# The Costs of Protecting the Wild: Evidence from Auctions for Natural Resource Development*

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**Abstract**

This paper investigates the effect of current and potential land use regulation on the value of natural resource development. We develop a model in which resource development rights for land parcels are sold through a first-price, sealed-bid auction and where regions differ in whether land use is currently regulated or may be regulated in the future. The model provides prescriptions on how to use regression discontinuity designs to identify the effects of current and potential regulation on the price for land. We employ this framework to analyze how auction prices for oil and gas development rights are affected by environmental land use regulations, and find that firms pay up to 16% less for land parcels subject to current regulation. We find evidence consistent with the notion that firms account not only for the costs of land use regulation but also for the expected costs from potential regulation in the future.

Keywords: land regulation, auctions, expected costs, natural resource development.

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# 1 Introduction

This paper investigates the effect of current and potential land use regulation on the value of natural resource development. To do this, we develop a model where rights to develop natural resources from land parcels are sold through a first-price, sealed-bid auction and parcels may be subject to land use regulation. If the auctions are competitive, firms will bid the net present value of profits derived from developing the resource on a given land parcels. By comparing the price for land parcels that differ in regulation but are otherwise identical, one can identify the costs of complying with the regulation.

We augment our model to consider how auction prices change if land use regulation changes over time. In particular, we consider the possibility that boundaries specifying regions under land use regulation may expand in the future. In this case, comparing the price for a land parcel subject to regulation to the price for a parcel that may in the future be subject to regulation will not identify the cost of regulation: firms purchasing the latter will account for the expected cost of complying with potential, future regulation when submitting their bids. If the likelihood of expansion is sufficiently high, then the expected cost may be nearly the same as the current costs, and the prices for the two land parcels will be the same.

Our model provides prescriptions on how to identify the costs of current and potential, future regulation using a regression discontinuity approach. We employ this framework to empirically examine how geographically-varying environmental land use regulation affects the winning bids from first-price, sealed bid auctions in the oil and gas industry in the Canadian province of Alberta.

We find evidence consistent with the notion that firms capitalize the cost of complying with existing land use regulation into auction prices for resource development rights and that firms capitalize the expected costs of complying with potential future regulation into auction prices for resource development rights. Specifically, we find that land parcels subject to current land use regulation are on average auctioned for prices 15% lower on average than lands that are never regulated.

We also find that land parcels that are never regulated are worth an economically and statistically significant amount more than parcels subject to potential, future land use regulation. This finding is consistent with the notion that firms account for expected costs of regulation in their bidding behaviour. Additionally, when we compare land parcels subject to current regulation that are adjacent to parcels subject to potential regulation, the difference in their auction prices is negligible, which is again consistent with firms accounting for expected costs of potential regulation.

This paper is interesting for two reasons. First, determining the optimal level of regulation requires balancing costs against the benefits. We show that, in practice, not only does existing land use regulation generate costs to firms, but so too does potential, future regulation. Critically, estimating these costs separately requires knowledge of how and where regulation exists and where it may arise in the future. Second, natural resource development is booming across North America: technological advances have made uneconomical resources recoverable using unconventional extraction methods. These methods require large parcels of land, take several decades to extract the resource, and require enormous sunk costs. Understanding the costs of land use regulation is vital for determining how to appropriately set regulation for resource development.

This paper makes at least three contributions. It is to our knowledge the first paper to use auctions to infer the costs of environmental regulations on industry. This indirect approach is similar to hedonic estimation of property values to infer the marginal benefits of environmental amenities used by, for example, Chay and Greenstone [2005].[1] In contrast to our analysis of auctions for natural resource development, the literature that estimates the effects of environmental regulation on industry has almost exclusively focused on manufacturing and employment, capital and output (Greenstone [2002]), manufacturing plant births (Becker and Henderson [2000]), and productivity (Greenstone et al. [2012]). Given that first-price sealed-bid auctions fully reveal the value of an object so long as the auction is competitive, auctions may more accurately reflect all of the costs of regulation.

The second contribution of this paper is that we identify and estimate the effect of potential future regulation on land values. The current literature focuses on identifying the effects of existing land use regulation on residential land values – see Turner et al. [2014] for a recent example – but to our knowledge the literature has not considered the effects of potential, future regulation.

The third contribution this paper makes is to estimate the cost of land use regulations aimed at protecting endangered wildlife. Much of this has focused on the U.S. Endangered Species Act (ESA): Ferraro et al. [2007] and Langpap and Kerkvliet [2012] have estimated the effect of the Act on species recovery, while the costs from the ESA have been analyzed for housing supply by Zabel and Paterson [2006] and residential prices by Greenstone and Gayer [2009] and Zabel and Paterson [2010]. In contrast, our study focuses on different, yet similar wildlife species regulations and its effects on industry.

[1] See Kuminoff et al. [2013] for a survey on the recent development of equilibrium models of residential sorting to estimate marginal willingness to pay for environmental goods.

The following section provides an overview of Albertan oil and gas development and the land use regulation that serves as the context for our analysis. Section 3 develops a theoretical model of spatial bidding that generates our identification arguments. Section 5 presents the empirical approach and results, and Section 6 concludes.

## 2 Context

The Canadian province of Alberta lies atop a geological formation known as the Western Canadian Sedimentary Basin, a region rich with underground deposits of carbon. Since the 1940s, significant amounts of oil and gas have been extracted using conventional methods. Beginning in the 1960s, vast reserves of unconventional oil and gas – typically referred to as the 'oil sands' – have been and continue to be extracted. Today, about 170 billion barrels of oil are considered recoverable given current technology and prices, third only to Saudi Arabia and Venezuela (ERCB [2013]). Alberta produced more than two million barrels of crude oil per day in 2013, and this number is projected to more than double by 2030 (see CAPP [2013]).

Most of the mineral wealth in Alberta – as in all provinces in Canada – falls under provincial jurisdiction and is collectively owned by the residents of Alberta. The provincial government administers the extraction of the carbon reserves and maintains the monetized wealth resulting from extraction. Although publicly-owned, the province has chosen to delegate extraction to private firms and recoup some of the monetized wealth by auctioning land rights for mineral extraction and royalty taxes on production.

To extract oil and gas in Alberta, a firm must lease the parcel of land below which the resource resides. To obtain a lease for a given land parcel, a firm must win a first-price sealed-bid auction for that parcel. Prior to the auction, a given land parcel is publicly announced by Alberta's Department of Energy as being up for lease for any entity interested in purchasing land lease rights. Information about the parcel – its location, the conditions of the lease, mineral analysis results from core samples, nearby encumbrances such as abandoned wells, and relevant environmental regulations – are included in the announcement.[2] This announcement provides a potential bidder with a comprehensive set of information from which to estimate the profitability of the parcel. In an auction, a bidder can purchase multiple adjacent parcels simultaneously and often do so. Currently, the Alberta government has

[2]Potential leasees must obtain an account to do business electronically with the Alberta Department of Energy through its Electronic Transfer System, which also houses all the information about land postings.

agreed to more than 100,000 leases for petroleum and natural gas development, and auction sales generated more than $3.6 billion in revenue in 2011-2012.[3]

Depending on the geographic location of the leased land, a winning bidder must satisfy certain start-up and production conditions between two and five years to ensure the lease is renewed. For leases that do not satisfy these conditions, the lease is terminated and the parcel is auctioned again; leases that do satisfy the conditions can be renewed for decades. Upon commencing production from a well, the production is subject to a royalty tax, which increases as the project surpasses the 'break-even' level in profits. In the fiscal year 2012-2013, royalties generated over $7 billion in revenues.[4]

Since large parts of the province are uninhabited by humans, Alberta has a rich set of wildlife within its boundaries. However, the growing human population and the expansion forestry, industrial agriculture, and oil and gas development has encroached on lands traditionally inhabited only by wildlife, causing population declines in some species and even putting some species at risk of extirpation.

Lands, habitat, and wildlife lying on provincial lands fall under provincial jurisdiction; in Alberta, wildlife protection is legislated under the *Wildlife Act*. Under the *Act*, species can be legally designated under several different legal at-risk categories, each of which prompt different policy responses. The 'endangered' and 'threatened' designations are for species facing the greatest risk of extirpation and, following such a designation, the government is legally required to develop a recovery plan for that species.[5] These designations are similar to the Canadian federal *Species at Risk Act*, the U.S. *Endangered Species Act*, and to the at-risk species designation by any country that is a signatory to the United Nations *Convention on Biological Diversity* of 1992.

Perhaps the most high-profile case of at-risk species in Alberta is the woodland caribou, which was listed as endangered in 1987 until 1997; in 1997, following an amendment of the *Wildlife Act*, the woodland caribou was designated as threatened and remains at this designation. The woodland caribou (hereafter referred to simply as 'caribou') exhibit population decreases that are considered unstable for population recovery: ASRD and ACA [2010] estimate that approximately 70% of caribou populations in Alberta are in decline. The declines

[3]For a brief statistical description of auctions for petroleum and natural gas leases in Alberta, see `http://www.energy.alberta.ca/Tenure/865.asp`.

[4]For a breakdown of royalty revenues, see `http://www.energy.alberta.ca/Org/pdfs/HistoricalRevenuesGraph.pdf`.

[5]The difference between the legal definitions of 'endangered' and 'threatened' are vague; see Fluker and Stacey [2012] for an overview and analysis.

are mostly due to alteration or degradation of caribou habitat and migration routes.[6] The increase in the price of oil coupled with the discovery of cheaper extraction technologies have significantly increased the expansion of the oil and gas extraction into these habitats. Alberta Woodland Caribou Recovery Team [2001] and ASRD and ACA [2010] attribute much of the recent and significant declines in caribou populations as caused by the energy industry.

Following the designation of caribou as endangered and threatened, the Albertan government developed a caribou recovery plan to stop the decline of caribou populations (Alberta Woodland Caribou Recovery Team [2001]). The primary instrument to mitigate the adverse effects to caribou populations from oil and gas development was the implemention of caribou protection zones, which follow the historical approach to wildlife conservation in North America of the past century.

A protection zone is a geographic area that is a subset of the range of a given caribou herd. A herd's range is determined by the historical limit of that herd's migration routes which were mapped from surveys in the late 1970s and early 1980s (Alberta Woodland Caribou Recovery Team [2001]).[7] The protection zone is determined by the location of the herd's critical habitat. For some herds, the zones are equal to the ranges; elsewhere, zones are proper subsets of herd ranges. Since 1991, the zones have incrementally been expanding (and never contracting); in 2013, the zones were expanded to equal the ranges everywhere. Currently, there are seventeen distinct caribou protection zones in Alberta, based off of the seventeen ranges of each individual herd in Alberta.

Oil and gas firms seeking to lease lands in the protection zones must satisfy certain guidelines. Within the boundaries of the zones firms must develop strategic plans to mitigate adverse effects on caribou habitat and migration, which must be approved by the provincial regulator. Operationally, the zones limit the activity or impost constraints on activities that support extraction, thereby imposing costs to producers not borne outside the zones. Examples include limiting the clear cutting of forests, specifying how transport routes – such as roads and pipelines – must circumvent caribou migration routes and habitats, potentially limiting the location of well sites, limting the seismic disturbances from drilling, and limiting the number of drilling sites on a given land lease. Note that any parcel that lies outside the zone is not subject to the regulations, even if that parcel lies in the herd range. However, there is no vintage-differentiation of regulation following zone expansion: any parcel that

[6]Habitat alteration affects the caribou in several ways. By cutting off migratory routes, caribou herds are unable to merge and grow populations. Second, the caribou require mature forests to survive. The clear-cutting of forests for oil and gas development makes caribou more susceptible as prey to wolves.

[7]Unlike boreal caribou, woodland caribou do not migrate large distances.

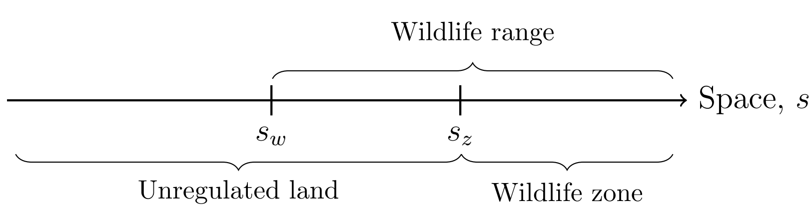
was historically outside the zone but subsequently lay within the zone following an expansion would be subject to the regulations. Thus, since zones are potentially expanding to encompass lands within the herd ranges, any parcels lying outside zones but within ranges face the prospect of future regulations.

# 3 Model of Auctions with Land Regulation

In this section, we develop and analyze a stylized model of spatial bidding behavior. We consider the situation where a large number of agents bid for land tracts of even size in a first-price sealed bid auction. The highest bidder wins the right to develop the land tract and pays his bid. Each agent's bid will maximize his expected payoff given the bidding behavior of all other agents. In such situation, we know that each agent's optimal bid approaches his true valuation of the object as the number of bidders increase. Hence, by focusing on the situation with a large number of bidders, we can assume the bids reflect the true valuation of the land tracts. In the case of development rights for oil and gas, this means that a firm will bid the expected present value of the discounted future cost and revenue stream from oil and gas development on a given tract of land.

To illustrate the effect of location on bids, we use a one-dimensional spatial model where tracts of land are located on a line from $s = 0$ to $s = \bar{s}$. There is one regulatory zone located on $Z = [s_z, \bar{s}]$. Hence, the regulatory zone is to the right of the zone border $s_z$ (see figure 1). Land tracts differ in terms of a number of factors, including how much oil and gas can be extracted, the technology needed to extract the resource, the depth and quality of the hydrocarbon deposit, and other location specific factors affecting development costs, output price, and the recoverable amounts of oil and gas. In addition, firms that locate in or close to wildlife zones will incur costs of complying with stricter environmental regulations.

Figure 1: The spatial model: Wildlife zone and range



Wildlife zones are subject to stricter environmental regulations. Hence, the costs of regulatory compliance is higher in a wildlife zone. In addition, proximity to a zone may impose costs also on firms operating on unregulated land. First, the presence of the zone nearby may constrain a firms access to its own land. Second, the risk of zone expansion means that a currently unregulated land unit may be subject to stricter regulations in the future.

## 3.1 Costs and revenues of oil development

Let $A(s)$ be a function that relates the present value of the stream of production revenues and costs from a tract of land, to its location, $s$. For ease of exposition, we assume that $A(s)$ is smooth and differentiable. The potential value of a tract of land, $A(s)$, depends on its location, since, as mentioned above, many factors that vary across space affect both production costs and revenues. For example, if tract $s$ does not have an oil or gas deposit, $A(s) \leq 0$ and no firm would place a bid for the development rights to that tract. The same would be the case if $s$ is located close to a city or elsewhere where development costs would be excessive relative to potential revenues. On the other extreme are land tracts that may yield large amounts of high quality oil and gas at a relatively low production cost. In such cases, the value of $A(s)$ is high and firms would likely be willing to bid large amounts for the development rights. However, this also depends on whether the land tract is, or is likely to become, part of the regulatory zone, as this incurs additional costs.

Proximity to the zone border, $s_z$, affects how much of the full regulatory cost a development firm faces. We distinguish between two types of regulatory costs, the regulatory cost associated with oil and gas development on the land, denoted $c_d$, and the regulatory cost of accessing the site, $c_a$. Both $c_d$ and $c_a$ represent the present value of the regulatory cost streams. The access cost $c_a$ includes the cost of getting personnel and goods to the site, and oil and gas from site to market. While only firms located within the wildlife zone incurs the fixed regulatory cost $c_d > 0$, also firms outside of the zone may incur costs of constrained access. The more zoned land that surrounds a tract of land, the higher the access cost $c_a$. Hence, the cost function $c_a(s, s_z) \geq 0$ depends on the location of land tract $s$ relative to the zone, $s_z$. The access cost approaches zero as we move away from the wildlife zone, and increases the closer to or deeper into the zone a tract is located. Hence, the access cost increases both in $s$ and $s_z$. In addition, it satisfies the properties $c_a(0, s_w) = 0$ and $\frac{\partial^2 c_a(s,s_z)}{\partial s \partial s_z} \leq 0$. Finally, we assume the access cost function is continuous and differentiable for all values of $s$.[8]

## 3.2 Risk of future zone expansion

The current wildlife zone lies within the wildlife range, $s_w \leq s_z$, where $s_w$ and $s_z$ denote the borders of the wildlife range and wildlife zone, respectively. See figure 1 for an illustration of the case where $s_w < s_z$. The border of the wildlife zone may shift left over time if the wildlife zone expands. However, the zone can never expand beyond the wildlife range, hence, $s_w \leq s_z$ must always hold.

Assume there is a known probability that tract $s$ will be included in the wildlife zone at a later point of time. Furthermore, firms have expectations as to when land $s$ will be included in the zone, if at all. Formally, $F(s) \in [0, 1]$ is the probability that land $s$ will be in the wildlife zone at some point in the future, while the timing of zone inclusion is captured by $\alpha(s) \in [0, 1]$. One can think of the term $\alpha(s)$ as a discount factor that gives the share of the net present value of the stream of regulatory costs from now until infinity. For example, a tract of land located within the zone from day 1 will have a discount factor of 1 since it incurs the full stream of costs. A tract of land that only is subject to the additional regulatory cost from some future date, on the other hand, pays a share $\alpha(s) < 1$ of the present value of the cost stream. In what follows, we discuss the probability and expected timing of zone inclusion in more detail.

First, the cumulative probability function $F(s) = \int_0^s f(\hat{s})d\hat{s}$, gives the probability of tract $s$ being within the zone in the future, where $\hat{s}$ denotes a possible future wildlife zone border. This probability distribution is shared by all firms. We know that the zone must lie within the wildlife range, and hence, $F(s) = 0$ for $s \leq s_w$. In addition, the zone cannot shrink, which implies that $F(s) = 1$ for $s > s_z$. Finally, for the intermediate case $s \in (s_w, s_z)$, the probability of zone inclusion is positive, $F(\cdot) \geq 0$.

Second, firms have expectations of when unregulated land will become zoned, if at all. To account for the fact that future zone inclusion means that firms incur only part of the regulatory cost streams, $c_a$ and $c_d$, we discount the cost of environmental regulations in these cases by the factor $\alpha(s)$. The discount factor varies across space, capturing that the expectation of when the zone expands into different unregulated areas might vary. Furthermore, since the zone must expand gradually, from right to left in figure 1, the discount factor must be increasing in $s$ as we approach $s_z$, hence, $\alpha'(s) \geq 0$. For completeness, we note that

[8]This implies that the access costs of two neighboring land tracts, one located inside and one outside of the zone border, are basically identical.

$\alpha(s) = 0$ for $s \leq s_w$ and $\alpha(s) = 1$ for $s > s_z$.

Another implication of the fact that the regulatory zone must expand gradually is that $\alpha(s)$ and the probability function $F(s)$ will be correlated. Note also that the discounted probability of zone inclusion, $\alpha(s)F(s)$, is discontinuous in the point $s = s_z$, unless firms expect the first land tract right of $s_z$ to be zoned immediately and with certainty.

## 3.3 Value of land

We can now calculate a firm's willingness to pay for a tract of land. This will depend on the location of a tract relative to the current wildlife zone, the probability and expected timing of zone expansion, and other factors:

$$B(s) = A(s) - c_a(s, s_z) - \int_{s_w}^{s_z} \alpha(\hat{s}) \left[c_a(s, s_z) - c_a(s, \hat{s})\right] f(\hat{s}) d\hat{s} - \alpha(s) c_d \int_{s_w}^{s} f(\hat{s}) d\hat{s} \qquad (1)$$

where $B(s)$ is the valuation (bid) of land tract $s$. The second term in equation (1) is the regulatory access cost of tract $s$, given that the zone border never changes. The third term accounts for the possibility that the border may shift left if $s_w < s_z$. In that case, we calculate the expected discounted change in regulatory cost caused by zone expansion. The last term in (1) gives the expected regulatory development cost. For $s < s_w$ this term is zero, while for $s > s_z$ the regulatory cost is $c_d$. For land tract $s_w < s < s_z$, this term is positive but lower than the full cost $c_d$, as there is a chance that the tract of land will be included in the zone at some point in the future.

The bid function, $B(s)$, is discontinuous in the point $s_z$ because of the discontinuity in this point in both the regulatory development cost $c_d$ and the discounted probability of zone expansion $\alpha(s)F(s)$. Furthermore, in what follows, we will assume there are no systematic differences in $A(s)$ across space, which implies $A(s) = A$ for all $s$ in this simple model.

## 3.4 Theoretical analysis

Based on the model presented above, we can derive several results on the effect of location on winning bids, and particularly, on how wildlife regulations affect bids. We start out by analyzing what happens to bidding behavior at the wildlife range and wildlife zone borders, $s_w$ and $s_z$. Next, we investigate how bids differ along the spatial dimension.

**Bidding behavior at the borders: Discontinuities**

Let us start by using the bid function (1) to derive the difference in winning bids across neighboring tracts of regulated and unregulated land:

$$\hat{D} = \alpha(s^+)c_d \int_{s_w}^{s^+} f(\hat{s})d\hat{s} - \alpha(s^-)c_d \int_{s_w}^{s^-} f(\hat{s})d\hat{s} = c_d \left[1 - \alpha(s^-)\right], \tag{2}$$

where $s^- = s_z - \epsilon$ and $s^+ = s_z + \epsilon$ are unregulated and regulated land tracts, and $\epsilon$ is a very small positive number. Note that differences in $A(s)$ and $c_a(s, s_z)$ cancel out, as these are negligible when we compare neighboring tracts of land. In addition, $\alpha(s^+) = 1$ regardless of the risk of zone expansion. The second equality in (2) follows from $s^-$ and $s^+$ being marginally below and above $s_z$, and hence, the term $\int_{s_w}^{s} f(\hat{s})d\hat{s} \approx 1$ for $s \in (s^+, s^-)$. Note that the discontinuity of $\alpha(s)$ in $s_z$ makes the $\hat{D}$ function discontinuous in this point.

From equation (2), we immediately see that the difference in winning bids across neighboring tracts of unregulated and regulated land depends on two factors: (i) the expected regulatory development cost, $c_d$, and (ii) the expected timing of zone expansion, $\alpha(s^-)$. Hence, differences in winning bids between neighboring tracts of land along the zone border give us information about both the regulatory development cost and the expected timing of zone expansion if this is at all a possibility. In addition, we can use equation (2) to separate these two effects from each other. Propositions 1 and 2 summarize this.

**Proposition 1.** *If the risk of zone expansion is zero ($s_w = s_z$), the difference in winning bids across neighboring tracts of unregulated and regulated land equals the regulatory development cost $c_d$.*

*Proof.* When $s_w = s_z$, there is no risk of zone expansion. Hence, $\alpha(s^-) = 0$ and $\alpha(s^+) = 1$, and equation (2) simplifies to $\hat{D}_0 = c_d$. □

It follows from proposition 1 that we can use the discontinuity at the wildlife zone's border ($s_z$), in the case when $s_z = s_w$, to identify the regulatory development cost, $c_d$. If the regulations are effective in the sense that they change firm behavior, we will have $\hat{D}_0 > 0$. However, if $\hat{D}_0 = 0$, then the additional regulations in the wildlife impose no additional development costs on the firms ($c_d = 0$).

**Proposition 2.** *The expected timing of zone expansion is given by the difference in difference of winning bids between unregulated and regulated land, for the cases $s_w < s_z$ (risk of zone* *expansion) and $s_w = s_z$ (no risk of zone expansion):*

$$\alpha(s^-) = \frac{\hat{D}_0 - \hat{D}_1}{\hat{D}_0}, \tag{3}$$

*where $\hat{D}_0$ denotes the difference between unregulated and regulated land when $s_w = s_z$ and $\hat{D}_1$ denotes the difference when $s_w < s_z$.*

*Proof.* Evaluating equation (2) for $s_w = s_z$ and $s_w < s_z$ yields $\hat{D}_0 = c_d$ and $\hat{D}_1 = c_d\,[1 - \alpha(s^-)]$. Substituting for $c_d = \hat{D}_0$ in $\hat{D}_1$ and rearranging yields equation (3). □

We have looked at the difference in winning bids across neighboring tracts of land on either side of the current wildlife border $s_z$. Depending on the probability density function $f(\hat{s})$ and the discount factor $\alpha(s)$, the bid function may also be discontinuous in $s = s_w$, the wildlife range border. This will be the case if $f(s_w) > 0$ and/or $\alpha(s_w) > 0$, since, by definition, $f(s_w^-) = \alpha(s_w^-) = 0$, where $s_w^-$ denotes the tract of land marginally left of the wildlife range border, $s_w$. We summarize this discussion in the following proposition.

**Proposition 3.** *If the bid function $B(s)$ is discontinuous in $s = s_w$ and $s_w < s_z$, then the market places a significant discounted probability on the wildlife zone expanding to $s_w$.*

*Proof.* If $f(s_w) > 0$ and $\alpha(s_w) > 0$, this will cause a discontinuity in the point $s = s_w$ since in this case the latter term in (1) is zero just below $s_w$ and positive above $s_w$.

If instead $f(s_w) = 0$ and $\alpha(s_w) = 0$, then the functions $f(\hat{s})$ and $\alpha s$ must increase from zero to unity over the interval $(s_w, s_z)$. By definition, both functions are continuous and differentiable in $s \in (s_w, s_z)$, as is the regulatory access cost function, $c_a(\cdot)$. Hence, from equation (1) it follows that with $f(s_w) = 0$ and $\alpha(s_w) = 0$, the $B(s)$ function is continuous in $s_w$, since both the regulatory access cost and development cost terms are continuous. It follows that the bid function can only be discontinuous in $s_w$ if $f(s_w) > 0$ and $\alpha(s_w) > 0$. □

### Bidding behavior across space

Having investigated what happens at the borders $s_z$ and $s_w$, we take a closer look at differences in bids along the spatial dimension. By differentiating the bid function (1), we can investigate how the valuation of land changes across space as we approach and go into the wildlife zone (cf. figure fig:SpatialMod). Taking the derivative of (1), which is continuous and differentiable everywhere except for the point $s = s_z$ and possibly $s = s_w$, yields:

$$B'(s) = A'(s) - \frac{\partial c_a(s, s_z)}{\partial s} - \int_{s_w}^{s_z} \alpha(\hat{s}) \left[ \frac{\partial c_a(s, s_z)}{\partial s} - \frac{\partial c_a(s, \hat{s})}{\partial s} \right] f(\hat{s}) d\hat{s}$$
$$- c_d \left[ \alpha'(s) \int_{s_w}^{s} f(\hat{s}) d\hat{s} + \alpha(s) f(s) \right]. \tag{4}$$

First, provided there are no systematic differences in $A(s)$ across space, the first term in (4) equals zero. The second term is the increased access cost as we move closer to or deeper into the current wildlife zone, while the third term captures the change in access cost if the zone border moves left (zone expands). The last term in equation (4) accounts for the higher expected regulatory development cost as we move closer to the wildlife zone.

This gives us Proposition 4.

**Proposition 4.** *Proximity to wildlife zones and ranges affect the valuation of land: As $s$ increases, the higher the expected regulatory costs and the lower the bids for development rights.*

**i)** *If we are sufficiently far from the wildlife zone and range (low $s$), $B(s) = A(s)$ and there are no systematic differences in winning bids across tracts of land.*

**ii)** *Case $s_w = s_z$ (zone cannot expand): Winning bids fall as we approach the zone, since the regulatory access cost increases in $s$.*

**iii)** *Case $s_w < s_z$ (zone can expand): Winning bids fall as we approach the zone, since both the regulatory access cost and the expected regulatory development cost increases in $s$.*

**iv)** *Within the wildlife zone, winning bids fall as we move deeper into the zone, since the regulatory access cost increases in $s$.*

*Proof.* The proof of (i) follows from equation (1) and the properties of the access cost and probability functions. As $s \to 0$, both the regulatory access cost and the discounted risk of zone inclusion approaches zero. Hence, for sufficiently low values of $s$, we have that $B(s) = A(s)$ which equals zero in absence of systematic differences in $A(s)$ across space.

The proof of (ii)-(iv) follows from evaluating the equation (4) for the cases $s_w = s_z$ and $s_w < s_z$. If $s_w = s_z$, the third term in the equation cancels out, while the fourth term is zero both below and above the discontinuity in $s = s_z$. Hence, $B'(s) = A'(s) - \frac{\partial c_a(s,s_z)}{\partial s}$ for $s \neq s_z$

when $s_w = s_z$. If $s_w < s_z$, equation (4) shows that changes in both expected access cost and expected development cost reduces the bid as $s$ increases. For the case when $s > s_z$, we know that $\alpha(s) = 1$ so that $\alpha'(s) = 0$, and hence, the last term in (4), which represents the marginal change in expected development cost, is zero.

Finally, to prove that $B'(s) \leq 0$, note that with $A(s) = A$, all terms in (4) are negative except the third term, which is positive given that $\frac{\partial^2 c_a(s,s_z)}{\partial s \partial s_z} \leq 0$. However, given the model assumptions, the sum of the second and third term must be negative, and hence, $B'(s) \leq 0$. $\square$

## The discounted risk of zone expansion across space

We want to separate the effect on winning bids of the regulatory access cost $c_a$, which varies across space, from the expected costs associated with the risk of zone expansion. This will enable us to fully characterize the effect of wildlife zone related costs on winning bids over space. Proposition 5 identifies the regulatory access cost, $c_a(s, s_z)$ by relating it to winning bids for different types of land.

**Proposition 5.** *The regulatory access cost in $s < s_z$ is given by the difference in winning bids between land far from the wildlife zone ($s = 0$) and land closer to the zone in the case when $s_z = s_w$:*

$$c_a(s, s_z) = B(0) - B_0(s), \text{ for } s < s_z, \tag{5}$$

*where $B_0(s)$ is the bid function (1) for the case when $s_w = s_z$.*

*Proof.* From equation (1), we know that $B(0) = A(0) = A$ since $c_a(0, s_z) = f(0) = \alpha(0) = 0$. For the case $s_w = s_z$, the bid function (1) is $B(s) = A - c_a(s, s_z)$, for $s < s_z$. Substituting in for $A = B(0)$ in this equation and solving for $c_a(\cdot)$ yields equation (5). $\square$

Next, we will use Proposition 5 to learn more about the expected cost of zone expansion. We summarize this result in Proposition 6.

**Proposition 6.** *For currently unregulated land, the expected regulatory cost of zone expansion, $E[c_z(s)]$ is given by the difference in bids on unregulated land tracts between the cases $s_w = s_z$ and $s_w < s_z$:*

$$E[c_z(s)] = B_0(s) - B_1(s), \text{ for } s < s_z, \tag{6}$$

*where $B_0(s)$ and $B_1(s)$ are the bid functions (1) for the cases $s_w = s_z$ and $s_w < s_z$, respectively.*

*Proof.* From Proposition 5, we know that $B_0(s) = A - c_a(s, s_z)$. Substituting this into equation (1) and rearranging yields:

$$B_0(s) - B_1(s) = \int_{s_w}^{s_z} \alpha(\hat{s}) \left[c_a(s, s_z) - c_a(s, \hat{s})\right] f(\hat{s}) d\hat{s} \text{ for } s < s_z, \tag{7}$$

Comparing this equation with the bid function (1) for $s < s_z$ confirms that the difference in winning bids for unregulated land tracts, $B_0(s) - B_1(s)$, captures the full expected cost of zone expansion when $s_w < s_z$. □

**Corollary 1.** *If $B_0(s) = B_1(s)$, the market considers the discounted risk of zone expansion to be zero, regardless of whether $s_w < s_z$, provided that regulatory access costs are positive.*

*Proof.* The proof follows from equation (7). If the discounted probability of zone expansion $\alpha(\hat{s})f(\hat{s}) = 0, \forall \hat{s} \in (s_w, s_z)$, then $B_0(s) - B_1(s) = 0$. □

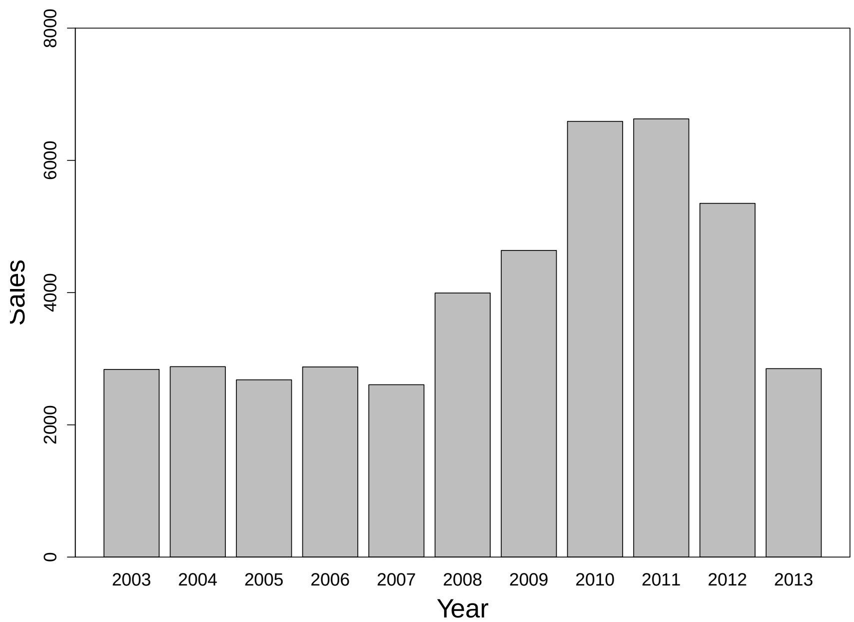
In the following, we empirically analyze the relationship between distance to regulatory zone and bid values by testing Propositions 1-6.

# 4 Data

We combine data from two main sources. The first component of our data is from the universe of oil and gas activity in Alberta, provided to us from IHS Incorporated. From these data, we make use of the winning bids for oil and gas land lease auctions in Alberta which, as Section 2 describes, are sold through a first-price, sealed-bid auction. For each auction transaction, we observe the date of purchase, the geographic location of the land parcel, for how much the lease was purchased, conditions laid out in the lease – such as whether the operation is conventional extraction or unconventional, such as oil sands projects – and, if available, who is the purchaser. We combine these data with information on the geological subsurface features of the land parcel: the pool over which it may lie, the type of substance (oil, or natural gas), the total volume of substance in the pool, and the depth and porosity of the pool. Finally, we also pair these data with the subsequent production activity of the leasee: the number and type of wells created, the depth of the wells, and whether any wells have been abandoned or decommissioned. Table 1 summarizes these data.

Although we observe the history of auction sales for oil and gas rights in Alberta, we focus on the period 2003–2013. We do this because the regulations that we focus on changed slightly in 2003. As a result, the dataset is comprised of 43,746 auctioned leases that we will use in our empirical analysis. Figure 2 plots the number of parcels sold at auction over the time period of our sample.

Figure 2: Auction Sales, 2003–2013

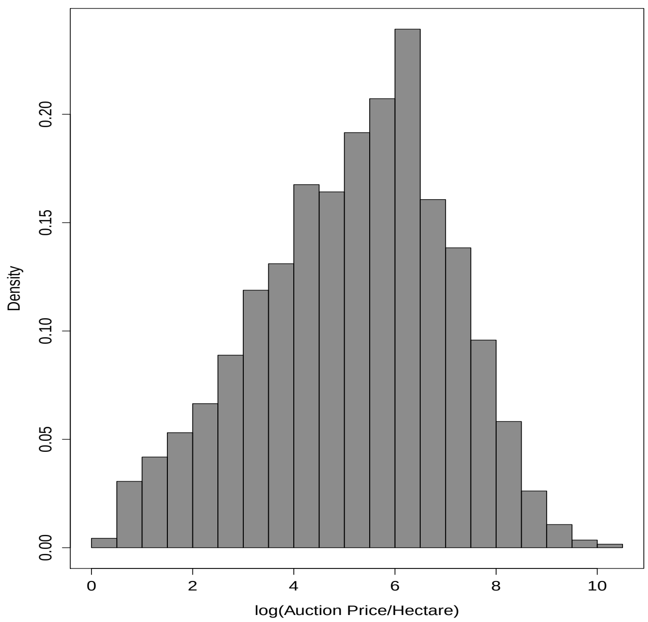



Winning auction prices vary significantly: the sample mean is \$457,867.70 while the standard deviation is over \$2.5 million; the maximum observed price is over \$123 million. Part of this variation is due to the variation in the size of the auctioned parcels: some parcels are the minimum size of a 'quarter-section' (where a 'section' is one square mile), while others are several sections in area. Although we use the logarithm of winning auction prices as the dependent variable in our empirical analysis, to depict the variation in prices Figure 3 plots the histogram of the natural logarithm of winning auction prices per hectare.

Our empirical analysis will rely on comparing geographically disparate land parcels. Figure 4 plots the geographic distribution of winning auction prices over the course of sample. As depicted in the figure, there is substantial variation in prices across space; there are some geographic concentrations of parcels with high prices in the northwest of Alberta, which is the area where the oil sands are developed. However, once accounting for parcel size, these regional differences disappear.

We overlay these geographic data with information about the local wildlife regulations. As

Figure 3: Histogram of Logarithm of Winning Auction Price

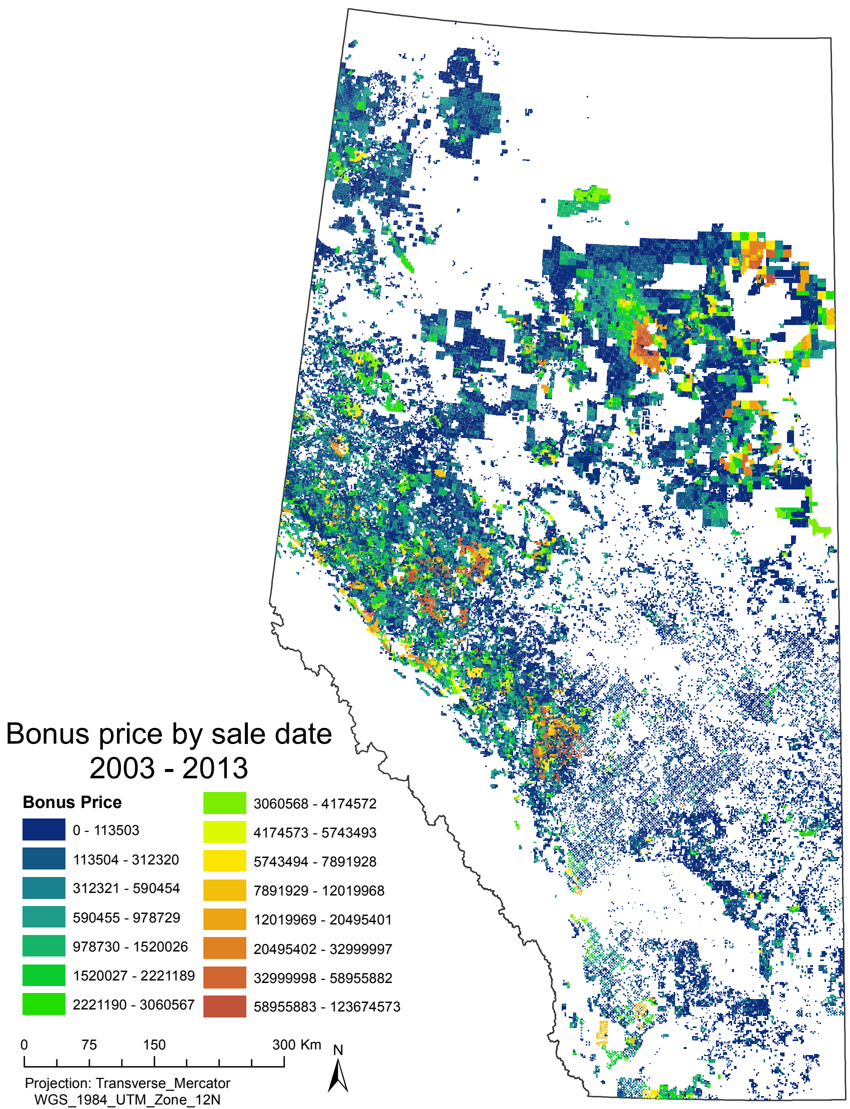



described in Section 2, these regulations vary geographically across the province. Specifically, there are 17 zones on which oil and gas developers must follow operating guidelines designed to mitigate adverse effects on caribou habitat and populations. These zones are determined not by the value of subsurface deposits, but by historical and current habitation areas and migration routes of residing caribou herds. These zones are depicted in blue in Figure 6(a). Since the ranges form the basis of the zones and since we will use the range boundaries as a source of variation in the empirical analysis, Figure 6(b) depicts how the zones are predominantly subsets of the ranges.

Of the 43,746 land parcels that were auctioned during the time period 2003–2013, 15% of these lie wholly or partially in one of the regulatory zones. The dark grey histogram is the distribution of the logarithm of winning auction prices on unregulated lands, while the light grey histogram is the distribution of the logarithm of prices for parcels lying within the regulation zones. It is clear from the figure that the histogram for regulated parcel prices is slightly leftward for that of the unregulated parcel prices.

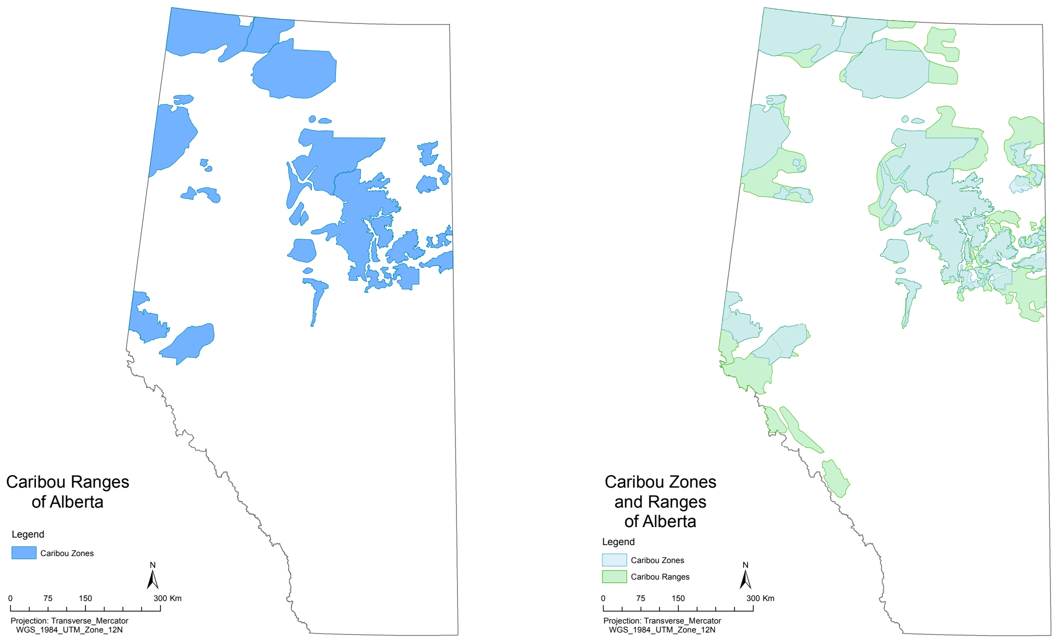
For some parcels, their overall geographic area only slightly overlaps with a regulatory zone; others lie wholly within a zone. If the costs of complying with regulations are larger if an entire parcel lies within a zone compared to partially lying within a zone, then the price

Figure 4: Auction Prices, 2003–2013




should be lower the greater the area within a zone. From our data, 87% of parcels lying at least partly on regulation zones are wholly contained within the regulation zone. This suggests that using an indicator variable for whether the land parcel lies partly or wholly within a given regulation zone is an appropriate measure of whether the land parcel is subject to wildlife regulations.

Figure 5: Regulation zones and ranges




(a) Wildlife protection zones

(b) Wildlife ranges and zones

To employ a regression discontinuity approach, we calculate the distance from each land parcel that was sold to the boundary of each regulation zone. This includes both land parcels within zones as well as land parcels lying outside of zones. The average distance is over 200 kilometers, but below 200 kilometers the average distance is 62.99 kilometers. As a cursory view to how distance to borders matter, we replicate the densities appearing in Figure 6, but for parcels lying within a certain distance from a zone boundary. Figure 6 plots the densities for regulated and unregulated land parcels lying within 50 kilometers of a zone boundary. Though not that different from Figure 3, there is a subtle shift to the right for the unregulated price density and a shift to the left for the regulated price density. This may reflect differences in regulatory costs within or outside regulatory zones, and is thus inline with the theoretical hypothesis presented in section 3.

Figure 6: Prices for Regulated and Unregulated Land

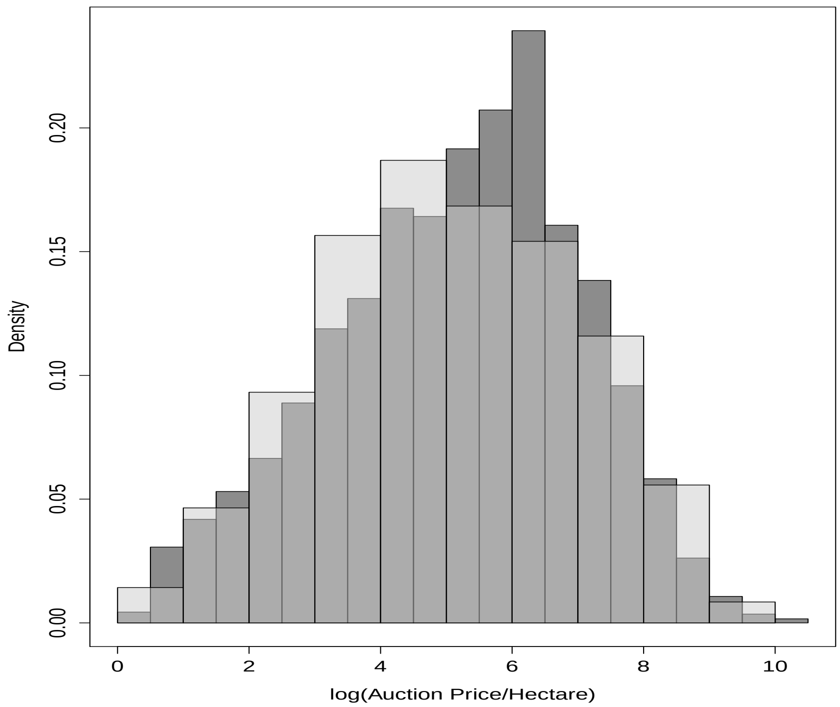



Table 1: Summary Statistics

| Variable (units) | Sample Mean | Standard Deviation |
|---|---|---|
| Auction Price (2013 $ Canadian) | 457,867.70 | 2,606,704.79 |
| Area (hectares) | 720 | 1,549 |
| Regulatory zone indicator | 0.087 | 0.282 |
| Range indicator | 0.107 | 0.309 |
| Fraction of Land Tract Area Regulated | 0.145 | 0.346 |
| Distance to nearest zone boundary within 200 km (km) | 62.70 | 57.39 |
| Distance to nearest range boundary within 200 km (km) | 68.69 | 56.58 |
| Oil sands operation indicator | 0.140 | 0.347 |

# 5 Empirical Analysis

Our empirical analysis will focus how the winning auction price for a given parcel is affected by whether it lies on or off a regulatory zone. In particular, we use the following as our base specification:

$$p_{it} = \gamma_0 + \beta D_i + \mathbf{X}_{it}\mathbf{\Gamma}_1 + \gamma_{iz} + \gamma_t + \varepsilon_{it}. \tag{8}$$

The dependant variable $p_{it}$ is the logarithm of the winning auction price paid for land parcel $i$ in year $t$. The variable $D_i$ is a binary variable indicating whether parcel $i$ lies in a regulatory zone. This variable forms the treatment: land parcels lying inside the regulation zone have $D_i = 1$, forming the treatment group. To control for differences in prices across disparate regions that are correlated with the location of the zones, $\gamma_{iz}$ is a time-invariant intercept that is meant to control for whether parcel $i$ is within a certain distance of zone $z$, irrespective of whether $i$ lies in $z$. $\gamma_t$ is a time-specific intercept meant to control for parcel-invariant differences across time in the winning bids for land tracts, such as the price of oil and natural gas. The vector $\mathbf{X}_{it}$ contains characteristics of the land tract affecting the bid, such as land parcel area, time constraints on production, and the type of fossil fuel being extracted (e.g., light oil, heavy oil, etc.). The random variable $\varepsilon_{it}$ measures idiosyncratic changes in winning land parcel bids.

The parameter $\beta$ captures the effect of the regulation on the winning bid in a lease auction for a given parcel of land. This parameter identifies the cost of environmental regulation according to a few assumptions. Since land is leased according to first-price, sealed bid auctions that are competitive, we assume that in equilibrium firms will bid their expected valuation of the land. If firms account for anticipated costs, then the cost associated with complying with the environmental regulations should be reflected in the price paid for the lease rights. So long as the boundaries are drawn irrespective of the underground carbon deposits, then we can compare two parcels of land sold in the same year, one subject to the regulation and one not, that are otherwise identical. The resulting differences in the winning bid for those two land parcels should be equal to the cost of environmental regulation.

Our differencing identification strategy, however, may be subject to limitations if regulated and non-regulated regions are permanently different in unobservable ways. For example, some regions may have better infrastructure for the extraction of carbon, such as established electricity grids or for transport using existing, nearby pipelines. In a region where there is little infrastructure, the producer may have to incur the cost of developing that infrastructure in order to develop the resource, which should be reflected in the auction price paid for the land parcel. By comparing the price paid for an unregulated parcel in an established development region to one where the producer pays to establish infrastructure that also lies in regulation zone, one may be incorrectly attributing the costs from infrastructure development to the environmental regulations.

To deal with bias from omitted variables, in later subsections we use the geographic granularity of our data to employ a border discontinuity approach motivated in Section 3. In particular, we augment equation (8) by examining auction prices for land parcels within a certain distance from the regulatory boundary. This forces our empirical analysis to compare adjacent or nearly adjacent land parcels on either side of a given regulatory zone. Given this approach, our additional identifying assumption is that adjacent or nearly adjacent parcels on either side of the boundary face similar conditions for the profitable extraction of the underground resources.

## 5.1 Baseline Estimation Results

Table 2 reports the results from estimating equation (8). Each column incorporates progressively more controls. All columns consider winning auction prices between 2003 and 2013.

Column (1) estimates a simplified version of equation (8) that includes no controls. The coefficient estimate for regulation is statistically significant, positive, and very large. This is likely due to the fact that larger, more expensive parcels which are the oil sands are located in and around the regulatory zones. The second column adds lease-specific controls, including the size of the parcel and the type of operation. The coefficient estimate for regulation in this case has decreased in magnitude and significance, but is still likely biased because it does not account for the upward trend in prices during the sample period. Column (3) incorporates year fixed effects, thereby changing the sign relative to the previous results. In particular, this coefficient estimate implies that parcels lying on the regulation zone are 5.44% lower on average than those off the zone. Finally, column (4) incorporates zone-specific fixed effects; the coefficient estimate in this case implies that prices for parcels lying on a zone are 6.71% lower than parcels off-zone.

To put the coefficient estimate from column (4) into context, the mean price is $456,867.70 over the sample period. For a parcel at the mean price, the estimate implies that such a parcel would decrease in value by $30,655.82 if it were located in the regulation zone.

As we discussed above, the profitability of parcels may be correlated with spatial characteristics that are unobserved. If they are, then this may bias the results in Table 2, since we

Table 2: Baseline Estimation Results

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Regulation Zone | $0.860^{***}$ | 0.042 | $-0.053^{*}$ | $-0.065^{*}$ |
| | (0.035) | (0.034) | (0.032) | (0.035) |
| Lease Controls | N | Y | Y | Y |
| Year FE | N | N | Y | Y |
| Zone FE | N | N | N | Y |
| $R^2$ | 0.0134 | 0.213 | 0.315 | 0.361 |
| Num. obs. | 43746 | 43746 | 43746 | 43746 |

Notes: Standard deviations in parentheses. $^{*}$,$^{**}$,$^{***}$ denote estimates different from zero at 10%, 5%, and 1% significance levels.

rely on geographic variation to identify the effect of the regulation zone. To overcome this potential issue, we reestimate the specification in column (4) of Table 2 by progressively narrowing our subsample to include only those parcels that are within a certain distance, but on other side, of a regulation zone. This border discontinuity approach will allow us to control for unobserved characteristics that are spatially correlated, but change that continuously across the borders of the zones.

Table 3 reports the coefficient estimate of the regulation zone variable for regressions that are, as one moves across the columns, progressively closer to the boundary of a zone. Each regression includes lease controls and year and zone fixed effects.

Table 3: Baseline Results with Distance to Zone Boundary

| | All | 50km | 25km | 10km | 5km |
|---|---|---|---|---|---|
| Regulation Zone | $-0.065^{*}$ | $-0.046$ | $-0.071^{*}$ | $-0.060$ | -0.020 |
| | (0.035) | (0.037) | (0.039) | (0.043) | (0.048) |
| $R^2$ | 0.361 | 0.377 | 0.3909 | 0.402 | 0.398 |
| Num. obs. | 43746 | 12590 | 9123 | 6498 | 5473 |

Notes: All regressions include lease controls, year fixed effects, and zone fixed effects. Standard deviations in parentheses. $^{*}$,$^{**}$,$^{***}$ denote estimates different from zero at 10%, 5%, and 1% significance levels.

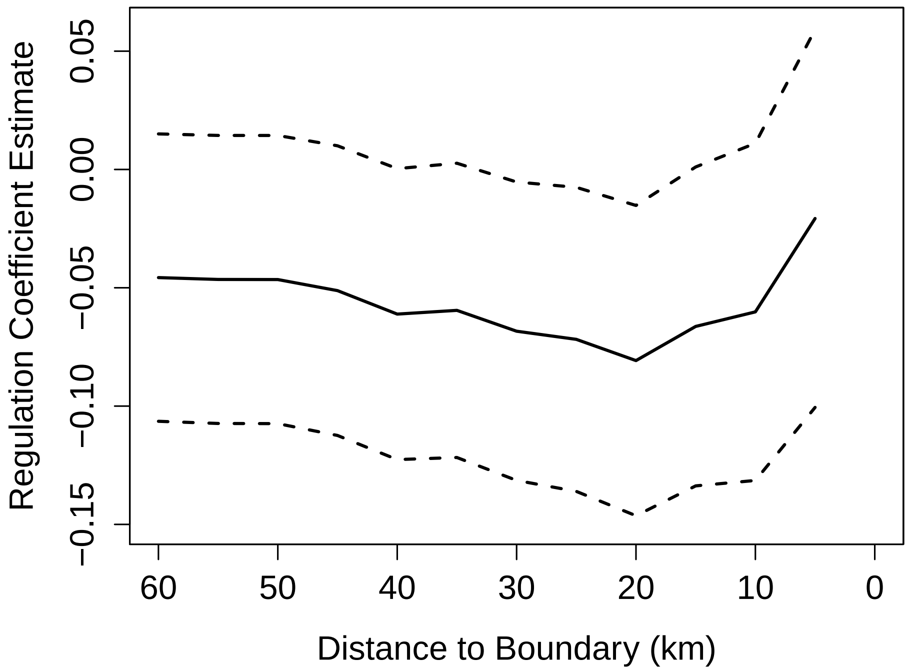
For comparison, the first column of Table 3, labelled 'All', replicates the results from the last column of Table 2. The second column includes only those parcels that are within 50 kilometres of a zone. This coefficient remains negative relative to the estimate in column (1), but is smaller in magnitude and is statistically insignificant. For parcels within 25 kilometres of a zone boundary, the coefficient estimate in the third column is larger in magnitude and statistically significant, and implies that parcels on a zone are 7.35% lower in price than those off the zones. Surprisingly, for parcels within 10 kilometres and 5 kilometres from the boundary, the coefficient estimate is statistically insignificant and progressively smaller in magnitude.

The fact that the coefficient estimates grow larger in magnitude and then become progressively smaller as we narrow the subsample to parcels closer to the border is atypical of border and regression discontinuity design studies, which typically find that coefficient estimates change monotonically as one moves progressively toward the discontinuity (see Imbens and Lemieux [2008] and Lee and Lemieux [2010]). To investigate the change in coefficient estimates of the regulation zone, we reestimated the baseline specification for subsamples of parcels that were within 60 kilometres of the boundary up to 5 kilometres of the boundary (for a total of 12 separate regressions). In Figure 7, we plot the coefficient estimates on the zone indicator, the solid line, and the associated confidence interval, the dashed lines.

From 60 kilometres to about 20 kilometres, the coefficient estimate seems to trend downward as the regression incorporates a narrower distance band around the zone boundary. However, from 20 kilometres to 5 kilometres from the zone boundary, the coefficient estimate decreases in absolute value toward zero. This U-shaped pattern seems to imply that although parcels within 20 kilometres of the zone are sufficiently different such that parcels in the zone are economically and statistically different from zero. Yet as one approaches the boundary, the difference in prices becomes negligible.

A possible reason for this is that, as described in Section 2, the boundaries of the regulation zones have been gradually expanding toward the boundaries of the ranges. Because the regulation is not vintage-differentiated, any firm that wins a parcel that is currently off the zone but is, in the future, included in an expanded regulation zone will be subject to the regulations. Thus any firm bidding for a parcel that is currently off-zone but has a likelihood of being included in the expanded regulation zone should take this into account when submitting its bid. For land parcels adjacent to the zone boundary, the likelihood of expansion is probably high, so the expected costs of potential regulation are nearly identical to that of the actual costs of current regulation. Thus, for adjacent parcels that are on or off the zone, but along the boundary, the differences in their prices are negligible. As one moves farther from the zone boundary and past the boundary of the range – which is the limit of

Figure 7: Estimated Zone Effect by Distance to Zone Boundary




zone expansion – the likelihood of expansion is zero. As a result, the parcels which are just off the range –in our sample, on average about 15 kilometres from the zone – the auction prices will not reflect any cost of regulation since there are none. Therefore, the potential for regulatory expansion is a possible explanation for the pattern observed in Figure 7. The following subsection tests this notion in greater detail.

## 5.2 The Effect of Regulatory Expansion

We augment the empirical specification (8) by incorporating information on whether a parcel of land lies in the range, but not in the zone. In particular, we use the following specification:

$$p_{it} = \gamma_0 + \beta_1 D_i + \beta_2 R_i + \mathbf{X}_{it}\mathbf{\Gamma}_1 + \gamma_t + \varepsilon_{it} \tag{9}$$

where all variables remain the same except for $R_i$, which equals 1 if parcel $i$ falls into the range (but not the zone) and 0 otherwise.

The parameter $\beta_2$ captures the effect on the auction price if the parcel lies in the range. Since the range is the region where the zone may in the future expand into, this effect is due to regulatory expansion. In particular, if firms are forward-looking and anticipate that the parcel they are bidding for may be enclosed in the zone in the future, then they should incorporate the expected costs from complying with the regulation when they submit their bids. If the likelihood of regulatory expansion is non-zero, then there should be a different between land prices on the range, which may be regulated at some point in the future, and land prices off the range and zone that will never be regulated.

Table 4: Estimation Results of Effects of Existing and Potential Regulation

| | (1) | (2) | (3) |
|---|---|---|---|
| Regulation Zone | $-0.065^{*}$ | | $-0.065$ |
| | (0.142) | | (0.155) |
| Range, Not Zone | | $-0.139^{**}$ | $-0.127^{*}$ |
| | | (0.065) | (0.071) |
| $R^2$ | 0.373 | 0.373 | 0.373 |
| Num. obs. | 16675 | 16675 | 16675 |

Notes: All regressions include lease controls, year fixed effects, and zone fixed effects. Standard deviations in parentheses. $^{*}$,$^{**}$,$^{***}$ denote estimates different from zero at 10%, 5%, and 1% significance levels.

Table 4 reports the coefficient estimates for the zone and range indicators, respectively. All regressions incorporate lease controls and year and zone fixed effects. Column (1) replicates the regressions from Table 2.[9] Column (2) incorporates the indicator for lying on the range and omits the zone indicator. The coefficient estimate for lying on the range is statistically significant and implies that parcels lying on the range are won for prices that are 13% lower than parcels lying off the range. When incorporating both zone and range indicators, in Column (3), yields coefficient estimates that are both negative, implying that lying on either the zone or the range reduces the value of the parcel relative to parcels that lie outside the range and zone areas. The coefficient estimate for the zone indicator is not statistically significant at conventional levels, but the point estimate is identical to the estimate in column (1). The coefficient estimate for the range indicator implies that parcels

[9]The number of observations used in column (1) of Table 4 is lower than in Table 2 because we have excluded all parcels for which the nearest zone and range boundary coincide. Instances in which they do coincide are part of the identification strategy outlined in Proposition 1 in Section 3, which we have yet to implement.

lying on the range are 11.9% lower on average than parcels that are never regulated.

A concern with the results reported in column (3) are that the coefficient estimate for the zone is smaller in magnitude than for the range. The costs associated with the zone are current costs of compliance; if there is a chance that the zone expands into the zone, the difference in price between range lands and never regulated lands should be the same costs as for the zone, but discounted by the likelihood that the zone will expand. As a result, one would expect that, if zone and range lands are otherwise identical, the effect of the zone should be no less than the effect of the range. However, all zone and range lands may not be identical in terms of unobservables, which may bias the coefficient estimates. To deal with this issue, we employ the border discontinuity approach to compare adjacent tracts of land.

If the likelihood of expansion is positive, then the auction prices for parcels in the range should reflect the expected costs from complying with the regulation in the future. Whereas for the land parcels outside the range, the likelihood of zone expansion is zero. The difference between the price for unregulated land parcels and the price for potentially regulated range parcels should be the expected costs and any difference in unobservables; by comparing parcels at the boundary of the range, the unobservables are assumed to be approximately equal, so the difference in prices will solely be due to the expected costs of regulation, should the likelihood of expansion be positive.

Table 5 reports estimation results from using a border discontinuity design at the boundary of the range. As one moves across the columns, the parcels used are progressively closer to the boundary of a range. Each regression includes the zone indicator (for distance bands for which there is a sufficient number of zone parcels still included), lease controls and year and zone fixed effects.

Table 5: Estimation Results with Distance to Range Boundary

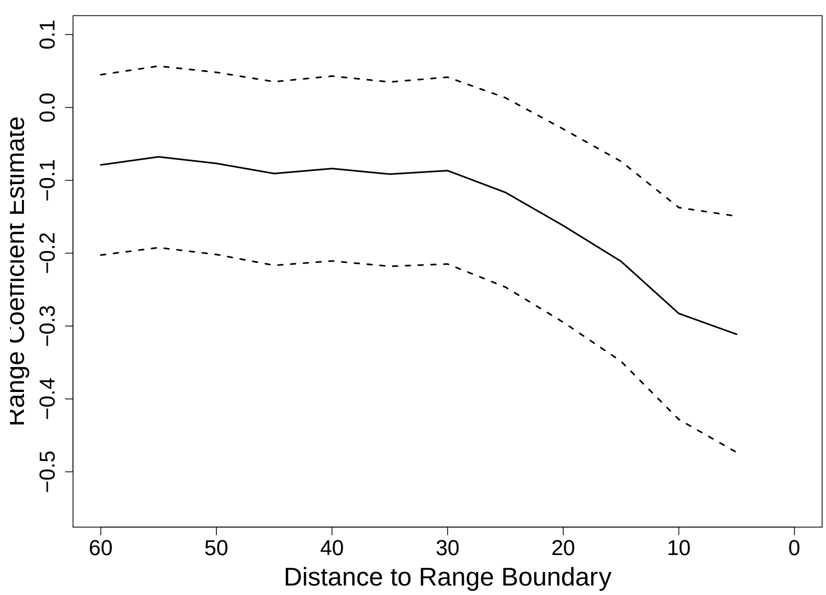
| | All | 50km | 25km | 10km | 5km |
|---|---|---|---|---|---|
| Range, Not Zone | $-0.127^{*}$ | $-0.076$ | $-0.116$ | $-0.282^{***}$ | $-0.311^{***}$ |
| | (0.071) | (0.075) | (0.078) | (0.088) | (0.098) |
| $R^2$ | 0.373 | 0.381 | 0.404 | 0.373 | 0.382 |
| Num. obs. | 16675 | 6575 | 4077 | 2390 | 1672 |

Notes: All regressions include lease controls, year fixed effects, and zone fixed effects. Standard deviations in parentheses. $^{*}$,$^{**}$,$^{***}$ denote estimates different from zero at 10%, 5%, and 1% significance levels.

The first column of Table 5 replicates the regression from column (3) of Table 4. The second column includes only those parcels that are within 50 kilometres of a range, and the following columns contract the subsample to include those parcels only within the specified distance. Noticeably, the coefficient estimates get larger in magnitude and statistical significance for parcels very close to the boundary. The coefficient estimate for parcels within 5 kilometres of the range boundary imply that parcels on the range are 26.7% on average lower than parcels on the other side of the range boundary.

To investigate the change in coefficient estimates of the range indicator, we reestimated the baseline specification for subsamples of parcels that were within 60 kilometres of the boundary up to 5 kilometres of the boundary (for a total of 12 separate regressions). We plotted the coefficient estimates on the range indicator, the solid line, and the associated confidence interval, the dashed lines, in Figure 8. Noticeably, the figure depicts a monotonicity in the coefficient estimates as one nears the boundary of the range, unlike the plotted coefficient estimates for the zone indicator in Figure 7. The coefficient estimates are consistent with the notion that expected costs from complying with potential future regulation are capitalized into auction prices, though the coefficient estimates near the border are very large.

Figure 8: Estimated Effects of Range by Distance to Boundary




It is clear from Tables 2 and 5 that the prices for parcels lying on the range are different than the prices on unregulated lands, but not different to parcels lying on zones along the zone boundary. Our final empirical approach is to rerun a version border discontinuity design along both the zone and range boundaries. However, in this case we will include only parcels within zones that are near to zone boundaries, and include never regulated parcels near range boundaries, and incrementally narrow the allowable distance to those respective boundaries. In this way, we will omit the confounding presence of parcels on ranges whose prices reflect the effect of potential expansion.

Table 6 reports estimation results from a border discontinuity design that excludes parcels within the range. The column labelled 'All' includes all parcels that are either on the zone or on never regulated lands. In this case, the effect of the regulation is much larger than in Table 2: parcels on the zone command prices that are 11% lower on average than parcels that will never be regulated. The second column includes all parcels within the zone that are 50 kilometres to the zone boundary and all parcels outside the range that are within 50 kilometres within the range boundary. As we move across columns, this distance narrows and contracts the subsample that use to estimate the effect of regulation. For 5 kilometres from the boundary of the zone and range, the coefficient estimate in the final column implies that parcels within the zone are valued at 15.6% lower than parcels that are never regulated. To put this number into context, at the mean auction price in our sample, this amounts to a change in price of $71,427.36.

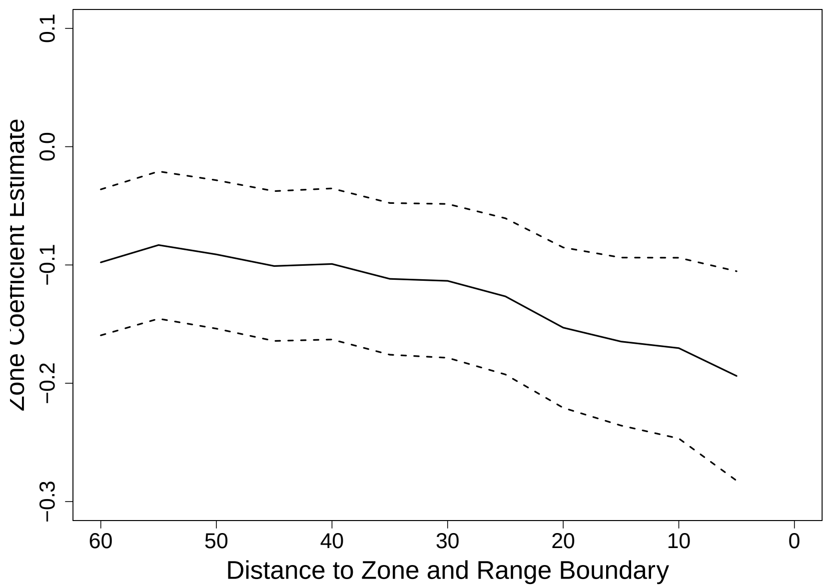
Table 6: Estimated Effects of Zone by Distance to Boundaries

| | All | 50km | 25km | 10km | 5km |
|---|---|---|---|---|---|
| Regulation Zone | $-0.119^{***}$ | $-0.091^{**}$ | $-0.126^{***}$ | $-0.170^{***}$ | $-0.194^{***}$ |
| | (0.036) | (0.038) | (0.040) | (0.046) | (0.053) |
| $R^2$ | 0.364 | 0.400 | 0.407 | 0.379 | 0.374 |
| Num. obs. | 41322 | 123370 | 8723 | 6150 | 5071 |

Notes: All regressions include lease controls, year fixed effects, and zone fixed effects. Standard deviations in parentheses. $^{*}$,$^{**}$,$^{***}$ denote estimates different from zero at 10%, 5%, and 1% significance levels.

Figure 9 reestimates the previous specification of subsamples of parcels that were within 60 kilometers of the respective boundary and up to 5 kilometres of the boundary (for a total of 12 separate regressions). We plotted the coefficient estimates of the zone indicator, the solid line, and the associated confidence interval, the dashed lines. In contrast to Figure 7 and similar to Figure 8, the coefficient estimates exhibit a monotonicity as one uses subsamples that are nearer to the relevant boundaries. This evidence suggests that comparing disparate land parcels is inappropriate for estimating the effect that regulation has on natural resource development.

Figure 9: Estimated Effects of Zone by Distance to Boundaries




## 6 Summary and Current/Future Work

This paper investigates the effect that existing and potential land use regulation has on the value of natural resource development. Using a dataset on first-price, sealed-bid auctions for oil and gas development rights in Alberta during 2003–2013, we employ a regression discontinuity design to test whether the costs, both current and expected, of complying with existing and potential environmental regulation are capitalized into auction prices. We find evidence consistent with the notion that firms that obtain land parcels in regulation zones pay lower prices, all else equal, than for parcels that will never be regulated. Additionally, we find that firms that bid for parcels in regions where there exists the risk of regulatory expansion pay lower prices, all else equal, than parcels in regions where there is no risk of future regulation.

Currently, we are honing our identification arguments in Section 3 and are in the process of fully integrating our theory with the empirical analysis. Additionally, we are currently expanding our analysis on a number of fronts. In particular, we know the identity of most of the auction winners for each parcel. We intend to use these data to control for whether firms experience economies of scale in agglomerating their development projects among nearby land parcels.

A currently unexplored margin that may be affected by the presence of regulation and potential regulation is whether firms neglect to purchase development rights for land parcels on zones or ranges. If this is the case, then incorporating the extensive margin will enable us to better infer how costly is the regulation to the development of natural resources. Given we have data on which land parcels are leased and when, we are currently developing these data to incorporate them into our analysis.

# References


Alberta Woodland Caribou Recovery Team. *Alberta Woodland Caribou Recovery Plan 2004/5-2013/14*. Alberta Sustainable Resource Development, Edmonton, AB, 2001. Alberta Species At Risk Recovery Plan No. 4.

ASRD and ACA. *Status of the Woodland Caribou (*Rangifer tarandus caribou*) in Alberta: Update 2010*. Alberta Sustainable Resource Development and Alberta Conservation Association, Edmonton, AB, 2010. Alberta Species At Risk Recovery Plan No. 30.

Randy Becker and Vernon Henderson. Effects of air quality on polluting industries. *Journal of Political Economy*, 108:379–421, 2000.

CAPP. Capp crude oil forecast, markets and transportation – production and supply data. Technical report, Canadian Association of Petroleum Producers, 2013. Publication No. 2013-0013.

Kenneth Y. Chay and Michael Greenstone. Does air quality matter? evidence from the housing market. *Journal of Political Economy*, 113:376–424, 2005.

ERCB. ST98-2013: Alberta's energy reserves 2012 and supply/demand outlook 2013-2022. Technical report, Alberta Energy Resources Conservation Board, 2013. http://www.aer.ca/documents/sts/ST98/ST98-2013.pdf.

Paul J. Ferraro, Craig McIntosh, and Monica Ospina. The effectiveness of the US Endangered Species Act: An econometric analysis using matching methods. 54:245–261, 2007.

Shaun Fluker and Jocelyn Stacey. The basics of species at risk legislation in Alberta. *Alberta Law Rev.*, 50:95–219, 2012.

Michael Greenstone. The impacts of environmental regulations on industrial activity: Evidence from the 1970 and 1977 Clean Air Act amendments and the census of manufactures. *Journal of Political Economy*, 110:1175–1219, 2002.

Michael Greenstone and Ted Gayer. Quasi-experimental and experimental approaches to environmental economics. *Journal of Environmental Economics and Management*, 57: 21–44, 2009.

Michael Greenstone, John A. List, and Chad Syverson. The effects of environmental regulation on the competitiveness of U.S. manufacturing. MIT working paper, 2012.

Guido W. Imbens and Thomas Lemieux. Regression discontinuity designs: A guide to practice. *Journal of Econometrics*, 142:615–635, 2008.

Nicolai V. Kuminoff, V. Kerry Smith, and Christopher Timmins. The new economics of equilibrium sortin and policy evaluation using housing markets. *Journal of Economic Literature*, 51:1007–1062, 2013.

Christian Langpap and Joe Kerkvliet. Endangered species conservation on private land: Assessing the effectiveness of habitat conservation plans. *Journal of Environmental Economics and Management*, 64:1–15, 2012.

David S. Lee and Thomas Lemieux. Regression discontinuity designs in economics. *Journal of Economic Literature*, 48:281–355, 2010.

Matthew Turner, Andrew Haughwout, and Wilbert van der Klaauw. Land use regulation and welfare. *Econometrica* (forthcoming), 2014.

Jeffrey E. Zabel and Robert Paterson. The effects of critical habitat designation on housing supply: An analysis of California construction activity. *Journal of Regional Science*, 46: 67–95, 2006.

Jeffrey E. Zabel and Robert Paterson. Land-use regulation and housing markets: The case of endangered species. working paper, 2010.