The Winds of Change: How Wind Energy Impacts Local Economies in Iowa

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ABSTRACT

As renewable energy has become less costly over time, chiefly since the mid-2000s, the wind energy industry has been expanding rapidly. This is especially true in Iowa, which has become a leading producer of wind energy in the United States. Most wind farms are built in rural communities, and many people rely on them for employment and income, but studies examining the effects on an economy-wide scale have been mixed. This paper seeks to determine how much the wind energy industry affects economies on a county-level scale in Iowa. Panel data was collected including the number of wind turbines in a county and annual retail sales from 1995 to 2019. Regressions were run with and without using wind speed as an instrument for the number of turbines. The results indicate that the presence of wind turbines in a county has a small, but positive, impact on the amount of retail sales in the county. This would suggest that wind energy not only benefits the environment but also the community.

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INTRODUCTION

Iowa is one of the leading producers of wind energy in the United States. In 2019, 42% of the state's electricity was generated by wind, the highest share of any state (American Wind Energy Association, 2019). Furthermore, Iowa's wind sector provided between 9,000 and 10,000 direct wind energy jobs in 2018 (American Wind Energy Association, 2020). Because wind energy capacity began to grow significantly in the mid-2000s, it has often been attributed as a means of softening the blows of economic recession. Indeed, wind energy can provide a reliable source of income for landowners and creates both temporary construction and long-term maintenance jobs. As wind energy technology becomes more affordable, turbines are being installed at an increasing rate. While job creation and tax revenue have often been cited as economic advantages of the wind energy industry, it would be interesting to see how else the growth of this industry could affect local economies at the county level (U.S. Department of Energy, 2015). Are other community members seeing the same benefits as those directly employed by the industry?

This paper will attempt to determine whether the addition of wind turbines to an Iowa community has a significant positive or negative effect on the local economy as well as estimate the magnitude of that effect. This topic is relevant as the wind energy industry continues to grow in Iowa and in other states. The paper is organized as follows. The next section reviews the prior literature on the economic impact of wind energy. The third section describes the county-level data set to be analyzed. The fourth section illustrates the methodologies used in the regressions. The fifth section describes the results of those regressions. The sixth section concludes.

LITERATURE REVIEW

This study is not the first that has examined the impacts of the wind energy industry at the county level. The various economic impacts of the wind energy industry have been a topic of research since the technology first began to develop. As wind energy has become increasingly common both in the U.S. and around the world over the last few decades, more papers examining its impact are being published. However, since wind energy is still a burgeoning industry, much of the research has mixed results. More studies need to be done to explore its long-term effects. The following is an overview of recent published literature regarding the local economic impacts of wind energy.

Brown et al. (2012) examined several of the potential economic benefits of wind energy often touted by policymakers and the industry's supporters. It was the first published research to take an ex post approach to analyze these impacts. The authors looked at claims that the wind industry would increase employment and personal income, among others. They found that each megawatt of installed capacity would result in a median increase of total county personal income by 0.22% and employment by 0.4% for U.S. counties generating wind power in the years 2000-2008. The authors also hypothesize that these effects could spill over into the local economy in other ways, such as through increased indirect demand for concrete and hardware during the construction phase, increased local government revenues from property taxes, and increased spending by local residents and governments from these additional sources of income.

Hartley et al. (2015) also looked at how the wind energy industry impacted employment on a county scale, but the authors compared this impact to that of shale gas, using panel data of Texas counties. They ran a finite distributed lag model, an autoregressive distributed lag model, and a spatial panel model to account for various lengths of time in which effects might occur. While the authors found that shale-related activities created between 25,000 and 125,000 net jobs in Texas in the years 2001-2011, they were unable to find significant numbers for the wind industry. As for wages, it was found that each megawatt of installed capacity increased local wages in all industries by 17 cents after a year, when the effect peaked. Given that the average Texas wind farm is 100 MW, that would only be a $17 average wage increase, a much smaller increase than that which was found by Brown et al. (2012).

Zerrahn (2017) looked at both these studies, among others, in order to perform a meta-analysis of wind power's externalities. Zerrahn looks at a number of claims made by both wind energy proponents and opponents about its effects on climate change, wildlife, noise, health, and economies. While evidence for the industry's economic impact on the local scale has remained mixed, such as was seen in the two studies discussed previously, Zerrahn finds some indications for positive economic effects at the macro (national or international) scale. Zerrahn also finds that substantial job creation from wind power in Europe is largely found in the manufacturing sector. Taking into account international trade and offsetting effects, many studies in Germany have found positive net effects on GDP, employment, and wages.

Ultimately, the local economic effects of wind energy have had varied results, with opposing papers finding either significant positive effects or little to no effect at all. In the least, it can be said that there is no evidence of economic harm from the wind energy industry. This paper will seek to further explore these local economic effects at the county level.

Theoretically, we would expect some kind of economic impact from the growth of the wind energy industry in a community. It would provide an extra source of income for landowners who allow turbines to be built on their land. Turbines would also provide temporary work in their construction and long-run work in their maintenance. If these jobs went to local residents and the extra income was spent in the community, the community would benefit economically. We know that some people, like landowners and those directly employed by the wind industry stand to gain from the addition of turbines to a community, but how much does this impact the rest of the community? How much of that extra money from wind power is percolating in the communities who host wind turbines?

DATA

To start examining these questions, data was gathered on the number of wind turbines per county as well as retail sales value as a measure of economic activity. Wind speed was used as an instrument for turbines. Other factors like land use (rural vs. urban) and population were also considered as controls.

Retail sales data are available from the Iowa Department of Revenue sales tax database at the county and town level. County wind speed data was accessed through USA.com, a publication of World Media Group, LLC. USA.com is a database of information for cities, towns, and neighborhoods in the United States. The database included the average wind speed in miles per hour for each Iowa county, but it did not include a time span for when that data was gathered. However, average wind speed does not vary much year-over-year, so the same values were used for every year in the dataset. Land use data came from the 1997, 2002, 2007, 2012, and 2017 Censuses of the USDA National Agricultural Statistics Service, which provides data on the percentage of land in a county being used for agriculture. Population data for 2010-2019 came from the US Census Bureau and the American Community Survey, while data before 2010 came from Iowa State University's Iowa Community Indicators Program.

The most difficult data to find was information on the number of wind turbines in a county over time. The Federal Aviation Administration (FAA) keeps a log of obstacles - objects, such as wind turbines, which are so tall as to interfere with planes and drones - called the Digital Obstacle File (DOF), which is updated every 56 days. Using this file, the coordinate location of every current wind turbine in Iowa was determined and placed in a county. These coordinates were cross-reference with data from the United States Wind Turbine Database (USWTDB) in order to create a timeline of wind farms being installed in Iowa.

This data will be well-suited to the research question, which is examining the effects of the wind energy industry on local economies. Retail sales were chosen as an economic indicator because it is a good measure of general economic activity in the community. Sales for retail stores should increase if general economic activity increases. The number of wind turbines in a county were used as a measure of presence of the wind energy industry. Counties with more turbines would be producing more wind power.

This data would be considered panel data because it is being used in a differences-in-differences analysis of wind energy. The same 99 Iowa counties are being observed as they change over time. The units of observation would be those 99 counties each year.

In order to get a picture of how rural a county was, its farmland area was compared to the total area of the county. To do this, the area of the county in square miles was multiplied by 640 to find the area in acres. Then, the total acreage of farmland was divided by the area of the county in acres to find the percentage of the county engaged in agriculture, a variable which was labelled rural. In order to examine the effects of the volume of wind turbines on the percentage change in retail sales, the natural logarithm of retail sales was used in the regression. This is because the addition of wind turbines to a community would presumably have a different magnitude of impact relative to the size of the community's economy. Therefore, the natural logarithm of population was also used because a percentage increase in population would have a corresponding percentage increase in retail sales.

All of the data is relatively easy to find and publicly accessible. Table 1 shows a brief list of relevant variables and their definitions. The main variables of interest are the number of wind turbines per county and the value of retail sales per county. Table 2 summarizes the data. Information on turbines was taken as the number of online turbines by the end of the calendar year. The county with the highest number of turbines had 511 in the year 2020, while some counties still do not have any turbines; these will make good controls. There are less values for rurality because the survey from which the data was gathered was only held every 5 years. The results in Table 2 show these values after they were linearly interpolated. The most rural county employed 99.8% of its land toward agriculture, while the least rural employed 53.1% of its land toward agriculture. There was much greater variation in retail sales values, with Polk County having the highest value of retail sales in 2019. There are also slightly fewer observations for retail sales because the data only went as far back as 1998, whereas wind turbine data was collected back to 1995.

Table 1: Variable Definitions

Variable	Definition	Formula
Population	The population of a county	
Sales	The value of taxable retail sales in a county	
Turbines	The number of wind turbines in operation in a county	
Rural	The percentage of a county engaged in agriculture	Farmland/area in acres
Wind Speed	The average wind speed in a county	

SOURCES: American Community Survey, 2010-2018; Iowa Department of Revenue, 1998-2019; United States Wind Turbine Database, March 2020; USDA NASS Census of Agriculture, 2017; USA.com

Table 2: Descriptive Statistics

	Number of observations	Mean	Standard deviation	Minimum	Maximum
Turbines	2,475	18.19	50.61	0	511
Retail Sales (in millions)	2,178	329	1.83	19.7	8,790
Population	2,475	30,379	51,203	3645	487,204
Rural	2,079	0.863	0.092	0.531	0.998
Wind Speed	2,478	17.96	1.83	13.98	22.45

SOURCES: American Community Survey, 2010-2018; Iowa Department of Revenue, 1998-2019; United States Wind Turbine Database, March 2020; USDA NASS Census of Agriculture, 2017; USA.com

METHODOLOGY

The regressions used to investigate the information in the data section estimate the following equation:

$$ln(sales) = \beta_0 + \beta_1 turbines + \beta_2 ln(population) + \beta_3 year + \beta_4 rural + \varepsilon$$

The outcome variable is the amount of retail sales in a county, and this is being used as a measure of economic activity. The treatment variable is the number of wind turbines in a county. Controls include population size and land use (rurality) as well as the year in order to account for normal economic changes over time.

The method of instrumental variables was used with wind speed as an instrument for turbines in order to correct for possible selection bias. Wind speed would affect the decision to install wind turbines in a county; windier counties would have the most to gain from installing turbines, so they may install more. However, it is hard to imagine wind speed affecting retail sales in any other way. It is as good as randomly assigned because wind speed has no bias between counties. Groups of counties with high and low wind speeds are still likely to have similar demographics, economies, and other characteristics.

The natural logarithm of the sales data was used in the regression so that the coefficient in front of turbines would represent how much impact a one turbine increase in a county would have on the percent of retail sales in that county. This is consistent with other analyses of the economic effects of wind energy (see Brown, et al., 2012). While it may be interesting or useful to know the dollar amount that a wind turbine would add to a county, when the regression was run with linear values, the results were inconsistent and did not make sense. For instance, the coefficient for the effect of population was found to be negative, when one would expect that a higher population would result in a higher value of retail sales. These issues were fixed by taking the natural logarithm of both retail sales and population.

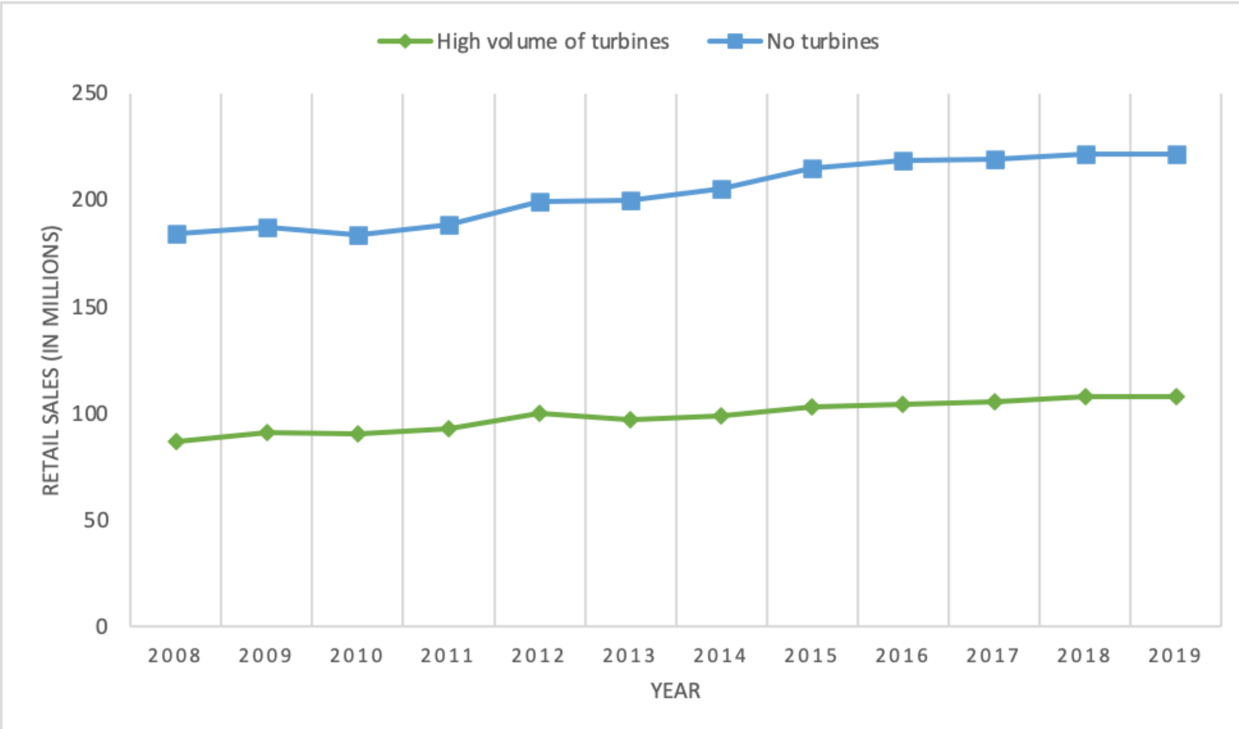
The coefficient β_1 represents the effect of one additional wind turbine on the percent change of retail sales in a county. This represents the effect of the wind energy industry on local economies that we are searching for.

Because most of the regressions are using panel data with a difference-in difference analysis, they effectively control for initial differences between counties. We can assume that a treatment county (a county with wind turbines) would follow the same general trend as a control county (a county without any turbines) had it not built any wind farms. Thus, any differences in trends can be attributed to the addition of wind farms. In regressions with random effects, omitted variables are assumed to be uncorrelated with the observed variables, so there may be omitted variable bias in these models. Nevertheless, random effects had to be used when wind speed was used as an instrument because the average wind speed data did not change over time.

There may be a risk of selection bias in that counties who have the most to gain from wind energy would build the most turbines. Wind speed was added as an instrument to control for this by accounting for the windiest counties possibly installing more wind turbines. However, there may be other factors that were not considered that would encourage a county to install wind turbines. For example, some counties have individual ordinances either encouraging or discouraging the growth of the wind energy industry. This was excluded from the data because these ordinances are hard to quantify in a way that can be generalized across all the units of observation, but they might contribute to the differences between counties in how many wind turbines are built.

Figure 1 shows the value of retail sales over time in counties that consistently added large numbers of wind turbines in this time period (more than 50 by 2010 and more than 100 by 2017) along with those who didn’t have any wind turbines by 2019. It is important to understand that counties with no turbines tend to have larger populations, and thus larger volumes of retail sales initially. The meaningful value here would be to see if there is any difference in the slopes of these lines, to see if those counties with higher numbers of turbines are growing at a faster rate than those with no turbines. Looking at the year 2010, for example, we can see that counties with no turbines take a dip in retail sales, while counties with high levels of turbines take a much smaller dip.

Figure 1: Average Retail Sales Per Year Among Counties with High Amounts of Turbines vs. Counties with No Turbines



SOURCES: Iowa Department of Revenue, 2008-2019; United States Wind Turbine Database, accessed March 2020

RESULTS

The regressions discussed above yielded the following results, shown in Table 3. Table 3 gives estimates for the effect of wind turbines on county retail sales along with different control variables and methods of regression. The ideal regression would use fixed effects and include wind speed as an instrument, but the data that had been gathered for wind speed did not vary over time, so it had to be dropped from the fixed effects regression. Instead, both a fixed effects regression and a random effects regression that included the instrument were run.

Table 3: Estimates of the Effect of Wind Turbines on Log of Retail Sales

	(1)	(2)	(3)	(4)	(5)
Turbines	0.001*	0.0001	0.0003*	0.006	0.007
	(0.0001)	(0.0001)	(0.0001)	(0.005)	(0.006)
Year		0.019*	0.020*	0.005	0.004
		(0.002)	(0.001)	(0.013)	(0.014)
Log Population			1.109*	1.338*	1.325*
			(0.361)	(0.062)	(0.039)
Rural					-0.245
					(0.556)
Overall R-square	0.0002	0.0106	0.9344	0.8787	0.8792
Number of observations	2,178	2,178	2,178	2,178	1,980

NOTES: Columns 1-3 show a panel regression with fixed effects. Columns 4-5 show a panel regression with random effects and using the method of instrumental variables with wind speed as an instrument. Dependent variable is log sales. Data include years from 1995 – 2019. Standard errors robust to heteroskedasticity are shown in parentheses. Asterisks (*) show significance with 95% confidence.

Nearly all of the estimates show that wind turbines have small, but positive, effect on retail sales. The coefficients for wind turbines would indicate that the addition of one wind turbine in a county would increase retail sales by 0.03-0.1%. Wind turbines are usually built in large numbers though, so we can extrapolate that number to determine that the addition of a 100-turbine wind farm would increase retail sales by about 3-10%, which is not as small as it first appeared. However, the estimate which gave the 0.1% value was that which did not include any of the control variables, so it should be taken with a grain of salt. That regression also showed a very low R-squared value, indicating that the model is not a very good fit for the data.

Column (3) of Table 3 shows a panel regression with fixed effects including the controls of the year and natural logarithm of population. This regression is the only one that shows significant effects at the 95% level for both the independent variable (turbines) and all the controls, as well as having the highest R-squared value. This model seems to be the best fit for the data. Although the regression shown in Column (4) uses the same variables as the one in Column (3), it uses random effects with the instrumental variable method, whereas the regression in Column (3) uses fixed effects and no instrumental variable.

Of course, the population of the county had the largest effect on retail sales in every regression in which it was included. The coefficients for this variable show that 1% increase in population would lead to about a 1.2% increase in retail sales. All of the signs of the coefficients make sense; we would expect increased population to cause an increase in retail sales, and we would also expect increased value of sales over time, partly because the data did not account for inflation and partly for general economic development. We would also expect the more rural a county is, the less retail sales it would have too. As a reminder, the rural variable has to do with land use, not necessarily population density.

CONCLUSIONS

This study set out to explore how the wind energy industry impacts local economies on a county level in Iowa. A number of regressions were run to determine this by using panel data from all 99 Iowa counties from the years 1995-2019 while controlling for population, year, and rurality. Wind speed was used as an instrument to account for the possibility of the windiest counties installing more wind turbines. The ideal regression would've had both this instrument and fixed effects, but the data did not allow for that. Instead, we must make conclusions from the data that are available.

The estimates given by the regressions suggest that wind farms have a small, but positive effect on local retail sales. The best-fitting model indicates that the addition of one turbine to a county increases the value of retail sales by an average of 0.03%. Thus, the addition of 100 turbines would increase retail sales by 3%. However, wind turbines must be built in large numbers in order to play an effective role, so the actual impact may increase with more turbines added or decrease with lower numbers of turbines. Additionally, there are many Iowa wind farms that span the borders between counties, and it is also possible that a wind farm in one county may employ workers in the adjacent county. Finally, wind power development in one community may affect employment and income in nearby communities. These effects were not controlled for in this study, so the actual impact of wind turbines may differ from the estimated values seen in the regressions.

The mechanism of this observed increase remains to be seen. Perhaps the extra income earned by landowners who allow for turbines and those directly employed by the wind energy industry is being spent in the local community. Perhaps citizens are saving money on energy bills and thus have more to spend on retail goods. Perhaps there is an element of tourism, as Zerrahn (2017) found, that is bringing more visitors to these counties. Or perhaps there is another mechanism whereby wind turbines increase local retail spending. More research needs to be done in this area.

The policy implications of these findings depend on a number of factors. We can conclude that wind farms provide a small economic benefit to local communities, but this must be weighed against any external benefits or harms that wind farms may bring. Local policymakers should consider not only economic factors, but also the environmental, health, noise, and wildlife impacts of wind turbine installation. Zerrahn (2017) suggests that many factors, like the impact of climate change, remain subject to uncertainties and other factors, like landscape aesthetics, may differ regionally and culturally.

There are still further questions that remain unanswered and deserve to be researched. This study looked at data from Iowa counties from 1995 to 2019. As wind energy technology continues to become more affordable and wind farms are being constructed at increasing rates, will the magnitude of its impact change over time? Is the impact similar in other states and communities? Are the positive economic and environmental benefits sufficient to outweigh the negative externalities to wildlife as found by Zerrahn (2017)? Finally, how will climate change affect these economic outcomes?

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APPENDIX A – Data Descriptions

The American Wind Energy Association (AWEA) provides wind energy fact sheets for each state in the U.S. The Iowa Fact Sheet was accessed on 9 April 2020 in order to gather the most up-to-date information about Iowa's wind energy production. The AWEA also releases quarterly market reports; the public version of the third quarterly market report was also accessed on 9 April 2020 in order to see how Iowa compares to the rest of the United States regarding employment in the wind energy industry. Both of these sources are available as PDF files on awea.org as of April 2020.

Retail sales data at the county level for Iowa is released annually to the public by the Iowa Department of Revenue and is available via tax.iowa.gov. The data spans the years 1998-2019 as of April 2020, so these were the years included in the dataset. The reports from 2011-2019 were available to download as an Excel spreadsheet, so the retail sales values were copied into a Stata file. The previous years' reports were only available as PDF files, so the values from these reports had to be manually entered into the Stata file.

County wind speed data was accessed through USA.com, a publication of World Media Group, LLC. USA.com is a database of information for cities, towns, and neighborhoods in the United States. The data was gathered on 9 March 2020 from a page titled "Iowa Average Wind Speed County Rank," but no dates were provided for when this average was taken. Since there was no available annual information on average wind speeds by county and given that wind speed doesn't vary much year-over-year, these values were used for every year in the dataset and were manually entered into the Stata file.

In order to get a sense of how rural a county was, the total acreage of farmland was divided by the total area in acres of the county. These values came from the 2007, 2012, and 2017 Censuses of the USDA National Agricultural Statistics Service, accessed through nass.usda.gov on 16 April 2020. The historical archive, used for the reports from 2002 and 1997, was accessed via agcensus.mannlib.cornell.edu on the same date. These values were manually entered into the Stata file. Because these values were only given every 5 years, they were linearly interpolated for the Stata model.

Population data for 2010-2019 came from the US Census Bureau and the American Community Survey (ACS), accessed through data.census.gov in March 2020. The data were taken from ACS 5-year Estimates Data Profiles for each individual county. These values were manually entered into the Stata file. Meanwhile, data from before 2010 came from Iowa State University's Iowa Community Indicators Program and were also accessed in March 2020 via icip.iastate.edu. This data was downloaded in spreadsheet form and copied into the Stata file.

The analysis required a comprehensive set of data that describes the status of wind turbines in the state of Iowa. The data were compiled from a number of different sources and used in a complementary way to build a timeline of wind turbine growth in the state. First, the Federal Aviation Administration provides a Digital Obstacle File (DOF) which is updated every 56 days and maintains a comprehensive list of all known obstacles of interest to aviation users in the United States, including the latitude and longitude coordinates of every wind turbine that is used for power generation. The DOF for the state of Iowa was downloaded via FAA.gov on 9 March 2020; at the time, it contained data accurate to the date of 23 February 2020. The data were copied into a spreadsheet and filtered to find all the obstacles labeled "windmill" included in the DOF.

Second, the United States Wind Turbine Database (USWTDB), created by the United States Geological Survey (USGS) in collaboration with the American Wind Energy Association (AWEA) and Lawrence Berkeley National Laboratory (LBNL), combines a 2014 USGS data set with a 2017 LBNL data set and includes regular updates from the AWEA as well as the FAA's DOF. The database includes a digital map of all locations of land-based and offshore wind projects in the United States, corresponding project information, and turbine technical specification. The map was accessed via eerscmap.usgs.gov throughout 9-13 March 2020 in order to cross-reference the data from the DOF. A spreadsheet was created to keep track of the coordinates of every turbine, which county those coordinates were a part of, and when each wind project was installed. This was used to create a timeline of the installation of wind turbines for each county. Any data which were not included in both databases were excluded from this dataset. The number of turbines in a given county each year was taken as the number of turbines that were located in that county and had gone online on or before 31 December of that year. These values were then manually entered into the Stata file.

Data and Stata code used to compute the estimates are available from the author on request.