Economic Impacts of Wind Turbine Development in U.S. Counties

What are the economic development impacts on U.S. counties of wind power projects, as defined by growth in per capita income and employment?

Objective

To address the research question using post-project construction, county-level data, and econometric evaluation methods.

Background

- Wind energy is expanding rapidly in the United States: Over the last 4 years, wind power has contributed approximately 35 percent of all new electric power capacity.
- Wind power plants are often developed in rural areas where local economic development impacts from the installation are projected, including land lease and property tax payments and employment growth during plant construction and operation.
- Wind energy represented 2.3 percent of the U.S. electricity supply in 2010, but studies show that penetrations of at least 20 percent are feasible.

Issue

- Several studies have used input-output models to predict direct, indirect, and induced economic development impacts. These analyses have often been completed prior to project construction.
- Available studies have not yet investigated the economic development impacts of wind development at the county level using post-construction econometric evaluation methods.
- Analysis of county-level impacts is limited. However, previous county-level analyses have estimated operation-period employment at 0.2 to 0.6 jobs per megawatt (MW) of power installed and earnings at $9,000/MW to $50,000/MW. [1,2]

Methods and Data

Econometric methods

- Estimate marginal impact of wind energy projects on county-level changes in per capita income and employment from 2000 to 2008, focusing on 15 Western and Midwestern States with substantial wind energy development.
- Use four models to explain changes in per capita income and employment:
  1. Ordinary least squares (OLS) on full sample of counties both with and without wind installations;
  2. OLS on wind energy counties only;
  3. OLS on propensity-score matched counties (including wind and non-wind); and
  4. Spatial lag model on full sample of counties, both with and without wind.
- Use spatial lag model to test and control for spatial spillover effects.[3,4] The following equation was estimated:

Structural equation: $y = \rho W y + X\beta + \varepsilon$

where y is the change in county-level per capita income/employment, Wy is the weighted average of the change in per capita income/employment of neighboring counties, X is a vector of covariates of observable county-level socioeconomic and demographic characteristics, and ε is a vector of errors.

Marginal effects: $$\underset{n \times n}{\frac{\partial y}{\partial x_k}} = (I - pW)^{-1}\beta_k$$

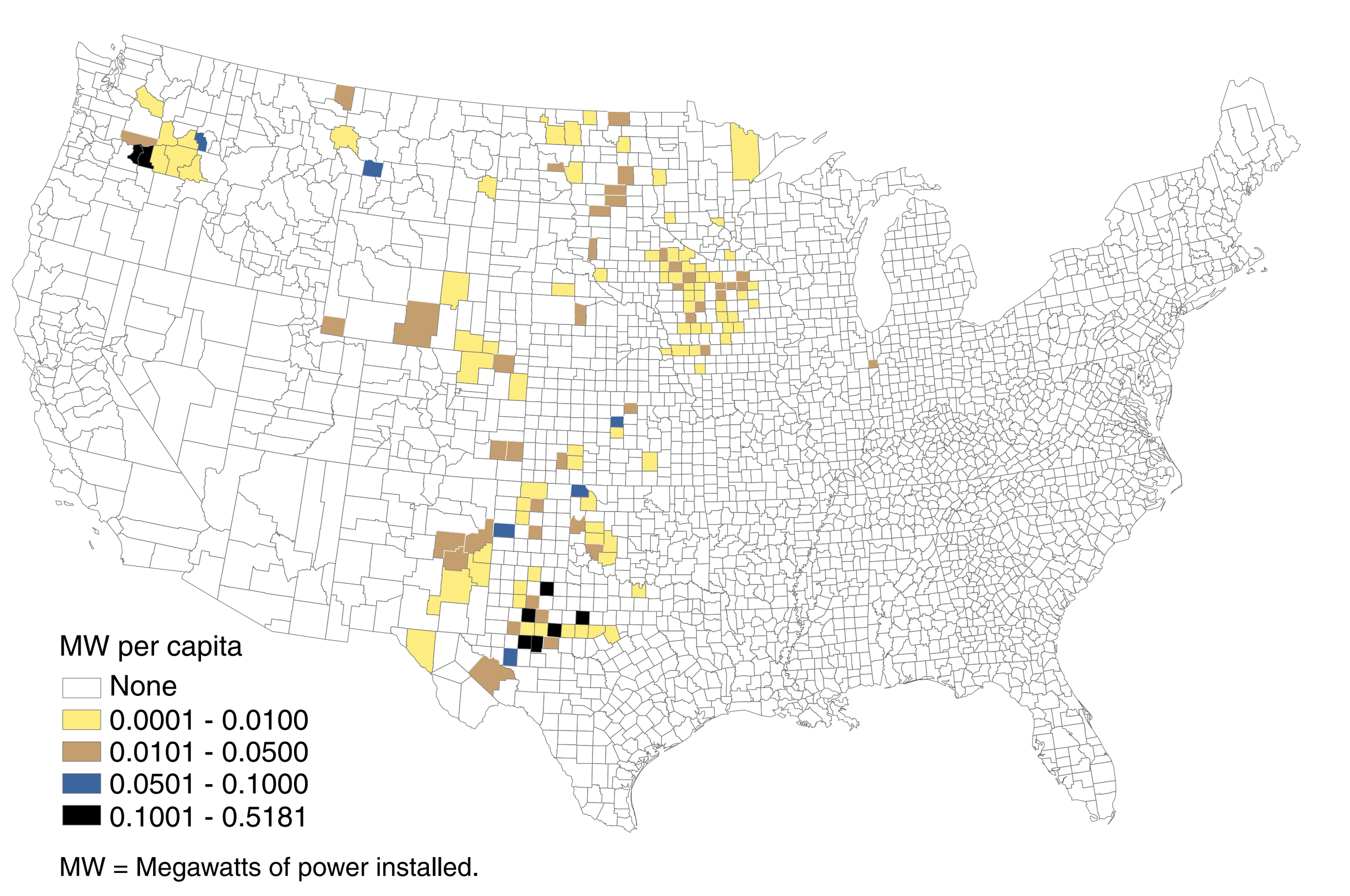
Data

- Wind turbine locations from Lawrence Berkeley National Laboratory, used to estimate per capita MW of wind power installed from 2000-2008; 139 wind counties in 15 States evaluated.
- Per capita income (2000-2008) and employment data (2001-2008) from Bureau of Economic Analysis, U.S. Department of Commerce.
- Controlling covariates measured in 2000, from the 2000 Population Census, USDA's Economic Research Service, and the National Agricultural Statistics Service, including:

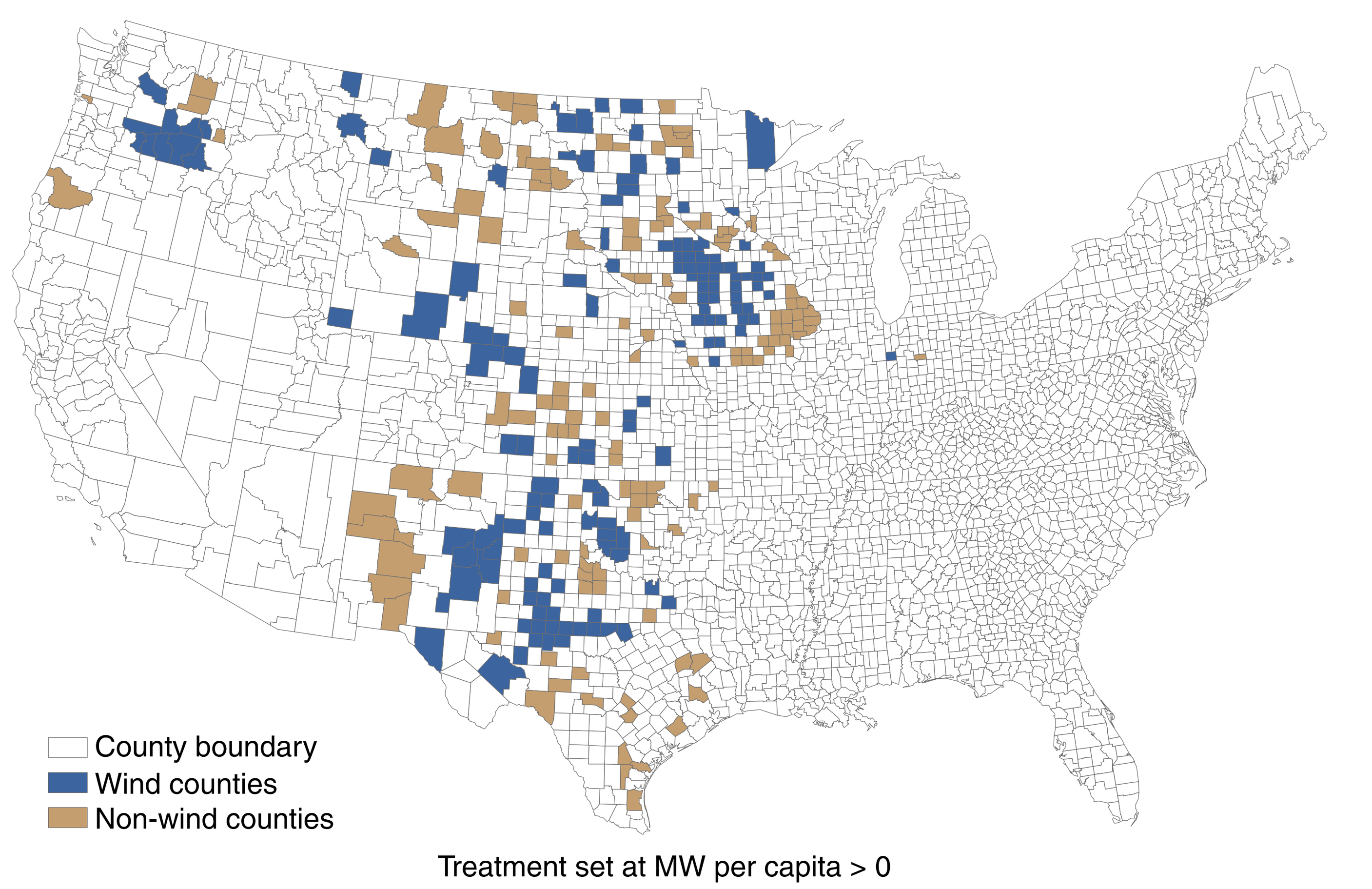
Socioeconomic and demographic characteristics
Per capita income
Population
Poverty
Population density
Rural share of population
Farm share of population
African American share of population
Child (< 18) share of population
Elderly share of population
Labor market characteristics
Agriculture, construction, manufacturing, and retail shares of employment
Share of adult population with an associate, bachelor's, or master's degree
Share of adult men and women working full time
Share of population in creative class occupations*
Unemployment rate
*ERS list of creative class occupations available at: http://www.ers.usda.gov/Data/CreativeClassCodes/
Infrastructure and other
Population-weighted distance to highway on-ramp
Available land (share of farm areas in a county)
Economic development grants per capita
Metro county identification
State-level fixed effects

In our sample, cumulative wind turbine capacity on a per person basis is largely concentrated in a band of counties from North Dakota to Texas. Counties with the largest per capita capacities are located in West-Central Texas and Eastern Oregon. Given the spatial distribution of counties with wind energy, economic spillovers may occur between neighboring non-wind counties. We account for this in two ways: (1) by excluding non-wind counties that are adjacent to wind counties in the propensity-score matching process, and (2) by modeling spatial spillovers explicitly.

Cumulative wind turbine capacity installed in selected States, 2000-08



Wind and non-wind counties from propensity-score matching



Balance tests of performance of propensity-score matching

Sample (N=1174)	Pseudo R^2	LR X^2	pval
Unmatched	0.187	159.76	0.000
Matched	0.048	18.25	0.998

Global balance tests demonstrate good matching (differences between the matched samples are statistically insignificant and the probit model has a low pseudo R^2). T tests of differences in the means of each covariate are also statistically insignificant for all covariates in the matched samples, with a small percentage absolute bias in covariate values (< 10 percent for all covariates except the farmland share of land (18 percent) and the metro area indicator (15 percent)).

Results

- We find statistically significant evidence of positive impacts of wind development on county-level per capita income from the OLS and spatial lag models when they are applied to the full set of wind and non-wind counties.
- The total impact on annual per capita income of wind turbine development (measured in MW per capita) in the spatial lag model was $21,604 per MW. This estimate is within the range of values estimated in the literature using input-output models.
- OLS results for the wind-only counties and matched samples are similar in magnitude, but are not statistically significant at the 10-percent level.
- We find a statistically significant impact of wind development on employment in the OLS analysis for wind counties only, but not in the other models. Our estimates of employment impacts are not precise enough to assess the validity of employment impacts from input-output models applied in advance of wind energy project construction.

Marginal effect changes in per capita income, 2000-08

	OLS full (N=1174)	OLS wind only (N=139)	OLS matched[2] (N=276)	Spatial model (ρ = 0.358***) (N=1174)		
				Direct	Indirect	Total
Wind additions (MW/capita)	$14,355**	$18,069	$14,085	$14,248**	$7,355**	$21,604**
	(7265)[1]	(12253)	(9579)	(6154)	(3466)	(9519)

[1]Robust standard errors are in parentheses; *, **, *** denote statistical significance at 10-percent, 5-percent, and 1-percent levels, respectively (two-sided test).
[2]Adjacent non-wind counties were excluded in the matching process.

Marginal effect changes in per capita employment, 2000-08

	OLS full (N=1174)	OLS wind only (N=139)	OLS matched[1] (N=276)	Spatial model[2] (N=1174)
Wind additions (MW/capita)	0.027	0.207**	0.040	N.A.
	(0.091)[3]	(0.087)	(0.097)	

[1]Adjacent non-wind counties were excluded in the matching process.
[2]Spatial model not appropriate as OLS residuals were not spatially dependent.
[3]Robust standard errors are in parentheses; *, **, *** denote statistical significance at 10-percent, 5-percent, and 1-percent levels, respectively (two-sided test).

Conclusion

The analysis provides empirical evidence of positive income effects at the county level from cumulative wind turbine development, consistent with the range of impacts estimated using input-output models. Employment impacts are less clear.

References

[1] Government Accountability Office (GAO). 2004. *Renewable Energy: Wind Power's Contribution to Electric Power Generation and Impact on Farms and Rural Communities*. U.S. Government Accountability Office.
[2] Torgerson, M., B. Sorte, & T. Nam. 2006. *Umatilla County's Economic Structure and the Economic Impacts of Wind Energy Development: An Input-Output Analysis*. Oregon State University Extension Service.
[3] Anselin, L. 1988. *Spatial Econometrics: Methods and Models*. Kluwer Academic, Dordrecht, Netherlands.
[4] LeSage, J., and R.K. Pace. 2009. *Introduction to Spatial Econometrics*. Chapman & Hall/CRC, Boca Raton, FL.

U.S. Department of Agriculture
Economic Research Service
www.ers.usda.gov

Jason P. Brown, jbrown@ers.usda.gov **Ben Hoen**, BHoen@lbl.gov **Eric Lantz**, eric.lantz@nrel.gov **John Pender**, jpender@ers.usda.gov **Ryan Wiser**, RHWiser@lbl.gov

The views expressed here are those of the authors, and may not be attributed to the U.S. Department of Agriculture, the Economic Research Service, the Lawrence Berkeley National Laboratory, the National Renewable Energy Laboratory, or the U.S. Department of Energy (DOE). Berkeley Lab's and NREL's contribution to this work was funded by the U.S. DOE (Wind & Water Power Program) under Contract No. DE-AC02-05CH11231.

Presented at the 2011 AAEA & NAREA Joint Annual Meeting, July 24-26, 2011, Pittsburgh, PA.