

## Commercial Wind Turbines and Residential Home Values: New Evidence from the Universe of Land-Based Wind Projects in the United States

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LBNL Release Webinar  
December 13, 2023

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*This work was funded by the U.S. Department of Energy Wind Energy Technologies Office , under Contract No. DE-AC02-05CH11231.*



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## Background and Methodology



# Why Study Wind Energy and Nearby Property Values Again?

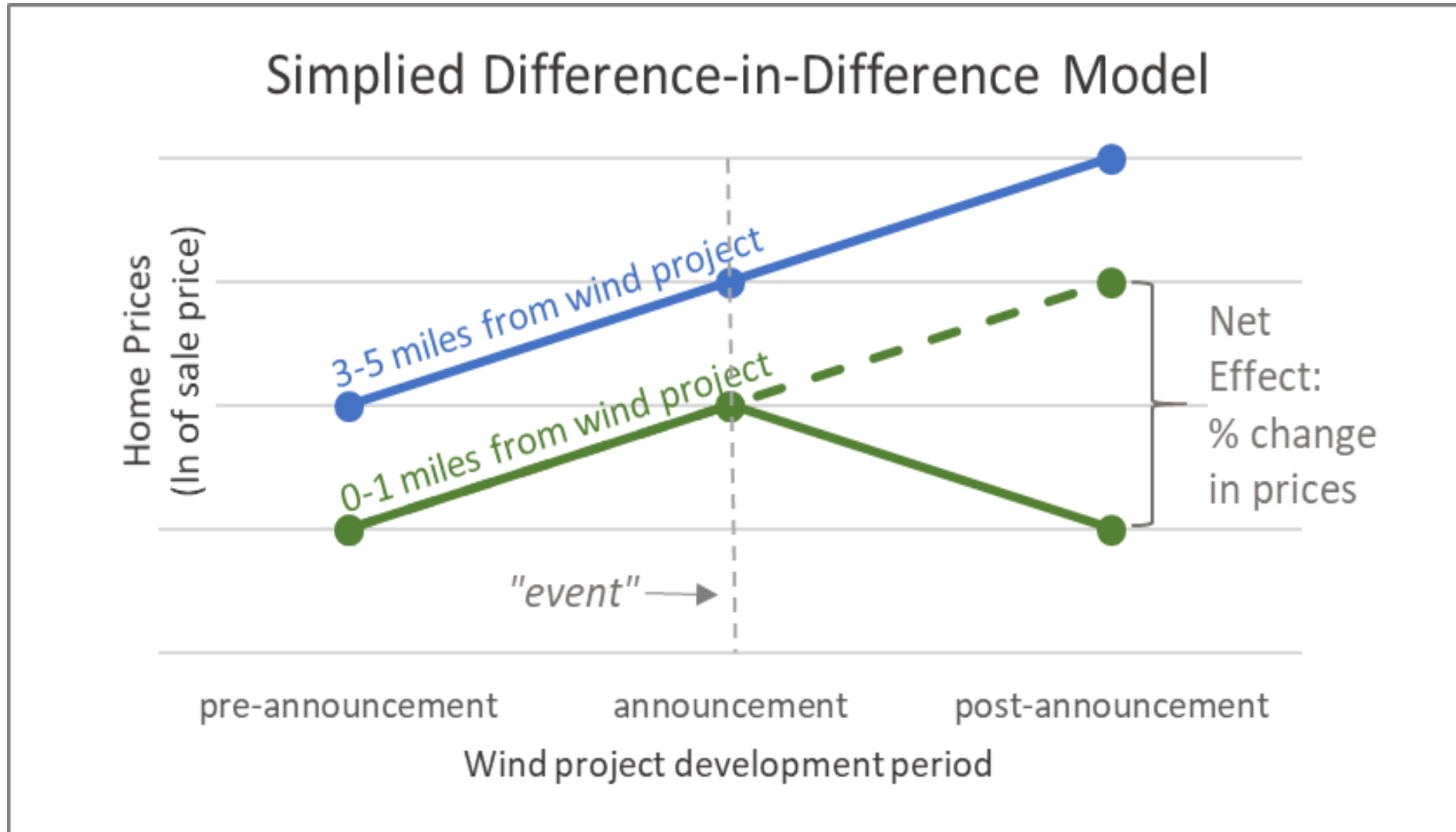
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- ❑ It remains one of the top concerns of local communities
- ❑ LBNL's previous studies did not find impacts, but we had relatively small datasets (2011, 2015, 2016)
- ❑ EU studies have accumulated and found statistically significant (SS) impacts (UK, Germany, Denmark, The Netherlands)
- ❑ A recent RI & MA study found SS effects near their wind turbines that abated after 3-5 years and were concentrated in the eastern, more-populous part of the state (Dong, et al., 2023)
- ❑ Two recent US solar property value impact studies have found effects modulate in ex-urban vs. rural areas (Elmallah et al., 2023; Guar & Lang, 2023)
- ❑ LBNL's wind neighbor survey found attitudes trend more positive over time as supporters self-select into communities (Hoen et al, 2019)
- ❑ Lots of data have accumulated since 2014, and methods have evolved

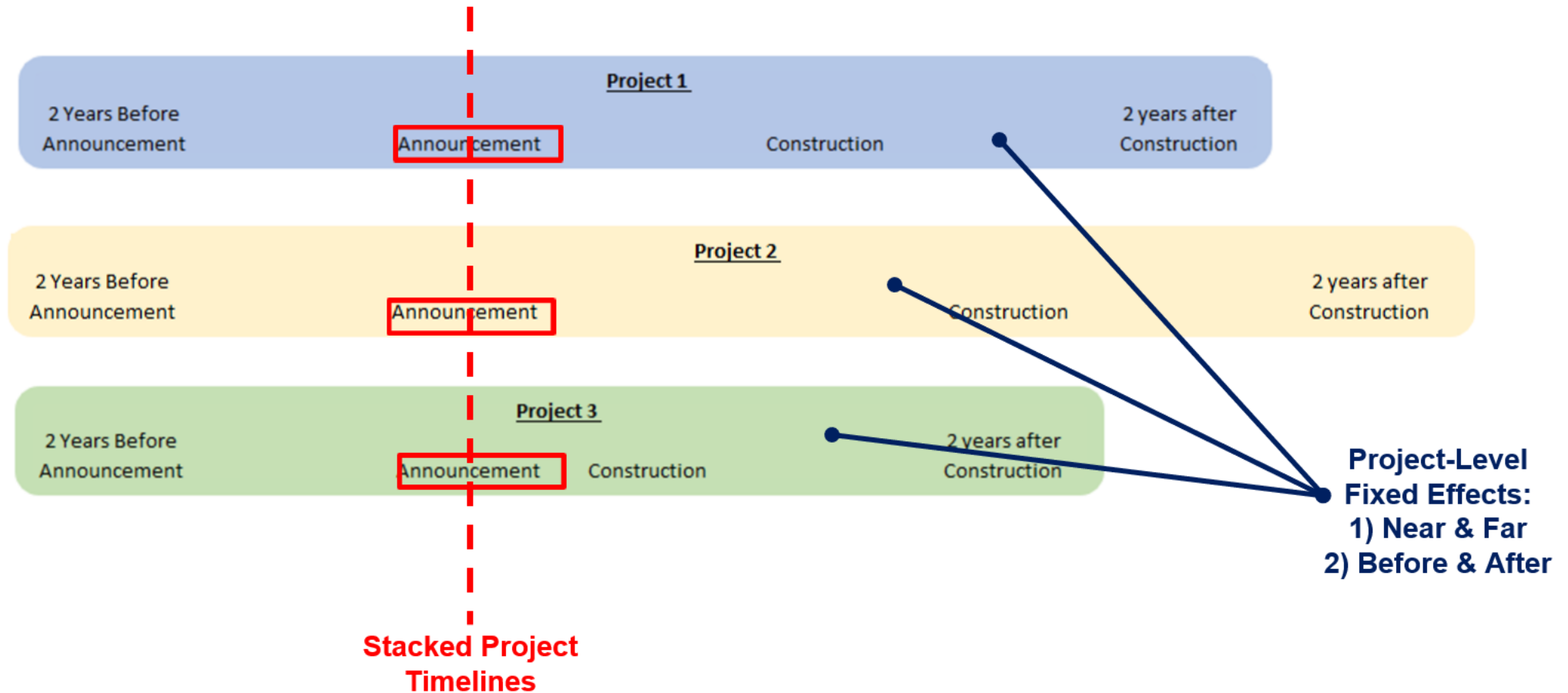
**In short:** New US wind-property value research was needed, and it could leverage the wealth of data collected since 2014 and use new techniques.



# The difference-in-difference (DiD) model is the standard for measuring “event” impacts with high precision and minimal bias

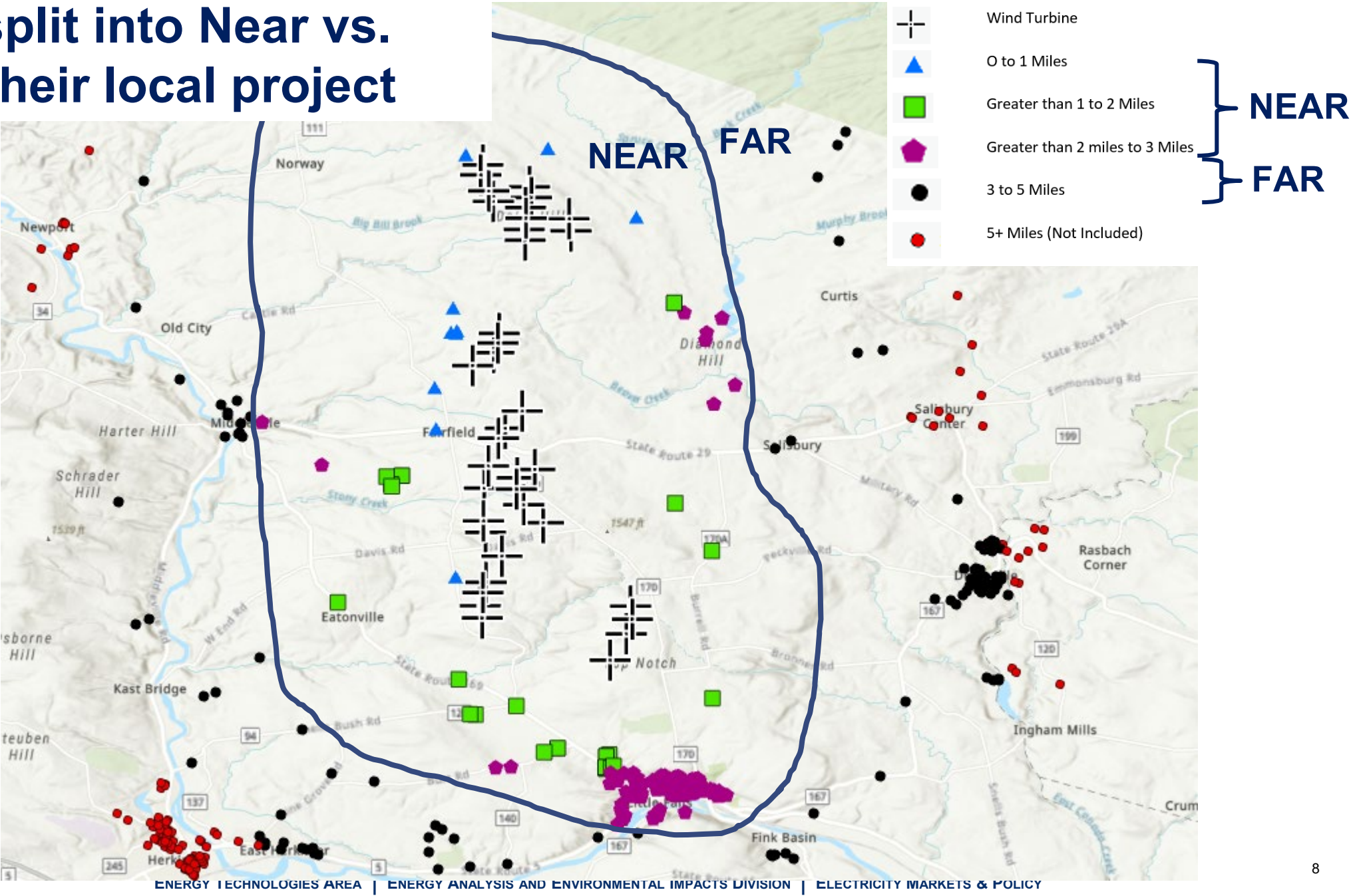


## Our Empirical Strategy Uses A Stacked Difference-in-Difference Model with Project-Level Fixed Effects





# Data are split into Near vs. Far from their local project





## Our Empirical Strategy:

$$\ln(P_{icdjt}) = \beta \mathbf{D}_{idt} + \mathbf{X}_i \alpha + \delta_{dc} + \lambda_{tc} + \varphi_{jc} + \varepsilon_{icdjt} \quad (1)$$

- $\ln(P_{icdjt})$ : log of sales price for transaction  $i$  in project  $c$  within distance bin  $d$  and census block group  $j$  that occurred in quarter and sale year  $t$
- $\mathbf{D}_{idt}$ : a vector of 3 distance bins for homes located 0 to 1 miles, 1 to 2 miles, and 2 to 3 miles from the nearest turbine, all interacted with an indicator if the transaction occurred after the **announcement** of the project  $c$ . The omitted category are transactions of homes 3 to 5 miles from the nearest turbine
- $\mathbf{X}_i$ : a vector of individual home characteristics
- $\delta_{dc}, \lambda_{tc}, \rho_{qc}, \varphi_j$ : distance bin-by-project, transaction quarter year-by-project, and census block group fixed effects

$$\ln(P_{icdjt}) = \sum_{k=-4}^{10} T_{k,idt} \gamma_k + \mathbf{X}_i \alpha + \delta_{dc} + \lambda_{tc} + \varphi_{jc} + n_{icdjt} \quad (2)$$

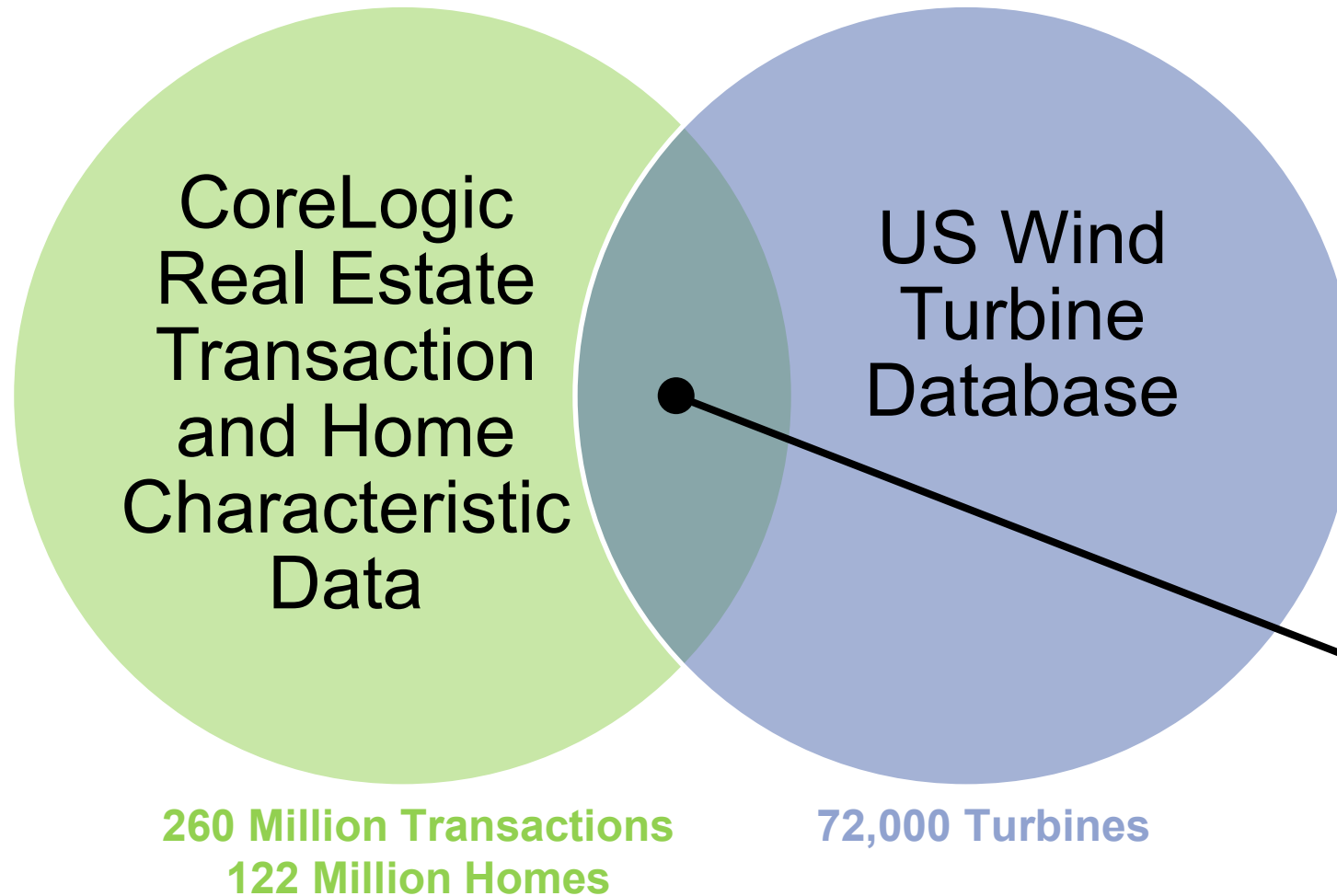
$T_{k,idt}$  is a series of lead and lag indicators for when a turbine project is announced for each of the three distance bins defined above for  $\mathbf{T}_{idt}$ . The omitted year is the year prior to the project announcement, with the study period being as much as 4 years before announcement and 10 years after.



## Data Summary



# Dataset Combines National CoreLogic Real Estate Data And US Wind Turbine Database Data



- 30 states, 250 counties, ~400 wind projects, ~20,000 turbines.
- 500,000 transactions of homes within 5 miles of projects
- sales occurred 4 years before to 10 years after wind project announcement
- Data period - January 2005 to December 2020

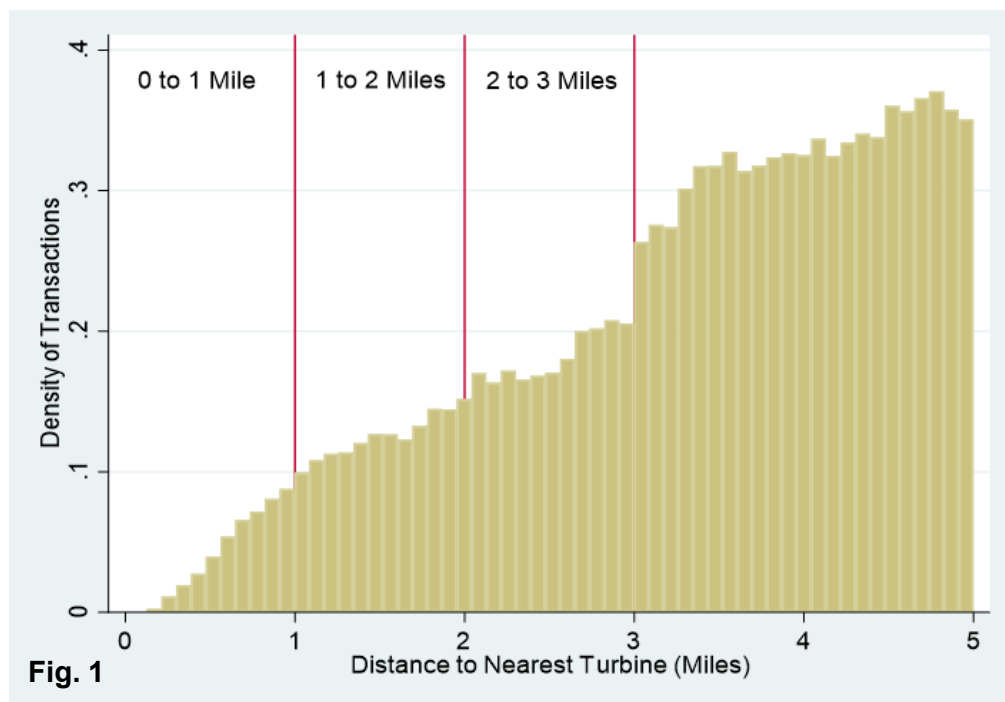


## Pre-Announcement Descriptive Statistics:

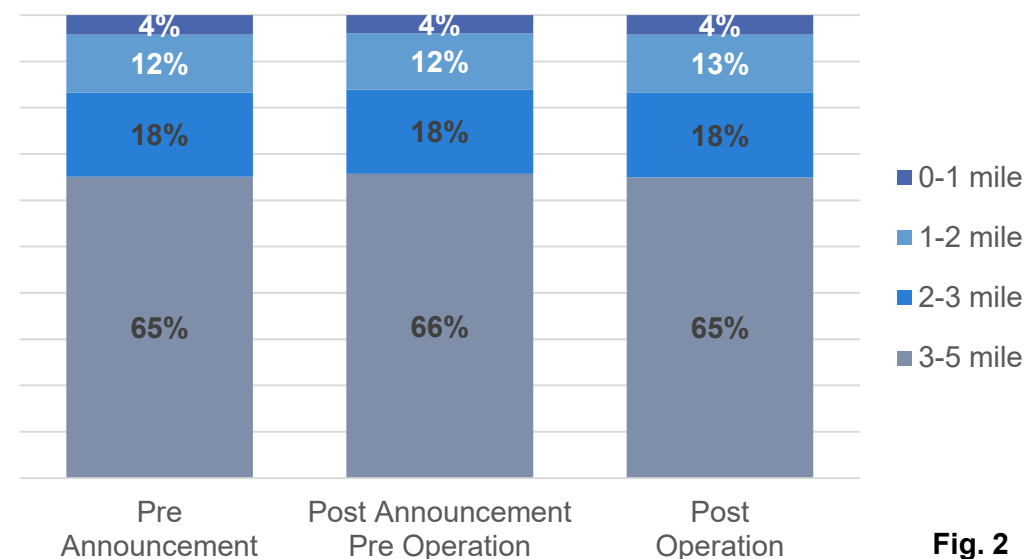
	Full Sample	Within 3 Miles	Greater than 3
Parcel Size (Acres)	0.43	0.44	0.43
Building Square Feet	1,817	1,793	1,831
Age of Building	54.72	59.81	52.01
Number of Stories	1.54	1.58	1.52
Number of Bedrooms	3.39	3.40	3.39
Number of Full Baths	1.82	1.79	1.84
Number of Half Baths	1.08	1.08	1.07
Adjusted Sale Price (\$)	\$186,050	\$178,774	\$189,927
Total Transactions	496,054	172,423	323,631



# Sales Are Concentrated Away From The Turbines, But There Are Plenty Of Transactions Near As Well



	Pre Announcement	Post Announcement Pre Operation	Post Operation	Total
0-1 mile	4,249	6,471	9,611	<b>20,331</b>
1-2 mile	12,652	20,347	28,818	<b>61,817</b>
2-3 mile	18,428	30,416	41,626	<b>90,470</b>
3-5 mile	65,739	109,346	148,351	<b>323,436</b>
<b>Total</b>	<b>101,068</b>	<b>166,580</b>	<b>228,406</b>	<b>496,054</b>



## Results

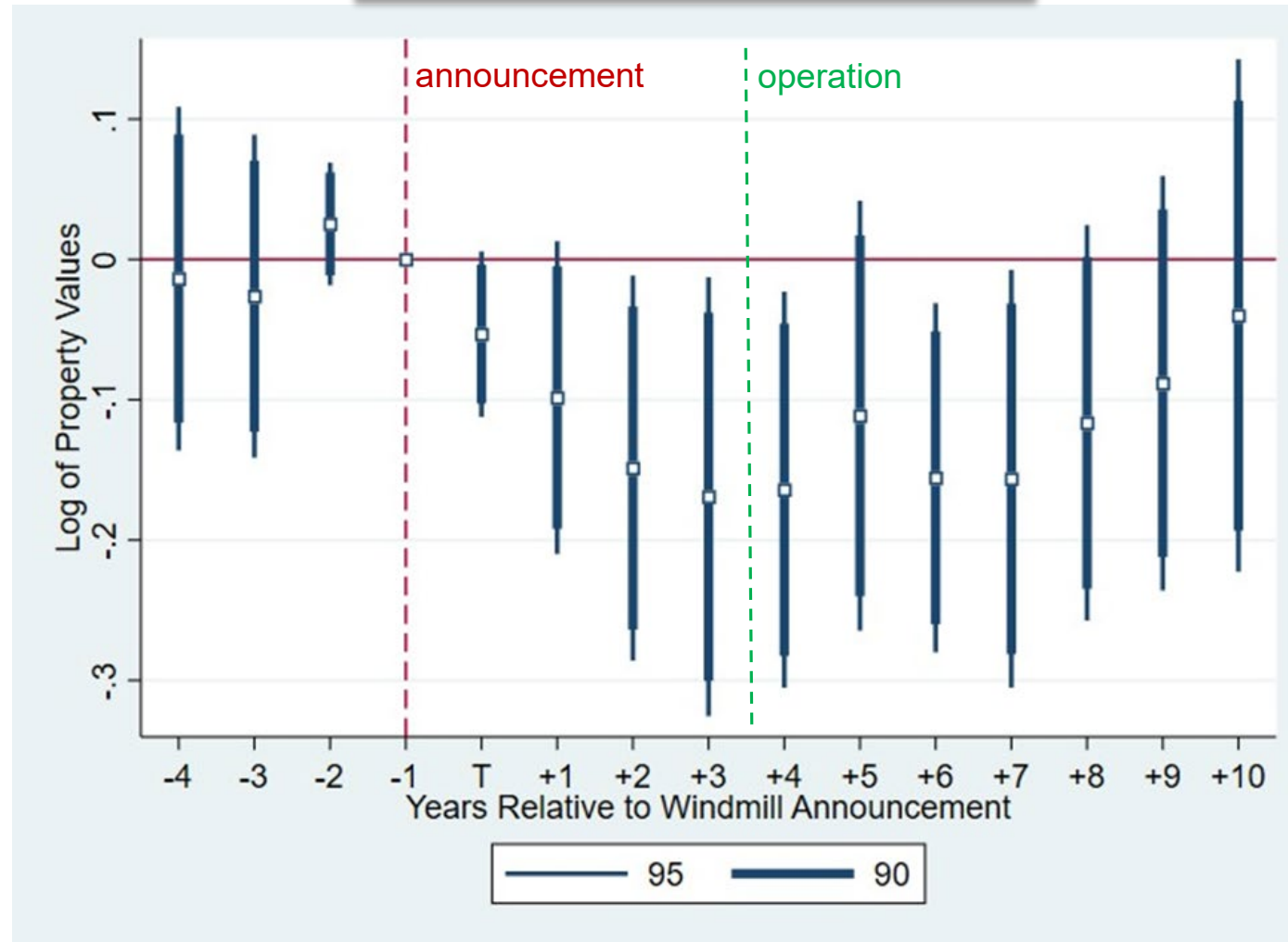


# Effects Are Apparent After Announcement Through Construction And Return To Pre-Announcement Levels For Homes Within 1 Mile

## Within 1 mile impacts

Home prices within 1 mile are compared to prices of homes 3 to 5 miles from the same wind project in the same period

Error bars represent 90% (thicker) and 95% (thinner) confidence intervals.



-11% post-announcement effect

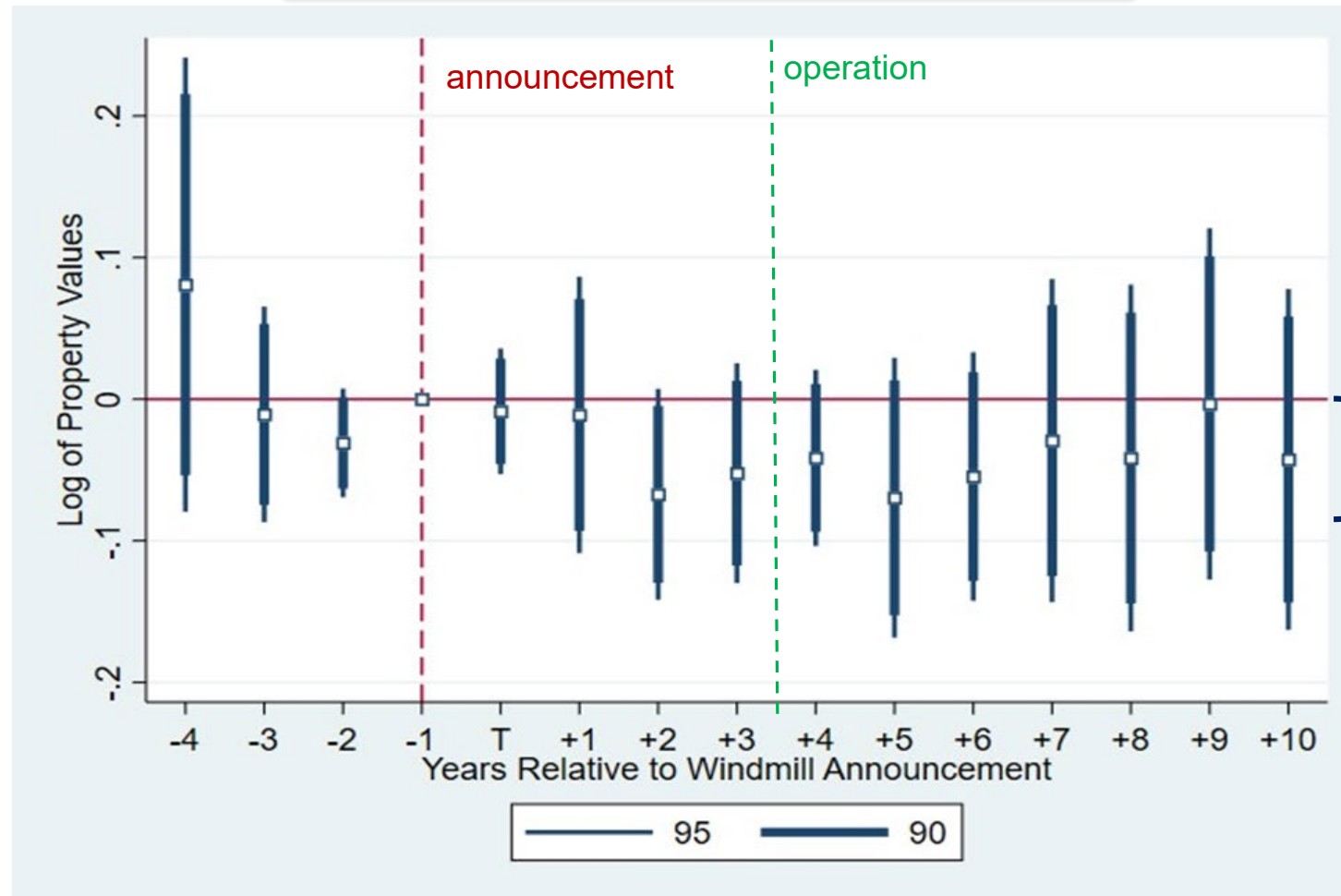




# No or Weak Statistically Significant Effects Are Evident Between 1 & 2 Miles

Between 1 and 2 mile impacts

Home prices between 1 and 2 miles are compared to prices of homes 3 to 5 miles from the same wind project in the same period



-3% post-announcement effect, though not consistently statistically significant

Error bars represent 90% (thicker) and 95% (thinner) confidence intervals.

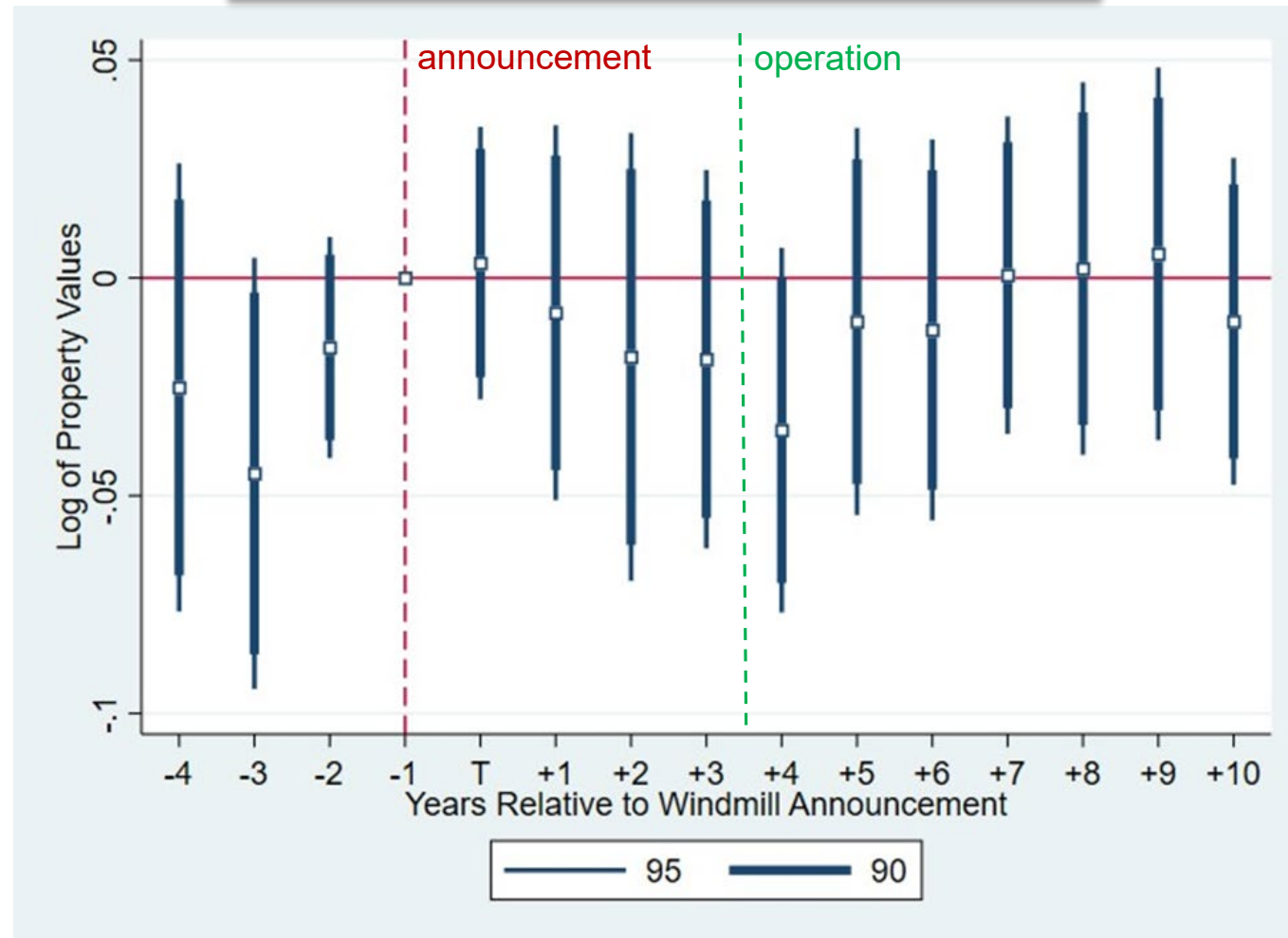


# Statistically Significant Effects Are Also Not Evident Between 2 and 3 Miles

## Between 2 and 3 mile impacts

Home prices between 2 and 3 miles are compared to prices of homes 3 to 5 miles from the same wind project in the same period

Error bars represent 90% (thicker) and 95% (thinner) confidence intervals.



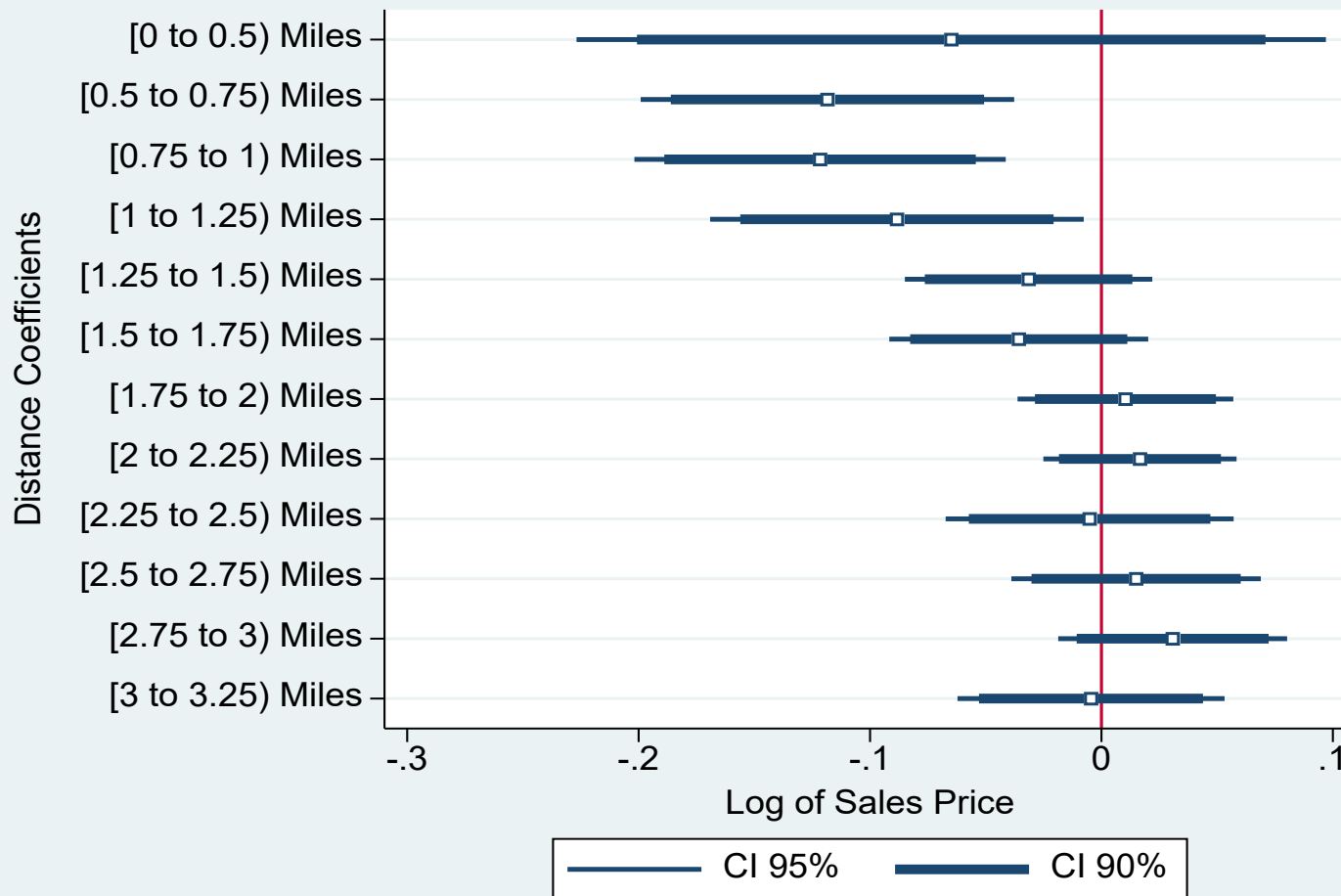
No statistically significant effect



# Unsurprisingly, Effects Are Concentrated Closer To The Turbines

## Average post-announcement impacts

Average post-announcement home prices in 0.25-mile increments as compared to prices 3.25 to 5 miles away from the same project



Error bars represent 90% (thicker) and 95% (thinner) confidence intervals.



# Across A Variety Of Models, Results Are Consistent, Including Our Preferred Parsimonious Models 7 and 8.

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
0 to 1 Mile	coef.	-0.1288***	-0.1267***	-0.1283***	-0.1270***	-0.1120***	-0.1101***	-0.1102***	-0.1091***
	se	-0.0389	-0.0406	-0.0368	-0.0383	-0.0367	-0.039	-0.0367	-0.0388
1 to 2 Miles	coef.	-0.0436*	-0.0400*	-0.0423*	-0.0400*	-0.0382**	-0.0305	-0.0383**	-0.0306
	se	-0.0233	-0.0241	-0.0224	-0.0231	-0.0192	-0.0204	-0.0191	-0.0203
2 to 3 Miles	coef.	0.0187	0.0152	0.0173	0.0134	0.018	0.0141	0.0177	0.0138
	se	-0.0232	-0.0223	-0.022	-0.0211	-0.0197	-0.018	-0.0196	-0.0179
Observations		479,841	479,841	475,607	475,607	496,215	496,215	496,054	496,054
R-squared		0.7952	0.8255	0.8072	0.8337	0.7188	0.7781	0.7193	0.7784
Distance Bin-Project FE		Y	Y	Y	Y	Y	Y	Y	Y
Tract FE		Y	Y	N	N	N	N	N	N
Tract-by-Project FE		N	N	Y	Y	N	N	N	N
Block Group FE		N	N	N	N	Y	Y	N	N
Block Group-by-Project FE		N	N	N	N	N	N	Y	Y
Year-Quarter-by-Project FE		Y	Y	Y	Y	Y	Y	Y	Y
Controls		N	Y	N	Y	N	Y	N	Y

} ~11% post-announcement adverse impact within 1 mile

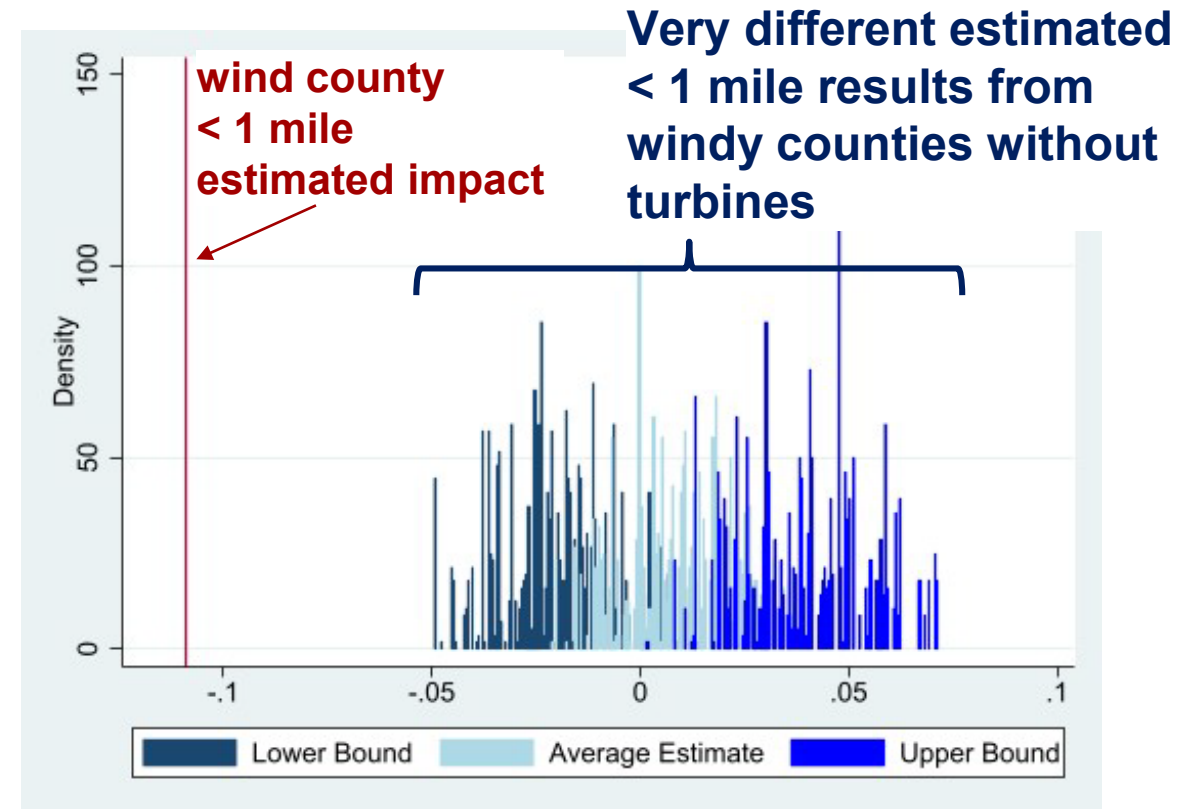
Statistical  
Significance

\*\*\* p<0.01  
\*\* p<0.05  
\* p<0.10



# Extensive Robustness Tests Found Stable Results

- **Falsification tests:** including nearby counties without wind development but with similar wind speeds (see right), we find very different results.
- **Different samples,** including top and bottom 1% of sale prices and foreclosures, both of which were left out of the main analysis dataset, does not change results.



## Urban vs Rural Counties



# We Define Rural vs Urban Using USDA Definitions.

## Most Of The US is Rural



Economic Research Service  
U.S. DEPARTMENT OF AGRICULTURE

### Rural-Urban Continuum Codes

The 2013 Rural-Urban Continuum Codes form a classification scheme that distinguishes metropolitan counties by the population size of their metro area, and nonmetropolitan counties by degree of urbanization and adjacency to a metro area. The official Office of Management and Budget (OMB) metro and nonmetro categories have been subdivided into three metro and six nonmetro categories. Each county in the U.S.,

### How we defined the two groups

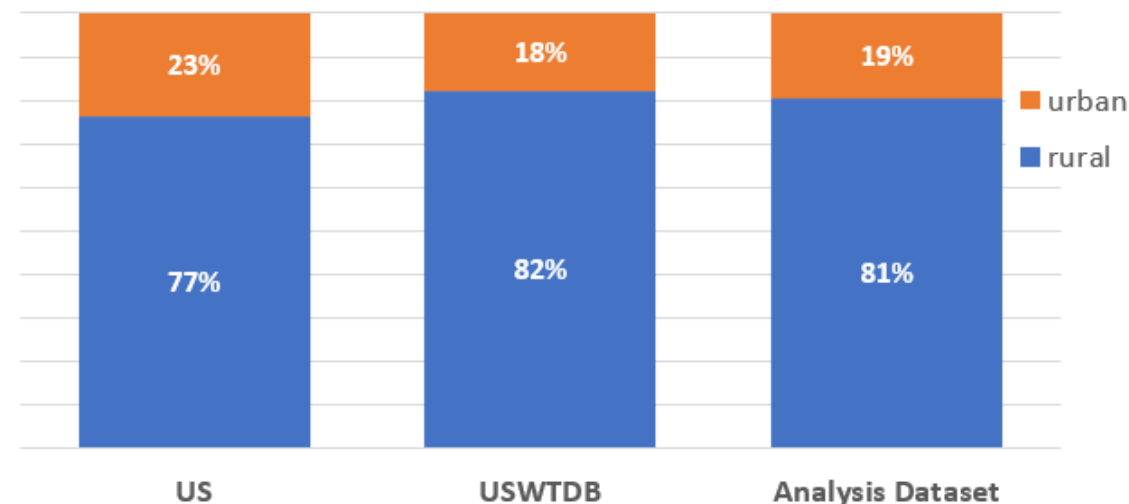
#### “Urban”

- County in metro area with >250,000

#### “Rural”

- County in metro area with fewer than 250,000, or
- County with < 20,000 population adjacent or non-adjacent to a metro area of any size

Percent Rural or Urban of Counties

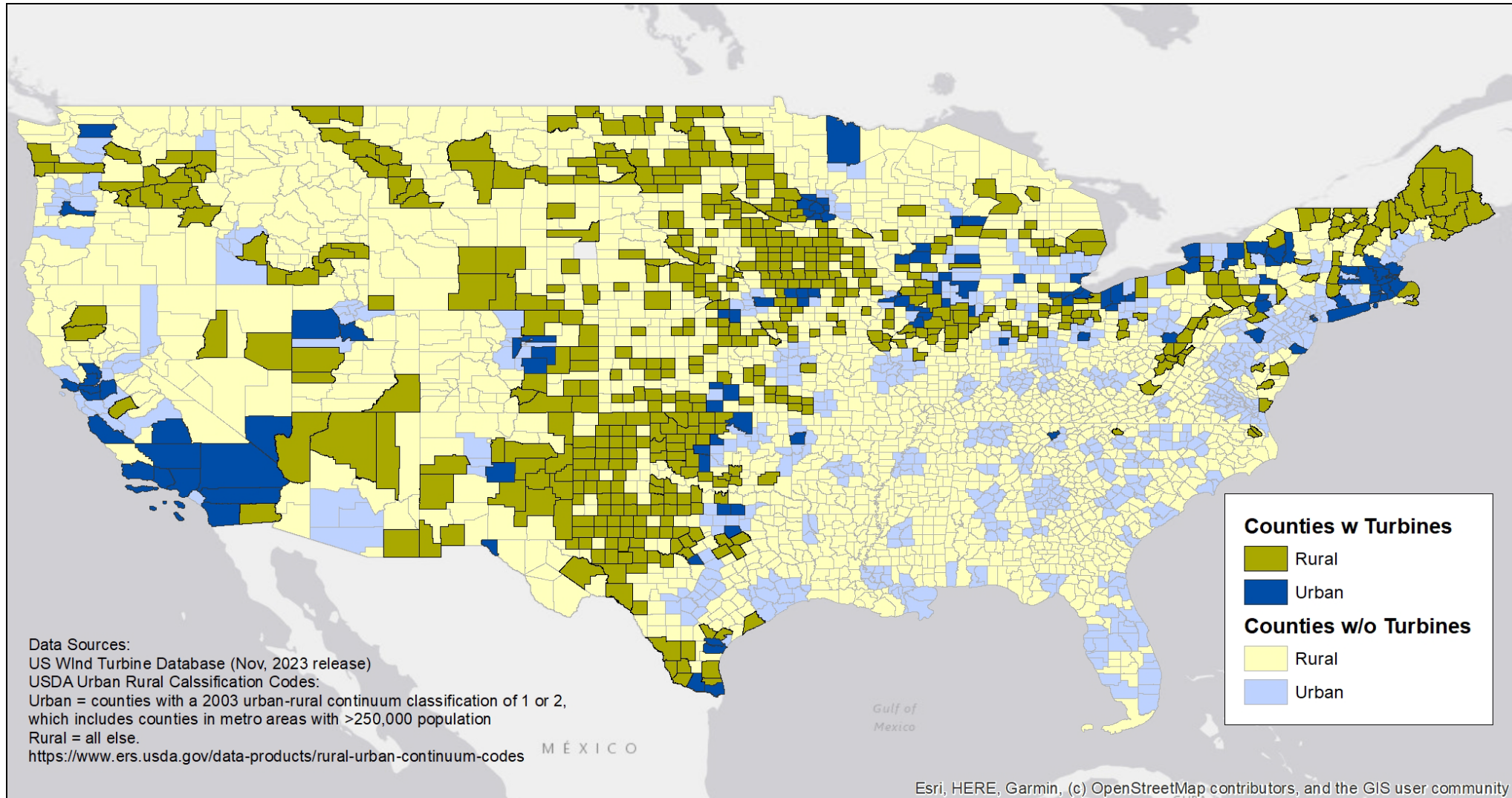


Data source: <https://www.ers.usda.gov/data-products/rural-urban-continuum-codes>





# Map Of US Shows Rural Wind Counties Are Covering Central States, And Many Urban Areas Abut Those Counties



# When We Break The Model Into “Urban” and “Non-Urban” Groups, We Find SS Effects Are Only Apparent In The “Urban” Sample

	Urban Sample		Rural Sample	
	Counties in Metro Areas with Pop $\geq$ 250,000		Counties in Metro Areas with Pop $<$ 250,000	
	(1)	(2)	(3)	(4)
0 to 1 Mile	-0.1471***	-0.1494***	-0.0157	-0.0071
	-0.0407	-0.0423	-0.0432	-0.0473
1 to 2 Miles	-0.0467**	-0.0427*	-0.0099	0.0059
	-0.0231	-0.024	-0.0227	-0.0185
2 to 3 Miles	0.0134	0.0094	0.0344	0.0324
	-0.0246	-0.022	-0.0233	-0.0229
Observations	358,734	358,734	135,874	135,874
R-squared	0.73	0.78	0.60	0.71
Controls	N	Y	N	Y

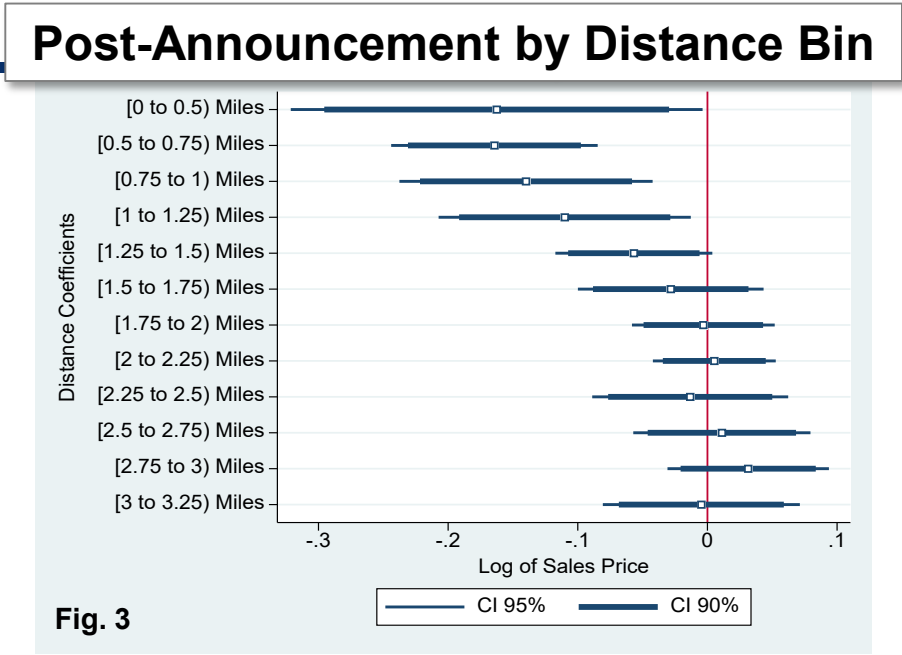
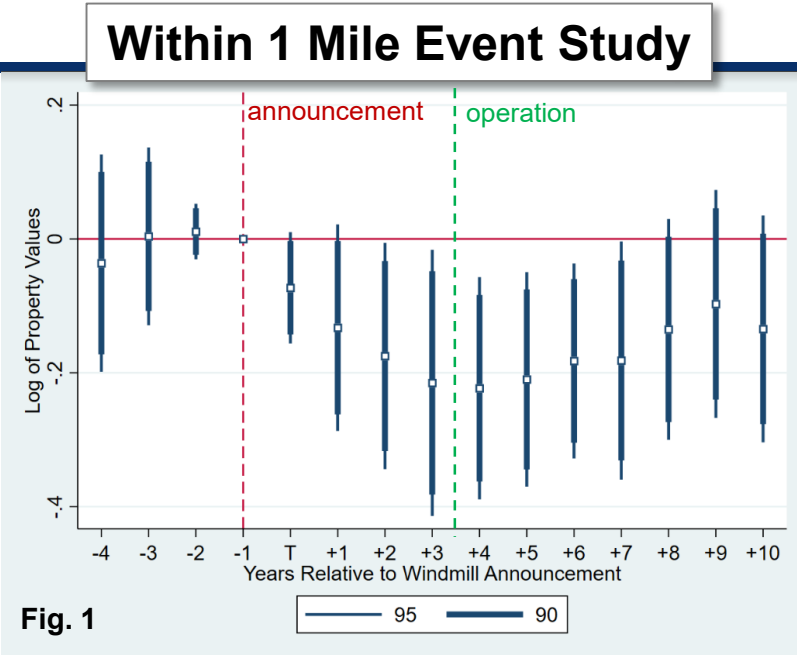
Statistical  
Significance

\*\*\* p<0.01  
\*\* p<0.05  
\* p<0.10

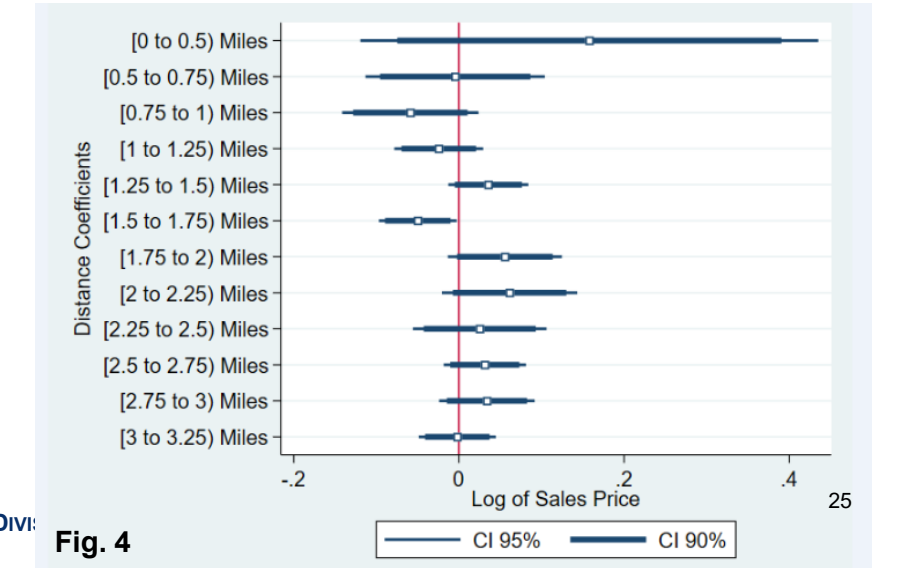
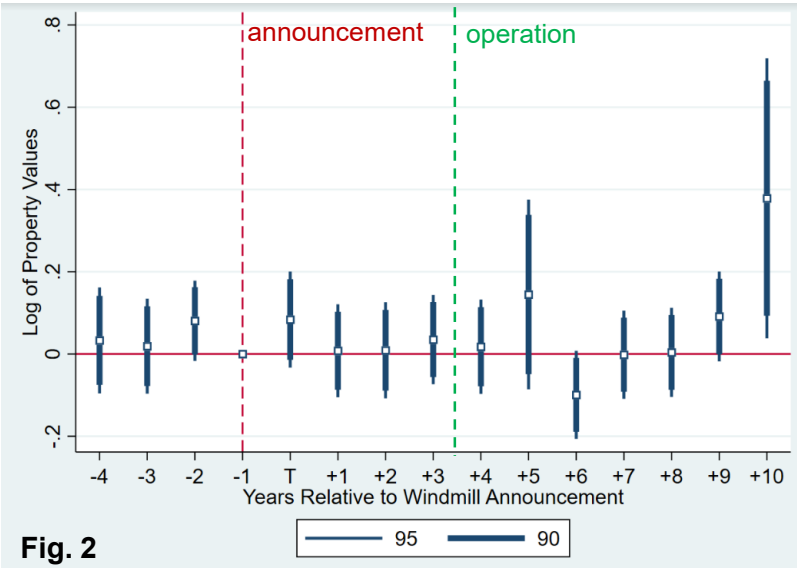


# Urban / Rural Differences Are Also Evident In Event and Distance Bin Results

Urban Sample



Rural Sample



# Conclusions

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- We analyze an unprecedented set of 500,000 home sales near US wind turbines
- For homes within 1 mile of a wind project compared to homes 3-5 miles away, we found an average reduction in home sale prices of approximately 11% after the announcement. Weak or no effects appear beyond that distance.
- Effects for homes within approximately 1 mile away begin an average of three years before construction starts, with home prices continuing to decline through project construction.
- Home prices return to inflation-adjusted pre-announcement levels three to five years after project operation commences.
- Impacts are only apparent in more populous US counties, those in metro areas with  $\geq 250,000$  people
- Impacts were not related to the size of the wind project, both in terms of capacity or number of turbines (not shown)
- **Caveats: Although this work significantly advances the literature, using the most comprehensive dataset assembled to date:** This study did not examine the impact of other economic effects, such as increased local tax revenue and worker income that might increase home prices across communities with wind development. As well, it did not examine how using views of turbines instead of distance to the nearest turbine might impact results. We hope to examine those in future iterations of this work.



## Questions / Comments?

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### Acknowledgment

This work was funded by the U.S. Department of Energy Wind Energy Technologies Office, under Contract No. DE-AC02-05CH11231.

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# Data Cleaning and Preparation Summary

Condition for retention	Rationale
Parcels hosting turbines are removed	The analysis examines disamenity effects only
Coordinate values are populated	Coordinates are needed to obtain distances between homes and wind turbines.
Land area, year built, and home square footage are populated	Land area, year built, and home square footage are essential property characteristics to control for in analysis
Coordinates appear 20 times or less	Repeated, identical coordinates for multiple properties may indicate data quality issue
Property type is residential (including single family residence, condominium, duplex, apartment)	Analysis only considers homes (i.e. residential properties) sold in arms-length transactions after the year 2000
Transaction is categorized as arms-length	
Year of sale between 2000 and December 2020	
Sale amount is greater than \$5000 or the 1 <sup>st</sup> percentile of sale price (whichever value is higher) and less than the 99 <sup>th</sup> percentile of sale amount values within a given state.	Removing outliers from analysis
Sale amount per unit area of living space is greater than the 1 <sup>st</sup> percentile and less than the 99 <sup>th</sup> percentile of sale amount per unit area of living space values within a given state	
Land area is greater than the 1 <sup>st</sup> percentile and less than the 99 <sup>th</sup> percentile of land area values within a given state	
Property was built before 2020, and after the 1 <sup>st</sup> percentile of values for year built within a given state	
Sale amount is greater than the mortgage amount, or mortgage amount is missing	Any other relationship (between sale amount & mortgage amount, land area & living space area, sale year & year built, set of variables representing land area) may indicate data quality issues
Land area is greater than living space area	
Age of property (sale year minus year built) is non-negative	
Both variables representing land area converge within 0.01 acres	Sale amount in a foreclosure may not accurately represent the value of a home
Deed is not categorized as foreclosure	
Sale occurred over one year after last recorded sale for that property	Removes potentially “flipped” homes, or homes that undergo a rapid renovation and are re-sold, from dataset; for those homes, characteristics in CoreLogic dataset may not be representative of characteristics after renovation
Property address was not determined from mail	Address determined from mail may reflect the address of an absentee owner, not of the physical property location

