Blowin' in the Wind:

The impact of wind farms on house prices

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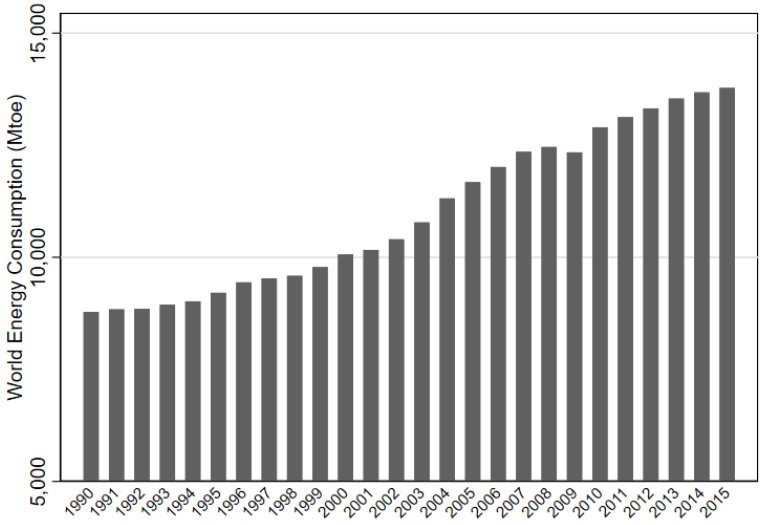
Introduction

Motivation

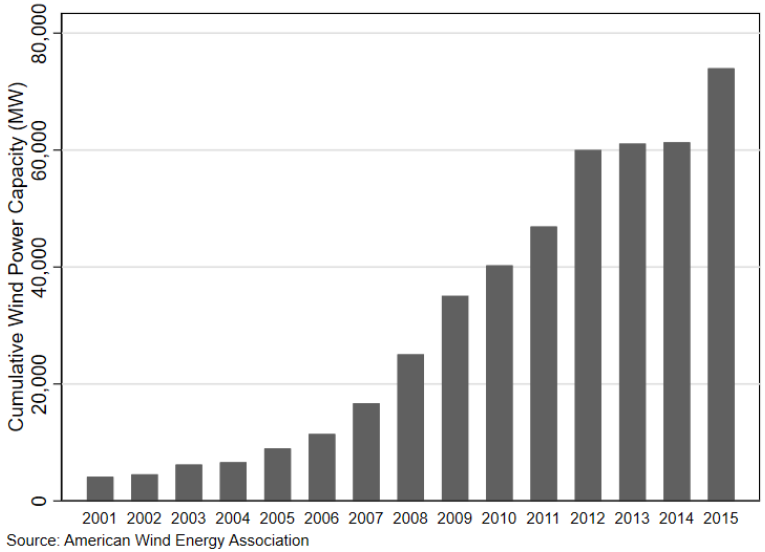
- Growing world overall energy consumption
- Response comes also through expansion of wind energy sector

World energy consumption



Source: Global Energy Statistical Yearbook 2016

US wind energy capacity



Source: American Wind Energy Association

Motivation

- Local communities concerned about visual and aural impact of wind turbines on house prices
- Literature
  - ◇ Non-significant effects: Sims et al. (2008), Hoen et al. (2013), Lang et al. (2014)
  - ◇ Negative effects: Droes & Koster (2014), Gibbons (2015), Sunak & Madlener (2016)
- Large majority of the previous attempts based on DD
- Literature on effects of wind energy on pollution
  - ◇ Cullen (2013), Novan (2015)

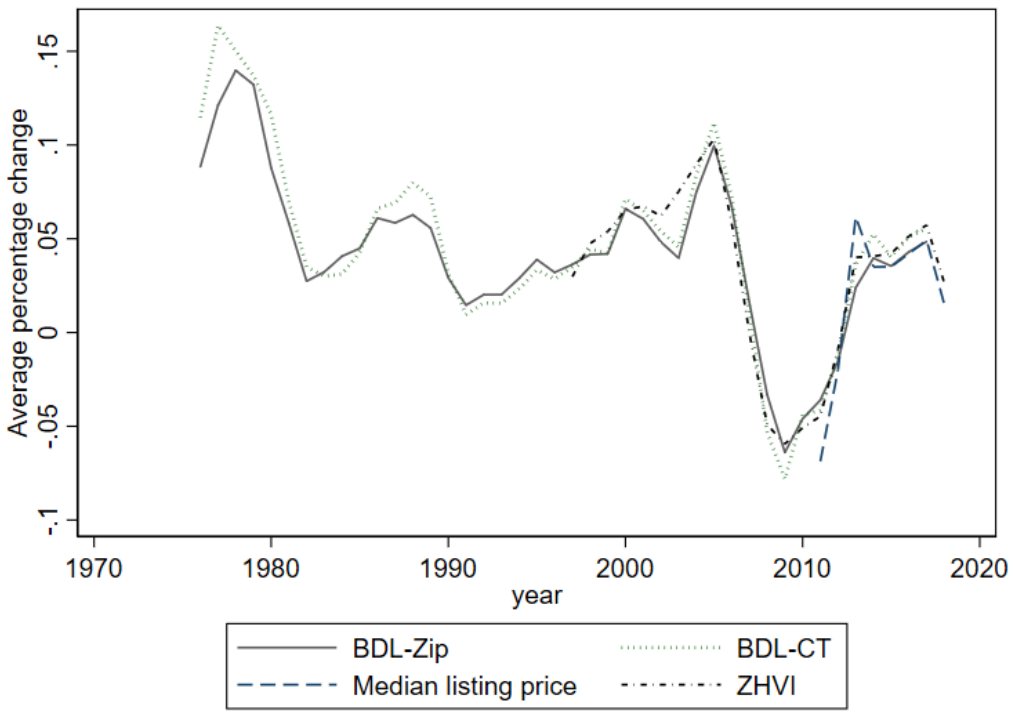
Data

House prices

- Zillow data
  - ◇ Zillow Home Value Index ZHVI
  - ◇ Median listing price per square foot for all houses
  - ◇ Both sources at the zip code-month level
- Bogin, Doerner & Larson (2016) Index:
  - ◇ Data on 97 million transactions from Federal Housing Finance Agency (FHFA)
  - ◇ Based on repeat-sales methodology (54 million transaction pairs) repeat-sales
  - ◇ Available at zip code and census tract level over a 40 year period coverage

House prices

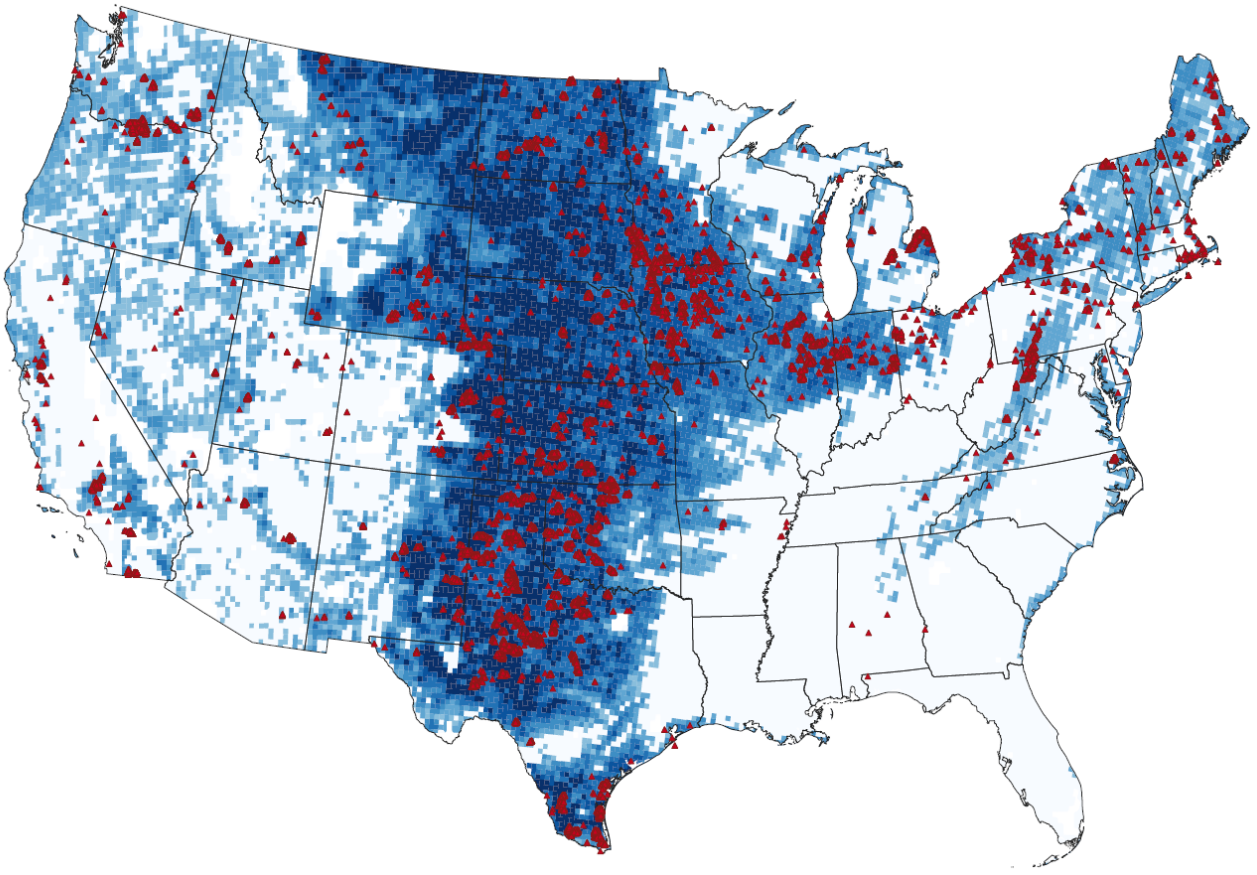
- BDL and Zillow data capture similar trend over time



Wind turbines & potential wind capacity

- Information on wind turbines collected by Federal Aviation Administration (FAA)
  - ◇ Records on 43,556 turbines in 1,261 distinct zip codes or 934 census tracts
  - ◇ Data includes geographic position, date in which the turbine is built, turbine height
  - ◇ Consider only turbines with height $>$ first percentile ($\sim$ 200 ft)
- Potential wind capacity in 2008 estimated by Lopez et al (2012)
  - ◇ Data on wind resources from National Renewable Energy Laboratory (NREL)
  - ◇ Positively correlated with current and "near future" potential wind capacity wind capacity
  - ◇ Correlated with wind power class and wind speed wind power class

Wind turbines & potential wind capacity



Darker areas have higher potential wind capacity in 2008. Red triangles represent currently installed wind turbines

Controls

- Census 2010 zip code demographic data
  - ◇ Total population, sex, race, education level
- Average income at zip code level from IRS
- Distance from coastline available from the Stanford EarthWorks database
- Land altitude

Identification

Identification strategy

- Estimate the impact of wind turbines on house prices

$$ln\left(p_{lt}\right) = \alpha_l + \beta turbines_{lt} + \mathbf{X}_{lt}\boldsymbol{\theta} + \tau_t + \varepsilon_{lt}$$

  - $ln\left(p_{lt}\right)$ log of price index in location l (zip code or census tract) and time t (year or month)
  - $turbines_{lt}$ number of wind turbines
  - Time and location fixed effects
  - $\mathbf{X}_{lt}$ vector of time varying control variables

Identification strategy

- If we assume $\mathbf{X}_{lt} = \mathbf{X}_l$ and rewrite the model in first differences

$$\Delta ln\left(p_{lt}\right) = \beta \Delta turbines_{lt} + \tau_t + \Delta \varepsilon_{lt}$$

Identification strategy

- If we assume $\mathbf{X}_{lt} = \mathbf{X}_l$ and rewrite the model in first differences

$$\Delta ln\left(p_{lt}\right) = \beta \Delta turbines_{lt} + \tau_t + \Delta \varepsilon_{lt}$$

- However
  - ◇ Biased: wind turbines are not randomly allocated to geographic locations
  - ◇ Infrastructure projects could be targeted towards growing economic poles or influenced by political variables

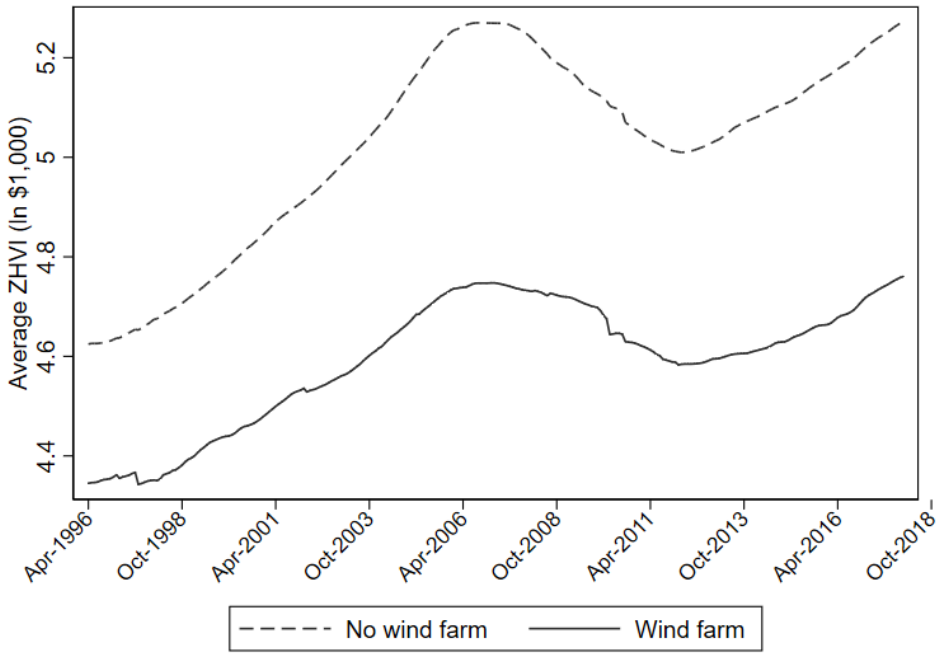
Sample characteristics

Table 1: Covariates balance, BDL-Zip data

	Full sample	Wind farm	No wind farm	Col 2-3
Average income	56.4481	47.6646	56.5888	-8.9242
	(34.3034)	(10.9847)	(34.5310)	(0.7304)
Total population	15055.1253	8975.5878	15152.5109	-6176.9231
	(14777.3287)	(10322.1167)	(14817.7508)	(648.1425)
Elevation	294.6454	501.8397	291.3265	210.5132
	(383.4397)	(402.8016)	(382.2216)	(25.0640)
Distance to coast	228.1892	373.4400	225.8625	147.5776
	(267.0270)	(320.6562)	(265.4457)	(19.9186)
Number of zip codes	16618	262	16356	16618

House prices time series

- Wind farm: 10 or more turbines installed in the same geographic location
- ZHVI time series, by presence of wind farm



Identification strategy

- Use instrumental variable (IV) approach

$$\text{First stage:} \quad \Delta turbines_{lt} = \pi Z_{lt} + \tau_t + \nu_{lt}$$

$$\text{Second stage:} \quad \Delta ln\left(p_{lt}\right) = \beta \Delta \widehat{turbines}_{lt} + \tau_t + \Delta \varepsilon_{lt}$$

  - Z_{lt} is the percentage of the area of location l having potential wind capacity in 2008 of 30% or more, interacted with a dummy set to one in the years after the first wind turbine was installed in the US (i.e., 1998)

instrument

Results

OLS results

Table 2: OLS regression

	(1) $\triangle ln(p)$	(2) $\triangle ln(p)$	(3) $\triangle ln(p)$	(4) $\triangle ln(p)$
$\triangle turbines$	0.0002	0.0001	0.0001	-0.0000
	(0.0001)	(0.0001)	(0.0002)	(0.0000)
Number of locations	46731	16786	9309	14082
Number of location-time	1147555	442092	722194	3309753

Notes: Specification (1) and (2) use BDL data at the census tract and zip level, respectively. Specification (3) uses ZHVI data, while (4) uses median price per sqft. Each regression includes calendar time fixed effects. Standard errors in parenthesis are clustered by location.

First stage

Table 3: First stage regression

	(1) $\triangle turbines$	(2) $\triangle turbines$	(3) $\triangle turbines$	(4) $\triangle turbines$
Percentage area with pot wind capacity > 30% x $\mathbb{1}$(year first turbine US)	0.0040 (0.0004)	0.0047 (0.0005)	0.0006 (0.0001)	0.0005 (0.0001)
Number of locations	46731	16786	9309	14082
Number of location-time	1147555	442092	722194	3309753

Notes: Specification (1) and (2) use BDL data at the census tract and zip level, respectively. Specification (3) uses ZHVI data, while (4) uses median price per sqft. Each regression includes calendar time fixed effects. Standard errors in parenthesis are clustered by location.

2SLS results

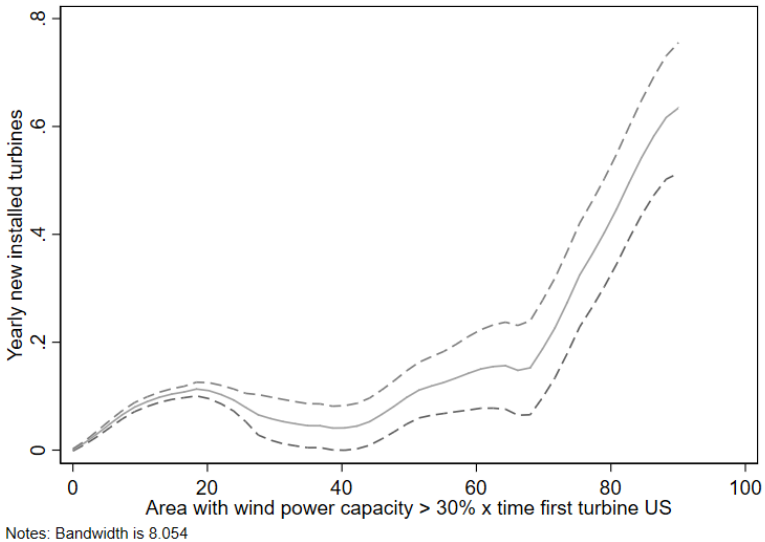
Table 4: IV regressions

	(1) $\triangle ln(p)$	(2) $\triangle ln(p)$	(3) $\triangle ln(p)$	(4) $\triangle ln(p)$
$\triangle turbines$	-0.0232	-0.0096	-0.0057	-0.0226
	(0.0024)	(0.0013)	(0.0029)	(0.0030)
Number of locations	46731	16786	9309	14082
Number of location-time	1147555	442092	722194	3309753

Notes: Specification (1) and (2) use BDL data at the census tract and zip level, respectively. Specification (3) uses ZHVI data, while (4) uses median price per sqft. Each regression includes calendar time fixed effects. Standard errors in parenthesis are clustered by location.

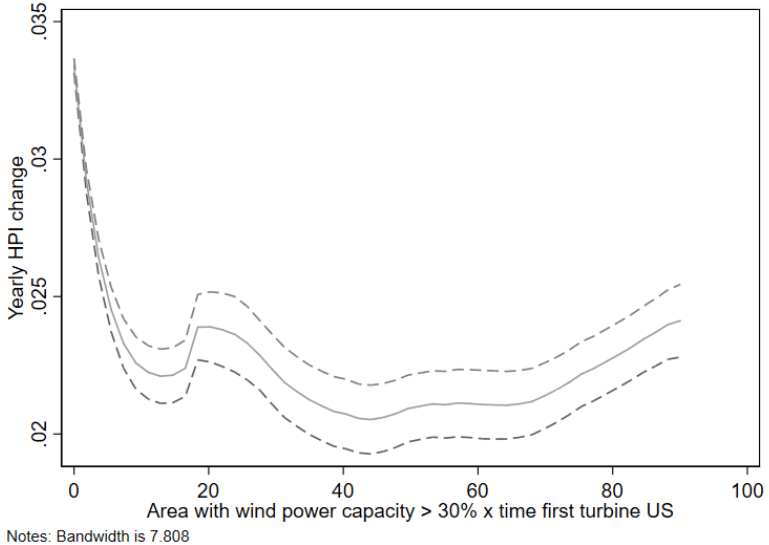
Graphic representation

First stage



Notes: Bandwidth is 8.054

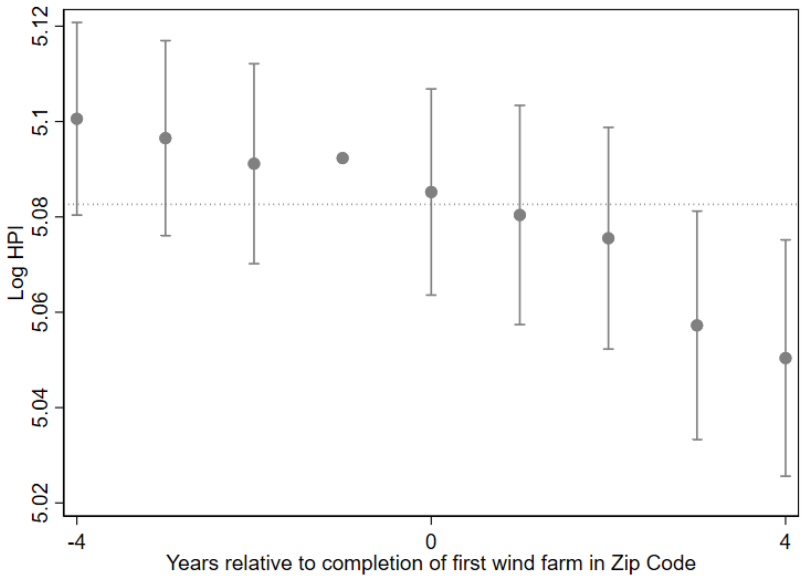
Reduced form



Notes: Bandwidth is 7.808

Event study

- Use BDL house index at the zip code level
- Define as "event" the year in which at least 10 turbines are operative in the zip code



Conclusions

- The absence of a consensus in the existing literature calls for investigation of the relation between wind turbines and house values
  - ◇ Using an IV approach, wind turbines are found to have a negative effect on house prices
  - ◇ Instrumenting for wind turbine presence with the percentage of the area of a zip code having potential wind capacity in 2008 $> 30\%$ likely satisfies the exclusion restriction
  - ◇ The monotonicity assumption seems violated
  - ◇ An event study using BDL data shows further evidence of a negative relation between wind farms and house prices

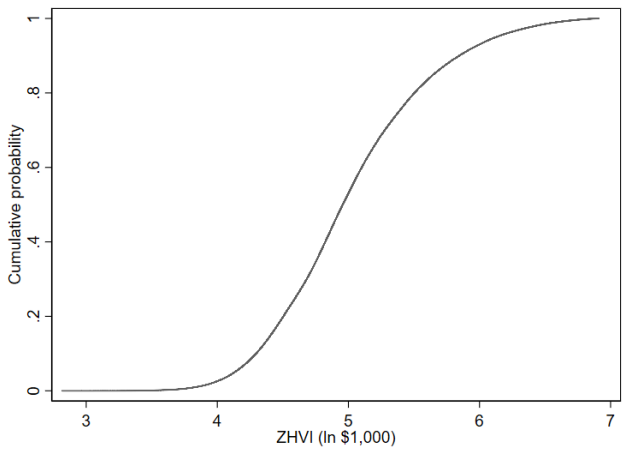
Next steps

- Look further into heterogeneous effects
- Use as control locations where projects about wind turbines are in the early stages of the permitting process (decision on whether they are hazard or not has not been made yet)
- Get data on individual house transactions for a subset of states (e.g. Indiana data publicly available)

Appendix

Zillow Home Value Index

- Zillow methodology:
  - ◇ Calculate Zestimates for more than 100 million homes using Automated valuation models (AVM)
  - ◇ Models re-trained 3 times a week and each Zestimate updated daily
  - ◇ Compute ZHVI as median of all Zestimates in a location or price tier



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Repeat-sales methodology

- Difficult to construct a house price index:
  - ◇ Homes are heterogeneous goods
  - ◇ The composition of homes sold throughout the year changes
- Consider only differences in sale prices of the *same* house
- Crucial assumption: the characteristics of a given house are unchanged over the period considered
- Issues:
  - ◇ All houses age and many undergo renovations over time
  - ◇ Clapp, Giacotto & Tirtiroglu (1991) find that repeat sales homes are systematically different than single sales homes

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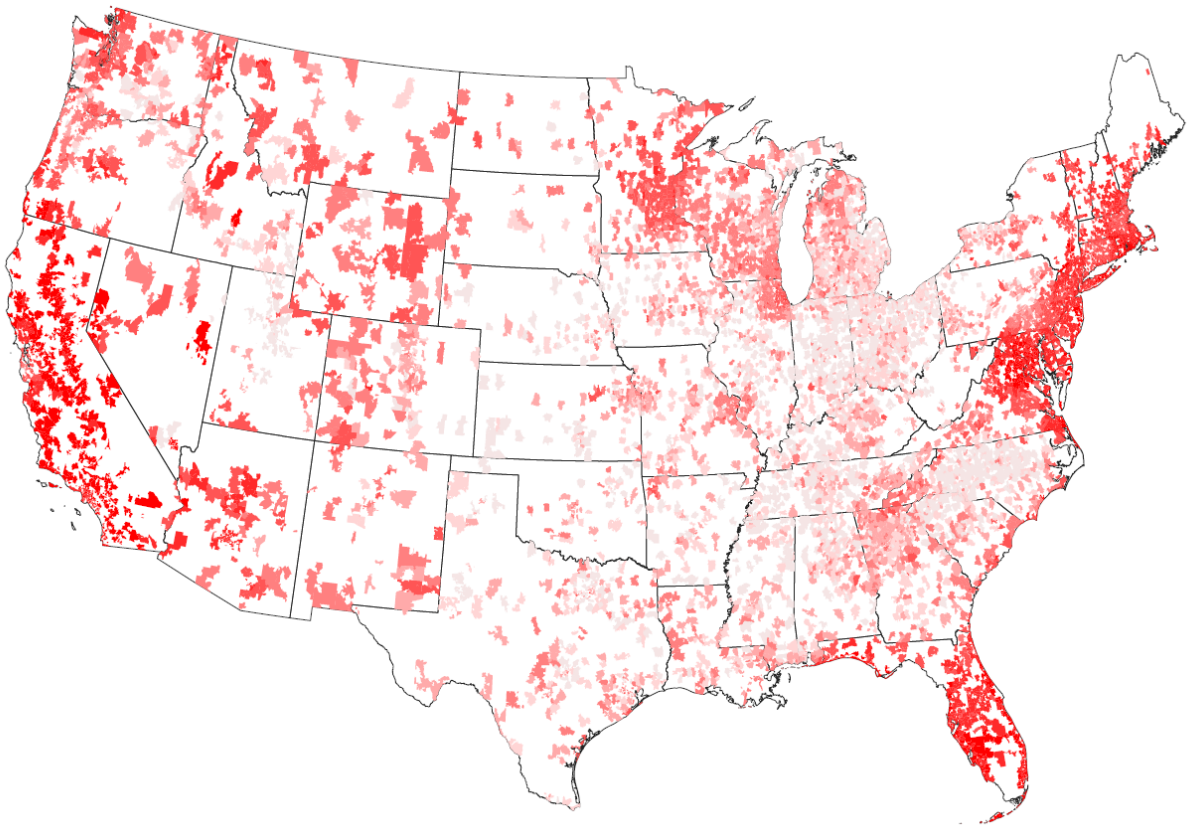
BDL Zip Code coverage



Darker zip codes experience larger increase in HPI between 2000 and 2005

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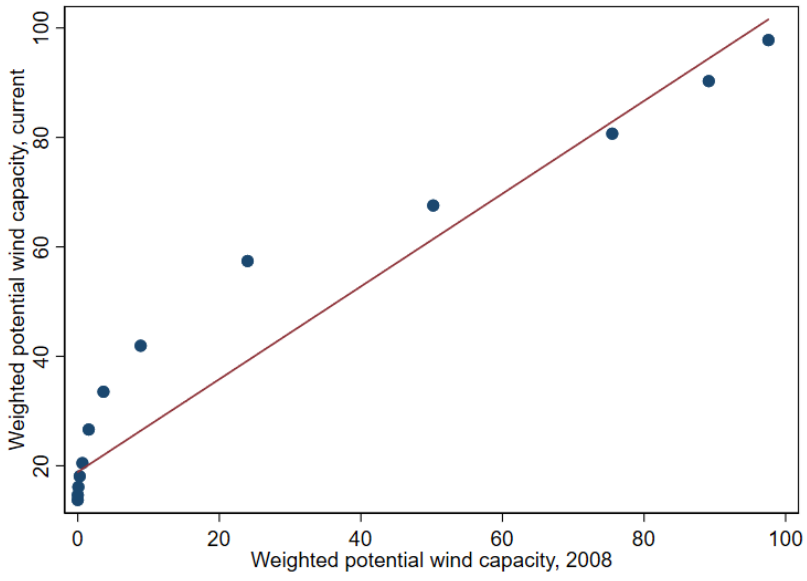
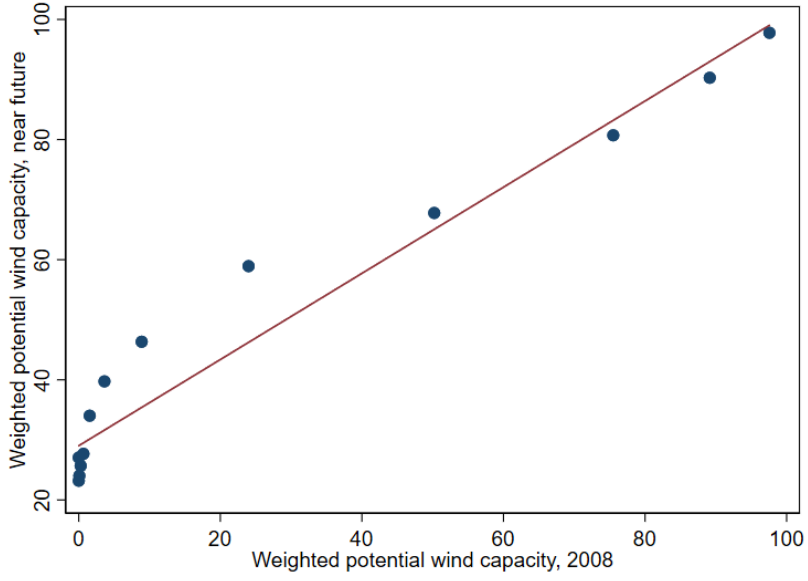
Potential wind capacity

Current estimate vs 2008



Near future estimate vs 2008



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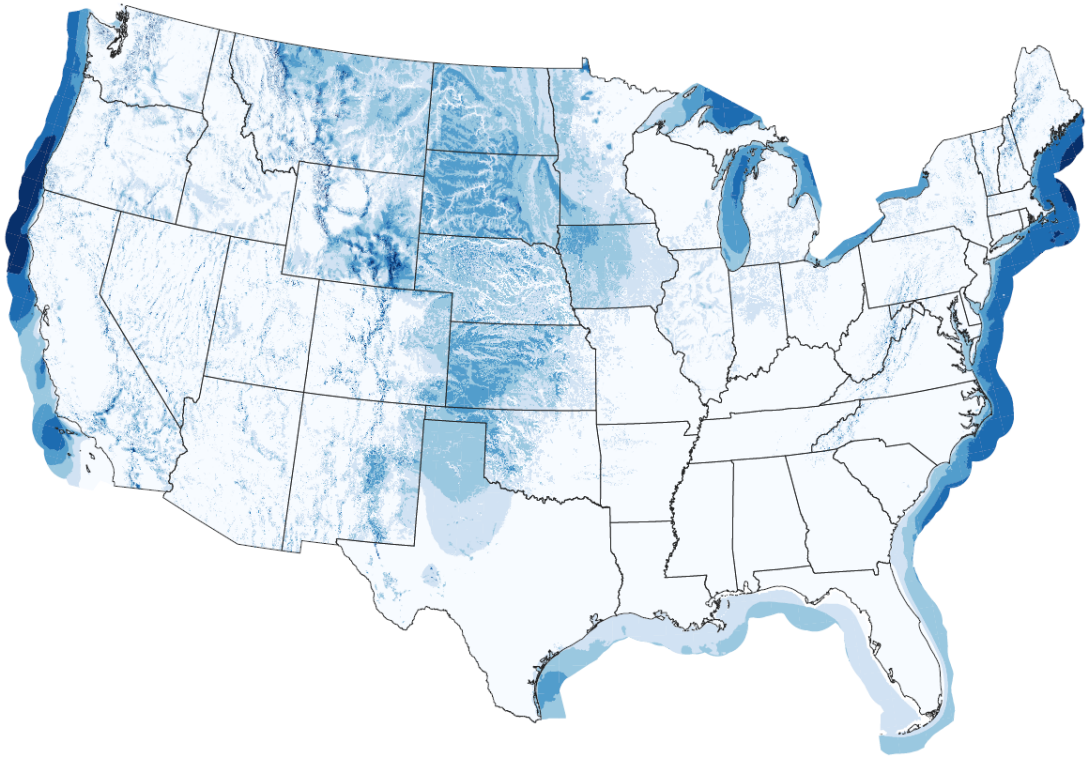
Wind power class

- Wind class varies from 1 to 7
- Usually wind turbines are built in locations with wind class $\geqslant 3$



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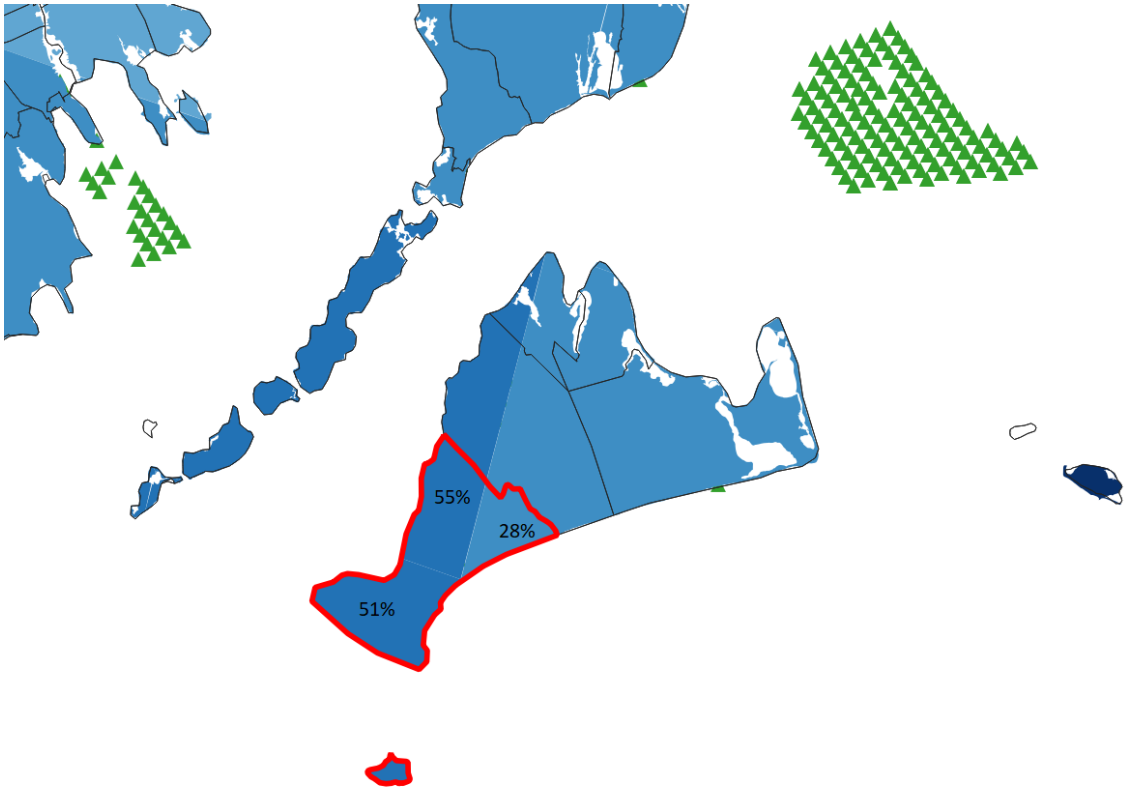
Instrument construction



- Taking weighted average: 47% of the zip code area has potential wind capacity in 2008 of 30% or more

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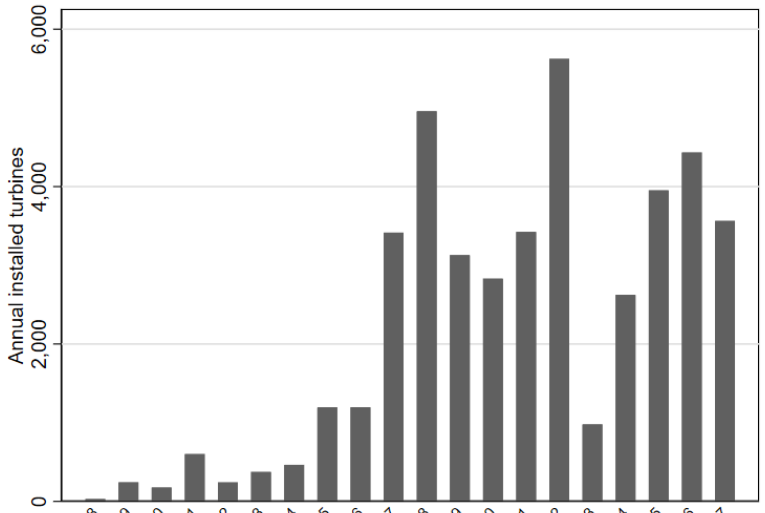
Alternative instrument

- Interact potential wind capacity with wind energy subsidies
  - ◇ Federal Production Tax Credit (PTC)
  - ◇ Renewable Portfolio Standards (RPS)
- Federal PTC expired many times and then renewed
- Drop in number of installed turbines coincides with the expiration of the PTC in the preceding year



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