The petroleum industry's response to an endangered species listing

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Abstract

This paper examines the effect of U.S. Endangered Species Act (ESA) regulations on oil and natural gas well drilling in Kansas and Oklahoma. In 2014 and 2015, petroleum companies faced land use restrictions when the imperiled lesser prairie chicken received threatened species-status under the ESA. In Kansas and Oklahoma, as elsewhere, the petroleum industry has been criticized for damaging environmental quality and developing wildlife habitat. Using data on well locations, I estimate a discrete choice model to measure the effects of ESA regulations on companies' location preferences. While the results show habitat avoidance increased with regulatory scrutiny, the effect is very modest, which suggests companies may have discounted the risk of penalties from ESA violations. Results also indicate that companies' location choice was influenced by pre-listing announcements related to ESA regulations.

Keywords: Well locations; conservation; energy; habitat; Endangered Species Act

JEL codes: D22; Q24; Q56; R11

1 Introduction

Prohibiting the destruction of threatened and endangered species habitat has made the Endangered Species Act of 1973 (ESA) a controversial law [1]. Land use restrictions slow habitat loss, which is the biggest driver of extinction risks [2], but they also place the burden of conservation on private landowners and industry. Individuals face civil and criminal penalties in the form of fines of up to $50,000 ($200,000 for corporations) and a year in prison per violation, with all items used to commit the crime seized and forfeited. This makes listing species under the ESA a contentious process, with environmental groups arguing that restrictions are necessary to prevent habitat loss, and landowners and industry arguing that the law violates property rights and hinders economic development.

Economists have long been interested in the debate over the ESA, given the important role behavior has in the success and failure of recovering endangered species. With the right incentives, landowners will protect and restore essential habitat [3–7]. However, in practice penalties for ESA violations are known to create perverse incentives, in which landowners engage in preemptive habitat destruction to avoid ESA land use restrictions [8–10]. Like landowners, companies also have a choice between avoidance/mitigation and development when faced with using land harboring an endangered species [11–16]. These issues have been and continue to be addressed in economic research. Although there is no explicit recognition of costs and benefits in the ESA, economic considerations have influenced amendments to the ESA, are implicit in recovery program funding decisions, and can determine the extent to which land use restrictions are applied [17–19]. In other countries, economic research plays an overtly prominent role in the design of endangered species protections [20].

This study extends research on the economics of protecting endangered species by examining the response of petroleum companies to ESA regulations. In 2014, landowners and companies in western Kansas and Oklahoma became subject to ESA regulations when the lesser prairie chicken (LPC) was listed as a threatened species, meaning that it was likely to become endangered in the near future. While largely isolated and rural, LPC habitat overlays several major oil and natural gas fields. The petroleum industry was therefore critical of the listing and claimed that regulations would deter oil and gas development in the habitat region [21]. This paper examines whether petroleum companies avoided locating wells in the habitat region due to regulations. The location decision is modeled as a discrete choice of a single well. I find the number of wells in protected habitat changed very little due to regulations, which means ESA regulations have generally not impeded energy development in the region as claimed by industry. Preemptive habitat development for oil and gas production may have occurred, but results indicate that this behavior was not extensive in size or over time.

I focus on the effect of regulations on petroleum companies for two reasons. First, the LPC's population decline is attributed to habitat loss and fragmentation, most recently due to construction projects undertaken in the energy industry, which includes wind turbines and powerlines, but primarily oil and natural gas wells. The LPC's strong aversion to vertical structures, probably as an instinctual defense against perched predators, means that oil derricks, holding tanks and similar structures can damage large areas of suitable habitat. Emerging energy development prompted the Fish and Wildlife Service—the agency in charge of administering the ESA for terrestrial species—to issue a proposal to list the LPC as threatened in 2012 although the LPC had been a candidate for listing since 1995.

Second, the petroleum industry has indicated a willingness to engage in activities that aid the LPC and thus avoid a listing. In 2013, the Western Association of Fish and Wildlife Agencies (WAFWA) developed a rangewide conservation plan to help companies avoid critical habitat areas and offset habitat lost to development with new habitat brokered through landowner agreements [22]. Thus, LPC conservation policy emphasizes working with industry and changing land use behaviors. Although WAFWA's conservation program was developed in an effort to work with any company operating in LPC habitat, a large share of participants has come from the petroleum industry [23]. This is likely because, after agriculture, petroleum development is the most prominent economic activity in the region. Furthermore, some petroleum companies expected that their voluntary conservation efforts and support for WAFWA's conservation plan would help avoid a listing. This argument was made by the Permian Basin Petroleum Association in the suit it filed against the listing decision; this suit was successful, and in September 2015 the U.S. District Court of West Texas vacated the listing rule that had been in place since May 2014 [24].

The paper is organized as follows. The next section presents the data, and in doing so provides an overview of petroleum development and LPC habitat in the study region. The third section examines graphical summaries of these data. The fourth section describes the location choice model. The fifth section presents and discusses the results. The final section concludes.

2 Data

This analysis draws primarily on two datasets. The first is oil and natural gas wells recorded by the corporation commissions of Kansas and Oklahoma. I focus on these states because they contain the vast majority of LPC habitat.[1] Individual wells in both databases are identified by their American Petroleum Institute (API) number, lease name and ownership. Descriptive information includes the location, spud date, completion date, geological formation targeted and whether the well is producing oil, natural gas or both.[2] Location is described by Public Land Survey System (PLSS) coordinates, which subdivides land in western states by section, range and township. Using this system, locations are described by 6×6 mile townships, which are further subdivided into 1×1 mile sections. Petroleum companies typically identify leases based on PLSS descriptions. More detailed location information is provided by latitude-longitude coordinates for most but not all wells. Every section is identified by a township and range designation and a section number. I narrow the span of time to wells spudded between January 1990 and May 2016 to focus on drilling activities in the time the LPC has been a species of conservation concern.

The second dataset contains information about the distribution of LPC habitat. The Southern Great Plains Crucial Habitat Assessment Tool (SGP CHAT) is a publicly-available online mapping function that classifies habitat for use by industry, to encourage habitat avoidance and participation in WAFWA's conservation plan [22,25]. Habitat is heterogeneous and is classified by WAFWA as: focal habitat, suitable habitat (which includes habitat corridors between focal areas) and unsuitable habitat within a 10-mile buffer around the known occupied range. I follow WAFWA's

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[1] LPC habitat is also found in Colorado, New Mexico and Texas. Of these states, Texas contains the next largest share. However, as will be discussed further on in the paper, the unit of choice in the model is a 1-square mile section. These sections come from the Public Land Survey System, which is used by Oklahoma and Kansas but was never adopted by Texas. Including Texas wells and spatial locations would have added considerable time to this analysis without adding much additional insight into the effect of regulations.

[2] For records missing the spud date, I assume drilling began three months prior to completion, which is the typical length of time it takes to complete a well. The sample excludes wells labeled as injection or "other" in order to focus on those drilled primarily for the purpose of extracting oil or natural gas.

definitions by including in the habitat region all land in the 10-mile buffer. Focal areas can be interpreted as pristine or near-pristine habitat that is a conservation priority. Figure 1 illustrates the study region; the fragmentation of LPC habitat is obvious, with large gaps in the species' range in Kansas and Oklahoma, and a much larger gap between the Kansas/Oklahoma subpopulation from the Texas/New Mexico subpopulation.

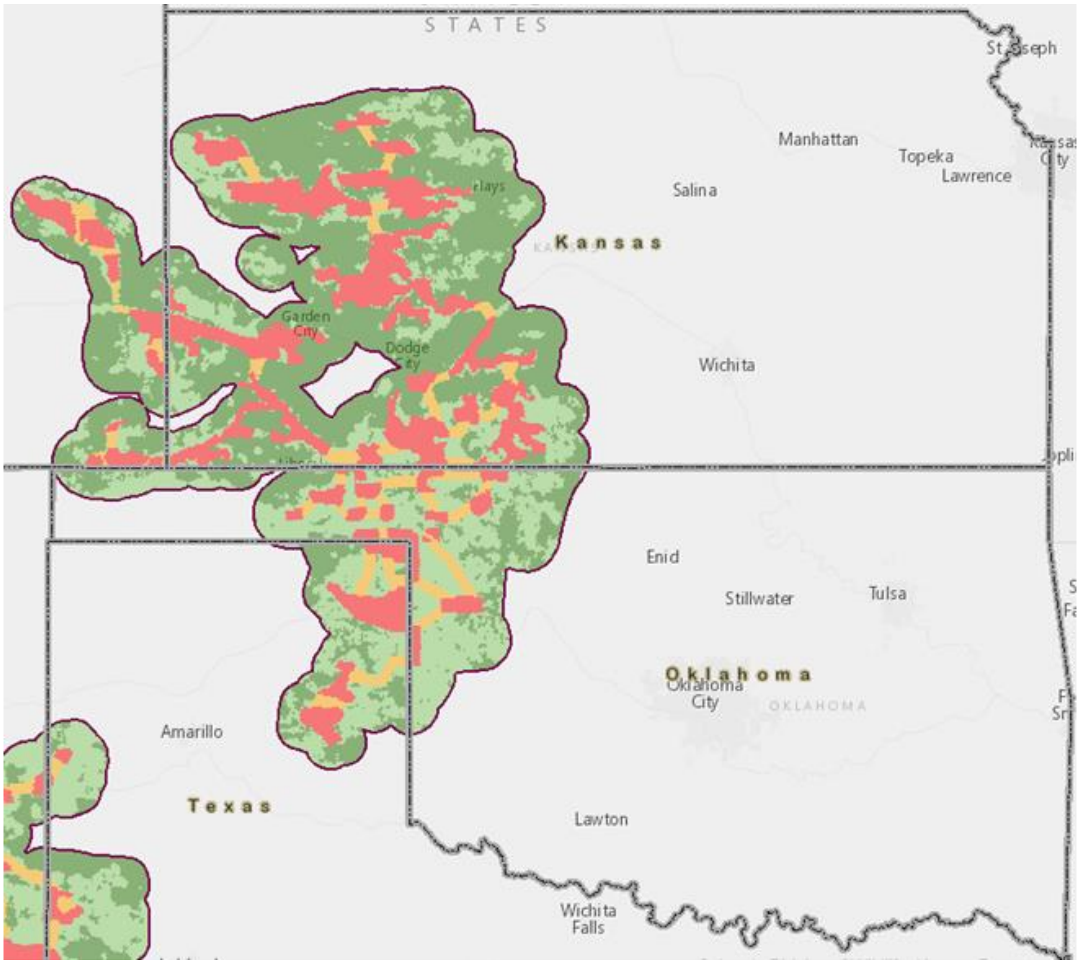

Figure 1: Map of LPC habitat in Kansas and Oklahoma. The red regions are habitat focal areas set determined by the rangewide conservation plan. The lightly shaded orange and green regions show, respectively, habitat corridors and other suitable habitat within a 10 mile buffer of the occupied range. The dark green regions are unsuitable lands in the buffer.

The study area for our analysis consists of western Kansas and Oklahoma. Both states' corporation commissions subdivide their state into four administrative districts. I exclude the easternmost districts, which roughly corresponds to the area east of a line running through Wichita and Oklahoma City.[3] Oil and gas activities are more prevalent in the western half of both states and petroleum companies are unlikely to view locations in the east as substitutes for those in the west; furthermore, LPC habitat is located exclusively in the west. This nevertheless leaves a very sizable area with which to examine land use behavior, with nearly 100,000 sections divided among 112 counties. In this region, between January 1990 and May 2016 nearly 70,000 oil and gas wells were spudded. Due to the 2009-2014 energy price boom, recent years predominate in the data; around 24,000 wells were spudded between January 2010 and May 2016.

I constructed a set of county and section-level variables to describe location attributes that could influence petroleum activity. This includes annual county population density, gathered from the U.S. Census' population estimates program, to proxy the influence of residential and commercial development; the density of natural gas processing plants in a county, interacted with an indicator for whether the well is producing gas, or both oil and gas; and the linear distance in miles from the centroid of a section to the nearest oil refinery, interacted with an indicator for whether the well is producing oil, or both oil and gas. Using National Agricultural Statistics Service data layers from 2008 (available from https://nassgeodata.gmu.edu/CropScape/), I created dummy variables for the primary land cover in each section, which include categories for pasture, crops, wetlands and developed land, using forest as the omitted category. Descriptive statistics are provided in Table 1.

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[3] This includes District 3 in Kansas and Districts I and IV in Oklahoma.

Location choice is also likely to be influenced by the presence of sedimentary basins and proven reserves. Sedimentary basins are subsurface depressions that over time have filled with rock, sediment, organic matter and water. Petroleum is formed when organic matter becomes buried by rock and then subjected to intense heat and pressure. Once a basin is found to be productive (i.e. a discovery well is completed and producing), development drilling begins. New wells are then placed in the productive basin and, usually, close to existing, proven wells. I developed two sets of variables related to reservoir production. First, dummy variables are included for subsurface features, including foreland, transtensional and sag basin types based on a catalog of sedimentary basins of the United States (available from https://pubs.usgs.gov/). Transtensional basins in particular are characterized by growth faults and strike-slip faults, which make for promising drilling targets, although petroleum deposits are by no means exclusive nor guaranteed in these areas. Second, I include a dummy variable for sections that had an existing well at the time of an observation to control for areas with proven reserves. I also include the count of wells in a section at the time of an observation to measure local agglomeration effects from petroleum development.

3 Graphical analysis

In this section I present several graphical summaries of the data, which may provide visual evidence that petroleum companies changed (or did not change) their location preferences in response to ESA announcements related to LPC conservation. To keep things simple, here I classify well locations as either inside or outside LPC habitat. If ESA regulations had no effect on companies' location choice, there would be little reason to expect the drilling locations to change between this broad spatial division before and after the listing.

Figure 2 shows the number of spudded wells in the area and time period under study. Overall, the two series exhibit similar trends, although more wells were placed inside the habitat region than outside the region over most of the study period. The steep decline in drilling activity beginning shortly before January 2015 follows the energy price bust. The timing of several key events are marked. The initial petition to list the LPC occurred in October 1995. After conducting a scientific review, the Fish and Wildlife Service announced listing was warranted but precluded in July 1998. The listing decision considers magnitude of threat, immediacy of threat, and taxonomic distinctiveness, which are amalgamated into a listing priority number (LPN) that ranges from 1 to 12. In general, a smaller LPN reflects a greater need for protection than a larger LPN. In 1998 the LPC was assigned an LPN of 8, a decision that was reaffirmed annually from 2001 to 2007. In December 2008 the Fish and Wildlife Service changed the LPN from an 8 to a 2, which reflected a change in the magnitude of threats from moderate to high [26]. Then, in December 2012, the Fish and Wildlife Service proposed listing the LPC with threatened species-status. After publishing a proposed rule, new information about the species (including conservation activities) is examined before making a final determination on whether to list. For the LPC, this final determination listed the species in May 2014, and ESA regulations were in force until the court-ordered delisting in September 2015. One pattern notable in the figure is that before 2010 more wells were generally drilled in habitat than not, but after the proposed listing rule was published (and before the listing) consistently more wells were drilled outside the habitat region. Visually, it appears that petroleum companies may have begun favoring locations outside habitat as concern over LPC conservation grew, rather than simply after the LPC was listed.

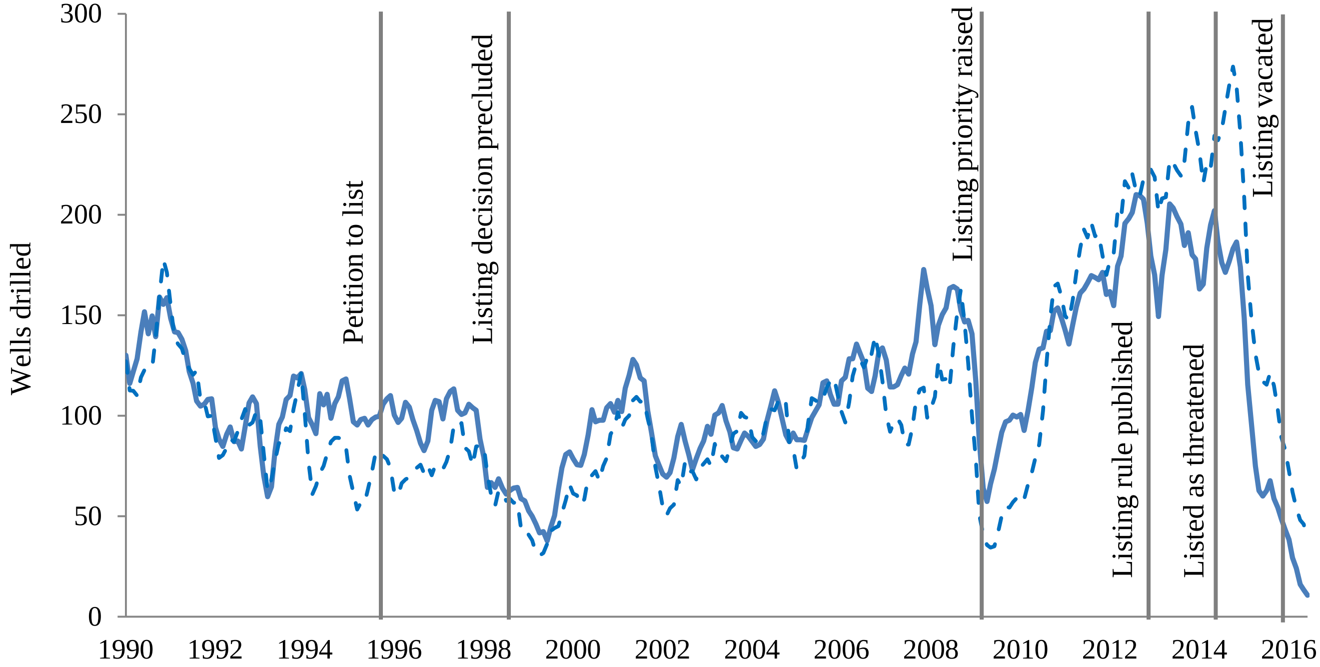

Figure 2: Three-month moving average of the number of wells drilled in the habitat region (solid line) and the non-habitat region (dashed line). The cross lines mark the timing of notable conservation announcements.

Figure 3 provides a much simpler comparison to judge the effect of ESA regulations on location choice. This graph shows the share of wells built in the habitat region when the the LPC was not listed, alongside the share built when the species was listed. Panel A suggests the average probability a petroleum company located a well in the habitat region fell by about 15 percentage points after the listing. However, this rudimentary, quasi-experimental analysis overstates the possible regulatory impact by ignoring shifting location preferences that occured before the listing. Panel B makes clear that the share of wells drilled in habitat was already down in the years before the listing. The next section uses regression analysis to determine how much of this decline can be attributed to pre-listing conservation actions.

4 Location choice model

This section develops a discrete choice model to describe where petroleum companies choose to drill a well. The economic return from a well is determined by location in section j, which includes $j = 1 \dots A$ alternatives. The return from choosing section j is:

$$\begin{aligned}
\pi_{jt} =& \boldsymbol{x_{jt}\beta} + \gamma habitat_j + \Big(\delta_1 petition_t + \delta_2 raised_t + \delta_3 proposed_t \\
&+ \delta_4 rwp_t + \delta_5 listed_t\Big) \cdot habitat_j + \epsilon_{jt} \\
=& w_{jt} + \epsilon_{it}.
\end{aligned} \tag{1}$$

The vector $\boldsymbol{x_{jt}}$ contains location attributes expected to influence the expected profitability of a well, and $habitat_j$ is a dummy variable for locations in habitat. Companies could have adjusted their location preferences after pre-listing announcements, in anticipation that a listing would eventually occur, so the following dummy vari-

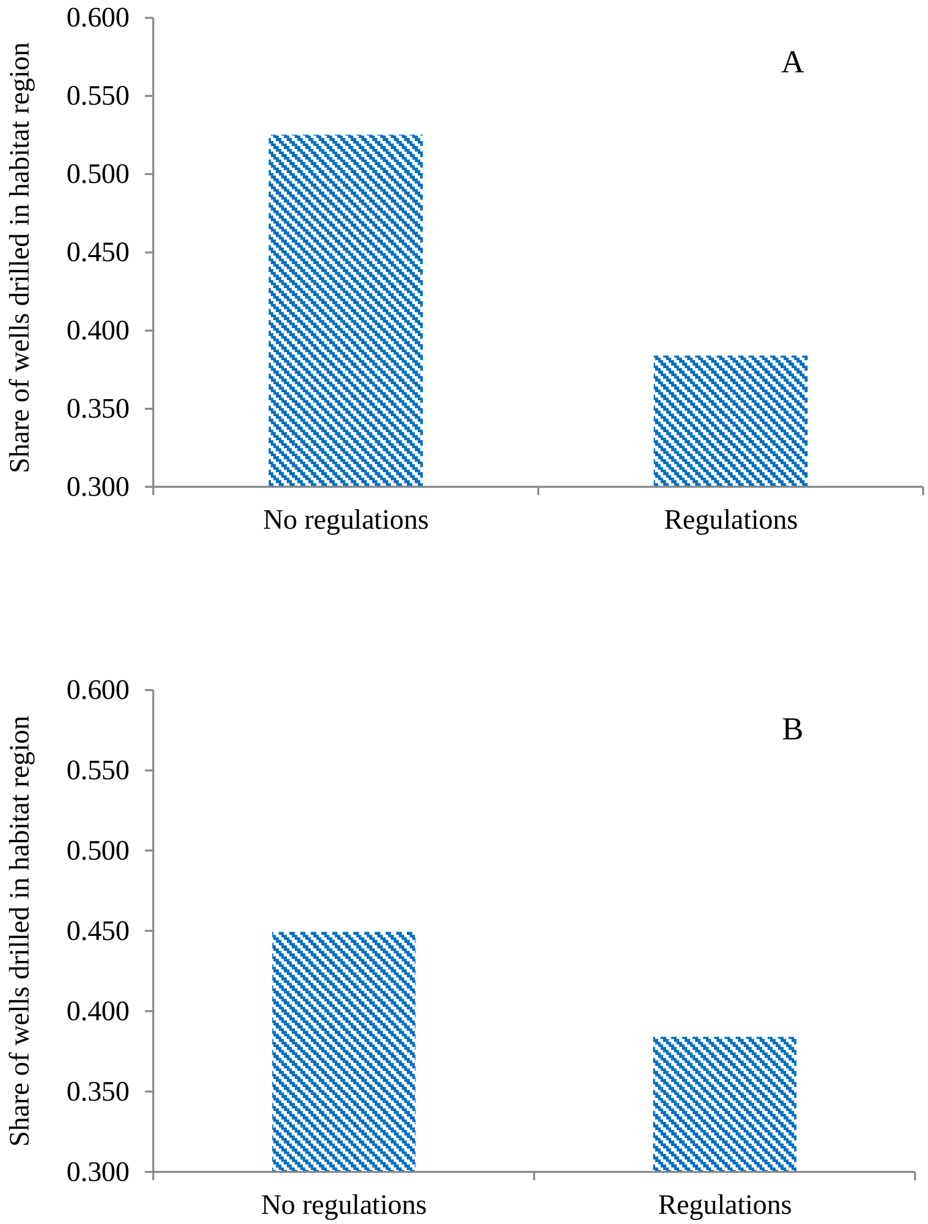

Figure 3: Share of wells in Oklahoma and Kansas that were placed in the habitat region. Panel A shows the share when the LPC was not listed and listed between January 1990 and May 2016. Panel A shows the share in the period between the proposed listing rule and the actual listing and during the listing, which covers the period January 2013 and September 2015.

ables are included to measure the effects of the listing *and* pre-listing conservation announcements: $petition_t$ controls for the original petition to list during the period October 1995 to July 1998 (after which it was clear a listing would not occur in the foreseeable future); $raised_t$ controls for the the Fish and Wildlife Service raising the listing priority up to the date of the proposed listing rule between December 2008 and November 2012; $proposed_t$ controls for the proposed listing rule up to the actual listing between December 2012 and April 2014; rwp_t measures the effect of WAFWA's rangewide conservation plan starting in January 2014 (the plan remains in place); and $listed_t$ controls for the listing from May 2014 to September 2015.

Companies choose section j where $\pi_{jt} > \pi_{kt}$ for all $j \neq k$, although the researcher does not observe the portion ϵ_{jt}. Assuming ϵ_{jt} is independent and identically distributed extreme value yields the conditional logit model, where the probability of placing a well in section j is

$$P_{jt} = \frac{e^{w_{jt}}}{\sum_{k=1}^{A} e^{w_{kt}}}. \tag{2}$$

The conditional logit is often used to model location choice because it can handle a large number of alternatives with varying attributes [27–30]. Firm and time-specific characteristics (such as the price of oil) are not included in the profit function because these are differenced away in equation (2).

The parameters in equation (1) can be used to measure the change in the share of wells in habitat attributable to ESA regulations. In particular, the sign and significance of δ_5 determines whether ESA regulations had an effect on location choice, although δ_5 does not measure the treatment effect per se as it would in a linear regression model. The treatment effect in section j is measured as

$$\tau_j = \frac{e^{w_{jt}^1}}{\sum_{k=1}^{A} e^{w_{kt}^1}} - \frac{e^{w_{jt}^0}}{\sum_{k=1}^{A} e^{w_{kt}^0}} \tag{3}$$

where w^1 is the observed outcome and w^0 is the unobserved but modeled counterfactual outcome. The change in the share of wells in the entire habitat region is

$$\tau_H = \frac{\sum_{j \in H} e^{w^1_{jt}}}{\sum_{k=1}^{A} e^{w^1_{kt}}} - \frac{\sum_{j \in H} e^{w^0_{jt}}}{\sum_{k=1}^{A} e^{w^0_{kt}}} \tag{4}$$

where H is the set of locations that contain habitat. The probabilities in equations (3) and (4) are monotonic, so the treatment effect in this "difference-in-differences" conditional logit is only zero if δ_5 is equal to zero [31]. A test of the hypothesis of $\delta_5 = 0$ is therefore a test of no treatment effect. By construction, the treatment effect is zero for choice occasions outside the treated time. Note, however, the treatment effect is not zero for the comparison group (locations outside habitat) during the treated time because the conditional logit assumes changes in a predictor affect the choice probabilities of every alternative. Unlike a traditional difference-in-differences linear regression, the location choice model allows the treatment effect to induce a spillover between the treated and untreated groups.[4]

The model treats choice occasions in different time periods as independent. This is an important simplification. However, the location decision is allowed to depend on previous drilling activity through the variables $wells_{dum}$ and $wells_{num}$ (Table 1). I also allow correlation between wells over time by clustering standard errors on leases. Petroleum companies in this area lease land for drilling, and wells located in the same lease are unlikely to be developed independently of each other. However, neighboring leases tend to be developed independently of each other [32].

The large choice set necessitates estimating the model on a sample of alterna-

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[4] It should be emphasized that the treatment effect calculated by multiplying (4) by the number of wells spudded during listing is a lower bound on the actual change, if regulations deterred the rate of drilling rather than simply moving it out of habitat. How far apart this estimate is from the actual treatment effect will depend on the degree of substitution across locations relative to outside alternatives, including the choice of not drilling the well.

tives. Following the procedure suggested by McFadden [33] and Feather [34], for each observation I randomly draw 499 sections without replacement from the set of alternatives excluding those classified as primarily surface water. The chosen section is then added to yield a sample of 500 alternatives.[5] Sampling of alternatives has been found to yield consistent estimates in several empirical settings [34–37]. Guevara and Ben-Akiva [38] demonstrate that sampling a few hundred alternatives in applications with thousands can produce estimates very close to those from the full set of alternatives.[6] I use the complete population of wells, rather than using a sample of observations, because prior work shows observed choices contribute significantly more to enhancing the efficiency of estimation than choice alternatives [40–42]; furthermore, I find evidence supporting this hypothesis in trials with different observation/choice set combinations.

County fixed effects are included in the model to account for unobserved location attributes.[7] Ignoring the influence of unobserved attributes will generate downward-biased standard errors. County fixed effects are group-specific constants that should control for much—although probably not all—unobserved location heterogeneity. I do not use a full set of alternative-specific constants (ASCs) because maximum likelihood estimation with thousands of ASCs is infeasible, although in general choice-specific constants would be preferable. Computationally, estimating large numbers of ASCs

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[5] An additional section was inserted into the sample of alternatives if the observation already had the chosen section included in the sample.

[6] Guevara and Ben-Akiva [39] recommend choosing a sample of alternatives large enough that further increases in the sample do not affect the estimates. I found the results changed modestly when moving from 100 to 250 alternatives, but hardly at all from 250 to 500 alternatives, which suggests additional increases will not improve on the estimates.

[7] Including county fixed effects precludes measuring the effect of time-constant, county-specific variables in the regression. This includes variables such as a dummy for Oklahoma locations or for flood plain counties (which likely influences location choice because petroleum companies avoid drilling wells in areas that can be damaged by floods). Since these variables are not pertinent to the paper topic, I do not report their effects, although they can be recovered by regressing the estimated county effects on the county-specific variables [43, 44].

is possible with a contraction mapping procedure, but would lead to inconsistent estimates in this application due to the small number of choice observations per site relative to the number of observations [45].[8]

5 Results

Table 2, column (1) presents the results from equation (1). The parameter on *habitat* is positive and statistically significant (the 0.05 level is the significance threshold throughout these results), which shows companies generally preferred to locate wells in habitat before any regulatory scrutiny. All of the effects of interest (the interactions between *habitat* and the decisions made by regulators) are statistically significant. The parameter on *petition* is positive, which indicates the preference for locating wells in habitat increased when the LPC was initially made a candidate for listing. This provides evidence that companies responded to the initial prospect of ESA regulations by accelerating habitat development, and thus engaged in preemptive habitat destruction. However, the parameters on *raised* and *proposed* are both negative, which suggests that once the Fish and Wildlife Service raised the listing priority and reconsidered listing, location preferences shifted and companies began to avoid habitat. The effect of *listed* is also negative, although clearly no greater than the preceding effects, which means ESA regulations per se did not further push petroleum development outside the habitat region. Moreover, the overall effect is quite small: the parameter on *listed* implies that ESA regulations kept only 4.0% of wells outside the habitat region that would have located there in the absence of the ESA.

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[8] The vast majority of sites were chosen zero or once; and among the chosen alternatives, only 15% were chosen two or more times.

The effects of the other variables are sensible. The parameters imply that companies prefer to avoid drilling in populated and growing counties, prefer to drill close to oil refineries and in areas with gas processing plants, and strongly prefer to drill in sections that have proven reserves. The type of sedimentary basin is also important, with companies preferring to drill in transtensional areas and avoid foreland and sag basins. The effect of land cover is less clear: the parameters on *pasture*, *crops*, *wetlands* and *developed* are not significantly different from zero, which may reflect the relative unimportance of existing land uses in location choice (conditional on the effect of *population*).

Columns (2) and (3) explore the potential influence of habitat heterogeneity triggered by WAFWA's rangewide conservation plan. I only consider the effects of habitat heterogeneity in the *rwp* and *listed* periods because these habitat classifications were only promoted after the rangewide conservation plan was developed. The model in column (2) distinguishes suitable from unsuitable habitat, and the model in column (3) divides suitable habitat into focal and non-focal areas. Ideally, habitat avoidance would be stronger in suitable habitat than in unsuitable habitat, and strongest in the focal areas. The parameters of the habitat heterogeneity variables, however, do not exhibit this relationship. In fact, the new variables provide essentially no improvement in model fit based on changes in the log-likelihood value. This means the effect of the rangewide conservation plan and ESA regulations changes very little with habitat quality, and that companies are not systematically avoiding the conservation priority areas advocated for in WAFWA's conservation plan.

Two reasons could explain the overall lack of response from petroleum companies. First, one characteristic of the LPC conservation strategy is voluntary conservation agreements with assurances (VCAAs). VCAAs provide participants assurances that if they engage in certain habitat conservation/mitigation activities they will never be subject to additional conservation measures. These agreements unequivocally lower the cost of regulations, so the listing effect would likely diminish in proportion to the number of companies participating. VCAAs were, in fact, made available to companies operating in LPC habitat through the Fish and Wildlife Service and WAFWA. However, most drilling projects did not participate in a VCAA: out of 2276 wells drilled in 2014 (authors calculation), only a few hundred reportedly signed up for a VCAA [23]. The second and probably more likely reason is that companies did not take the threat of regulation credibly. Langpap and Wu [4] note that information asymmetries and a high burden of proof can make enforcing ESA regulations on private land difficult and lower the incentive to participate in VCAAs. Petroleum companies probably discounted ESA regulations when deciding where to drill.

Finally, I performed a series of placebo and robustness checks to determine whether the results could be spurious. Table 2 shows the estimates from three additional regressions. Column (1) presents the results of a placebo test, which tests for a change in habitat location preferences between 1998 and 2008—that is to say, the years when there was no regulatory scrutiny. A placebo effect different from 0 would indicate the original comparion is biased. The model is fitted with the regulation at a randomly chosen period (March 2004), lasting for 18 months (the same duration as the *listed* period). The new parameter is not significantly different from zero.

Column (2) of Table 3 adds a region-specific time trend to control for the possibility of a continuous, linear change in the share of wells in habitat. The new variable is the product of the *habitat* dummy and a count of the months since the initial period, January 1990.[9] This generalizes the model to allow for petroleum companies to have

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[9] Specifically, the term $\delta_6 t \cdot habitat_j$ is added to the model, which changes the systematic portion to $w_{jt} = \boldsymbol{x_{jt}\beta} + \gamma habitat_j + (\delta_1 petition_t + \delta_2 raised_t + \delta_3 proposed_t + \delta_4 rwp_t + \delta_5 listed_t + \delta_6 t) \cdot habitat_j$,

increasingly favored or avoided the habitat region, unrelated to any specific decisions by regulators. Given the timing of regulations in the data, without controlling for a region-specific trend, a gradual shift in location preferences toward (away from) habitat over time would bias the parameters of interest toward (away from) zero. And, indeed, this new parameter is negative and significant, which shows companies increasingly avoided drilling in habitat independent of regulations. More importantly, including the region-specific trend attenuates the parameters on *petition*, *raised* and *listed* enough that their confidence interval overlaps with zero. This makes earlier evidence that regulatory scrutiny accelerated habitat development between 1995 and 1998 less convincing. It also robustly demonstrates that regulations did not appreciably affect location preferences. Interestingly, though, the parameter on *rwp* is now twice as big as the other effects of interest, which may reflect the attempt by WAFWA to promote habitat avoidance and avert the need for listing, although the effect size remains very small.

Lastly, the parameters in column (3) are estimated from a new sample of alternatives to test if the results are sensitive to the sample. Signs, effect sizes and significant levels do not appreciably differ from the original estimates.[10]

6 Conclusions

This paper makes two contributions. First, it documents the effect of a recent ESA listing on petroleum development. In areas of protected habitat, the number of new oil and natural gas wells probably declined no more than 4% due to ESA activities, and that most of this change began before the listing. Indeed, in one of the richer

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where $t = 1, 2, \ldots, T$ with T the final time period.

[10] I also examined alternative formulations of the choice set by restricting the set of alternatives to the state in which the well was located, but this also did not qualitatively affect the results.

models that controls for a potentially confounding region-specific trend in location preferences, the ESA effect is statistically indistinguishable from zero. This indicates ESA regulations did not discourage new petroleum development in habitat, except perhaps to a small degree. Industry and decision-makers raised concerns at the time of the listing that regulations would impede economic development in the region. These estimates show that development has not been substantially harmed, so, in all likelihood, habitat destruction continued despite the risk of penalties.

Second, this study found the threat of ESA regulations affected drilling location preferences before listing. In general, the effect of regulators' pre-listing actions discouraged companies from locating wells in habitat. This contrasts with other research that found ESA regulations encouraged preemptive habitat destruction. Although the effect of initially petitioning the LPC for the ESA may have spurred some preemptive habitat development by petroleum companies, the effect was small and statistically indistinguishable from zero in some models. This shows that significant preemptive habitat destruction is not a general outcome of land use restrictions that protect habitat. Moreover, later pre-listing announcements are robustly associated with increased habitat avoidance; this effect was small but it does suggest companies purposefully limited the number of their projects in the habitat region before May 2014, ostensibly to reduce the probability of a listing. Industry self-regulation is known to occur when there are strategic complementaries in companies' environmental decision making [46]. Nevertheless, this study shows only a fraction of petroleum projects were affected by conservation activities and related environmental regulations, which lends further support to research that concludes regulations do not effectively protect habitat on private land [6,8,47]. For species like the LPC, incentives may be more effective at promoting conservation.

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Table 1: County characteristics used in the well location models

Characteristic	Description	Mean	St. Dev.
$population$	Annual county population density (thousand persons/mile^2)	0.047	0.154
$refinerydistance$	Distance from section to nearest oil refinery (in miles)	33.492	54.516
$gasplants$	Density of natural gas processing plants in county (plants/mile^2)	0.155	0.660
$pasture$	Dummy for sections in pasture	0.488	0.500
$crops$	Dummy for sections in crops	0.417	0.493
$wetlands$	Dummy for sections that are wetlands	0.002	0.043
$developed$	Dummy for sections that are developed (urban)	0.024	0.152
$foreland$	Dummy for sections overlaying foreland basins	0.001	0.035
$transtensional$	Dummy for sections overlaying transtentional basins	0.411	0.492
sag	Dummy for sections overlaying sag basins	0.169	0.375
$wells_{dum}$	Dummy for the presence of wells in the section at time of spud	0.002	0.048
$wells_{num}$	Number of existing wells in the section at time of spud	0.008	0.242
$habitat$	Dummy for section in habitat area	0.331	0.471
$petition$	Dummy for wells spudded during initial listing petition	0.078	0.269
$raised$	Dummy for wells spudded between risk level raised and proposed rule	0.187	0.390
$proposed$	Dummy for wells spudded between proposed listing rule and before listing	0.099	0.299
rwp	Dummy for wells spudded after creation of rangewide conservation plan	0.109	0.312
$listed$	Dummy for wells spudded while the species was listed under ESA	0.074	0.262
Alternatives	Number of sections in the choice sets		500
Wells drilled	Number of choice occasions		69,698

Table 2: Location choice model coefficients

	(1)		(2)		(3)	
	Coef.	St. Err.	Coef.	St. Err.	Coef.	St. Err.
$population$	-2.554	(0.511)	-2.554	(0.511)	-2.556	(0.511)
$refinerydistance$	-0.004	(0.0003)	-0.004	(0.0003)	-0.004	(0.0003)
$gasplants$	0.423	(0.010)	0.424	(0.010)	0.424	(0.010)
$pasture$	0.040	(0.029)	0.040	(0.029)	0.040	(0.029)
$crops$	0.012	(0.030)	0.012	(0.030)	0.011	(0.030)
$wetlands$	0.141	(0.118)	0.141	(0.118)	0.140	(0.118)
$developed$	-0.046	(0.048)	-0.046	(0.048)	-0.047	(0.048)
$foreland$	-3.197	(1.001)	-3.197	(1.001)	-3.197	(1.001)
$transtensional$	0.093	(0.031)	0.093	(0.031)	0.094	(0.031)
sag	-0.125	(0.034)	-0.125	(0.034)	-0.125	(0.034)
$wells_{dum}$	6.571	(0.015)	6.571	(0.015)	6.571	(0.015)
$wells_{num}$	0.009	(0.004)	0.009	(0.004)	0.009	(0.004)
$habitat$	0.183	(0.029)	0.189	(0.029)	0.182	(0.029)
$habitat \times petition$	0.112	(0.040)	0.112	(0.040)	0.112	(0.040)
$habitat \times raised$	-0.311	(0.032)	-0.311	(0.032)	-0.311	(0.032)
$habitat \times proposed$	-0.356	(0.042)	-0.356	(0.042)	-0.357	(0.042)
$habitat \times rwp$	-0.307	(0.059)				
$habitat \times listed$	-0.241	(0.071)				
$unsuitable \times rwp$			-0.320	(0.079)	-0.320	(0.079)
$unsuitable \times listed$			-0.223	(0.094)	-0.223	(0.094)
$suitable \times rwp$			-0.299	(0.066)		
$suitable \times listed$			-0.252	(0.080)		
$nonfocal \times rwp$					-0.225	(0.079)
$nonfocal \times listed$					-0.305	(0.094)
$focal \times rwp$					-0.408	(0.092)
$focal \times listed$					-0.183	(0.112)
Log-likelihood		-235561.3		-235561.2		-235559.1

Standard errors, clustered on lease, in parentheses.

Table 3: Location choice model robustness checks

	Placebo test on 7/98-11/08 sample		Habitat-specific trend		Resampling of alternatives	
	Coef.	St. Err.	Coef.	St. Err.	Coef.	St. Err.
population	-4.276	(2.041)	-2.991	(0.528)	-2.545	(0.523)
refinerydistance	-0.009	(0.0005)	-0.004	(0.0003)	-0.004	(0.0003)
gasplants	0.643	(0.020)	0.424	(0.010)	0.424	(0.010)
$wells_{dum}$	6.752	(0.027)	6.576	(0.015)	6.562	(0.015)
$wells_{num}$	0.009	(0.007)	0.009	(0.004)	0.008	(0.004)
pasture	0.042	(0.049)	0.040	(0.029)	0.051	(0.029)
crops	-0.003	(0.051)	0.012	(0.030)	0.023	(0.030)
wetlands	0.164	(0.182)	0.146	(0.118)	0.183	(0.116)
developed	-0.109	(0.078)	-0.045	(0.048)	-0.044	(0.048)
foreland	*		-3.195	(1.001)	-3.234	(1.001)
transtensional	0.040	(0.051)	0.093	(0.031)	0.114	(0.031)
sag	-0.405	(0.061)	-0.125	(0.034)	-0.116	(0.034)
habitat	0.099	(0.046)	0.405	(0.036)	0.190	(0.029)
habitat × *petition*			0.055	(0.040)	0.096	(0.039)
habitat × *raised*			-0.054	(0.040)	-0.304	(0.032)
habitat × *proposed*			-0.085	(0.049)	-0.382	(0.042)
habitat × *rwp*			-0.157	(0.061)	-0.271	(0.059)
habitat × *listed*			-0.056	(0.073)	-0.283	(0.071)
habitat × *placebo*	-0.077	(0.051)				
habitat × *t*			-0.002	(0.0002)		
Log-likelihood		-73035.9		-235486.4		-235732.4

Standard errors, clustered on lease, in parentheses.

*This coefficient not estimated because no wells were drilled in foreland areas in this time.