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Research article

The effect of listing the lesser prairie chicken as a threatened species on rural property values

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A B S T R A C T

This paper estimates the effect of Endangered Species Act protections for the lesser prairie chicken (*Tympanuchus pallidicinctus*) on rural property values in Oklahoma. The political and legal controversy surrounding the listing of imperiled species raises questions about the development restrictions and opportunity costs the Endangered Species Act imposes on private landowners. Examining parcel-level sales data before and after the listing of the endemic lesser prairie chicken, we employ difference-in-differences (DD) regression to measure the welfare costs of these restrictions. While our basic DD regression provides evidence the listing was associated with a drop in property values, this finding does not hold up in models that control for latent county and year effects. The lack of a significant price effect is confirmed by several robustness checks. Thus, the local economic costs of listing the lesser prairie chicken under the Endangered Species Act appear to have been small.

1. Introduction

The U.S. Endangered Species Act (ESA) is a powerful and controversial law. Designed to prevent extinction events, the ESA makes harming an endangered animal or damaging the habitat of an endangered species illegal on public and private land. Significant civil and criminal penalties for violating the ESA are considered necessary because habitat loss due to economic development is one of the greatest threats to biodiversity (Millennium Ecosystem Assessment, 2005). However, detractors of the ESA argue that the land use restrictions implied by the law are too costly to private landowners. This has made extending ESA protections to new species a highly contentious process. Despite the attention focused on endangered species conflicts, though, the impact of the ESA on the demand for development land remains uncertain. Yet this information is critically needed to assess the costs of the ESA and respond to the concerns of landowners.

We address this research need by estimating the effect of the ESA on land prices following a recent listing event in Oklahoma. Since land prices reflect the stream of benefits produced by a location, our estimates allow us to draw conclusions about the opportunity costs and welfare effects of ESA regulations. The data used in our study come from parcel-level land sales in Oklahoma made between 2007 and 2015. During this period the lesser prairie chicken (*Tympanuchus pallidicinctus*), hereafter abbreviated as LPC, a grassland bird native to western Oklahoma, was listed as a threatened species. A subset of land transactions took place in the LPC habitat region after the listing, so this regulatory event provides a quasi-experiment to evaluate the land use costs of the ESA. We use regression difference-in-differences (DD) in a hedonic model of rural land prices to measure the effect of ESA regulations.

Our results have important implications for the debate on environmental regulations. Most individuals assume that environmental regulations have negative local economic impacts, but negligible and even positive impacts are possible in the case of the ESA. Preserving habitat can attract land buyers who value the flora, fauna and natural amenities provided by undeveloped landscapes (Eichman et al., 2010). Enough such buyers could tilt the impact of ESA regulations toward higher land values. Preemptive habitat destruction and voluntary habitat conservation programs may also buffer land values by mitigating the regulatory burden of the ESA to landowners (Lueck and Michael, 2003; Langpap and Kerkvliet, 2012). The effect of the ESA on land values is thus an empirical question (Greenstone and Gayer, 2009).

While the local economic effects of the ESA remain up for debate, many studies on this topic find that costs can be significant. By placing restrictions on land use, the ESA can reduce the productivity of working lands, displace workers, and drive down wages

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(Shogren and Hayward, 1997). Ferris (2009) and Eichman et al. (2010) both find the ESA reduced employment in areas of threatened species habitat. Boskovic and Nøstbakken (2017) show similar restrictions in Canada imposed significant aggregate costs on natural resource production. Meyer (1998) demonstrates a positive association between the number of endangered species in a state and construction growth, although Crellin (2002) finds properties subject to ESA regulations tend to be sold at lower prices; both studies demonstrate that ESA regulations and real estate outcomes can be correlated. Zabel and Paterson (2006) build on this work by using a DD estimator to measure the effect of designating critical habitat on land prices and find that regulations resulted in slower local housing stock growth. Similarly, Greenstone and Gayer (2009) use a quasi-experimental approach to investigate the causal relationship between ESA regulations and land prices, and find that the presence of endangered plants (but not endangered animals) can cause housing values to decline. Greenstone and Gayer also demonstrate that failure to adopt a quasi-experimental approach can lead to results that overstate the negative price impacts of the ESA, as endangered species are often found in areas with less economic activity and thus lower land values. Our paper adds to this literature by presenting another quasi-experimental study, which is the first to use parcel-level sales data to measure the effects of ESA regulations.

Our analysis is focused around a linear model of land prices, in which different parcel characteristics influence the price. The parameter of interest measures the effect that ESA regulations have on prices in the LPC habitat region at the time the species was listed. However, as mentioned above, the ESA effect is contingent upon the preferences of individuals (and firms) in the habitat region and land management activities, which may be influenced by contemporaneous habitat conservation programs. In other words, context matters, so the next section provides some background on LPC conservation efforts.

2. Lesser prairie chicken conservation efforts

The LPC is a type of grouse with habitat in the grass and scrublands of the Southern Great Plains of the United States, including the five-state region of Oklahoma, Texas, New Mexico, Colorado, and Kansas. At one point, two million LPCs inhabited the region, but as of 2014 the population had dwindled to about 17,000 (Wertz, 2015). The LPC is especially prone to habitat fragmentation, in which historic habitat ranges are reduced to smaller, isolated ranges that are not contiguous. This can be seen in a map of LPC habitat today, in which a large swath of habitat in western Texas and eastern New Mexico has been separated from the habitat in western Kansas and Oklahoma (SGP CHAT, 2016).[1]

Due to the LPC population decline, in 2012 the U.S. Fish and Wildlife Service (FWS), the agency charged with implementing the ESA, released a preliminary decision to list the LPC as a "threatened" species under the ESA. The FWS attributed the downward population trend to habitat loss and fragmentation due to agricultural practices, energy development and manmade vertical structures. The LPC's aversion to vertical structures means that power poles, wind turbines and tall buildings (such as holding towers at oil and gas wells) can result in the loss of large amounts of suitable habitat. The FWS's announcement therefore put much of the onus for habitat conservation on the agricultural and energy industries.

In response to these threats and the proposed listing under the ESA, the Western Association of Fish and Wildlife Agencies (WAFWA), with representatives from the wildlife conservation departments of the five states with LPC habitat, drafted the Lesser Prairie Chicken Range-wide Conservation Plan (RWP) in 2013 (WAFWA, 2013). The RWP is a two-part voluntary habitat mitigation program that, first, encourages companies to pay mitigation fees for their land development projects and, second, uses the fee revenue to incentivize landowners (farmers and ranchers) to improve LPC habitat conditions. In essence, the RWP provides offsets for habitat lost to development. Companies have an incentive to enroll projects in the RWP plan because doing so provides assurances that the projects will not be subject to ESA regulations in the event the LPC is listed and the project incidentally kills an LPC or damages LPC habitat. Landowners with LPC habitat on their land receive incentives for managing their property in a way that protects LPC habitat. The RWP is one of several habitat conservation incentive programs in the region, which includes the Conservation Reserve Program (CRP), the Environmental Quality Incentives Program (EQIP), and the FWS's Candidate Conservation Agreement with Assurances (CCAA), although it is the only program that allows non-agricultural land uses to participate (WAFWA, 2013).[2]

An important component of the RWP is the establishment of the Southern Great Plains Crucial Habitat Assessment Tool (CHAT). The CHAT system defines the extent of LPC habitat and divides the landscape into habitat and non-habitat regions. The CHAT includes an online mapper that shows the distribution of LPC habitat, and was designed for use by landowners and industry to encourage participation in the RWP. The CHAT mapper was published in 2013, so industry and the public had access to information about the distribution of the LPC at the time the species was listed (and thus the spatial extent of ESA regulations).

The RWP was drafted to jumpstart LPC conservation and make ESA regulations unnecessary. However, despite implementation of the RWP, the FWS determined that not enough landowners had chosen to enroll in the voluntary program, and used that fact as part of its justification to certify its earlier preliminary decision to list the bird as "threatened." In May 2014 the LPC was officially listed under the ESA, although the FWS listing rule allowed incidental LPC habitat damages to be exempted for RWP participants.

Many local individuals and companies were not happy with the listing, and one industry trade group quickly filed suit against the FWS's decision, saying the agency did not properly take into account the benefits that had been realized from the RWP's implementation when certifying the final listing decision. On September 1, 2015, the U.S. District Court for the Western District of Texas sided with the plaintiffs and agreed with their claims that the FWS did not properly analyze the RWP and its benefits before listing the LPC as threatened (Permian Basin Petroleum Association, et al. v. Department of the Interior, U.S. Fish and Wildlife Service, et al., 2015). Paramount to the plaintiff's argument was the fact that the bird's population had increased back to 29,000 from 17,000 just a year earlier (Wertz, 2015). As of now, the LPC is not listed.

1 For a thorough discussion of habitat fragmentation and many other issues that imperil wildlife species in the U.S. Great Plains, including the LPC, see David Naugle's Energy Development and Wildlife Conservation in Western North America (2011).

2 CCAAs are a FWS program for landowners whose property includes the habitat of a species that is a candidate for listing under the ESA. Landowners place property into a CCAA to gain regulatory assurances before a listing occurs. By entering into a CCAA, a landowner agrees to undertake certain conservation activities, and in return they will not be required to implement additional conservation measures or be subject to additional land use restrictions in the event the species is listed.

3. Methods

We adopt a DD estimation strategy to measure the effect of the LPC's ESA regulations on land values. We use variation in the distribution of LPC habitat and the timing of the FWS's listing decision (and subsequent delisting) to identify the effect on the price of land sold in the habitat region. The DD methodology exploits the pre-and-post intervention state plus the non-intervention region to identify a causal effect.

DD methods are commonly used by social scientists to measure the impacts of policies on economic or individual outcomes (Angrist and Pischke, 2009). DD estimation can be used in situations where there is a quasi-experimental treatment applied to one group, while another group does not receive the treatment. The data on the outcome of interest must include observations for the treated and the comparison group both before and after the treatment or intervention has been applied. Thus, the DD methodology is synonymous with the Before-After, Control-Intervention (BACI) experimental design. One of the first documented uses of DD was conducted by physician John Snow, who linked cholera deaths in London to the consumption of water from the Thames River (Snow, 1855). A natural experiment was made possible by the fact that one water company stopped using Thames water and switched to cleaner water, while another company continued using Thames water. Snow was able to empirically link cholera deaths to the Thames River by comparing cholera deaths over time between the two groups. In environmental policy, DD methods have been used to examine the effect of hydraulic fracturing on wages, employment, and property values (Cosgrove et al., 2015; Boslett et al., 2016), the impact of air quality regulations on polluting industries (Becker and Henderson, 2000), the impact of ESA regulations on labor market outcomes (Ferris, 2009), and the effect of invasive species on property values (Horsch and Lewis, 2009). All studies that use DD methods are made possible by the fact that a natural experiment takes place in which a treatment, at some point in time, is applied to one group but not another.

In the canonical DD example, the effect of interest is estimated using linear regression with three explanatory variables. The first is a dummy variable for the time that the treatment is applied, the second is a dummy variable for the treated group, and the third is a dummy variable for the treated group at the time of treatment, which is calculated as the interaction between the treated group and the treated time variables. The effect of interest is measured by the parameter on the third dummy variable. To correctly estimate this effect, the DD model assumes the treated and untreated groups would have changed identically over time in the absence of treatment (Greenstone and Gayer, 2009).

The spatial extent of habitat as documented by the RWP sets up a type of quasi-experiment conducive to DD regression methods. To estimate the effect of ESA regulations on land prices, parcels sold in the LPC habitat region make up the treated area and the LPC listing period from May 2014 to September 2015 determines the treated time. Parcels that fall outside of LPC habitat range should not have been affected by the listing decision and form the untreated/comparison group. Fig. 1 shows the extent of LPC habitat in Oklahoma. Assuming land prices in and outside LPC habitat were changing at the same rate prior to the listing, DD regression is a valid method of estimating the effect of ESA regulations on land values.

We incorporate the DD strategy into a hedonic model of land prices. The hedonic model decomposes the value of a parcel into the value of its constituent characteristics, such as the size and age of structures, the presence of natural amenities and access to municipal services. We focus exclusively on undeveloped, primarily agricultural parcels, because these properties are most at risk of ESA land use restrictions, as developed land does not naturally harbor LPCs. The basic hedonic regression specification we use is

$$\begin{aligned}\ln(price_{it}) = \alpha + \ &\beta Habitat_i + \gamma Listed_i + \delta Habitat_i \cdot Listed_t \\ &+ \zeta Habitat_i \cdot Trend_t + \mu X_i + \varepsilon_{it}\end{aligned} \tag{1}$$

where $price_{it}$ is the price per acre of parcel i sold at time t, $Habitat_i$ is a dummy variable for parcels sold in the CHAT-defined habitat region, $Listed_t$ is a dummy variable for the time of the listing, $Trend_t$ is a yearly trend, X_{it} is a vector of other covariates expected to influence price, and ε_{it} is the error term. Note that Equation (1) includes an interaction between $Habitat_i$ and $Trend_t$ to control for a group-specific price trend for the habitat relative to the comparison region (Angrist and Pischke, 2009). The parameter of interest is δ, which measures the change in the natural log of price per acre from listing the LPC. The percent change in price attributable to the listing can be measured as $100 \times (e^{\delta}\text{-}1)$ (Wooldridge, 2013).

The vector X_{it} includes several parcel, landscape and weather characteristics. $Acres_i$ is the size of the parcel in acres, $Cropland_i$ is a dummy variable equal to one if the parcel is primarily in crops, and $Irrigated_i$ is a dummy variable equal to one if the parcel is irrigated. Crop and irrigated parcels are expected to sell at higher prices. While larger parcels are also expected to be sold at higher prices, $Acres_i$ measures whether the price per acre changes with total acreage. To control for oil and natural gas production, $Wells_i$ measures the number of oil and natural gas wells built in the county in the month the parcel was sold, which we expect to exert a positive influence on prices. To control for the effect of weather, *Rainfall* is the county's average annual rainfall in the 1980–2010 period and $Drought_{it}$ is the county's Palmer Drought Index in the month of the sale.[3]

To address any remaining influential but omitted variables, we examine specifications that add year and county effects. The second model we estimate is

$$\begin{aligned}\ln(price_{it}) = \alpha + \ &\beta Habitat_i + \gamma Listed_i + \delta Habitat_i \cdot Listed_t \\ &+ \zeta Habitat_i \cdot Trend_t + \mu X_i + \tau_t + \varepsilon_{it}\end{aligned} \tag{2}$$

where τ_t is a vector of year effects (dummy variables) to capture the effects of year-to-year price changes, which could be driven by changes in commodity prices, such as for beef, wheat, and oil. The third model we estimate is

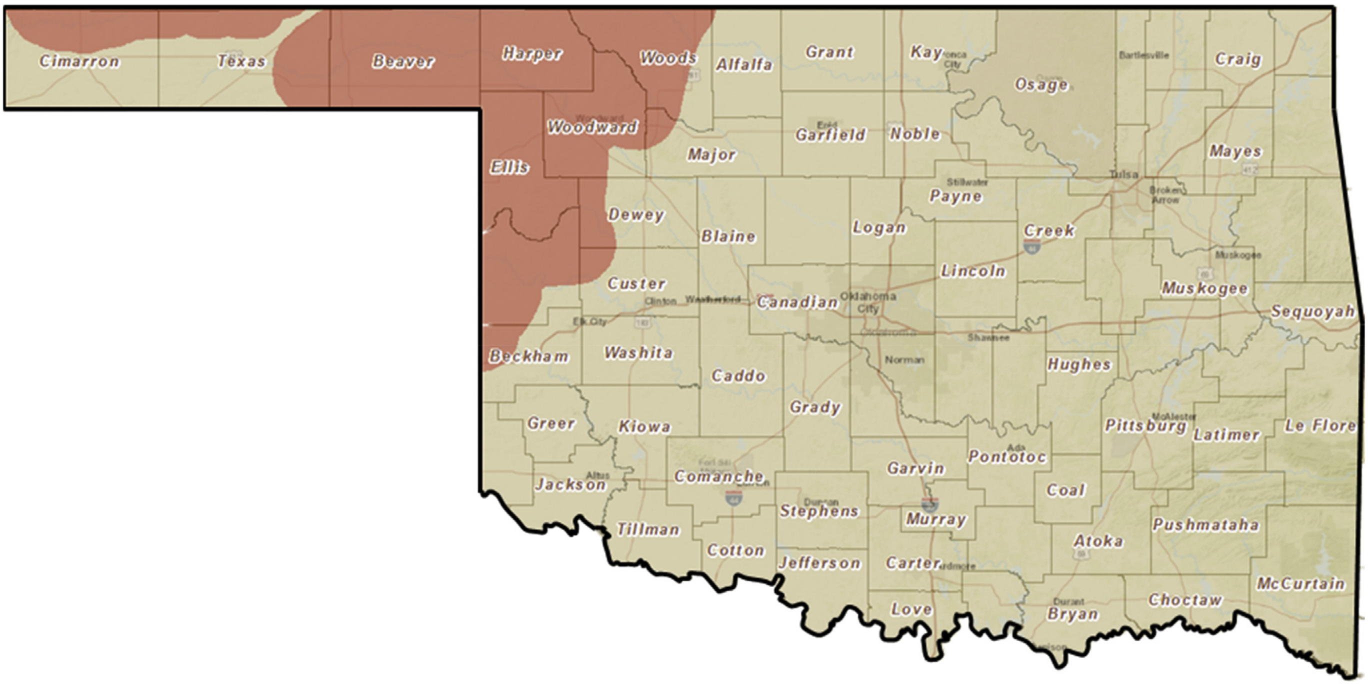
$$\begin{aligned}\ln(price_{it}) = \alpha + \ &\beta Habitat_i + \gamma Listed_i + \delta Habitat_i \cdot Listed_t \\ &+ \zeta Habitat_i \cdot Trend_t + \mu X_{it} + \tau_t + \upsilon_i + \varepsilon_{it}\end{aligned} \tag{3}$$

where υ_i is a vector of county effects measuring the influence of local amenities on land prices, such as labor market size and transportation infrastructure.

4. Data

The database we used includes nearly all rural land sales in Oklahoma occurring in the period 2007 to 2015. The data were collected by the Farm Credit Associations of Oklahoma and include land sales in all 77 counties in the state. Due to software changes, data prior to 2007 could not be readily accessed. We presorted the data to include only parcels greater than 10 acres and that were being used for something other than a residential or commercial purpose (i.e. cropland, irrigated, pasture, etc.), leaving 14,919 land sales. Following the approach used in an earlier hedonic study of Oklahoma land values by Guiling et al. (2009), parcels used in the analysis had to be sold between \$150 and \$10,000 per acre. The

[3] Negative (positive) drought index values indicate that an area experienced below (above) normal precipitation.



Note: Author-prepared map using GIS data from SGP CHAT (2016) and the USA Counties and World Street Map layers in ArcGIS.

Fig. 1. Lesser prairie chicken habitat in Oklahoma. Sources: USA Counties – Esri, TomTom, Department of Commerce, Census Bureau, U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS), United States Central Intelligence Agency; World Street Map – Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, © OpenStreetMap contributors, and the GIS User Community.

Table 1
Summary statistics of the variables used in the analysis.

	Minimum	Median	Mean	Maximum	Standard Deviation
Habitat	0.000	0.000	0.078	1.000	0.268
Listed	0.000	0.000	0.196	1.000	0.397
Habitat × Listed	0.000	0.000	0.013	1.000	0.112
Habitat × Trend	0.000	0.000	0.379	9.000	1.515
Acres	10	140	198	9952	430
Cropland	0.000	0.000	0.201	1.000	0.401
Irrigated	0.000	0.000	0.007	1.000	0.081
Drought index	−6.990	0.050	0.170	6.840	2.530
Average annual rainfall	18.250	39.070	38.120	51.890	8.182
Wells constructed	0.000	0.000	1.643	30.000	3.653
Price Per Acre (Not Logged)	153	1500	1762	10,000	1190

minimum filters out sales that may have occurred between acquaintances and not representative of the true market value of the land, while the maximum excludes mislabeled parcels that are in fact residential or developed. We also filtered out parcels located in Metropolitan Statistical Areas (MSAs), as the value of these parcels may be significantly influenced by proximity to urban centers (Guiling et al., 2009).[4] Dropping parcels that did not fall within the price restrictions, were located in a MSA county, or were a duplicate of another sale, left 10,880 observations for analysis.

Each sales record includes several descriptive characteristics, including sales price, sales date, acreage, and land use separated primarily into pasture, cropland and recreation categories. Table 1 provides summary statistics for these variables. Each record also includes the location of the parcel by township, range, and section. We used the location description to sort parcels into habitat and non-habitat categories based on the CHAT habitat boundaries.

To confirm that the trend in sales price between the treated and comparison groups were similar prior to treatment, we tested for statistically significant differences in year-to-year changes between the two groups prior to the listing. We based this test on the procedure described in Angrist and Pischke (2009), by including leads of the variable of interest in the regression model. This was performed for each year in the data before the listing of the LPC (so all years before 2014) by interacting the treated area variable with a dummy variable for each year. While land in LPC habitat (and western Oklahoma generally) tends to be worth less per acre than elsewhere, we found no year in which the change in prices between the two groups of land sales were significantly different ($p < 0.05$) conditional on the variables in Equation (1). Fig. 2 provides visual evidence of a common price trend between the groups of parcels sold in and outside the habitat region. This implies that parcels in

[4] Excluded Counties by MSA: Oklahoma City, OK MSA – Canadian, Cleveland, Grady, Lincoln, Logan, McClain, Oklahoma; Tulsa, OK MSA – Tulsa, Rogers, Wagoner, Creek, Osage, Okmulgee, Pawnee; Ft. Smith, AR-OK MSA – Le Flore, Sequoyah; Lawton-Ft. Sill, OK MSA – Comanche, Cotton.

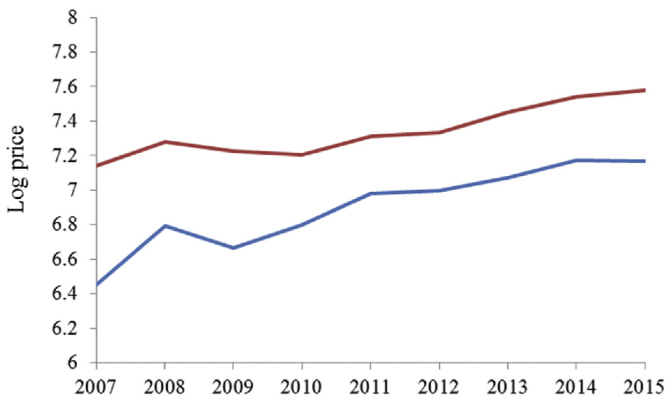


Fig. 2. Property value trends in habitat (bottom line) and comparison (top line) counties.

Specifically, the parameter estimate implies that parcels in the habitat region sold for about 18.6% less per acre on average than they would have if the LPC was not listed under the ESA.

Acreage, irrigation, local rainfall and oil well construction also play a role in determining prices. The coefficient on total acreage is negative and statistically significant, meaning as parcel sizes grow the price per acre tends to fall, so smaller parcels enjoy a per-acre price premium. Not surprisingly, with water a limiting factor in Oklahoma agricultural production, irrigation and rainfall levels exert a positive influence on price. Prices are also higher when the parcel is sold at a time of oil well construction in the county, probably due to expectations that the owner will benefit from royalty payments.

Model 2 adds year-specific dummy variables to control for time-varying effects. The parameters on *Habitat* and *Listed* are no longer statistically significantly different from zero. The parameter of interest is also no longer statistically different from zero, and is much smaller in magnitude than its counterpart in Model 1. Relative to Model 1, controlling for year effects reduces the estimated ESA effect by about two-thirds.

Table 2
Parameter estimates of the hedonic model of Oklahoma rural land prices.

Model	(1)	(2)	(3)
Habitat	−0.345* (0.142)	−0.215 (0.142)	−0.157 (0.086)
Listed	0.255** (0.024)	−0.014 (0.027)	−0.006 (0.025)
Habitat × Listed	−0.206* (0.088)	−0.067 (0.084)	−0.020 (0.063)
Habitat × Trend	0.063** (0.017)	0.032 (0.017)	0.024 (0.014)
Acres	−0.0002** (0.00002)	−0.0002** (0.00002)	−0.0002** (0.00002)
Cropland	−0.052 (0.028)	−0.039 (0.027)	0.038 (0.026)
Irrigated	0.483** (0.082)	0.462** (0.083)	0.500** (0.130)
Drought Index	−0.002 (0.004)	0.006 (0.005)	−0.005 (0.003)
Rainfall	0.029** (0.003)	0.029** (0.003)	
Wells	0.021** (0.004)	0.018** (0.004)	0.016** (0.003)
Year effects		X	X
County effects			X
R^2	0.291	0.315	0.419

Note: Standard errors clustered by county are denoted by ( ). The number of observations is 10,880.
A ** indicates significance at the 0.01 level, and * significance at the 0.05 level.

the treated and comparison groups shared a common sales price trend prior to ESA regulations in 2014, and that the comparison group provides a good counterfactual in this quasi-experiment.

We use ordinary least squares to estimate models (1)–(3) and compute cluster-robust standard errors that allow for correlations across parcels sold in the same county. The regressions were performed in R and the code is available from the corresponding author upon request. R does not report cluster-robust standard errors in its packaged estimators, so the errors were calculated using a combination of functions available from the 'lmtest' and 'multiwayvcov' R packages (Zeileis and Hothorn, 2002; Graham et al., 2016).

5. Results and discussion

5.1. Primary results

Table 2 presents the results from the three specifications. Column (1) shows the parameter estimates for Model 1. The parameter on *Habitat* in Model 1 is negative and statistically different from zero, which confirms that parcels in the habitat region sold for less per acre on average than other parcels, before and after the LPC was listed. Additionally, the parameter on *Listed* is positive and statistically significant, implying that at the time the LPC was listed (May 2014–September 2015) parcels sold for more per acre on average than parcels sold outside the treated period. The parameter of interest is negative and statistically significant, which suggests that ESA regulations did push land prices down in the habitat region.

Model 3 retains all the variables used in Models 1 and 2 while adding county dummy variables to control for county-level unobserved characteristics.[5] Now the parameter on *Habitat × Listed* implies that parcels in the habitat region sold for about 2.0% less per acre due to the listing, although this estimate is not statistically different from zero. This implies that parcels sold in the habitat region changed little more or less in price when the LPC was listed than could have been expected by chance.

Our preferred specification is Model 3 because it includes the richest set of controls. Any influential unobservables that vary year-by-year could bias the regression estimates in Model 1, and any relevant unobservables specific to counties could bias the regression estimates in Models 1 and 2. This bias could occur if the characteristics of specific habitat counties systematically differed from those of other counties; note that most habitat lies in northwestern Oklahoma, a region with a climate, landscape and economy unlike the rest of the state. Model 3 avoids these biases by comparing price changes between the habitat and comparison regions, before and after the LPC was listed, after netting out the differential price trend in the habitat region, land uses, year-specific

[5] The effect of rainfall is not estimated due to perfect multicollinearity with the county effects.

Table 3
Results of the robustness checks.

Model	(4) Excluding sales between 12/12–4/14	(5) Township and range effects	(6) Sales in counties on the border of habitat
Habitat	−0.153 (0.085)	−0.162* (0.073)	0.046 (0.092)
Listed	0.318** (0.033)	−0.014 (0.025)	−0.012 (0.079)
Habitat × *Listed*	−0.037 (0.091)	0.016 (0.065)	0.015 (0.085)
Habitat × *Trend*	0.027 (0.018)	0.025 (0.014)	−0.178 (0.015)
Acres	−0.0001** (0.00002)	−0.0002** (0.00002)	−0.0001 (0.00006)
Cropland	0.036 (0.028)	0.041 (0.023)	0.100* (0.049)
Irrigated	0.521** (0.112)	0.401** (0.128)	0.601** (0.165)
Drought index	−0.007* (0.003)	−0.006** (0.003)	0.003 (0.009)
Wells	0.013** (0.003)	0.011** (0.003)	0.009** (0.003)
Year effects	X	X	X
County effects	X	X	X
Township and Range effects		X	
R^2	0.429	0.458	0.492

Note: Standard errors clustered by county are denoted by ( ). The number of observations is 8931 in model (4), 10,880 in model (5), and 1811 in model (6).
A ** indicates significance at the 0.01 level, and * significance at the 0.05 level.

price shocks and county characteristics. After controlling for these influences, there is little evidence that ESA regulations had an effect on land prices. This leads us to conclude that extending ESA protection to the LPC did not impact land prices.

This result is consistent with the finding of Greenstone and Gayer (2009). In their study, Greenstone and Gayer found that after controlling for county effects the presence of endangered animals had no significant effect on mean housing values in a county, similar to the findings of this study that the LPC listing decision had no effect on rural property values. Additionally, Greenstone and Gayer warn of the potential for overstatement of negative effects attributable to the ESA when quasi-experimental methods are not utilized. This potential overstatement is captured by the negative and statistically significant coefficient on *Habitat* in Model 1, which is corrected by adding the county dummy variables in Model 3. Thus, this paper's pairing of DD with time and geographic fixed effects avoids that potential overstatement to find no significantly negative impact of the ESA, in contrast to several studies that have not used quasi-experimental methods (Meyer, 1998; Crellin, 2002).

5.2. Robustness checks

We performed a series of robustness checks to probe the sensitivity of the results to possible violations of the DD assumptions. Table 3 presents the estimates from three additional regressions. The first column tests whether individuals grew increasingly certain that the LPC would be listed before the final announcement and thus priced-in the effects of ESA regulations prior to the listing. As a shift from uncertainty to certainty of ESA regulations could have occurred gradually over several years, we re-estimated the model after dropping transactions made between December 2012 and April 2014, to ensure a large discrete change in expectations forms across the before-and-after periods (e.g. see Boslett et al., 2016).[6] The coefficient of interest is more negative than in model 3, but still statistically insignificant. This suggests the small effect we estimated is not entirely due to landowners anticipating the listing and a preemptive change in prices. The second column of Table 3 adds township and range effects to the model to ensure the coefficients are not attenuated by latent physical characteristics that exert influence along other (non-county) geographic dimensions.[7] Although adding these controls generally increases the precision of the estimates, the effect of ESA regulations remains statistically insignificant. Finally, the estimates in the third column of Table 3 come from a revised treatment-control comparison. We strengthen the good counterfactual assumption by restricting the sample to properties in counties divided between the habitat and non-habitat regions, i.e. focusing on sales near the boundary of the habitat region. Assuming there are minimal spillovers across the border, this restriction should minimize the bias from unobservable, time-varying processes that differentially affect land prices across the boundary. As in the first two robustness checks, though, this restriction does not provide any evidence of a significant effect of regulations on property values.

5.3. Additional discussion

It is important to consider the inherent limitations of quantitative analysis, specifically hypothesis testing in this case. We could not reject the null result—that the effect of listing the LPC on land sale prices is indistinguishable from 0—but this does not mean there were no instances of LPC protections affecting property values. The hypothesis that ESA regulations had a small negative effect on land values (e.g. around −1%) also cannot be rejected at a reasonable confidence level. Nevertheless, it is at least clear that the local economic cost was—if not entirely absent—very small, despite claims by industry that ESA regulations can be crippling economically.

This finding contrasts with most published research on the economic consequences of endangered species regulations. These studies have focused on species with habitat on public land or with critical habitat designations, and tend to find large negative effects. However, the situation of the LPC is different because the species is found mainly on private lands and was the focus of a vigorous pre-listing conservation program that sought to accommodate traditional agricultural land uses and industry.

Thus, the lack of a large price effect could be due to a number of circumstances. First, conservation activities in the habitat region may have buffered prices when ESA regulations went into effect. The FWS's CCAA program and the RWP's habitat conservation subsidies for rural landowners should have counteracted some of

[6] December 2012 is the date of the most recent proposed listing rule. As pointed out by a reviewer, however, it is possible that the shift from uncertainty to certainty began earlier. The initial listing petition was made in 1995, and the FWS determined that listing was warranted but precluded in 1998. A lawsuit to compel listing was filed in 2005. Unfortunately, it is not possible to test for these pre-listing effects because data prior to 2007 was not accessible through the appraisal software made available to us.

[7] This is similar to controlling for latitude and longitude in spatial regression discontinuity experimental designs (Boskovic and Nøstbakken, 2017).

the opportunity costs of ESA regulations by putting upward pressure on the price of farm and ranchland in the habitat region around the time of the listing. Prior research has shown land prices have a positive response to government assistance programs similar to the RWP (Latruffe and Le Mouël, 2009). Second, the listing was in place for a short time, during most of which it was being challenged in court on the basis of the RWP. It is possible that landowners significantly discounted or did not take ESA regulations into account when buying and selling land. Finally, the RWP and FWS focused relatively more effort on mitigating the habitat impacts of energy companies' projects than on restricting the amount of agricultural land; changes in farm and ranch management could have been small if most landowners expected regulatory enforcement to be weak.

6. Conclusions

This study found that listing the lesser prairie chicken as a threatened species did not significantly affect rural property values in Oklahoma. While the effect of these regulations is negative in the most basic hedonic model specifications we considered, ultimately the preferred model, which controls for a rich set of potentially confounding variables, estimates an effect that is small and statistically indistinguishable from zero. This insignificant effect is confirmed through several robustness checks. The results of this study thus suggest that the decision to extend ESA protections to the LPC resulted in little-to-no net welfare loss.

Our findings could be interpreted as promising for LPC conservation, although they come with an important caveat. Listing the LPC under the ESA did not put a substantial economic burden on landowners as a whole, possibly due to the conservation policies pursued by the FWS and WAFWA. However, it is also possible that individual landowners simply ignored ESA regulations and failed to change their land use practices. This means that habitat loss could have remained a problem in spite of regulations. Future research should examine how landowners and land use in the region responded to ESA regulations. Because LPC habitat is located almost entirely in a rural, privately-owned landscape, partner-centric conservation is crucial to getting landowners to change their practices, and thus developing a conservation strategy that balances wildlife population goals with natural resource production. Ultimately, it may be to the LPC's benefit that its habitat is located on rural land distant from suburban influences. Policy makers and practitioners should recognize that, in this setting, working with private landowners can present as many opportunities as challenges in recovering endangered species.

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