2 land (acres)			34.8607	34.0552
Wooded area	Total wooded area (acres)			8.4696	15.5694
Location Variables					
Commercial	= 1 if property abuts a commercial property	0.0216	0.1454		
Highway	Distance to nearest highway interchange (km)	51.6053	20.2351		
City	Distance to the nearest city (km)	21.7040	14.1423	26.3604	14.3842
Adjala	= 1 if property is in the township of Adjala-Tosorontio	0.1745	0.3796	0.0692	0.2538
Amaranth	= 1 if property is in the township of Amaranth	0.0643	0.2453	0.0698	0.2549
Clearview	= 1 if property is in the township of Clearview	0.1655	0.3717	0.1358	0.3427
East Garafraxa	= 1 if property is in the township of East Garafraxa	0.0425	0.2017	0.0491	0.2161
East Luther	= 1 if property is in the township of East Luther Grand Valley	0.0153	0.1229	0.0308	0.1729
Grey Highlands	= 1 if property is in the township of Grey Highlands	0.1376	0.3445	0.1767	0.3816
Melancthon	= 1 if property is in the township of Melancthon	0.0600	0.2376	0.0667	0.2495
Mono	= 1 if property is in the township of Mono	0.1047	0.3062	0.0673	0.2506
Mulmur	= 1 if property is in the township of Mulmur	0.0687	0.2530	0.0503	0.2187
Southgate	= 1 if property is in the township of Southgate	0.0539	0.2259	0.1528	0.3599
Wellington	= 1 if property is in the township of Wellington North	0.1129	0.3164	0.1314	0.3380

Table 4. Description and summary statistics of variables included in the hedonic models (cont'd)

Variable	Description	Rural Residential Properties		Farm Properties	
		Mean	Std. Dev.	Mean	Std. Dev.
Time Variables					
Y2002	= 1 if property sold in the year 2002	0.1337	0.3404	0.1616	0.3682
Y2003	= 1 if property sold in the year 2003	0.1431	0.3503	0.1616	0.3682
Y2004	= 1 if property sold in the year 2004	0.1304	0.3368	0.1629	0.3694
Y2005	= 1 if property sold in the year 2005	0.1328	0.3394	0.1447	0.3519
Y2006	= 1 if property sold in the year 2006	0.1169	0.3214	0.1132	0.3169
Y2007	= 1 if property sold in the year 2007	0.1356	0.3424	0.1044	0.3059
Y2008	= 1 if property sold in the year 2008	0.0964	0.2952	0.1327	0.3394
Y2009	= 1 if property sold in the year 2009	0.0996	0.2994	0.0189	0.1361
Y2010	= 1 if property sold in the year 2010	0.0115	0.1064		
January	= 1 if property sold in the month of January	0.0467	0.2111	0.0535	0.2250
February	= 1 if property sold in the month of February	0.0408	0.1979	0.0459	0.2094
March	= 1 if property sold in the month of March	0.0587	0.2352	0.0673	0.2506
April	= 1 if property sold in the month of April	0.0739	0.2616	0.1088	0.3115
May	= 1 if property sold in the month of May	0.0888	0.2845	0.1013	0.3018
June	= 1 if property sold in the month of June	0.1084	0.3109	0.1063	0.3083
July	= 1 if property sold in the month of July	0.1114	0.3146	0.0786	0.2692
August	= 1 if property sold in the month of August	0.1226	0.3281	0.0836	0.2769
September	= 1 if property sold in the month of September	0.0896	0.2856	0.0887	0.2844
October	= 1 if property sold in the month of October	0.1007	0.3009	0.1038	0.3051
November	= 1 if property sold in the month of November	0.0839	0.2772	0.0950	0.2933
December	= 1 if property sold in the month of December	0.0630	0.2430	0.0673	0.2506

Table 5. Estimated coefficients for the hedonic models for rural residential properties

Variable	Model 1			Model 2			Model 3		
	Coefficient		Std Err	Coefficient		Std Err	Coefficient		Std Err
Turbine Variables									
Proximity	0.0165		0.0187				0.1782		0.1480
Visibility				-0.0092		0.0141	-0.0241		0.0191
Proximity*Visibility							-0.0455		0.0488
Property Variables									
ln(Lot size)	0.1348	***	0.0070	0.1349	***	0.0070	0.1348	***	0.0070
ln(Square footage)	0.2794	***	0.0224	0.2787	***	0.0224	0.2795	***	0.0224
Bathrooms	0.0093		0.0111	0.0094		0.0111	0.0095		0.0111
Fireplaces	0.0598	***	0.0096	0.0596	***	0.0096	0.0599	***	0.0096
Pool	0.0704	**	0.0277	0.0702	**	0.0277	0.0703	**	0.0276
Air	0.0173		0.0157	0.0171		0.0157	0.0172		0.0157
Quality	0.1381	***	0.0130	0.1382	***	0.0130	0.1378	***	0.0130
ln(Building value)	0.0075	***	0.0018	0.0075	***	0.0018	0.0075	***	0.0018
Location Variables									
Commercial	-0.1007	***	0.0362	-0.1008	***	0.0362	-0.1010	***	0.0362
ln(Highway)	-0.0620	*	0.0362	-0.0611	*	0.0362	-0.0627	*	0.0363
ln(City)	-0.0671	***	0.0085	-0.0670	***	0.0085	-0.0674	***	0.0085
Constant	9.2178	***	0.2389	9.2166	***	0.2389	9.2229	***	0.2393
R-squared	0.5654			0.5654			0.5656		
Number of Sales	5,414			5,414			5,414		

Note: Asterisks (***, **, *) indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 6. Estimated coefficients for the hedonic models for farm properties

Variable	Model 1			Model 2			Model 3		
	Coefficient		Std Err	Coefficient		Std Err	Coefficient		Std Err
Turbine Variables									
Proximity	0.0113		0.0668				-0.7543		0.4600
Visibility				0.0246		0.0246	0.0202		0.0319
Proximity*Visibility							0.2478		0.1558
Property Variables									
ln(Lot size)	0.2742	***	0.0262	0.2743	***	0.0262	0.2738	***	0.0262
ln(Square footage)	0.0366	***	0.0087	0.0365	***	0.0087	0.0363	***	0.0086
Bathrooms	0.0945	***	0.0250	0.0944	***	0.0250	0.0936	***	0.0250
Fireplaces	0.0868	***	0.0247	0.0871	***	0.0248	0.0883	***	0.0248
ln(Building value)	0.0174	***	0.0043	0.0175	***	0.0043	0.0174	***	0.0042
Water/sewer	0.0975	**	0.0493	0.0984	**	0.0494	0.0988	**	0.0493
Class 1 land	0.0035	***	0.0005	0.0035	***	0.0005	0.0035	***	0.0005
Class 2 land	0.0015	***	0.0004	0.0015	***	0.0004	0.0015	***	0.0004
Wooded area	-0.0010		0.0007	-0.0010		0.0007	-0.0009		0.0007
Location Variables									
ln(City)	-0.1327	***	0.0271	-0.1338	***	0.0271	-0.1326	***	0.0272
Constant	10.8291	***	0.1389	10.8328	***	0.1389	10.8220	***	0.1393
R-squared	0.6116			0.6117			0.6127		
Number of Sales	1,590			1,590			1,590		

Note: Asterisks (***, **, *) indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 7. Comparison of the coefficients for the turbine variables across alternate model specifications for rural residential properties (standard errors in parentheses)

	1	2	3	4	5	6	7	8
Turbine	Primary	Alternate Post-Turbine Periods		Distance Band	SAR Model	Repeat Sales	Turbine Density	
Variable	Model	Pre-Constr.	Post-Constr.	Specification			2 km	5 km
Proximity	0.0165	-0.0274	0.0058		0.0150	0.0300		
	(0.0187)	(0.0335)	(0.0192)		(0.0158)	(0.1046)		
Band 0-1 km				0.0390				
				(0.0442)				
Band 1-3 km				-0.0501				
				(0.0478)				
Band 3-5 km				-0.0452				
				(0.0513)				
Density 2 km							0.0044	
							(0.0032)	
Density 5 km								0.0001
								(0.0008)
R-squared	0.5654	0.5655	0.5654	0.5655	0.5901	0.8098	0.5655	0.5654

Note: Asterisks (***, **, *) indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 8. Comparison of the coefficients for the turbine variables across alternate model specifications for farm properties (standard errors in parentheses)

Turbine Variable	1 Primary Model	2 Alternate Post-Turbine Periods Pre-Constr.	3 Post-Constr.	4 Distance Band Specification	5 SAR Model	6 Repeat Sales	7 Turbine Density 2 km	8 5 km
Proximity	0.0113	0.0183	0.0006		0.0318	-0.6112		
	(0.0668)	(0.0504)	(0.0812)		(0.0620)	(0.5570)		
Band 0-1 km				-0.0579				
				(0.1144)				
Band 1-3 km				0.0694				
				(0.0921)				
Band 3-5 km				-0.1366				
				(0.1401)				
Density 2 km							0.0019	
							(0.0092)	
Density 5 km								0.0008
								(0.0023)
R-squared	0.6116	0.6116	0.6116	0.6122	0.6315	0.9398	0.6116	0.6116

Note: Asterisks (***, **, *) indicate statistical significance at the 1%, 5%, and 10% levels, respectively.