Wind Turbines Impact on Housing Prices: Why is there Scholarly Disagreement?

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Abstract

There have been a significant number of papers written about whether or not wind turbines negatively effect nearby property prices. Interestingly, these papers do not come to a consensus as to whether wind turbines negatively impact property prices. I completed a mini meta-analysis and determined that differing ways to account for the visibility of the turbines drives whether a study has a significant result. I concluded that utilizing a binary variable to account for visibility influences whether a study finds a significant result.

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Introduction

In recent years the use of wind power as a source of energy has greatly increased. As of 2016 the installed global capacity had reached 487 gig watts. Wind is an attractive energy source because it is clean energy, and it can be harnessed in many places throughout the world. Consequently, many more wind turbines have been built throughout the United States and around the world. Unfortunately, the construction of a wind farm oftentimes angers nearby residents.

There is a common public perception that wind turbines negatively effect nearby property prices. For example, in September of 2016 there was public outcry Hopkinton New York concerning the announcement of the North Ridge Wind Farm project (Lewis). Residents were outraged because they believed that the wind farm would lower property prices. This widely held public belief has spurred economists to investigate the subject.

Early papers on the subject could not find statistically significant evidence that wind turbines impacted property prices. As technology allowed scholars to run more relevant regressions the number of papers increased, and some people found significant results. However, some still found no evidence of any impact. This has lead to a lack of consensus on whether wind turbines do effect nearby property prices. In this paper I attempt to explain why there is a lack of agreement.

My paper is a watered down meta-analysis that uses data visualization to analyze why different papers concerning wind turbines find different results. After analyzing 15 different hedonic studies on wind turbines I concluded that how a study accounts for visibility influences whether the study obtains a statistically significant result. Studies that use a binary variable to account for visibility obtained significant results, while most papers that accounted for visibility in a different way had no significant results. I use data visualization to illustrate this result and also to examine other differences in variables and methodology.

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Lit review

The main methodology for examining the impact of wind turbines on property prices is a hedonic study, but there are other methods. One such method is a survey-based study. These surveys often target both residents who could be impacted by the wind farm and real estate agents. Haughton et al. (2004) conduct a study of 546 real estate agents and residents to investigate the effect of a proposed offshore wind farm in the Nantucket Sound. The study found that both realtors and residents believe the wind farm would adversely affect housing prices. This result makes sense because of the public perception of wind farms. Since, many people believe that wind farms hurt housing prices, a survey would display those beliefs. Consequently, I do not think a survey study is the best way to evaluate the impact of wind turbines on property prices.

When people first became interested in the possible adverse effects of wind farms there was very little existing research. This led to interested parties turning to property value studies of high voltage transmission lines (HVTL), and attempting to make a benefit transfer to wind farms. There was plenty of literature on HVTL, and it was a conceivable notion that their impact would be similar to wind turbines. Des-Rossiers (2002) finds that any adverse effect from HVTL disappeared after 500 feet. Des-Rossiers concludes "other physical as well as neighborhood attributes prevail [over proximity to HVTL] in the price determination process." (p. 277) Although comparing wind turbines to HVTL made have made sense at the time, these papers do not really offer any insight on the effect of wind farms. Wind turbines are very different from HVTL. Since wind is a renewable and clean resource there is a symbolic meaning attached to a wind turbine may attract people who are environmentally conscious. Also, many people are unfamiliar with the sight of wind turbines, which could increase the perceived adverse impact. These differences make it difficult to make any meaningful assumptions based the HVTL benefit transfer papers.

As technology made it easier to obtain information on houses and viewsheds from properties, more scholars used hedonic studies. Hedonic studies have become the premier methodology for papers assessing the effects of wind turbines on housing prices. However, there are still other methodologies used that produce interesting results. Ladenburg and Dubgaard (2007) conduct a willingness to pay study, in which they calculate the willingness to pay for offshore wind turbines to not be built. They find that households would pay 46 euros per year to have the turbines be 12 kilometers away, 96 euros per year for them to be 18 kilometers away, and 122 euros per year to be 50 kilometers away. The results are interesting, but again since it is a survey model it just shows the public perception, rather than actually displaying the effect on property prices.

The shortcomings and rarity of the other literature concerning wind turbines and housing prices led to me focusing exclusively on hedonic models. The studies I have chosen have built upon each other as time has gone on. Consequently, they have similar characteristics that make them ripe for a comparison.

Methodology

Since this paper could be considered a watered down meta- analysis, my methodology was to collect from the literature on wind turbines effect on housing prices. In order to have a sense of uniformity amongst the studies I chose to only analyze hedonic studies. By only using hedonic studies, I am able to look at other factors that could contribute to differing results. Moreover, it would have been difficult to compare the results of a hedonic study and a survey study, since their methodologies are so different.

To visualize the differing aspects of each study, I create a dataset that laid out the variables of each study, where the study took place, how many observations were in the study, and whether the study found significant results. I then look for any trends in this data and use data visualization to further understand the data. This leads to some interesting results, which help explain why these seemingly similar studies obtain different results.

Data

My data illustrates that these papers have lack of agreement on this issue because 7 papers say that wind turbines have a negative impact on nearby housing prices, while 8 say there is no significant effect. These papers come

from all over the world. In fact, 8 come from the United States, and 7 come from foreign countries. The variables in these studies can differ as well. 12 out of the 15 papers use a variable that measures distance, but only 10 of these papers has a variable that independently accounts for visibility. Of those 10 papers, 5 of them use binary measurement for visibility, while 5 use a ranking system. The number of observations varies from 201 to 122,000.

Heinzelmann and Tuttle (2012) apply a Hedonic study with a fixed effects framework to the counties of Clinton, Franklin, and Lewis in upstate New York. They have 11,331 observations, and they use inverse distance to measure distance of houses from the turbines. They also establish distance zones that broke the homes into groups based on how close they are to the turbines in each county. They do not have an independent variable accounting for the visibility of the turbines, stating that visibility impact would be captured by proximity to the turbines. Heinzelmann and Tuttle do find significant evidence that proximity to wind turbines negatively effects housing prices in the counties of Clinton and Franklin. Their results seem to be driven by the strong effect that occurred on homes within a half-mile and a mile of turbines. Hoen, Brown, Jackson Wiser, Thayer, and Cappers (2013) take a slight issue with this paper because they felt that Heintzelmann and Tuttle did not have enough observations within a half-mile and a mile of the turbines and that could have skewed their results. In a working paper, Hoen, Brown, Jackson Wiser, Thayer, and Cappers (2013) conduct a spatial process difference in difference hedonic analysis that encompasses 27 counties in 9 states with 50000 observations. The high number of observations gave them more data on homes within a mile of turbines. They have a variable to measure for distance from the turbines, but do not have a variable for visual impact. They include models that exclusively focus on homes within 1 mile and within a half mile of turbines. Like Hoen's previous working papers, they do not find any significant evidence that housing prices are negatively impacted by close proximity to wind turbines.

In a working paper Hoen, Wiser, Cappers, Thayer and Sethi (2009) conduct a hedonic study in 9 states with 7500 observations that did not find any significant for a negative impact of housing prices. In this paper they have a variable to account for distance, and a variable to account for visibility. They use a ranking system to measure visibility. Observations were ranked from no view, minor view, moderate view, substantial view, and extreme view. Vyn and McCullough (2014) use a point system that Hoen (2006) first utilized in their hedonic study concerning a wind farm in Ontario, Canada. In this point system an observation is assigned 1 point if a turbine is visible from the property, 2 points if the hub is fully visible, and 3 points if the entire vertical span is visible. Vyn and McCullough (2014) obtained 7004 observations, but do not find any evidence that nearby homes were negatively effected. These studies both focus on rural regions; however there are studies that look at more densely populated regions.

In a working paper Atkinson-Polambo and Hoen (2014) look at homes in close proximity to wind farms throughout Massachusetts. Massachusetts is a very densely populated state, which differs from many previous studies. They have a binary variable accounting for distance that indicates whether the property is with a half-mile of a turbine. They assert that any visibility effects will be captured by their distance variable. With 122,000 observations Atkinson-Polambo and Hoen do not find an evidence of a negative impact. Lang, Opaluch and Sfinarolakis (2014) also conducted a study that focuses on a densely populated region, Rhode Island. In this hedonic difference in difference study they account for distance and create distance bands. They also have a visibility variable that divides visibility into 5 categories. The categories are no visibility, minor, moderate, high, and extreme. With 48,544 observations Lang, Opaluch and Sfinarolakis do not find significant evidence of a negative effect on housing prices.

Ben Hoen has shown a tendency during his career to not find any significant evidence for the negative effects of wind turbines on properties' prices. In a working paper Hoen (2006) found no significant evidence of a negative impact in his 280 observations in Madison County New York. He accounted for both distance and visibility. He measures visibility by creating a point system that assigned 1 point if a turbine is visible from the property, 2 points if the hub is fully visible, and 3 points if the entire vertical span is visible. Hoen claims to have visited every property in the study to determine the proper visibility point value. O'Hara and Evans (2015) also perform a study in Madison County New York, however they do find evidence for effect on housing prices. They use inverse distance to measure distance, and they determine visibility by using viewsheds. Viewsheds are constructed by using GIS software that takes into account the contours of the land to indicate whether the turbines would be visible from a property. The GIS software does not account for trees or other objects that could be blocking a house from seeing the turbines. Despite this shortcoming, viewsheds are a good way to calculate visibility because it eliminates subjectivity, and does not require a personal visit. To account for visibility they use a binary

variable, which indicates whether a turbine can be seen from the property. These studies exemplify the lack of consensus amongst scholars, when it comes to the impact of wind turbines.

One interesting fact about this data is the studies that took place outside of the United States are more likely to find a negative impact. Two foreign papers were conducted in the United Kingdom. Sims, Dent and Oskrochi (2008) conduct a hedonic study in Cornwall, in a neighborhood that used to be housing for Americans stationed at a nearby air force base. They account for both distance and visibility. They measure visibility on a scale of 1 to 4 for both the front and the rear of the house. 1 indicated a partial view of a turbine, 2 noted a complete view of one turbine and a partial view of another, 3 meant that there is a complete view of two turbines, and 4 indicated a complete view of 3 or more. With 201 observations they do not find any significant evidence that housing prices were negatively impacted by proximity to the wind farm. Gibbons (2015) completes a hedonic study throughout England and Wales that found significant evidence that housing prices are negatively affected by wind turbines. Gibbons uses variables to account for both distance and visibility. Visibility is given a binary variable that indicates whether or not a turbine is visible from the property. They determined whether a turbine was visible from the property by utilizing viewsheds.

Sunak and Madlener did two studies in Germany in which they find a negative impact. In the first study Sunak and Madlener (2015) use a spatial hedonic study, in which they account for both distance and visibility. Visibility is measured through viewsheds, and a binary variable is used to indicate whether or not a turbine is visible from the property. They have 1,405 observations in the cities of Rheine and Neunkirchen. In their second paper Sunak and Madlener (2016) look at the effects throughout Germany, obtaining 2141 observations. In this paper they have a variable for just visibility, but visibility is not a binary variable. Instead visibility is broken up into 6 different levels of prominence. They found that asking prices fell from 9%-14% for properties whose view was substantially or extremely impacted by wind turbines.

Two other foreign papers that both find significant evidence of the adverse effects of wind turbines on property are Droes and Koester (2014), and Jensen, Panduro, and Lundhede (2014). Droes and Koester (2014) do a hedonic difference in difference study in the Netherlands in which they obtain 90,000 observations. They have a variable for distance, but did not have an independent variable for visibility. A unique feature of this paper is that Droes and Koester individualize the impact of each turbine. They find that house prices within 2 kilometers of a turbine decrease by 1.4%- 2.3%. Jensen, Panduro and Lundhede (2014) complete a hedonic study in Denmark. They do not have a distance variable; instead they just look exclusively at properties within 2500 meters of a turbine. They do have a binary visibility variable, and were also the only study to have a variable accounting for the noise caused by the turbines. Although they do not have an individual variable for distance, they do multiply their viewshed variable by distance. They find significant negative effects for the visibility and noise variables, but do not find a significant effect when multiplying viewshed by distance.

One paper that slightly differed from the rest in terms of methodology was Laposa and Mueller (2010). This paper is about a wind farm on Maxwell Ranch in Northern Colorado. They do not have a variable that independently accounts for distance or visibility. Instead, they just look at homes in the adjacent homeowner's association, properties in the census tract of the ranch that are not included in a homeowner's association, and the census tract that is west of the Maxwell Ranch census tract. With 2910 observations they do not find any statistical evidence that the wind farm impacted housing prices.

Below, I have included two refined dateset. The first table shows the study, the result, and what type of variables each study used. The second table shows the study and what variables each study found significant. I also included some tables that summarize my data. For the tables concerning variable significance, 1 means the variable is significant, while 0 indicates that it is not significant.

Study	Year	Result	Distance	Visibility	Binary
Hentzelman and Tuttle Clinton	2012	Yes	Yes	No	
Hoen, Brown, Jackson Wiser, Thayer, and Cappers	2013	No	Yes	No	
Hoen, Wiser, Cappers, Thayer and Sethi	2009	No	Yes	Yes	No
Atkinson-Polambo, Hoen	2014	No	Yes	No	

Study	Year	Result	Distance	Visibility	Binary
Lang, Opaluch and Sfinarolakis	2014	No	Yes	Yes	No
Sims, Dent and Oskrochi	2008	No	Yes	Yes	No
Gibbons	2015	Yes	Yes	Yes	Yes
Sunak and Madlener	2016	Yes	No	Yes	No
Droes and Koster	2014	Yes	Yes	No	
Vyn and McCullough	2014	No	Yes	Yes	No
Sunak and Madlener 2	2015	Yes	Yes	Yes	Yes
O' Hara and Evans	2015	Yes	Yes	Yes	Yes
Jensen, Panduro, and Lundhede	2014	Yes	No	Yes	Yes
Laposa and Mueller	2010	No	No	No	
Hoen	2006	No	Yes	Yes	No
Hentzelman and Tuttle Franklin	2012	Yes	Yes	No	
Hentzelman and Tuttle Lewis	2012	Yes	Yes	No	

Study	Year	Vis.Significant	Dis.Significant
Hentzelman and Tuttle Clinton	2012	NA	1
Hoen, Brown, Jackson Wiser, Thayer, and Cappers	2013	NA	0
Hoen, Wiser, Cappers, Thayer and Sethi	2009	0	0
Atkinson-Polambo, Hoen	2014	NA	0
Lang, Opaluch and Sfinarolakis	2014	0	0
Sims, Dent and Oskrochi	2008	0	0
Gibbons	2015	1	1
Sunak and Madlener	2016	1	NA
Droes and Koster	2014	NA	1
Vyn and McCullough	2014	0	0
Sunak and Madlener 2	2015	1	1
O' Hara and Evans	2015	1	1
Jensen, Panduro, and Lundhede	2014	1	NA
Laposa and Mueller	2010	NA	NA
Hoen	2006	0	0
Hentzelman and Tuttle Franklin	2012	NA	1
Hentzelman and Tuttle Lewis	2012	NA	0

Country	n
Canada	1
Denmark	1
Germany	2
Netherlands	1
UK	2
USA	8

Binary	n	Binary.Visibility
	5	
No	6	No
Yes	4	Yes

Visibility	n
No	5
Yes	10

Distance	n
No	3
Yes	12

Result	n
No	8
Yes	7

Vis.Significant	n
0	5
1	5
NA	5

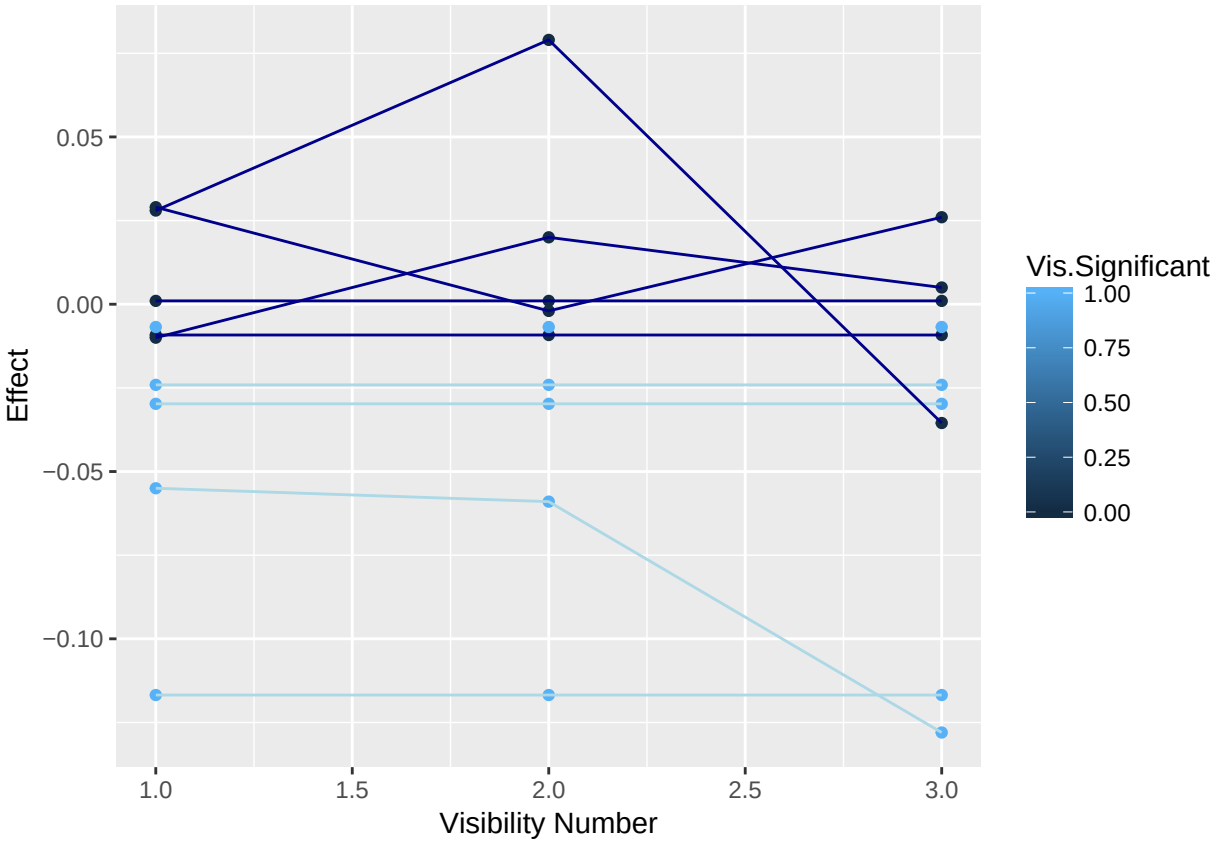
Dis.Significant	n
0	7
1	5
NA	3

Results

After initially being puzzled as to what variable could be driving these results, I realized a trend. Every study with a binary variable has a significant result, as shown in the table below. Moreover, only one study that utilizes a ranking system for the visibility variable has a significant result. These results are also shown in the graph. To visualize these results I created the line graph below. In this graph I utilize a 3-point ranking system for the studies that have a ranking system for their visibility variable. For the studies with the 5 rankings of visibility, including none, I equaled the minor view to 1 point, the moderate view to 2 points, and averaged the high and extreme view for the 3-point value. I took the average of the high and extreme values because there were a relatively small number of observations in the extreme range, and I wanted to include the substantial view values. For Sunak and Madlener (2016) I average the marginal and minor rankings together for the 1 point values, take the moderate ranking for the 2 point value, and average the substantial and extreme rankings for the 3 point value. For Sims, Dent, and Oskrochi (2008) I use the rear view measurements because only 2 scores had observations for the front view. The rear view had values for rankings 2, 3 and 4. Consequently, I assign the 2 ranking to the 1-point value in graph, the coefficient of 3 to 2, and the coefficient of 4 to 3. In the graph the dark blue lines indicate the studies do not find their visibility measurements significant. The light blue lines represent the studies that have a significant result for their visibility variable.

Study	Binary	Result
Gibbons	Yes	Yes
Sunak and Madlener 2	Yes	Yes
O' Hara and Evans	Yes	Yes

Study	Binary	Result
Jensen, Panduro, and Lundhede	Yes	Yes



The graph illustrates the success of binary variables. The studies, which take on the same value for all three-visibility rankings, are the ones that utilize a binary ranking. Every one of these studies is represented by a light blue line, which displays that they all find a significant impact. On the graph it appears that two studies with insignificant results takes the same value for every visibility ranking. However, this only occurs because all of the results from Hoen (2009) and Sims, Dent and Osrochi (2008) were so small that is difficult to show they actually had different values for each ranking. The only study without a binary variable that is shown to be significant is Sunak and Madlener (2016). Although on the graph the whole line is light blue, they only found significant effects for properties where the turbines were substantially visible and extremely visible, or the 3-point ranking in my graph. The difference in visibility measurement appears to be the only driver of differing results in these studies.

Out of the five studies that used a ranking or point system to measure distance, only Sunak and Madlener (2016) obtained significant evidence from there distance variable. On the surface this seems strange because visibility and distance are two separate variables and they should not influence each other. A possible answer to this scenario is that both variables are picking up the same effect. This makes sense because a ranking system for visibility would most likely mean that the houses in the lower tiers of the visibility rankings would be a greater distance from the turbines. Conversely, the houses closer to the turbines would have a higher visibility score. This means that the visibility variables would just be another way of measuring proximity. This explanation is not perfect though because there could be houses within a mile of the turbines that do not have a view of them because of other objects or the contours of the land, or houses that are 2 miles away that have complete view of multiple turbines. Despite these shortcomings, this explanation can at least partially explain why these studies do not find significant evidence for either variable.

The twelve studies that had a variable for distance accounted for it in similar ways. Any differences in how distance was measured did not appear to influence whether the study obtained a significant result. Each study

that measured distance had either just a singular variable for distance, such as inverse distance, or they had both the singular variable and distance bands. Neither methodology seemed to influence whether or not the authors find a significant result. Instead the area in which the study is conducted could drive differing distance results. For example people in a certain region may be more environmentally conscious and therefore amenable towards wind turbines. Also, the wind farm could be designed in such a way that it is hidden from nearby residences. Further investigation would be required to determine why results vary even when similar distance variables are used. The only two studies that conflict with this explanation are Hoen (2006) and O'Hara and Evans (2015) because they are both studying Madison County, New York. Hoen (2006) uses a singular measurement for distance, while O'Hara and Evans (2015) break distance up into bands. This should not cause different results because according to other studies such as Sunak and Madlener (2015), and Hentzelman and Tuttle (2012). If the distance bands are significant, then the singular measure can also be significant. Consequently, there must be some other difference in how the authors of each study developed their regressions. Since, Hoen has never found a significant result in any of his working papers, it is fair to wonder if bias is showing up in his papers.

It is intriguing that a visibility ranking system impacts whether one obtains a significant result, while breaking the distance variable up into distance bands does not appear to influence the results. On the surface these may seem like similar methods to account for these variables, but there is an important difference. A visibility ranking requires one to make a subjective choice about the ranking, while distance bands do not require a subjective choice. This subjectivity could influence results, especially if the author has an agenda or any pre-conceived notions about wind farms. This difference can help explain why a visibility ranking discourages significant results, while distance bands do not influence whether the result will be significant.

One interesting finding is that studies that took place outside of the United States were much more likely to find a significant negative result. Out of the seven studies that discovered a significant negative impact five took place outside the United States, which is shown in the table below. This data may be skewed because I have four papers from the same author, Ben Hoen. As stated before, his methodologies have proven to be more likely to find no significant negative impact of wind turbines.

The amount of observations does not have any apparent impact as to whether a study has significant results.

Study	USA	Result
Sims, Dent and Oskrochi	No	No
Gibbons	No	Yes
Sunak and Madlener	No	Yes
Droes and Koster	No	Yes
Vyn and McCullough	No	No
Sunak and Madlener 2	No	Yes
Jensen, Panduro, and Lundhede	No	Yes

Conclusion

In this analysis I succeed in finding one possible explanation for why these papers fail to reach a consensus. The use of a binary variable to measure visibility drove significant results in the studies I examined. By using a ranking system one could be hiding the impact of houses with an extreme view because there are so few observations in that ranking, which makes finding a significant result difficult. This means that even if those houses show a negative impact, like in Lang, Opaluch and Sfinarolakis (2014), the lack of observations make it difficult to achieve significance. It would be interesting to see those houses interact with the observations with different visibility scores. This could lead to a significant result. The best way to cause this interaction is to use a binary variable. The ranking systems also may be capturing the same effect of the distance variable because in most cases visibility decreases as distance increases. Another issue with the point system is that determining an individual house's ranking requires a subjective choice. This subjectivity means that personal bias could be an issue, leading to a bias result and conclusion. Also, there is the more problematic issue that an author could be using this ranking system to achieve a desired result. The majority of scholars would not knowingly use a ranking system to manipulate results, but someone who as an agenda to promote wind energy may be tempted.

My paper indicates that the public perception that wind turbines negatively effect nearby housing prices could be correct. To verify this perception more studies need to be conducted in which visibility is measured with a binary variable. With more studies the public should be able to understand the complete impact of wind turbines. Unfortunately, my paper shows that it is quite possible that a clean energy source does have negative externalities, which could slow down its development in the future.

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