A Additional Figures

Figure A1: Bald Eagle Relative Abundance Map, EBird (Sullivan et al., 2009)

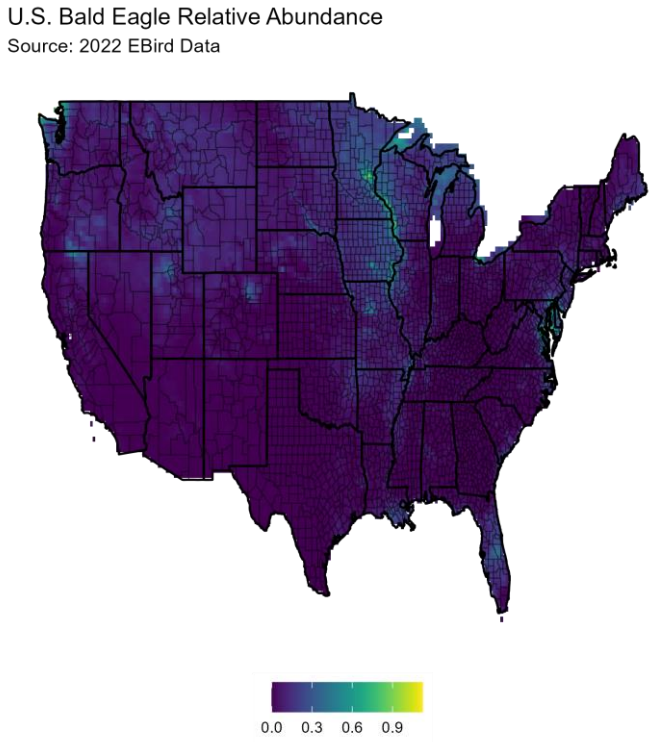


Figure A2: Golden Eagle Relative Abundance Map, EBird (Sullivan et al., 2009)

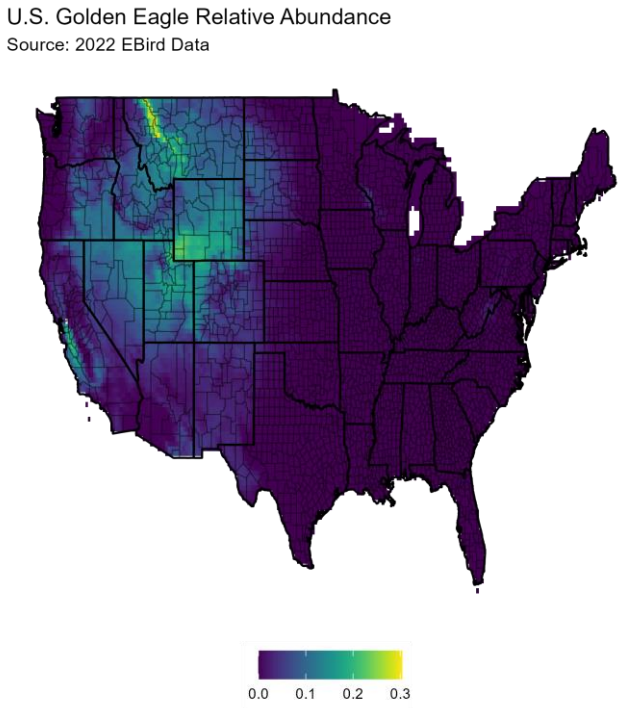


Figure A3: Mean Capacity Additions by Treated Status

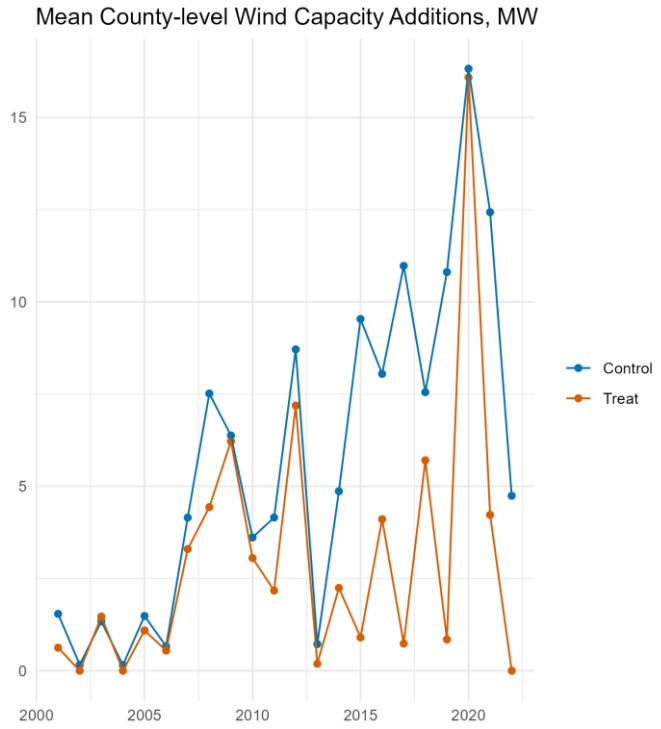


Figure A4: Mean Turbine Additions by Treated Status

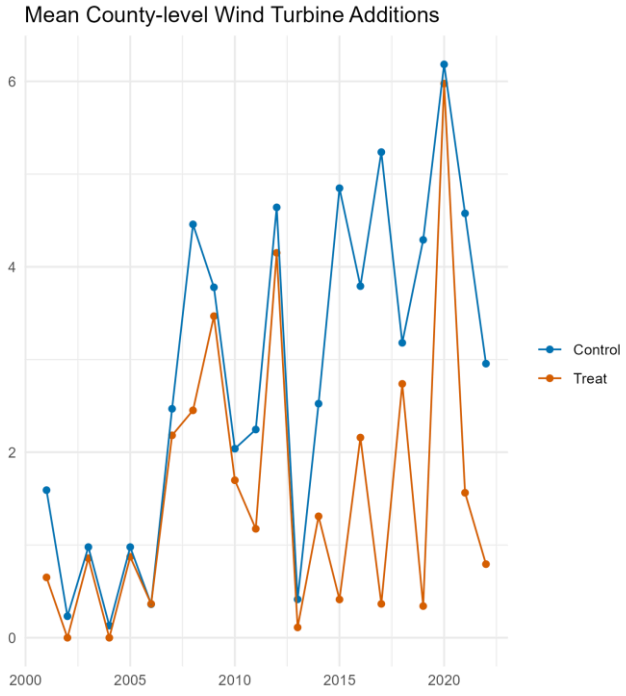


Figure A5: Wind Turbine Locations, USWTDB (Hoen et al., 2022)

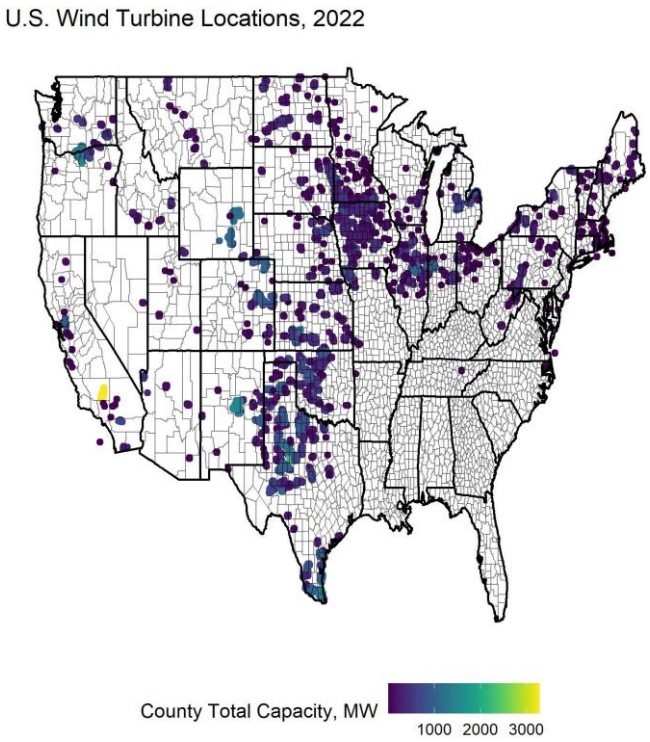


Figure A6: Wind Turbine Locations through 2012, USWTDB (Hoen et al., 2022)

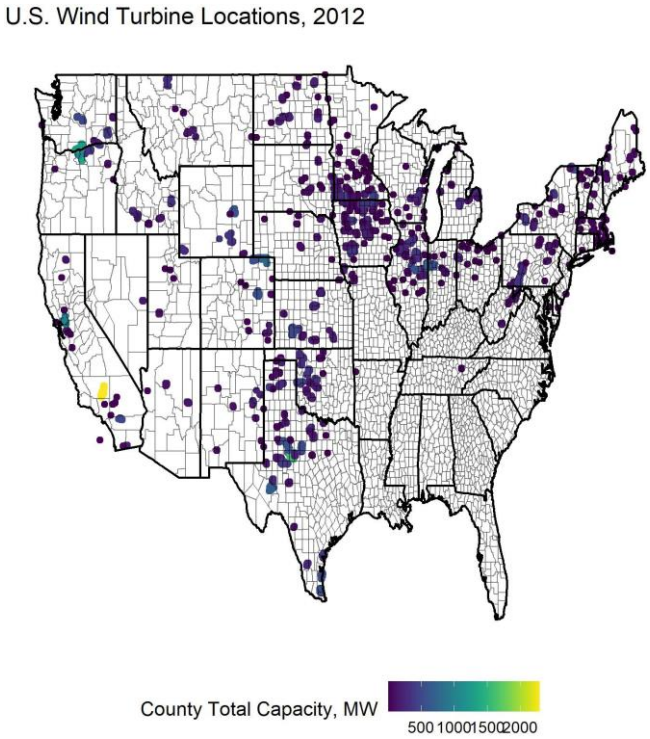


Figure A7: Wind Speeds (MPH), NREL Wind Supply Curve Data (Lopez et al., 2021)

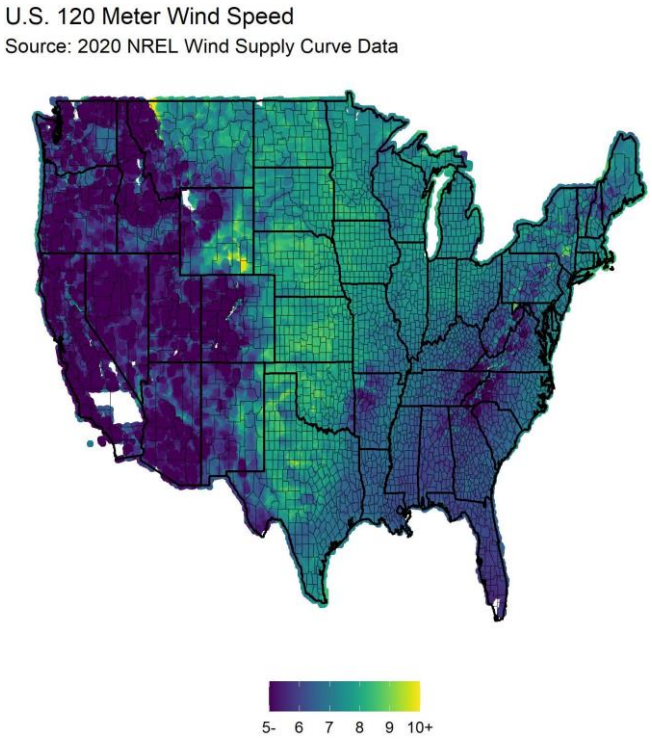


Figure A8: Potential Capacity (MW), NREL Wind Supply Curve Data (Lopez et al., 2021)

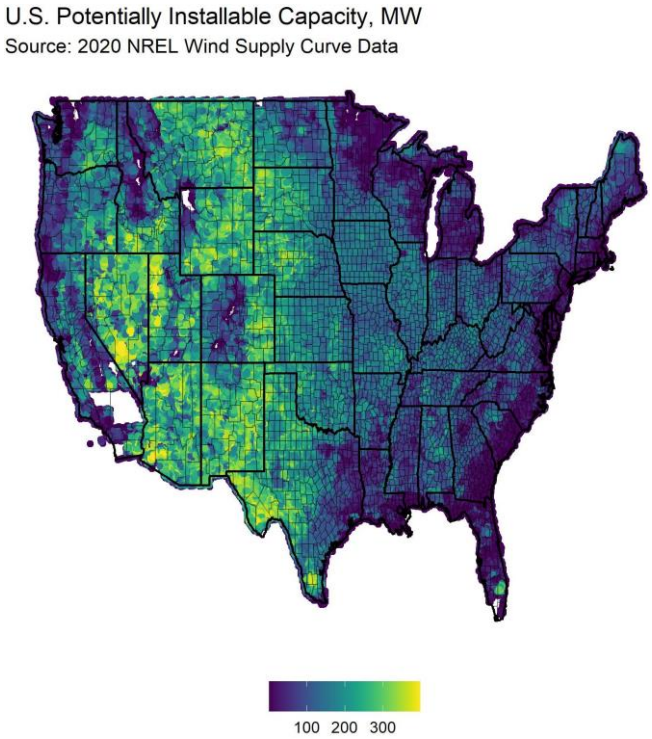
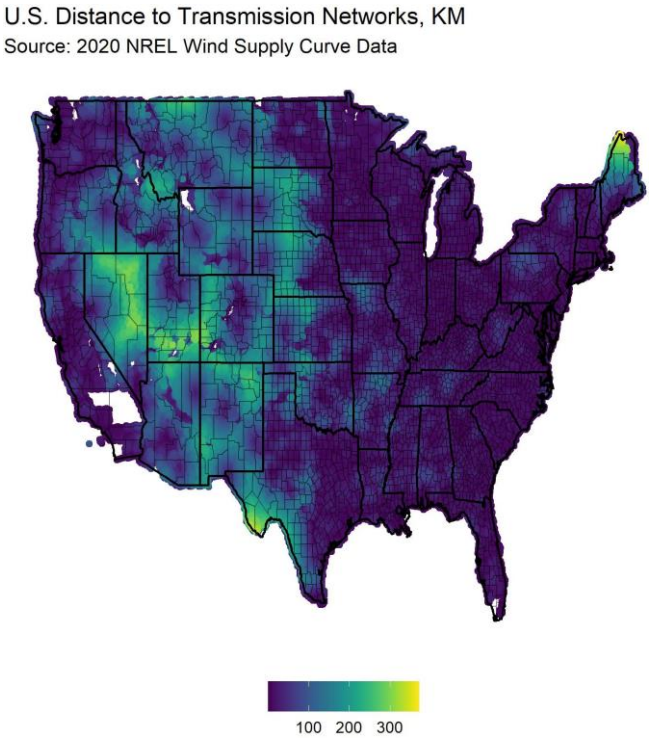


Figure A9: Transmission Dist. (KM), NREL Wind Supply Curve Data (Lopez et al., 2021)



B Robustness Check Tables

Table B1: Robustness checks: Covariates

	(1) Added Capacity	(2) Added Capacity	(3) Added Capacity
County exceeds cutoffs * Post	-4.812***	-4.924***	-5.297***
	(1.108)	(1.398)	(1.489)
Wind Speed * t		0.399***	
		(0.119)	
Potential Cap. * t		0.00650***	
		(0.00189)	
Transmission Dist. * t		-0.00677***	
		(0.00160)	
County FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Characteristics * Year FE	No	No	Yes
Cluster	County	County	County
N	18722	18722	18722

Standard errors in parentheses

* p<0.10, ** p<0.05, *** p<0.01

Notes: Column (1) reiterates the baseline results for added capacity from table 2. Column (2) shows results from a model that includes three key covariates – wind speed, potential capacity, and transmission distance – interacted with a linear time trend. Column (3) shows results from a model that includes the same three covariates interacted with year fixed effects.

Table B2: Robustness checks: Covariates

	(1) Added Turbines	(2) Added Turbines	(3) Added Turbines
County exceeds cutoffs * Post	-1.950***	-1.922***	-2.158***
	(0.510)	(0.671)	(0.679)
Wind Speed * t		0.165***	
		(0.0525)	
Potential Cap. * t		0.00240***	
		(0.000892)	
Transmission Dist. * t		-0.00260***	
		(0.000725)	
County FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Characteristics * Year FE	No	No	Yes
Cluster	County	County	County
N	18722	18722	18722

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Notes: Column (1) reiterates the baseline results for the count of added turbines from Table 2. Column (2) shows results from a model that includes three key covariates – wind speed, potential capacity, and transmission distance – interacted with a linear time trend. Column (3) shows results from a model that includes the same three covariates interacted with year fixed effects.

Table B3: Robustness checks: Within-state variation

	(1) Added Capacity	(2) Added Capacity
County exceeds cutoffs * Post	-4.812***	-2.654**
	(1.108)	(1.344)
County FE	Yes	Yes
Year FE	Yes	Yes
State-Year FE	No	Yes
Cluster	County	County
N	18722	18722

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Notes: Column (1) reiterates the baseline results for added capacity from table 2. Column (2) shows results from a model that includes state-by-year fixed effects.

Table B4: Robustness checks: Within-state variation

	(1) Added Turbines	(2) Added Turbines
County exceeds cutoffs * Post	-1.950***	-0.713
	(0.510)	(0.638)
County FE	Yes	Yes
Year FE	Yes	Yes
State-Year FE	No	Yes
Cluster	County	County
N	18722	18722

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Notes: Column (1) reiterates the baseline results for the count of added turbines from Table 2. Column (2) shows results from a model that includes state-by-year fixed effects.

Table B5: Robustness Check: Control Counties Omitted by Distance to Treated Counties

	(1) Added Capacity	(2) Added Capacity	(3) Added Capacity
County exceeds USFWS cutoffs * Post	-5.834***	-6.475***	-8.489***
	(1.217)	(1.301)	(1.615)
County FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Distance from Treated, KM	50	100	200
Cluster	County	County	County
N	15070	13178	9130

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Notes: Column (1) shows the results of the baseline model where control counties closer than 50 km to the nearest treated county are excluded from the sample. Columns (2) and (3) show the results of the baseline model where control counties closer than 100 km and 200 km to the nearest treatment county are excluded from the sample, respectively.

C Sensitivity to Sample Selection

Our baseline results are derived from a sample of only counties in central US states with average wind speeds above 7 MPH and average potentially installable capacities above 100 MW. The purpose of these sample restrictions is to limit identification to comparisons within a group of counties with similar wind energy potential at the outset. However, the precise choices of thresholds are arbitrary.

In this appendix, we show evidence that our main results are not sensitive to these specific sample restrictions. We do so in two ways. First, we reduce the wind speed minimum to 6.5 MPH, while keeping the 100 MW potential capacity minimum; results are shown in Table C.1 and Figure C.1. Second, we impose no sample restrictions on counties within the sample states; results are shown in Table C.2 and Figure C.2. In both specifications, results are qualitatively similar to the baseline results.

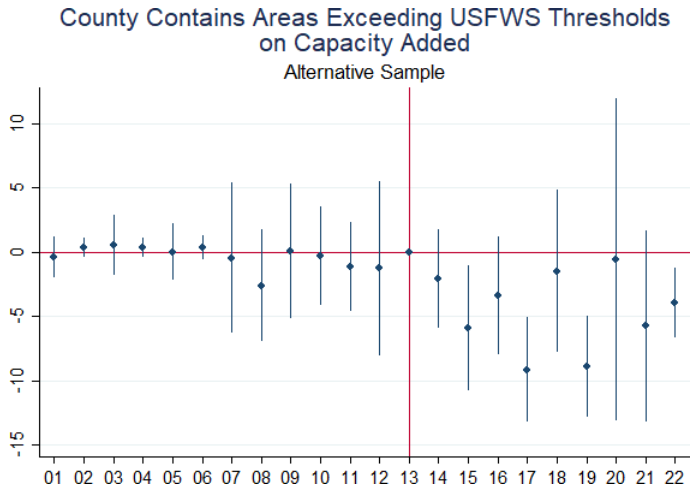
Table C1: Effects of BGEPA enforcement (alternative sample restrictions)

	(1) Added Capacity	(2) Added Turbines
County has area exceeding USFWS cutoffs * Post	-4.242***	-1.654***
	(1.046)	(0.487)
County FE	Yes	Yes
Year FE	Yes	Yes
Cluster	County	County
N	20086	20086

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Notes: Table reports estimates from regressions of the form in Equation 1, using a binary treatment variable that equals 1 if a county contains area that exceeds seasonal USFWS general permit thresholds for either golden or bald eagles. Here, the sample is restricted to counties with a mean wind speed above 6.5 MPH and potential capacity above 100 MW.

Figure C1: Event study: Effects of BGEPA enforcement (alternative sample restrictions)



Notes: Graph plots point estimates and 95% confidence intervals from an event study regression of the form in Equation 2, using a binary treatment variable that equals 1 if a county contains area that exceeds seasonal USFWS general permit thresholds for either golden or bald eagles. The outcome is regressed on binary indicators for years 2001 through 2022, each interacted with the treatment variable, along with county and year fixed effects. The *x*-axis labels years since 2000; enforcement begins after 2013. Standard errors are clustered by county. Here, the sample is restricted to counties with a mean wind speed above 6.5 MPH and potential capacity above 100 MW.

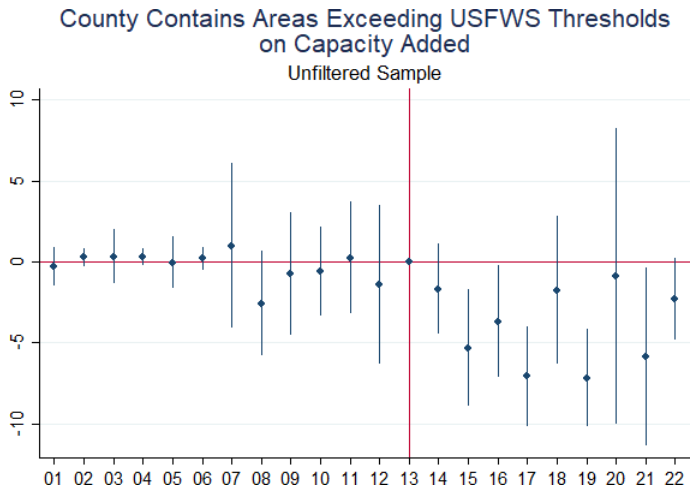
Table C2: Effects of BGEPA enforcement (unrestricted sample)

	(1) Added Capacity	(2) Added Turbines
County has area exceeding USFWS cutoffs * Post	-3.715***	-1.490***
	(0.782)	(0.370)
County FE	Yes	Yes
Year FE	Yes	Yes
Cluster	County	County
N	26730	26730

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Notes: Table reports estimates from regressions of the form in Equation 1, using a binary treatment variable that equals 1 if a county contains area that exceeds seasonal USFWS general permit thresholds for either golden or bald eagles. Here, the sample is unrestricted beyond selecting states located within the wind-rich Great Plains region.

Figure C2: Event study: Effects of BGEPA enforcement (unrestricted sample)



Notes: Graph plots point estimates and 95% confidence intervals from an event study regression of the form in Equation 2, using a binary treatment variable that equals 1 if a county contains area that exceeds seasonal USFWS general permit thresholds for either golden or bald eagles. The outcome is regressed on binary indicators for years 2001 through 2022, each interacted with the treatment variable, along with county and year fixed effects. The *x*-axis labels years since 2000; enforcement begins after 2013. Standard errors are clustered by county. Here, the sample is unrestricted beyond selecting states located within the wind-rich Great Plains region.

D Continuous Treatment Specifications

In this appendix, we use a continuous treatment model to supplement the baseline binary treatment results. This method potentially avoids the issue of ambiguous treatment definitions and may gain statistical power by leveraging all differences in relative abundance across counties. Instead of defining the treatment variable as a binary discretization of relative abundance, we simply use the raw values of relative abundance as treatment variable: $EagleExposed_i := RelativeAbundance_i$. The coefficient β then captures an average marginal impact of unit increases in relative abundance on the outcome variable y_{it}. Since relative abundance values are not comparable across species, we perform this specification separately with bald and golden eagle relative abundance.

Regression results are shown in Table D.1. In the golden eagle model, a one-percentage-point increase in golden eagle relative abundance is significantly associated with a decline in capacity additions of 0.52 MW and 0.24 turbines per year. In the bald eagle model, a one-percentage-point increase in bald eagle relative abundance is significantly associated with a decline in in capacity additions of 0.33 MW and 0.14 turbines per year. To put these results in perspective, the standard deviation of golden eagle relative abundance is 0.02, so a one-standard-deviation increase in golden eagle abundance reduces capacity additions by 1.05 MW per year. Similarly, a standard deviation of bald eagle relative abundance is 0.09, so a standard deviation increase in bald eagle relative abundance reduces capacity additions by 3.0 MW per year. Event study figures using the continuous treatment variable are shown in Figures D.1 and D.2 for golden eagles, and Figures D.3 and D.4 for bald eagles. Overall, results are qualitatively similar to the baseline binary treatment results.

The reason we prefer a binary treatment variable in the main body of this paper is that continuous treatment models feature unique challenges for causal inference under heterogeneous effects, as shown in recent work by Callaway et al. (2021). Continuous treatment models feature different treatment groups with potentially different treatment effects; if there exists systematic differences in treatment effects between realized treated outcomes and unrealized untreated outcomes by treatment group, these differences confound the identification of the marginal impact of a unit increase in treatment intensity. Therefore, continuous treatment models require a strong parallel trends assumption. This requires that each treatment group's unrealized outcomes at all different treatment intensities be parallel to all corresponding groups with those realized treatment intensities. This condition allows for different treatment groups to serve as valid counterfactuals for each other, allowing the identification of the marginal impacts of treatment intensity.

The strong parallel trends assumption is defensible for this study. Differences in unrealized treatment effects between treatment groups are a particular concern when observing agents optimizing their treatment intensity choices based on unobserved factors. This is why Callaway et al. (2021) frame this issue as "selection bias." In this application, observation units are counties. Treatment depends on plausibly exogenous golden eagle distributions, and units have no way to select into different exposures based on their unobserved wind tur- bine potential. Furthermore, just as in the basic difference-in-differences case, county fixed effects absorb potentially confounding differences such as wind speed and terrain. Finally, transmission networks grant developers some flexibility in wind turbine siting, diminishing variation in potential treatment effects across space.

Table D1: Effects of BGEPA enforcement (continuous treatment)

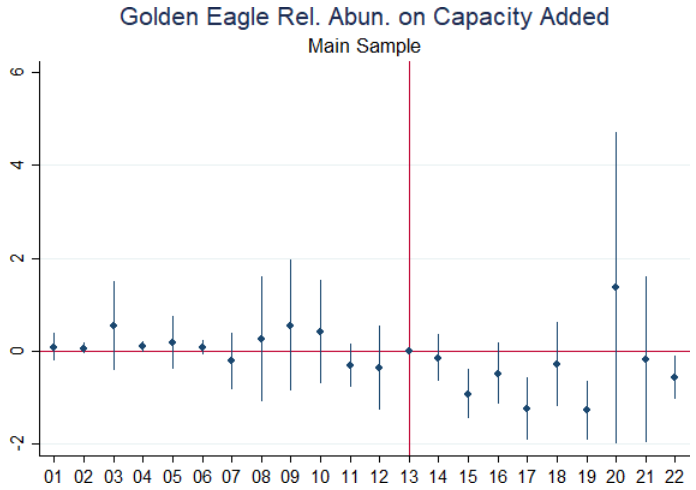
	(1) Added Capacity	(2) Added Turbines	(3) Added Capacity	(4) Added Turbines
Post * Golden Eagle Rel. Abun. * 100	-0.523**	-0.242***		
	(0.228)	(0.0838)		
Post * Bald Eagle Rel. Abun. * 100			-0.328***	-0.136***
			(0.0581)	(0.0264)
County FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Cluster	County	County	County	County
N	18722	18722	18722	18722

Standard errors in parentheses

* p<0.10, ** p<0.05, *** p<0.01

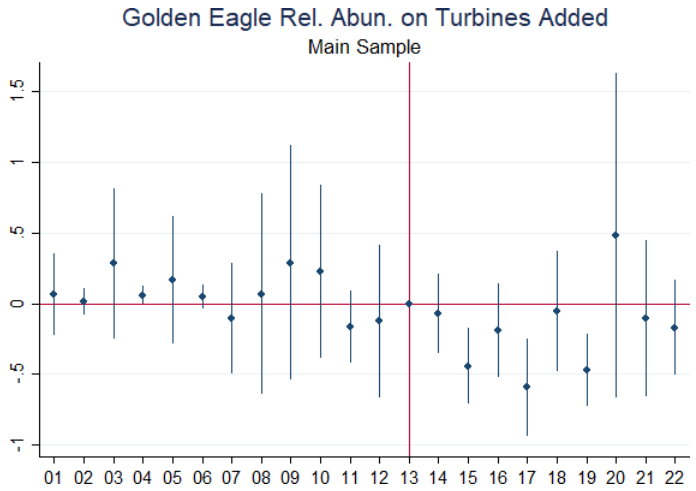
Notes: Table reports estimates from regressions of the form in Equation 1, using relative abundance as a continuous treatment variable. Results are displayed separately for golden and bald eagles, respectively.

Figure D1: Event study: Effects of BGEPA enforcement (continuous treatment)



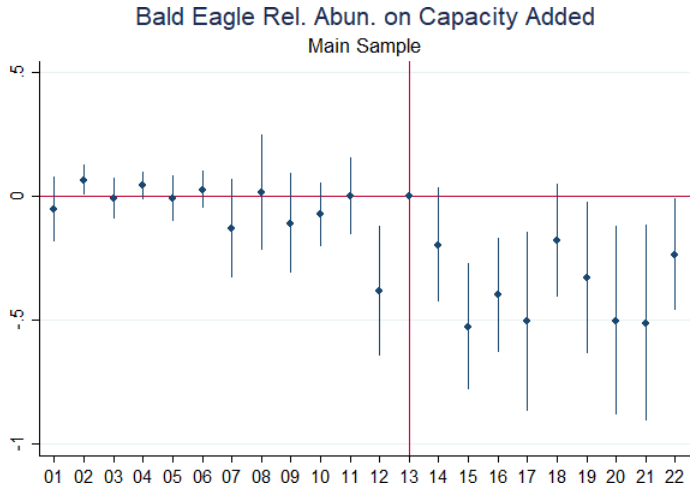
Notes: Graph plots point estimates and 95% confidence intervals from an event study regression of the form in Equation 2, using golden eagle relative abundance as a continuous treatment variable and added capacity as an outcome variable. The outcome is regressed on binary indicators for years 2001 through 2022, each interacted with the treatment variable, along with county and year fixed effects. The *x*-axis labels years since 2000; enforcement begins after 2013. Standard errors are clustered by county.

Figure D2: Event study: Effects of BGEPA enforcement (continuous treatment)



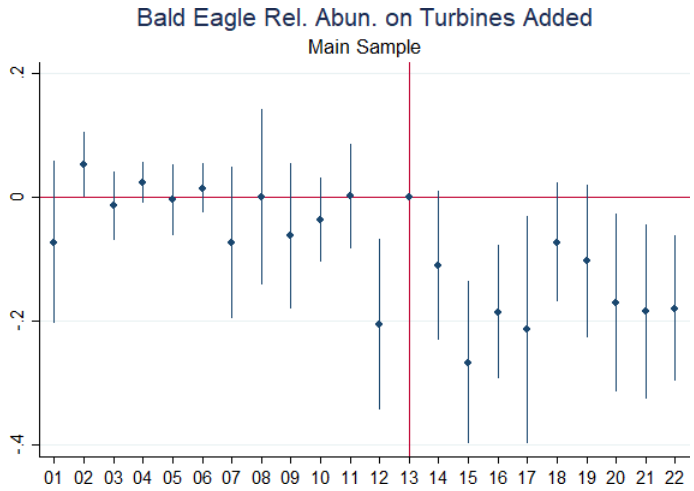
Notes: Graph plots point estimates and 95% confidence intervals from an event study regression of the form in Equation 2, using golden eagle relative abundance as a continuous treatment variable and added turbines as an outcome variable. The outcome is regressed on binary indicators for years 2001 through 2022, each interacted with the treatment variable, along with county and year fixed effects. The *x*-axis labels years since 2000; enforcement begins after 2013. Standard errors are clustered by county.

Figure D3: Event study: Effects of BGEPA enforcement (continuous treatment)



Notes: Graph plots point estimates and 95% confidence intervals from an event study regression of the form in Equation 2, using bald eagle relative abundance as a continuous treatment variable and added capacity as an outcome variable. The outcome is regressed on binary indicators for years 2001 through 2022, each interacted with the treatment variable, along with county and year fixed effects. The *x*-axis labels years since 2000; enforcement begins after 2013. Standard errors are clustered by county.

Figure D4: Event study: Effects of BGEPA enforcement (continuous treatment)



Notes: Graph plots point estimates and 95% confidence intervals from an event study regression of the form in Equation 2, using bald eagle relative abundance as a continuous treatment variable and added turbines as an outcome variable. The outcome is regressed on binary indicators for years 2001 through 2022, each interacted with the treatment variable, along with county and year fixed effects. The *x*-axis labels years since 2000; enforcement begins after 2013. Standard errors are clustered by county.

E Treatment Within Separate Grid Regions

Figure E1: Grid Regions Map

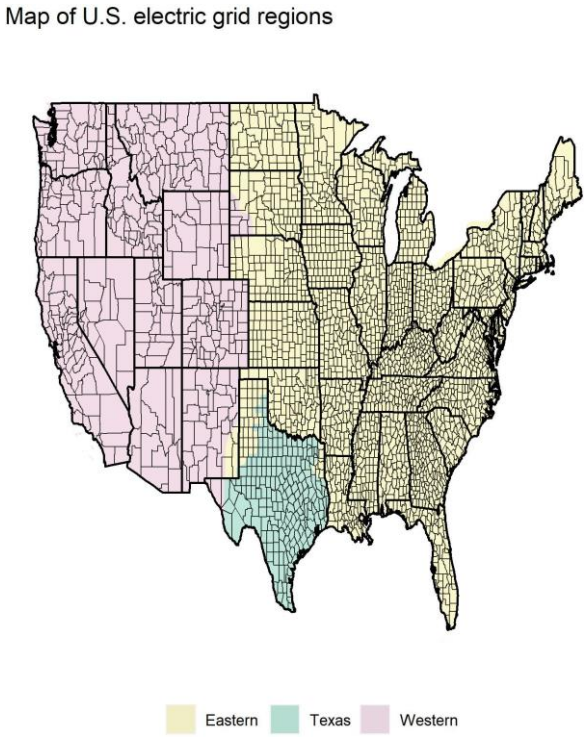


Figure E2: Baseline Treatment Sample bounded within Grid Regions

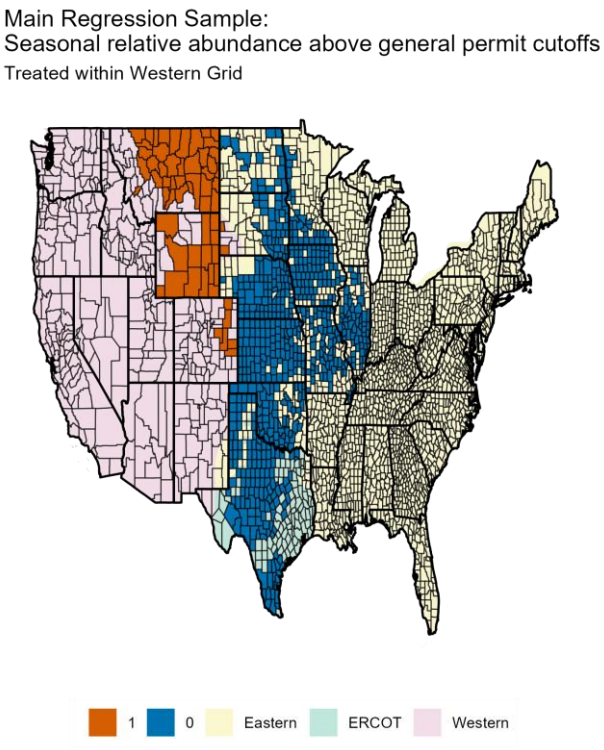


Table E1: Main effects of BGEPA enforcement on wind capacity additions

	(1) Added Capacity	(2) Added Turbines
County exceeds USFWS cutoffs * Post	-4.223**	-2.029**
	(1.767)	(0.818)
County FE	Yes	Yes
Year FE	Yes	Yes
Cluster	County	County
N	15466	15466

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Notes: Table reports estimates from regressions of the form in Equation 1, using a binary treatment variable that equals 1 if a county has any area with seasonal golden eagle relative abundance above USFWS general permit cutoffs, bald eagle relative abundance above USFWS general permit cutoffs, or either species above general permit cutoffs, respectively. In these specifications, the sample is restricted to include only eagle-exposed counties in the Western grid and unexposed counties outside of the Western grid.

F Details of Valuation Methods

F.1 Valuation of Foregone Electricity: Electricity Added Method

To value the electricity generation foregone as a result of BGEPA enforcement, we first apply USGS wind turbine output estimates to the total loss of 605 MW. Using a 843 MWh/-month output estimate for 2.75 MW of capacity (USGS, 2020), we estimate that 605 MW of capacity would have output 185, 460 MWh/month. Using the USGS estimate that 843 MWh/month could power 940 average U.S. homes, we calculate that 185, 460 MWh/month could have powered 206,800 homes.

To value this level of output, we obtained electricity price information from publicly-available EIA datasets. We chose wholesale electricity prices from the Southwest Power Pool (SPP) for their geographical overlap with the eagle-exposed counties in our sample. We take the annual average of 2022-2023 SPP North Hub LMPs due to data availability. This yields an average electricity price of $49.68/MWh.

The final valuation is the product of 185, 460 MWh/month, 12 months/year, and $49.68 per MWh, which equals $111 million per year.

F.2 Valuation of Foregone Electricity: Emissions Displaced Method

As an alternative to the above method, we value the foregone wind turbines through assuming that the generation from these turbines would have completely displaced an equal amount of generation from fossil-fuel generators. The wind turbines can then be valued using the social cost of carbon of the averted fossil-fuel emissions.

To estimate this at an annual level, we first use the same steps shown in the previous method to arrive at an estimate of 185, 460 MWh/month of electricity generation. Multiplying this by 12 yields a result of 2, 225, 520 MWh/year.

We combine this estimate with EPA greenhouse gas equivalence estimates from EPA AVERT data (EPA, 2023). AVERT data gives an average of $7.09 * 10^{-4}$ tons of CO2 per KWh of generation. Multiplying by the displaced generation above, we obtain a total of 1, 577, 894 tons of CO2 per year.

Finally, we apply the U.S. federal government's current estimate of the social cost of carbon, which is $51 per ton of CO2 (Hersher et al., 2023). Multiplying this by the annual CO2 estimate yields a total valuation of approximately $80.5 million per year.

F3 Eagle Fatalities

We estimate the number of fatalities of golden eagles from forgone wind turbines using a process employed in USFWS (2012), New et al. (2015), and New et al. (2018). The estimation procedure involves a Bayesian process, in which site-specific eagle observations are used to update golden eagle exposure priors. Given a lack of site-specific observations, we employ the priors-only model using the most recent available priors from New et al. (2018). We perform this process separately for both species.

Estimated eagle mortality is defined as the following:

$$F_s = C_s \lambda_s \varepsilon \tag{1}$$

Where C_s represents collision probability for species s, λ_s represents exposure for species s, and ε represents the cumulative annual hazardous footprint across turbines in a unit.

Species-specific collision probability C has the following distributions:

$$C_{BaldEagle} \sim \beta(1.61, 228.2) \tag{2}$$

$$C_{GoldenEagle} \sim \beta(1.29, 227.6) \tag{3}$$

The parameters for this distribution are taken from realized eagle collision data detailed in New et al. (2018).

In the priors-only model, eagle exposure λ_s has the following distributions:

$$\lambda_{BaldEagle} \sim \Gamma(0.077, 0.024) \tag{4}$$

$$\lambda_{GoldenEagle} \sim \Gamma(0.287, 0.237) \tag{5}$$

These parameters are similarly taken from New et al. (2018).

Finally, hazardous footprint ε is defined as follows:

$$\varepsilon = \tau n h \pi r^2 \tag{6}$$

Where τ represents annual daylight hours, n represents the number of turbines, h represents turbine hazardous space defined as the maximum vertical height from blade tip to ground,[1] and r represents the radius of the circular area of a wind turbine's blades. The geometric components of ε represent a cylindrical space centered at the base of each turbine with

height h and radius r, while τ scales the estimated eagle exposure and collision probability to an annual estimate based on the annual hours during which eagles are active.

We choose values for the parameters of ϵ to represent the average annual count of bald and golden eagles that would have been killed by wind developments in the treated group in the absence of treatment. We first assume 12 daylight hours per day, for a total of 4380 daylight hours per year for τ. To estimate the number of turbines, we take the coefficient -1.95 from the baseline binary treatment model with turbine additions as the outcome variable. We multiply this by the 126 treated counties to obtain a total of 246 foregone turbines. For the remaining variables, we take averages of turbine specifications found in USTWDB data. To represent average wind turbines constructed in the post-BGEPA enforcement period, we filter USWTDB data to years after 2013. This resulted in the following parameters:

$$\tau = 4380 \tag{7}$$

$$n = 168 \tag{8}$$

$$h = 0.14km \tag{9}$$

$$r = 0.06km \tag{10}$$

We run 100, 000 repetitions of simulations of C_s and λ_s, calculating the estimated mortality F_s for each set of values per species. The resulting distribution of $F_{BaldEagle}$ has a mean of 37 fatalities per year, while $F_{GoldenEagle}$ has a mean of 11 golden eagle fatalities per year.

F*4* Eagle Valuation: ESI Energy Case Method

To obtain the implicit eagle life valuation from the ESI energy case, we combine USFWS predicted mortality measures with costs levied against ESI as a result of the case. We employ predicted mortality measures rather than the observed measures shown in the case to avoid the possibility that the number of eagles cited in the case underestimates the true number of eagles killed due to imperfect detection. A summary of the case, including the dollar value of all costs and USFWS predicted mortality, can be found at DOJ (2022).

Using the 5-year eagle mortality estimates across all ESI wind facilities mentioned in the case, we obtain a predicted mortality value of 5.4 bald eagles per year and 12.6 golden eagles per year.

The one-time fixed costs imposed against ESI are as follows:

$$\$1,861,600 \text{ Fine} \tag{11}$$

$$+\$6,210,991 \text{ Restitutions} \tag{12}$$

$$+\$27,000,000 \text{ Compensatory Mitigation} \tag{13}$$

$$= \$35,072,591 \text{ Total Fixed Cost} \tag{14}$$

The fines against ESI also contain a variable cost component of \$29, 623 per bald or golden eagle. We expand this to an annual cost using the 18 eagles/year mortality rate:

$$\$29,623/\text{ Eagle} \tag{15}$$

$$*18 \text{ Eagles/Year} \tag{16}$$

$$= \$533,214 \text{ /Year} \tag{17}$$

To calculate the total per-eagle cost across the lifetime of the wind facility, we use a standard 20-year lifetime assumption for the wind facilities. Abstracting from time preferences, the calculation becomes the following:

$$(FC + VC_{\text{Annual}} * 20 \text{ Years})/(20 \text{ Years} * 18 \text{ Golden Eagles/Year}) \tag{18}$$

This implies a total cost per eagle of \$127,000.

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