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Abstract

Regulation often evolves, and affected consumers or firms may adjust their behavior in anticipation of potential changes to regulation. Using shifting land use regulation boundaries and oil lease prices from Canada, we estimate the effect of anticipated regulatory change on the value of land. We find that anticipated rezoning decreases the price of unregulated leases. Based on our estimates, not accounting for anticipation underestimates the total cost of the regulation by nearly one-third. Overall, the evidence suggests that anticipation effects are significant and that the cost of anticipated regulation is capitalized into land values.

JEL-Codes: Q580, D440, Q520, Q300.

Keywords: regulation, anticipation, land values, zoning, oil leases, endangered species.

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1 Introduction

Land markets are useful for assessing the effect of regulation. In particular, if the cost of complying with regulation is capitalized into land values, one can compare the values of regulated to unregulated land to measure the cost. However, regulation is rarely static and often changes over time, and any anticipated costs from expected future regulation will also be capitalized. Because it is difficult to observe where or when such anticipation arises, it may be challenging to measure separately the effects of existing and anticipated regulation, potentially compromising policy evaluation that is based on land values.[1]

In this paper, we estimate the effects of existing and anticipated land use regulation on the value of land. We base our estimation strategy on a standard model of land use regulation and land prices that is adapted to allow for possible rezoning in the future, in which case the boundaries defining where the regulation is applied will change. Land markets are competitive, so that the price of a land parcel is equal to its value. Any factors affecting its value, such as the cost of complying with regulation, are capitalized into its price. If regulation boundaries are anticipated to change, forward-looking markets will incorporate the likelihood of rezoning and capitalize any expected costs of anticipated regulation into the price of affected parcels.

If regulation boundaries are permanent, one can compare the price of parcels on either side of existing boundaries to identify the effect of regulation: parcel values are identical except for their regulation status, so any difference in price is due to the effect of the regulation. If rezoning is anticipated, this strategy no longer works. To see this, suppose regulation boundaries are anticipated to shift out. The information that unregulated parcels near current boundaries will be regulated if rezoning occurs will be incorporated into the value of those parcels. In this case, rather than identifying the cost of regulation, the price difference across existing boundaries underestimates it, and instead identifies the difference between the costs of existing and anticipated regulation. A similar logic applies when boundaries are anticipated to shift inward.

To identify separately the effects of existing and anticipated regulation on land values requires observing where rezoning is anticipated, which allows one to categorize which parcels

[1] Economists using land prices have been aware of the empirical challenges caused by expectations. For instance, Freeman (2003) notes that in hedonic analyses, "it might be necessary to take account of expected changes in the characteristics of a house... For example, if there are widespread expectations of an improvement in air quality and the market adjusts reasonably quickly to these expectations, the price differential between currently dirty houses and clean houses should decrease. Correlating these prices with existing levels of air pollution would lead to an underestimate of the marginal implicity price of air quality."

are anticipated to be regulated in the future. One can then compare the price of regulated and unregulated parcels, holding fixed the anticipated rezoning status, to identify the effect of existing regulation. Comparing the price of parcels that differ only in whether they are likely to be regulated in the future identifies the effect of anticipated regulation.

We apply this empirical approach to data from the Canadian province of Alberta. In particular, we use prices for leases granting the right to develop 'oil sands' and land use regulations that aim to protect endangered species from the adverse effects of oil sands production. The regulations impose development restrictions in geographic zones determined as critical habitat for the endangered species, and producers there incur costs of complying with the regulations that they do not incur outside the zones. A key feature of these regulations is that the zones have been gradually expanding over time, and we can observe where rezoning is likely to occur and where it is unlikely to occur. Altogether, this information allows us to categorize leases as being either regulated, currently unregulated but likely to be rezoned in the future, or unregulated now and in the foreseeable future.

Using information on the nearly 3,000 oil sands leases sold between 2003 and 2012 and employing a regression discontinuity design, we find that the price per hectare for a lease inside a regulation zone is 30% lower on average than a lease that is not regulated and is not likely to be regulated in the future. At the mean price per hectare in our sample, this amount is equal to $238 per hectare in 2012 Canadian dollars. This finding suggests that lease holders do capitalize the cost of regulation into the price they pay for their leases.

For leases that are unregulated but for which rezoning in the future is likely, we find that their prices per hectare are about 16% lower on average than for leases that are unregulated and not at risk of being rezoned. Though this estimate is imprecise, we find this effect depends on the proximity to existing zone boundaries: for leases that are, for example, within 5 kilometers of a zone boundary, the price per hectare discount is 22% and is statistically significant at conventional levels; the effect dissipates the farther is a lease from the existing boundaries. This finding is consistent with the notion that, given the historical practice of gradual zone expansion, leases near existing boundaries are believed to be at greater risk of rezoning than leases farther away. However, realized boundary changes were not gradual but instead were quite expansive, and our results suggest that firms underestimated the likelihood of rezoning of unregulated leases far from existing boundaries. Overall, we take these results as evidence that the costs of anticipated regulation are capitalized into lease prices.

We use our estimates to calculate the total present value (PV) cost of the regulation. We find that the total PV cost of the existing and anticipated regulation for leases sold during 2003–2012 is between \$1.6 and \$2.3 billion in 2012 Canadian dollars. Estimates based on specifications that fail to account for anticipation effects underestimate this amount by 29%.

Our study is relevant because anticipated changes to existing regulation, particularly in the context of zoning, are a common feature of policymaking and our estimates suggest that land values do fluctuate with anticipation about potential policy changes. Furthermore, the results suggest that failing to account for anticipatory behavior by firms (or consumers) can lead to underestimates of the total cost of regulation, causing problems for evaluating policy in practice. More particular to the context of our application, the behavior caused by anticipated regulatory change has negative implications for broader public policy, since the costs are borne entirely by the government.

Research inferring the valuation of local amenities from housing prices has always dealt with expectations, either implicitly or explicitly. One strand of the literature exploits quasi-experimental variation and careful empirical analysis to nullify concerns about expectations (see, for example, Chay and Greenstone (2005)). Another strand of the literature focuses more directly on expectations: Kiel and McClain (1995) estimate the effect of the location of an incinerator through the rumor, proposal, construction, and operation stages on nearby housing prices, and find that expectations about the negative effects of a local incinerator do decrease prices; in contrast, Greenstone and Gallagher (2008) find that the proposal of Superfund clean up by the U.S. Environmental Protection Agency does not affect local house prices. And a recent set of papers takes account of expectations by forward-looking consumers by explicitly incorporating them into models of housing demand (see Bishop and Murphy (2011) and Bayer et al. (2016)).

We contribute to this literature in two ways. To the best of our knowledge, ours is the first paper that considers how anticipation about potential changes to regulation boundaries may be capitalized into land values. This contribution extends beyond the context of land use regulation to research that, like our paper, applies regression discontinuity around administrative boundaries to estimate causal effects. If boundaries in those contexts are known to change over time, then anticipation effects may arise as they do in our study, posing an identification challenge. For example, studies have compared property values across school catchment boundaries to estimate the willingness to pay for school quality (see, for example, Black (1999)).[2] The redrawing of school zone boundaries over time is a well-known

[2]While many regression discontinuity-based studies exploit international or state/provincial boundaries that are likely permanent and thus not subject to the anticipation effects we study, local administrative boundaries are more likely to change over time. For example, municipal boundaries change because of sprawl

characteristic of the public school system. To the extent that school boundary changes are anticipated, the housing market will incorporate this information and property values will adjust accordingly.[3] In this case, only by accounting for anticipated boundary changes will the willingness to pay for school quality be identified.[4] More generally, in contexts where the threshold in a regression discontinuity can change over time, anticipation about potential changes to the threshold may in part cause the behavior being studied.[5]

Our second contribution to the literature on land values is that this paper is, to the best of our knowledge, the first to investigate to what extent anticipated changes to land use regulation are capitalized into the value of land. A large literature estimates the effect of land use regulation, or zoning, on property values, with a recent example being Turner et al. (2014). We contribute to this literature in two ways. First, we show that when boundaries can change, accounting for anticipation about potential regulatory change is necessary to identify the effect of regulation; not accounting for anticipation will lead to an underestimate of the effect. Second, some land use regulation studies investigate how zoning can cause externalities upon unregulated land values (Zhou et al. (2008), Turner et al. (2014)), such as how curb appeal restrictions improve the value of unregulated but nearby properties. Our study presents an alternative motivation – anticipation about potential rezoning in the future – for why land prices vary systematically in proximity to existing regulation zones.

We also contribute to a nascent literature on anticipation effects, which mainly focuses on behavior in anticipation of the implementation of a policy that has already been announced. For example, Coglianese et al. (2016) investigate how gasoline consumption increases prior to the implementation of a rise in the gasoline tax, and how such behavior alters how to use taxes as instrumental variables to estimate the price elasticity of gasoline consumption. Similarly, Lueck and Michael (2003) find that private landowners prematurely harvest their timber to prevent forests from becoming inhabited by endangered species, thereby avoiding costly land

and annexation of adjacent lands, so comparing outcomes across municipal boundaries may be subject to anticipation effects.

[3]The possibility of school boundary changes causes some real estate agents to warn clients about such changes. In particular, some advise clients to search for housing strategically within neighborhoods or blocks in order to maximize the chance of being in a desired school zone. For an example, see `http://juliekinnear.com/blogs/school-boundaries-toronto`.

[4]Though they do not estimate anticipation effects, Ries and Somerville (2010) exploit variation from school catchment rezoning in Vancouver to estimate the effect of school quality on housing prices. Bogart and Cromwell (2000) also examine the effects of school redistricting, and find that redistricting decreased property values in Shaker Heights, Ohio.

[5]In their survey on the use of regression discontinuity in economics, Lee and Lemieux (2010) suggest as much by warning that "optimizing behavior in anticipation of sharp regime change may either accentuate or mute observed effects."

use restrictions under the U.S. Endangered Species Act (ESA). In contrast, Malani and Reif (2015) provide a framework for identifying treatment effects in the presence of anticipation of expected future treatment and apply their approach to study how physician labor supply is affected by anticipated reform of tort laws.[6] Our paper contributes to this literature by studying how to account for and exploit anticipated changes of administrative boundaries to evaluate policy.

This paper also contributes to the literature that measures the cost of protecting endangered species. With the exception of Lueck and Michael (2003), mentioned above, this literature focuses on estimating the effects of existing endangered species regulation. For example, Bošković and Nøstbakken (2016), on which this paper builds, find that existing endangered species regulations impose significant and negative effects on oil lease prices. Greenstone and Gayer (2009) find that ESA critical habitat designations may decrease housing values, while Zabel and Paterson (2006) find that the number of building permits in cities are lower in areas designated as critical habitats for endangered species. Given that endangered species are typically protected using land use regulations and that zoning designations evolve over time, our paper contributes to this literature by providing evidence that anticipated potential changes to endangered species regulations negatively affect the value of land and causes a downward bias in the estimated cost of endangered species protection if unaccounted for.

In the next section, we describe a simple model that guides our empirical strategy. Section 3 describes the data we use. Section 4 describes the empirical specification and identification, while Section 5 reports estimation results. Section 6 uses the estimates to calculate total costs of regulation, which is then followed by concluding remarks.

2 A model of anticipated rezoning and land prices

This section describes a one-dimensional spatial model of land prices where land use is regulated and the market anticipates a shift in the geographic boundaries defining where the regulation is applied. Adapted from hedonic models of land prices, such as the seminal paper by Rosen (1974) and, more recently, Turner et al. (2014), the purpose of the model is to shed light on challenges to identifying the effect of regulation on prices when the market anticipates rezoning.

The location of a parcel of land is denoted by x, and lies on the real line. The value of

[6] In contrast to the literature on anticipation effects, Boslett et al. (2016) exploit a lack of anticipation about New York's moratorium on hydraulic fracturing to measure, using property values, the housing market's expected net benefits of shale gas development to private landowners in New York.

owning a parcel x, exclusive of any costs from regulation, is described by the function $V(x)$, which is unobserved by the researcher. In our application, the owner of x has the right to extract natural resources, so $V(x)$ represents the net present value of profits excluding any costs from land use regulation. Land values are spatially correlated, so that $V(x') \approx V(x)$ for x' sufficiently close to x.

Land use regulation applies to parcels in certain areas or zones. For simplicity, suppose that there is one such zone and the boundary is located at $\overline{x}$: any parcel x such that $x \geq \overline{x}$ is subject to regulation, while any parcel $x < \overline{x}$ is not subject to regulation. An owner of a regulated parcel incurs a cost, c, which represents the net present value cost of complying with the regulation over the lifetime of owning the parcel.

It is possible that rezoning may occur, implying the boundary may move left or right of $\overline{x}$. Suppose, for simplicity, that the boundary $\overline{x}$ may expand leftward to $\underline{x}$.[7] If there is no grandfathering with respect to the regulation, then parcels that are unregulated, which lie between $\underline{x}$ and $\overline{x}$, will be subject to the regulation under rezoning. Commonly-held beliefs about the likelihood of rezoning are described by the probability function $F(x)$, where $0 \leq F(x) \leq 1$ for any $x \in [\underline{x}, \overline{x})$, and $F(x) = 0$ for any $x < \underline{x}$ and for any $x \geq \overline{x}$.

The market for land is competitive, causing the price of a parcel, which is observed by the researcher, to equal the net present value from owning the parcel. For parcels that are not regulated and for which there is no anticipation that status will change, i.e., $x < \underline{x}$, $F(x) = 0$ so that $p(x) = V(x)$. For parcels that are subject to regulation, $x \geq \overline{x}$, the competitiveness of the market implies that regulatory costs will be capitalized into land prices, so that $p(x) = V(x) - c$ for all $x \geq \overline{x}$. Similarly, leases that are not regulated but may be subject to regulation, $x \in [\underline{x}, \overline{x})$, as a result of rezoning will have the expected cost of anticipated regulation capitalized into their prices: $p(x) = V(x) - F(x)c$. Summarizing the price of land, we have:

$$p(x) = \begin{cases} V(x) & \text{if } x < \underline{x}; \\ V(x) - F(x)c & \text{if } \underline{x} \leq x < \overline{x}; \\ V(x) - c & \text{if } x \geq \overline{x}. \end{cases} \tag{1}$$

Figure 1 depicts a version of this model. The top panel, Figure 1a, plots land values exclusive of the cost of regulation. For the purposes of illustration, we have depicted $V(x)$

[7] If the zone contracts, so that the boundary shifts to the right, the identification problem is much the same, and unaccounted for anticipation effects will also in this case lead to underestimates of the effect of regulation.

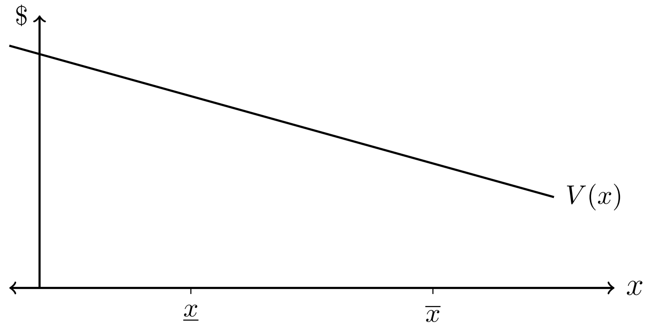
as linearly decreasing along the real line. The next two panels depict the price of land by solid lines. Figure 1b is drawn under the assumption that rezoning will not occur. Figure 1c relaxes this assumption with the additional assumption, for illustrative purposes, that the probability of being subject to rezoning is constant and between 0 and 1, i.e., $F(x) = F$ and $1 > F > 0$ for all $x \in [\underline{x},\ \overline{x})$. In Figures 1b and 1c, the dotted line represents the counterfactual price of land if there was no cost of complying with regulation.

Figure 1b depicts the standard motivation for using regression discontinuity (RD) around geographic borders, with a recent example being Turner et al. (2014). Comparing average land prices on either side of the border will not identify the cost of regulation, c, because parcels are unobservably less valuable in the regulation zone. Due to an assumption that land values are continuous, an RD approach that controls for geographic location by either accounting for proximity to the boundary (thereby proxying for $V(x)$) or by restricting the sample to parcels near the boundary identifies the cost parameter.

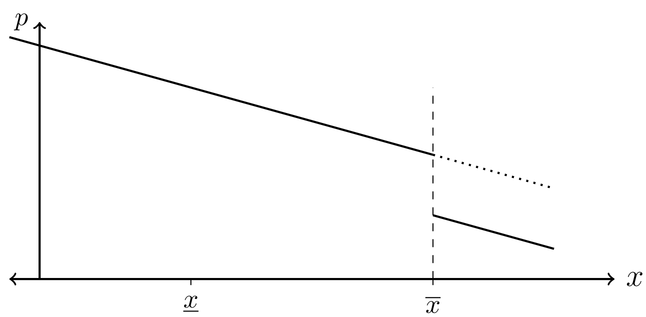
The scenario in Figure 1c is the focus of this paper. The possibility of rezoning induces the market to capitalize expected costs into the price of parcels for which the status as being unregulated is anticipated to change. While the market may be able to accumulate information about rezoning prospects, such information may be difficult for the researcher to obtain. If rezoning is unobserved by the researcher and the standard RD approach is used, then the cost parameter will not be identified; instead, a difference in prices around the existing boundary will yield $(1 - F(x))c$ for x just to the left of the boundary $\overline{x}$.

Figure 1c depicts the likelihood of being rezoned, and thus the expected cost of anticipated regulation, as being constant over the unregulated area where rezoning is anticipated. However, it may be the case that zones are anticipated to undergo gradual expansion, so that parcels near the zone boundary $\overline{x}$ face a greater likelihood of being regulated sooner than parcels farther away. In that case, the prices depicted in Figure 1c may instead look like they do in Figure 2. In the latter, and for illustrative purposes, we assume that parcels lying just to the left of the zone boundary $\overline{x}$ face a probability of being rezoned that is equal to 1, so that the expected cost of anticipated regulation is exactly equal to the cost of regulation; in this case, as depicted, there is no discontinuity in prices around $\overline{x}$. At the other end, $\underline{x}$, the probability is equal to 0, so expected costs are equal to 0 and there is also no discontinuity in prices there.[8] For parcels in between the two boundaries, the probability of rezoning increases with x, so that prices decrease at a faster rate toward $\overline{x}$ than do the

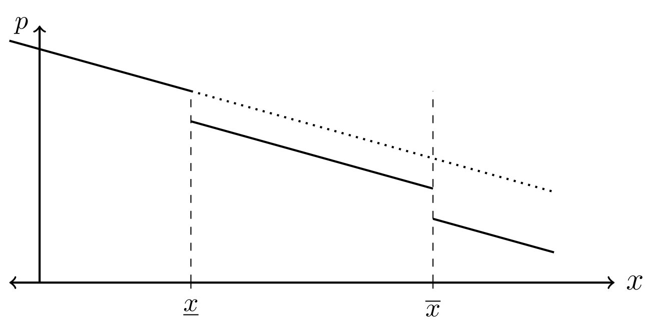
[8] If the probability is not equal to 1 near $\overline{x}$, then there will exist a discontinuity in prices, though not likely equal to the cost parameter. Similarly, if the probability is not equal to 0 near $\underline{x}$, a price discontinuity will exist there.



(a) Land values excluding regulatory costs



(b) Land prices with no possibility of rezoning



(c) Land prices with possibility of rezoning

Figure 1: Anticipated rezoning and the price of land

counterfactual prices under no regulation, depicted as the dotted line. As with Figure 1c, if rezoning is unobserved by the researcher, a standard RD approach will identify the difference in prices around the boundary $\overline{x}$, which in the case of Figure 2 equals 0.

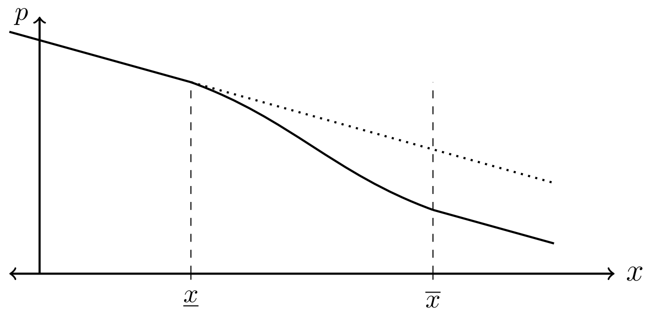


Figure 2: Land prices when rezoning is anticipated to happen gradually

In econometric terms, the identification problem from not accounting for anticipation effects arises because of a misspecification of treatment and control groups: being unregulated, the group of parcels that anticipate regulation are misspecified as part of the control group. The fact that they do incur expected costs from anticipated regulation means their inclusion in the control group will make prices between treatment and control group seem smaller than is the actual cost of existing regulation.

An obvious way to deal with this issue is to account for anticipated boundary changes, so that the omitted variable is controlled for. In doing so, one will have to specify two treatment groups: (1) those parcels facing existing regulation, and (2) those unregulated parcels that may become regulated after rezoning. The existence of the boundary defining the limit of anticipated rezoning, the point $\underline{x}$ in Figure 1c, allows us to define those that anticipate regulation as a separate group from all other parcels. Parcels never subject to regulation, $x < \underline{x}$ in our model, form the control group.

To identify the cost of regulation in practice, one cannot use the subsample of prices for parcels near the regulation boundary. Instead, one must proxy for the unobserved value function $V(x)$ and potentially use the entire sample. Using the example depicted in Figure 1c for illustration, by controlling for the relative location of a parcel by using a linear function of proximity to the boundary $\overline{x}$, one should be able to control for $V(x)$. In doing so, this effectively separates the land value exclusive of regulatory costs from the price of land. By controlling for which parcels form the two treatment groups – those that are subject to existing regulation and those unregulated parcels anticipating regulation – one can identify the cost of regulation, c. However, unless the probability function $F(x)$ is constant for all parcels in the rezoning area, this approach will not identify $F(x)$. Instead, because $F(x)$ changes over space – as it does in Figure 2 – this approach will identify the average expected cost for unregulated parcels in the rezoning area, $\overline{F(x)}c$, where $\overline{F(x)}$ is the average probability that regulation is anticipated for parcels lying in the rezoning area. In our empirical analysis, we investigate how $F(x)$ changes over space by testing whether price discounts consistent with anticipation effects decrease the farther is a given lease from the existing regulation boundary, $\overline{x}$, as depicted by Figure 2.

Overall, our analysis shows that anticipated boundary changes will confound identification of the effect of existing regulation on land prices and will yield underestimates of the cost of regulation. To deal with this issue requires accounting for anticipated regulation in the empirical analysis. Furthermore, identifying the cost of regulation, as well as the expected cost of anticipated regulation, requires an RD approach that accounts for the geographic location of parcels as controls in price regressions. As we describe in the following sections, we employ this approach in our empirical specifications.

3 Context and data

The setting for our application comes from Alberta, a province in Canada that is rich in underground deposits of hydrocarbons. We make use of auction prices for oil leases and landuse regulations aimed at protecting the environment for which there is reasonable anticipation of rezoning. We describe each of these in turn.

Though mineral rights in Alberta are publicly owned, the provincial government sells development rights to industry. Land leases are sold through first-price, sealed-bid auctions. The government maintains that the auctions for development rights are competitive (Government of Alberta (2009)).[9] Auctions are announced publicly ahead of the auction date, and the winner and winning bid for each auctioned parcel are made public immediately. Leases can be held indefinitely so long as they continue producing.

Predominant among Albertan hydrocarbons are oil sands, a mix of bitumen, water, and sand from which synthetic crude oil can be produced. As of 2013, the prevalence of oil sands puts Alberta as having the third-highest reserves of oil in the world (ERCB (2013)). Oil sands production requires large start-up and operating costs relative to conventional sources, which make oil produced from sands the marginal barrel for world oil supply (International

[9] Watkins (1975) and Watkins and Kirby (1981) found that Alberta's oil and gas auctions were competitive; the industry has only grown since the time of these studies.

Energy Agency (2015)). The nearly 4,000 oil sands leases sold between 2003 and 2012, the time period for our sample, generated about $4 billion in revenue (all dollar figures in this paper are in 2012 Canadian dollars). The average price for these leases is about $800 per hectare; Figure 3 plots their geographic price distribution.

The development of oil sands imposes significant negative effects on the environment. Though known for its high greenhouse gas emissions, oil sands production creates immense land disturbances. Among other impacts, this has caused and continues to cause severe population declines in woodland caribou, a species designated as endangered in Alberta (Boutin et al. (2012)). To protect the endangered caribou from continued risk, the provincial government has imposed land use regulations in caribou protection zones that restrict development. The 31 geographically distinct zones, depicted in the darker shade in Figure 4, are drawn based on critical caribou habitat areas for herds.[10] An owner of a lease located in one of the zones must develop a strategic plan to mitigate adverse effects on caribou habitat and migration, and the regulator must approve the plan. Operationally, the zones impose constraints on production, implying lease holders incur costs from complying with the regulation that would not be incurred outside the zones.[11]

While a protection zone is based narrowly on a herd's critical habitat, the associated caribou range defines the broader area in which the herd migrates and lives.[12] As can be seen from Figure 4, the caribou zones, the darker shade, are geographic subsets of caribou ranges, depicted in the lighter shade. The reason this distinction is important is because the zones, since their inception in 1991, have been expanded incrementally in the direction of range boundaries and have never been contracted.[13] The boundaries of caribou ranges, describing the outer limits of a herd's habitat and migratory areas, provide a natural endpoint for zone expansion. Indeed, in 2013 the government expanded the zones a final time: protection zones are now defined by range boundaries everywhere.

Even though a lease may lie in a range, as long as it lies outside zone boundaries it is not subject to the regulation. A firm bidding on such a lease will know that, because of the history of caribou zone expansion, its desired lease faces a positive probability of being

[10]These critical habitat areas are old-growth forests that that take approximately 80 years to develop (see Dzus (2001)).

[11]Examples of such activities include reducing the clear-cutting of forests, creating roads and pipelines that circumvent caribou routes and habitats, limiting seismic disturbances from drilling, and restoring seismic lines and cleared areas to original conditions as soon as possible.

[12]The ranges were mapped from surveys in the late 1970s and early 1980s (Alberta Woodland Caribou Recovery Team (2005)). And, unlike boreal caribou, woodland caribou do not migrate long distances.

[13]This expansion is well-documented in government reports; see Dzus (2001) and ASRD and ACA (2010).

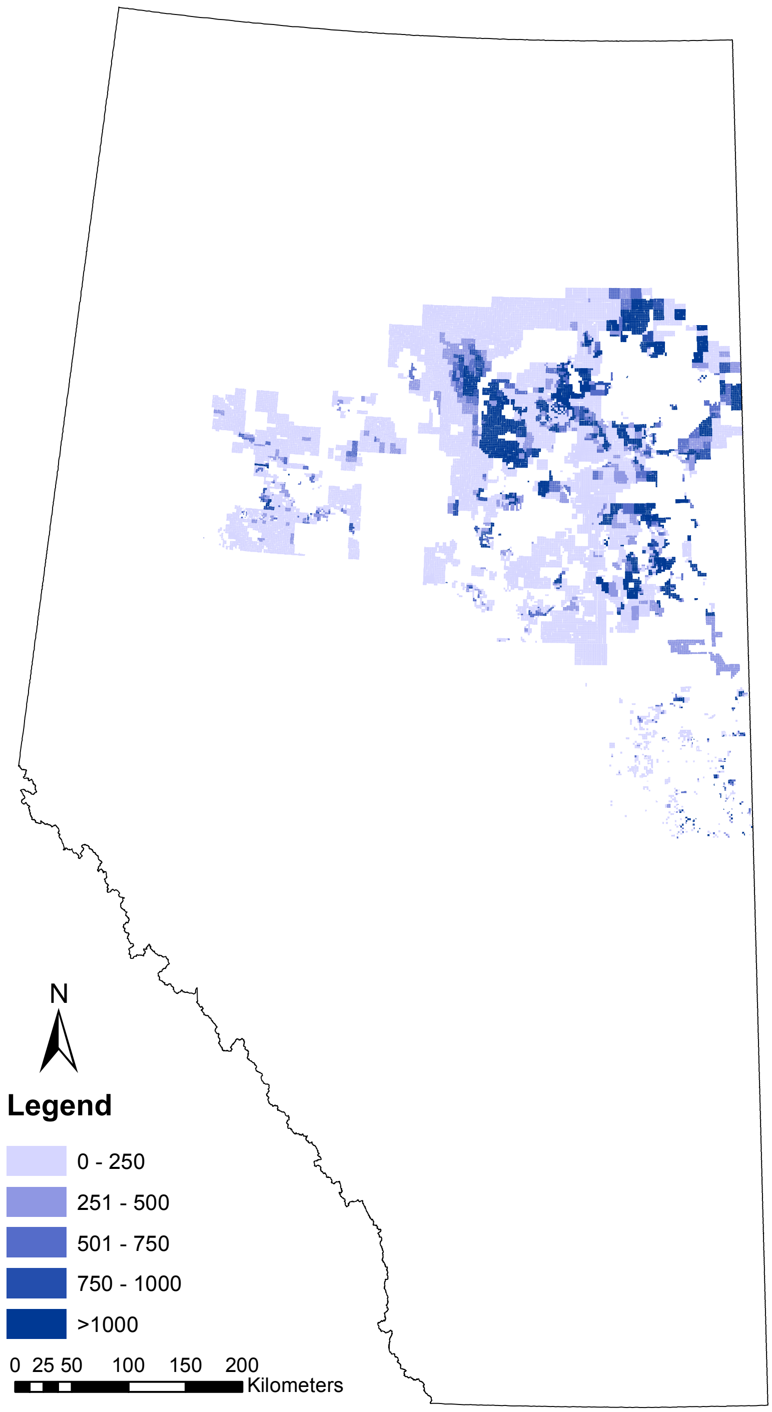


Figure 3: Price per hectare, in 2012 Canadian dollars, of oil sands leases auctioned during 2003–2012

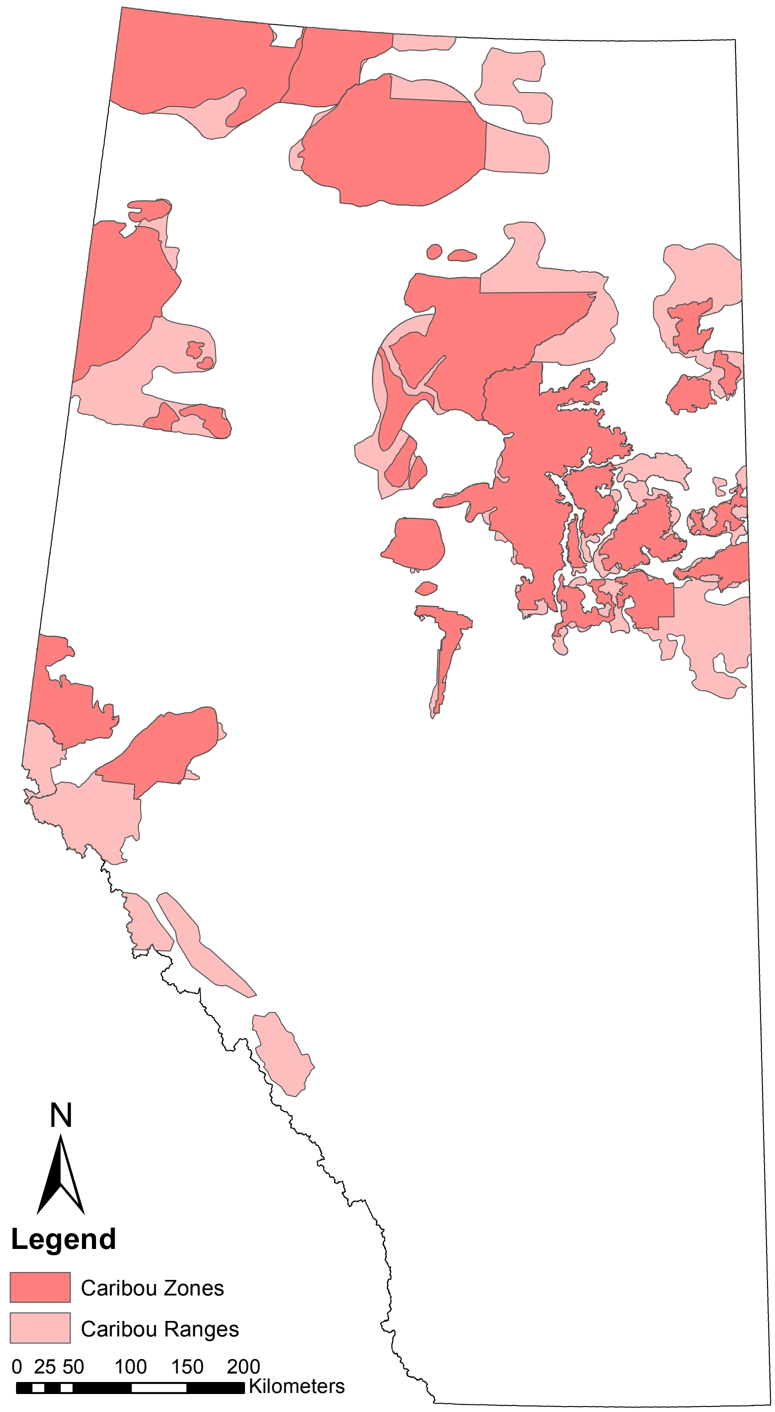


Figure 4: Caribou zones and ranges, 2003–2012

rezoned as part of an expanded protection zone. The firm will incorporate its belief about this likelihood and the net present value of complying with the regulation into its bid for the lease. As a result, this setting is an appropriate context for testing the model's predictions in Section 2 by producing the three categories of land: (1) the protection zones, where leases are currently subject to regulation; (2) the range areas outside protection zones, where lease holders can reasonably expect to be subject to regulation following rezoning, and; (3) the area outside both range and zone boundaries, which will never be regulated.

We follow this categorization by overlaying the auctioned leases on the map of regulation zones and ranges to determine whether a given lease falls within a particular zone or outside the zone but within the associated range. We categorize any lease falling outside any zone and any range as never being regulated, either now or in the future. We exclude any leases that fall into multiple zones.

For each lease, we determine its geographic centroid, in degrees latitude and longitude, to calculate distances to zone boundaries. We exclude any leases more than 200 kilometers outside a zone or range and any leases overlapping a boundary. Also, for estimation purposes, we exclude any lease whose owner is observed only once in our sample. We also focus on leases sold between 2003 and 2012, since the boundaries were shifted in 2002 and again, as mentioned above, in 2013.[14] Altogether, these criteria narrow our sample to 2,918 leases that lie inside or near 17 protection zones and 13 ranges.

Table 1 reports sample means and standard deviations for leases for the full sample in the first column, and by regulation status in columns 2 to 4. Also reported in the final three columns are difference in means for each subsample of regulation status and the associated standard error in parentheses. The number of regulated leases – those located inside protection zones – equals 1,326 in our sample, which is roughly equal to the number of leases that are and never will be regulated – those located outside zone and range boundaries – of which there are 1,272. There are 320 leases for which rezoning is anticipated, which constitutes approximately 10% of the sample.

The first row reports statistics for the auction price per hectare of individual leases. The price measure is higher on average for leases within protection zones than everywhere else, although the differences are statistically insignificant. The distribution of price per hectare

[14] We obtained the location of the zones and ranges from shapefiles available on the Government of Alberta's website. Prior maps are not available in digital form and repeated requests to the government for precise maps have proved unsuccessful. The expansion in 2013 was followed by an intervention by the federal government, under the auspices of the federal *Species at Risk Act (SARA)*, into saving the caribou. Under *SARA*, new rules are due in 2016; the uncertainty of what rules will be implemented caused us to cut off the sample at 2012.

Table 1: Summary statistics for oil sands leases by regulation status

		Regulation status:			Difference in sample means:		
	Full sample	Zone	Range	Neither	Zone - Range	Zone - Neither	Range - Neither
Price/hectare (2012 CDN $)	768.92	801.22	664.92	761.41	136.30	39.81	-96.50
	(1885.85)	(1753.94)	(1505.39)	(2093.44)	(106.41)	(75.65)	(124.41)
Number of joint owners	1.10	1.10	1.16	1.08	-0.06**	0.02	0.08***
	(0.36)	(0.35)	(0.51)	(0.33)	(0.02)	(0.01)	(0.02)
Special access area	0.02			0.04			
	(0.13)			(0.19)			
Key wildlife area	0.13	0.05	0.21	0.211	-0.10***	-0.16***	-0.05**
	(0.34)	(0.22)	(0.41)	(0.407)	(0.02)	(0.01)	(0.02)
Depth (meters)	828.76	803.63	824.36	856.08	-20.72***	-52.44***	-31.72***
	(110.74)	(61.96)	(101.74)	(141.89)	(4.45)	(4.27)	(8.43)
Number of firms	94	66	49	88			
Observations	2918	1326	320	1272	1646	2598	1592

Notes: The first four columns report means and standard deviations, in parentheses, of variables in the full sample, for leases within zones, for leases within ranges but outside zones, and for leases outside of both zones and ranges, respectively. The next three columns report sample mean differences and standard errors for: (1) leases in zones and leases in ranges; (2) leases lying in zones and leases outside zones and ranges, and; (3) leases in ranges and leases outside zones and ranges. *, **, and *** denote difference in means different from zero at the 10%, 5%, and 1% significance levels. The final two rows report the number of unique firms in each sample and the total observations in each sample, respectively.

for our sample has a long right tail; this fact motivates us to use the natural logarithm of price per hectare for our empirical analysis in the next section.

The second row reports summary statistics for the count of firms with an ownership stake in a given lease. On average leases are owned by a single firm.[15] The total number of firms in the sample is 94, and the number of firms in a given group is reported in the bottom row of the table.[16] In the full sample, 66 of the 94 firms own leases inside zone boundaries, 49 firms own leases in unregulated range areas, while 88 of the firms own leases outside of the zones.

Rows three and four report summary statistics for binary variables indicating whether the lease falls into areas where other forms of regulation are applied, known as key wildlife and special access areas, which impose different land-use regulations to protect biodiversity.[17] The final row reports summary statistics for the depth, in meters, of the core sample for that lease.[18] This variable provides information on the cost of extracting oil sands for that lease, since deeper deposits require greater effort and more cost to produce to the surface. This is consistent with the correlation with average prices: leases outside zones are deeper on average and command lower prices per hectare than leases in zones.

4 Empirical specification and identification

In this section, we describe the empirical specification for estimating the effects of the current caribou protection regulation and the anticipated rezoning of unregulated areas on the price of oil sands leases. We then discuss how we identify the effects of interest and potential identification issues.

To estimate the effect of existing and anticipated regulation on lease prices, we follow the analysis in Section 2 by specifying a regression that exploits the discontinuity in regulation and anticipated regulation at zone and range boundaries, respectively. The model makes clear that accounting for geographic location is critical for identification. To do so in two-dimensional space, we follow Dell (2010) by employing a multidimensional RD that accounts

[15] If a lease is owned by more than one firm, we will refer to the owner that interacts with the regulator as the main owner.

[16] As we mentioned above, we excluded from our sample any leases for which we observe the owner only once. This criterion removes 26 unique firms from our sample and does not affect the distribution of firms across the areas of different regulation status.

[17] See Government of Alberta (2013) for more details on these regulations. Conversations with some of the producers revealed that complying with the caribou land-use regulation is of much greater concern.

[18] Core samples are made publicly available by the Government of Alberta; see `http://www.ags.gov.ab.ca/services/mcrf/`.

for geographic location using latitude and longitude as well as the identity of the nearest zone. In particular, for lease i near zone z, purchased by firm j in year t, we estimate:

$$p_{izjt} = \alpha + \beta_1 \, \text{zone}_i + \beta_2 \, \text{range}_i + W_i\Gamma + f(x_i, y_i) + \lambda_z + \lambda_{jt} + \varepsilon_{izjt}. \qquad (2)$$

The dependent variable, p_{izjt}, is the logarithm of the auction price per hectare for lease i. The variable zone_i describes whether lease i is subject to the land use regulation: the variable is equal to 1 if lease i is located inside any zone, implying that the lease is regulated, and is equal to 0 otherwise, in which case it is unregulated. The variable range_i is equal to 1 if lease i lies inside a caribou range but outside any caribou protection zone, and is otherwise equal to 0. This indicator variable defines the group of leases that are currently unregulated but can reasonably anticipate, given the history of these regulations, to be subject to regulation in the future following an expansion of the zones. Should zone_i and range_i both equal 0, then lease i lies outside of any zone or range and is not and never will be regulated. Though leases for which $\text{range}_i = 1$ are unregulated, for convenience we will refer to them as "range leases" to distinguish them from unregulated leases located outside ranges, which we will refer to as "unregulated leases."

The multidimensional RD is based on the variables x_i and y_i, describing the latitude and longitude in degrees of lease i, the function f, and the parameters λ_z. The unknown function f controls for smooth functions of geographic location that affect the profitability of land and, thus, the observed winning bid for lease i, such as the underlying resource stock and distances to hubs where producers obtain their inputs for production. The parameters λ_z are fixed effects that account for the zone to which lease i is near (regardless of regulation status), and control for differences in lease prices across zone regions.[19]

A practical issue is how to estimate equation (2) given the function f is unknown. Here we again follow Dell (2010) and specify f as a series of polynomials in latitude and longitude. While there is no rule on which degree polynomial to employ, though too high a degree may result in overfitting, we use a quadratic polynomial for our baseline specification.[20] To test the sensitivity of our results to this specification, we will report results from re-estimating equation (2) using polynomials of lower and higher degree.

The vector W_i contains information specific to the lease, such as the number of joint

[19]Recall that each zone is a subset of a range and that multiple zones might fall into a range. As a result, employing a range fixed effect is less flexible than employing zone region fixed effects and range fixed effects are redundant given we use zone region fixed effects.

[20]If latitude and longitude are denoted by x and y, then the quadratic in latitude and longitude is $x^2 + y^2 + xy + x + y$.

owners, all of which are listed in Table 1. The parameters λ_{jt} are fixed effects that account for time-varying firm-specific differences in winning auctions bids that account for, among other factors, differences in production technologies and the timing of when firms obtain leases.

The parameters β_1 and β_2 are the parameters of interest. The parameter β_1 captures the price effect for a lease that is regulated because it is located inside a protection zone. If the regulation imposes costs over the lifetime of owning the lease and such costs are capitalized into the winning bid for the lease, then we expect that the regulation will impose a negative effect on price, so that $\beta_1 < 0$.

The parameter β_2 captures the average price effect of owning a lease that is located inside a range but outside any protection zone. Being outside a protection zone implies the lease is not regulated, while being located inside the range implies there is reasonable anticipation it will be subject to regulation in the future following rezoning of the protection zones. If the anticipated regulation imposes expected costs and those costs are capitalized into lease prices, then we expect that $\beta_2 < 0$. If bidders believe that the probability that such a lease will be rezoned is close to 1 and that rezoning will occur sufficiently soon, then the expected cost of anticipated regulation will approximately be equal to the cost of existing regulation, in which case we expect that $\beta_2 = \beta_1$. Otherwise, the expected costs should be smaller in magnitude than the cost of regulation incurred by a lease inside a zone, so that $\beta_2 > \beta_1$.

Equation (2) does not capture any heterogeneity in anticipation effects, though there is reason to suspect that different range leases may be perceived as more or less likely to be regulated in the future. In particular, as we described in Section 3, the caribou zones have been gradually expanded over time. Figure 2 of Section 2 depicts how lease prices may change if the zones are anticipated to change gradually: leases near the existing regulation boundary are anticipated as more likely to be regulated than leases farther away, implying that the anticipation effects depend on proximity to existing zone boundaries and are stronger the closer is a lease to a boundary. We test this prediction by augmenting the baseline specification in equation (2) to take the following form:

$$p_{izjt} = \alpha + \beta_1 \,\text{zone}_i + \widetilde{\beta}_2 \,\text{range}_i + \widetilde{\beta}_3 \,\text{range}_i \times \text{distance}_i + W_i \Gamma + f(x_i, y_i) + \lambda_z + \lambda_{jt} + \varepsilon_{izjt}, \quad (3)$$

where distance_i is the distance, in kilometers, of lease i to the nearest zone boundary. According to this specification, the effect of lying in a range area is equal to $\widetilde{\beta}_2 + \widetilde{\beta}_3 \text{distance}_i$. At the mean value for the distance measure, this effect should equal β_2 from equation (2). If range leases near zone boundaries face greater expected costs from anticipated rezoning than leases farther away, then we expect that $\widetilde{\beta}_3 > 0$.

4.1 Identification

The identification strategy premised on equation (2) (and equation (3)) attributes, after controlling for geographic location, firm-specific time-varying heterogeneity, and lease-specific differences, any difference in prices between leases inside zones and unregulated leases to be caused by the regulation. Similarly, after incorporating our full set of controls, we attribute any price difference between range leases and unregulated leases to be caused by anticipation of potential future regulation. Several issues affect the identification and interpretation of the effect of existing and anticipated regulation, such as: (1) the determination of zone and range boundaries; (2) selection of leases by firms; (3) externalities caused by the regulation, and; (4) competitiveness of auctions. We discuss each of these in turn.

An implicit identification assumption we are making is that the zone and range boundaries are determined independently of the underlying oil sands resource. If that were not the case, then we may be erroneously attributing any difference in prices as being caused by existing or anticipated regulation, whereas the difference may be due in whole or in part to the unobservable resource quality associated with the leases that discontinuously changes at zone or range boundaries. However, we have no reason to believe the boundaries were determined by the location of the resource. The range boundaries, describing the outer limits of a caribou herd's habitat and migration area, were drawn by ecologists decades prior to the initial implementation of the land use regulations (Dzus (2001)). The zones describe critical habitat for caribou, which is determined mainly by the location of old-growth boreal forests on which caribou rely for survival (Environment Canada (2012)).[21] Such boreal forests cover not only most of the northern half of Alberta, but also the northern area of most Canadian provinces, and woodland caribou exist in most of those regions. It is a coincidence that oil sands deposits lie below caribou ranges and critical habitats in Alberta.

The second potential identification issue is whether leases are chosen based on whether they are located in zones or ranges; the ability to manipulate the regulation treatment by selecting a lease based on location would invalidate a typical RD application. However, in our application, regardless of whether the lease is inside a zone or a range or is unregulated, in equilibrium bidders will pay the value of owning that land. As such, a firm that chooses

[21] Oil sands extraction projects do not necessarily involve forest removal and land clearing: *in situ* projects, which are the more prevalent form of oil sands operations, create linear land disturbances by creating access roads but otherwise keep much of the forest intact.

to purchase a lease in a regulated area can fully compensate itself for the cost of complying with the regulation by decreasing its bid in an amount equal to the cost and still win the lease. This behavior does not pose an identification problem, but instead we rely on this behavior to identify the effect of existing and anticipated regulation on land prices.[22]

A similar issue is whether some leases that would have been purchased in the absence of regulation are left unsold because the regulation causes them to be unprofitable. We are unable to deal with this selection issue, in which case we will be identifying the effect of existing and anticipated regulation on leases for which the net present value of owning the lease, including the cost of regulation, is non-negative.[23]

The third identification issue is externalities arising from the regulation. The presence of such externalities motivates part of the analysis in Turner et al. (2014), who study how land use regulation for residential housing, such as restrictions that homeowners maintain curb appeal, can impose externalities on prices for housing across a nearby administrative boundary. If such externalities exist, then they may cause a similar effect on lease prices as does anticipation about potential rezoning.

We do not suspect externalities to pose an identification problem for two reasons. The first reason is based on context: externalities such as those present in the zoning of residential housing are unlikely to arise in our context. Aside from the spatial correlation in resource stocks, how one oil sands firm bids for a lease should not be affected by the fact that nearby leases are regulated. The second reason is due to our identification strategy. If externalities can arise in our context, then because both unregulated leases and range leases are located near zones, both will equally be subject to externalities. Our strategy for identifying the effect of anticipated rezoning compares prices for range and unregulated leases, in which case the effect of externalities should be differenced out. As a result, we do not suspect that this should confound our estimates of the effect of existing anticipated regulation. Nonetheless, we perform robustness checks to determine externalities may be driving our baseline estimates, which we report in the next section.

The final identification issue we consider is the competitiveness of the auctions. Although we observe the winning auction bid, we do not observe, and neither does anyone but the regulator, any non-winning bids or the number of bidders. The government claims that the

[22] It may be the case that certain firms are better able – in the least-cost sense – to comply with regulations and so are more likely to obtain leases in the zones. However, assuming auctions are competitive, we are able to control for producer identity, and thus our identification strategy is robust to this issue.

[23] We discussed this issue with several members of the industry, who claimed that the costs of complying with the caribou protection regulation were not large enough to dissuade the purchase of any lease their firm was considering.

auctions are competitive (Government of Alberta (2009)) and there is no evidence suggesting otherwise. Watkins (1975) and Watkins and Kirby (1981) found that Alberta's oil and gas lease auctions in the 1970s were competitive, and the oil and gas industry in Alberta has only grown since then.

5 Estimation results

Table 2 reports results from estimating equations (2) and (3) as well as a specification that misspecifies range leases as unregulated leases. Each of these sets of results is reported in a separate panel. The columns indicate estimates from using progressively richer specifications. Robust standard errors, which account for spatial correlation by adjusting for clustering within a zone region, are in parentheses. We discuss each panel of results in turn.

Panel A of Table 2 reports our baseline results from estimating equation (2). Column (1) reports coefficient estimates from a regression that controls only for whether a lease is located inside a zone or a range. The coefficient for the zone variable, 0.0289, indicates that a lease inside a zone is associated with a price per hectare that is 2.9% larger on average than the price per hectare for an unregulated lease. The coefficient estimate for the range variable, −0.0199, indicates that a lease in a range is associated with a price per hectare that is nearly 2% lower on average than an unregulated lease. These estimates reflect the pattern of unconditional mean prices per hectare reported in Table 1.

Columns (2) and (3) in Panel A add the polynomial in latitude and longitude and the zone region fixed effects, respectively, that form the multidimensional RD. The addition of the latitude-longitude polynomial in column (2) decreases the value of both zone and range coefficients so much that both estimates are of the predicted sign and are statistically significant. The estimates reported in column (3) include the zone region fixed effects, which control for the identity of the nearest zone to a given lease; their inclusion reduces the magnitude of both coefficient estimates relative to column (2), although much less so for leases lying in zones.

Column (4) adds the firm-year fixed effects, which are important not only in controlling for time trends in this volatile industry but also in how each firm responds idiosyncratically to those trends. These fixed effects control for a significant amount of variation in the dependent variable, which can be seen from the substantial increase in the R^2 value. The coefficient estimate for the zone variable, −0.3179, is statistically significant at the 1% level, while the coefficient estimate for the range variable, −0.1535, is insignificant at conventional levels.

Table 2: Estimates of the effect of existing and anticipated regulation on lease prices

	(1)	(2)	(3)	(4)	(5)
			A. Baseline estimates		
Zone	0.0289	-0.3326**	-0.2254*	-0.3179***	-0.3536***
	(0.1743)	(0.1362)	(0.1144)	(0.0976)	(0.0878)
Range	-0.0199	-0.5339***	-0.2578	-0.1535	-0.1721
	(0.2085)	(0.1737)	(0.1901)	(0.1173)	(0.1174)
R^2	0.0001	0.1002	0.1549	0.5534	0.5543
		B. Heterogeneous anticipation effects by distance to zone boundary			
Zone	0.0289	-0.3345**	-0.2296*	-0.3245***	-0.3604***
	(0.1744)	(0.1356)	(0.1157)	(0.0940)	(0.0850)
Range	-0.2573	-0.6277**	-0.3730	-0.2479	-0.2687*
	(0.3269)	(0.2958)	(0.3365)	(0.1522)	(0.1513)
×Distance to zone boundary	0.0219	0.0087	0.0109	0.0094	0.0096
	(0.0142)	(0.0148)	(0.0177)	(0.0089)	(0.0092)
R^2	0.0016	0.1004	0.1552	0.5536	0.5545
		C. Misspecifying anticpated leases as unregulated			
Zone	0.0329	-0.1465	-0.1346	-0.2604**	-0.2879***
	(0.1489)	(0.1126)	(0.0886)	(0.1046)	(0.0905)
R^2	0.0001	0.0942	0.1536	0.5531	0.5539
Quad. poly. in lat/lon	N	Y	Y	Y	Y
Zone fixed effects	N	N	Y	Y	Y
Owner-Year fixed effects	N	N	N	Y	Y
Lease controls	N	N	N	N	Y
Observations	2918	2918	2918	2918	2918

Notes: The dependant variable is the logarithm of price per hectare at the lease level. Robust standard errors, adjusted for clustering by caribou zone region, in parentheses. *, **, and *** denote estimates different from zero at the 10%, 5%, and 1% significance levels.

The estimates in column (5) are from the full specification, which adds the lease-specific controls listed in Table 1.[24] These controls do not change the estimates much numerically relative to the column (4) estimates. Because it uses the full set of controls, the specification in column (5) is our preferred one, so the estimates in that column deserve a closer look. The coefficient estimate for the zone variable, -0.3536, is statistically significant at the 1% level. The estimate indicates that the price per hectare for a lease located inside a zone and

[24]For brevity, we omit the coefficient estimates for the lease-specific controls here, but do provide them in the Appendix.

thus subject to the endangered caribou regulations is 30% lower on average than the price per hectare for an unregulated lease. At the mean and median prices per hectare in our sample of \$803 and \$135, this estimated effect amounts to a decrease in price of a lease by \$238 and \$41 per hectare. We take the estimated negative effects on the price of zone leases as evidence that the land use regulations impose costs on producers.[25]

The coefficient estimate reported in column (5) of Table 2 for the range variable, -0.1721, is not significant at conventional levels, but has a p-value of 0.162 even though our sample contains only 320 ranges leases. An equality test between the zone and range coefficient estimates yields a p-value of 0.14. The range coefficient estimate implies that the price per hectare for a lease in a range, even though it is not regulated, is about 16% lower on average than the price per hectare for an unregulated lease. At the mean and median price per hectare, the estimate implies a price discount of approximately \$128 and \$22 per hectare, respectively. The negative price effect for range leases is consistent with the prediction that the expected costs of anticipated future regulation are capitalized into auction prices for those leases. Note that this specification assumes the anticipation effect to be constant for all range land. Hence, heterogeneity in anticipation effects – arising, for example, if the anticipation effect decreases with the distance to a zone boundary – will raise the p-value of the range coefficient.

In Panel B, we report results from estimating equation (3), which allows the anticipation effect to vary with the distance of a range lease to the nearest zone boundary. For the specification given by each column, the coefficient estimate for the range indicator variable, in the second row, is negative, while the coefficient estimate for the interaction of the range variable with distance to the nearest zone boundary, in the third row, is positive. The signs of these coefficient estimates are consistent with the prediction depicted in Figure 2 and with the notion that rezoning is anticipated to occur, based on historical practice, through gradual shifts in zone boundaries. Focusing on the preferred estimates in column (5), the estimate for range indicator, -0.2687, is statistically significant at the 10% level, while the coefficient estimate for the interaction term is positive, though insignificant at conventional levels. For the range lease that is closest to a zone boundary – less than 20 meters from the boundary – the estimated effect of being located in the range is equal to -0.2675, is statistically significant at the 10% level, and implies a price per hectare discount of about

[25]We discussed these estimates with several stakeholders, who all thought they were reasonable. For example, a leading investor in oil and gas in Alberta told us he expected the caribou regulations to have a slightly larger effect than our estimates indicate, while an executive with the provincial regulator expected the effect to be smaller than what we found.

23.5% relative to unregulated leases. Given that our estimate for the effect of lying in a zone causes price per hectare discounts of more than 30%, this implies that range leases virtually adjacent to a zone boundary internalize expected costs that are smaller in magnitude than the costs capitalized into prices for regulated leases. For a range lease that is 5 kilometers from the zone boundary, the price per hectare is 22% on average lower than the price for an unregulated lease. The effect decreases in magnitude the farther is a range lease from the boundary, and for leases that are greater than about 5 kilometers the price effect is statistically insignificant at conventional levels; for example, the negative price per hectare effect for a range lease that is 20 kilometers from the nearest zone boundary, about one-standard deviation farther than the mean distance of range leases, is about 7.4% on average.

Altogether, the estimation results in Panel B of Table 2 support the prediction that the effect on the price for range leases increases the nearer is a lease to the zone boundary. This evidence is consistent with the notion that future regulation in the form of expanding zones are anticipated to occur through gradual boundary shifts, which was the historical practice in this context up until that time. However, it is noteworthy that the boundary changes in 2013 did not follow historical practice: instead of gradual expansion of the zones, the boundaries shifted dramatically so that every zone boundary coincided with every range boundary. In some cases, that meant a shift of more than 50 kilometers, which, based on the results reported in Panel B, was not anticipated to occur soon by the firms that purchased leases. Because firms' anticipation about potential future regulation relied on their likely belief that zones would expand gradually – as they always had been – it is not a surprise that they underestimated the likelihood that distant range leases would be rezoned relatively soon.

Panel C of Table 2 reports results from a specification that omits the range variable in equation (2) and naively categorizes range leases as unregulated leases. As predicted by the model in Section 2, not accounting for which land parcels lying outside zones may be rezoned leads to an underestimate of the effect of regulation on lease prices. Comparing the results in Panel C to those in Panel A provides evidence in favor of the prediction: across the specifications in each column, the coefficient estimates describing the effect on the price for a lease located inside a protection zone in Panel C are consistently smaller in magnitude than the corresponding estimates in Panel A. Focusing on column (5) and Panel C of Table 2, the coefficient estimate of -0.2879 implies a negative price per hectare effect of 25% for leases inside zones, which is 5 percentage points smaller in magnitude than when we control for which leases are located in ranges. To put this difference in estimates into perspective, the effect for the mean price per hectare, based on the estimate in Panel A of -0.3536, implies a price per hectare decrease of $238; this amount is underestimated by $38 when not accounting for which leases may be plausibly rezoned in the future.

5.1 Sensitivity analysis

In this section, we report results from two robustness checks that investigate the stability of the estimates reported in Table 2. The first re-estimates the specifications using subsamples based on the distance of leases to the nearest protection zone boundaries. The second re-estimates the specifications from that table using polynomials in latitude and longitude of higher and lower degree. We discuss each in turn.

The first robustness check we perform is re-estimating the empirical specifications using subsamples based on decreasing proximity of leases to protection zone boundaries. This check is useful for two reasons. First, as described in Dell (2010), who first employed a multi-dimensional RD, narrowing the distance of observations to the relevant boundary allows one to assess the validity of the RD estimates in a similar way to the approach in conventional, one-dimensional RD settings. The second reason is to assess whether our anticipation effects are being driven by externalities cause by the regulation, which is a potential identification issue we discuss in Section 4.1. As we stated there, our strategy to identify the effect of anticipated regulation will, if unregulated leases and range leases are equally affected by externalities (because of their proximity to zone boundaries), difference out any effect of externalities on lease prices. However, in our sample, unregulated leases are on average farther from zone boundaries than range leases. Because externalities caused by the regulation likely dissipates with distance from zone boundaries, unregulated lease prices are on average less affected by externalities than range lease prices. As a result, our comparison of range and unregulated lease prices may not fully difference out the effect of externalities, since on average range and unregulated leases are not equally affected by externalities. Though we do account for geographic location in our estimation specification, likely controlling for this issue, a simple way to determine whether this is an issue in practice is to restrict our sample so that range and unregulated leases are of similar proximity to zone boundaries and then re-estimate equation (2). We do this by restricting leases to be no farther from zone boundaries than 100, 75, 50, and 25 kilometers, and report estimation results in Table 3. Each panel reports a different set of estimation results using the specified distance cutoff, and the specification in each column is either the baseline estimating equation (2), the specification allowing for heterogeneous anticipation effects by distance to zone boundary, (3), or the specification that categorizes range leases as unregulated leases. All specifications include the full set of controls, making the estimates directly comparable to the corresponding estimates in column (5) of Table 2.

The estimates in each panel are fairly similar to the estimates reported in Table 2. Consider first the zone coefficient estimates in the first column. With the exception of the 50-kilometer estimate, the coefficient estimates are virtually the same numerically as −0.3536, the main estimate from column (5), Panel A of Table 2. The same can be said for the zone coefficient estimates in the second column. The estimates in the third column are obtained from misspecifying range leases as unregulated, and follow the pattern of results obtained in Table 2. For example, the 25-kilometer estimate of −0.2736, which is statistically insignificant at conventional levels, implies a price per hectare discount for leases inside zones of about 24% on average; the price per hectare discount implied by the 25-kilometer estimate of −0.3766 from the first column – from the specification that does account for anticipation effects – is more than 7 percentage points greater in magnitude.

Consider now the range coefficient estimates from the baseline specification, in the first column of Table 3. The estimates are, for every subsample, slightly lower in value numerically than the main estimate of −0.1721 from Table 2. For example, the 100-kilometer estimate of −0.2064 implies an average price per hectare discount for range leases of nearly 19%, while the main estimate implies an average price per hectare discount of about 16%. For the most part, the estimates also have lower standard errors than the estimate in Table 2, with p-values at 0.11 for the 100- and 25-kilometer subsamples, while the 75-kilometer subsample is statistically significant at the 10% level. We take these estimates as evidence that our main estimate of the effect of a lease being located in a range area is fairly robust.

Finally, consider the range variable estimates in the second column, from the specification that includes an interaction term with the distance of a range lease to the nearest boundary. The coefficient estimates of the range variable, in the second row of each panel, are all greater in magnitude than the estimate of −0.2687 from Table 2 and, like that estimate, are all statistically significant at conventional levels. The sign of the estimate of the interaction term, in the third row of each panel, is positive, though statistically insignificant, and fairly similar to the main estimate of 0.0096 from Table 2. In terms of what these estimates across all the panels imply, for a range lease that is 5 kilometers from a zone boundary, the price per hectare is between 20% and 24% lower on average than an unregulated lease and these differences are all statistically significant at conventional levels. These estimated effects are similar to the one based on the main estimates in Panel C of Table 2, which imply a 22%

Table 3: Sensitivity of estimates based on proximity of leases to nearest zone boundary

	Baseline	Heterogeneous	No anticipation
	A. Within 100 km of nearest zone boundary ($n = 2503$)		
Zone	-0.3817***	-0.3914***	-0.2989***
	(0.1245)	(0.1249)	(0.0997)
Range	-0.2064	-0.3446**	
	(0.1252)	(0.1386)	
×Distance to zone boundary		0.0135	
		(0.0082)	
	B. Within 75 km of nearest zone boundary ($n = 2239$)		
Zone	-0.3329**	-0.3416**	-0.2424*
	(0.1549)	(0.1543)	(0.1259)
Range	-0.2197*	-0.3221**	
	(0.1170)	(0.1326)	
×Distance to zone boundary		0.0099	
		(0.0089)	
	C. Within 50 km of nearest zone boundary ($n = 1902$)		
Zone	-0.2556	-0.2593	-0.1633
	(0.2138)	(0.2068)	(0.1661)
Range	-0.2058	-0.2601*	
	(0.1448)	(0.1281)	
×Distance to zone boundary		0.0058	
		(0.0168)	
	D. Within 25 km of nearest zone boundary ($n = 1576$)		
Zone	-0.3766*	-0.3790*	-0.2736
	(0.2150)	(0.2161)	(0.1858)
Range	-0.2286	-0.3992**	
	(0.1364)	(0.1485)	
×Distance to zone boundary		0.0224	
		(0.0196)	

Notes: The dependant variable is the logarithm of price per hectare at the lease level. All specifications include the specified latitude-longitude polynomial, zone region fixed effects, firm-year fixed effects, and lease-specific controls. The number of observations for each subsample is denoted by n. Robust standard errors, adjusted for clustering by caribou zone, in parentheses. *, **, and *** denote estimates different from zero at the 10%, 5%, and 1% significance levels.

statistically significant price discount per hectare. Altogether, we take these estimates as suggestive that our main estimates in Table 2 are stable across smaller subsamples of our data, based on distance to regulation boundaries.

For the second robustness check, we investigate the role that the quadratic polynomial in latitude and longitude plays in our estimates in Table 2. As we describe in Section 4, we arbitrarily chose a quadratic polynomial to approximate the unknown function f in equation (2). To evaluate how sensitive our estimates are to the choice of latitude-longitude polynomial, we re-estimate the full specifications from Table 2 using polynomials of lower and higher degree. Panel A reports estimates from a linear polynomial, Panel B reports estimates from a cubic polynomial, while Panel C omits latitude and longitude.[26] The first column reports estimates from the baseline specification, the second column reports results from estimating equation (3), while the third reports estimates when misspecifying range leases as unregulated. Since each specification utilizes all of the controls, the estimates in each column are directly comparable to the corresponding panel estimate in column (5) of Table 2.

Consider first the estimates based on the linear polynomial, reported in Panel A. The first column reports estimates from the baseline specification. The zone coefficient estimate of -0.2885 implies that the price per hectare for a lease inside a zone is 25% lower than the price per hectare for an unregulated lease, which is smaller in magnitude than the price discount of 30% implied by the estimate of -0.3536 in column (5), Panel A, of Table 2. The range coefficient estimate of -0.1735 is virtually identical to the estimate in Table 2. The second column reports estimates from the specification that allows anticipation effects to vary by proximity to zone boundary. The coefficient estimates for the range variables are similar to the ones in Panel B of Table 2: range leases that are near existing zone boundaries incur statistically significant price discounts relative to unregulated leases, and the price discount dissipates the farther is a lease from the boundary. The final column of Panel A reports the zone coefficient estimate from a specification where range leases are categorized as unregulated. Like the zone coefficient estimates in the first two columns of this panel, the estimate is numerically smaller in magnitude than the corresponding estimate of -0.2879 in Table 2, but – supporting the prediction that misspecifying anticipation as non-existent will underestimate the effect of existing regulation – the estimate is smaller in magnitude than the zone coefficient estimates in the first two columns.

[26] We were unable to use polynomials of degree four or higher because, given the rich set of fixed effects that we employ and the geographic concentration of leases by firms and over time, using polynomials of such a high degree causes collinearity problems.

Table 4: Sensitivity of estimates using different latitude-longitude polynomials

	Baseline	Heterogeneous	No anticipation
	A. Linear polynomial		
Zone	-0.2885**	-0.2920***	-0.2261**
	(0.0999)	(0.0967)	(0.1050)
Range	-0.1735	-0.2618*	
	(0.1181)	(0.1398)	
×Distance to zone boundary		0.0089	
		(0.0088)	
	B. Cubic polynomial		
Zone	-0.3563***	-0.3606***	-0.3014***
	(0.1046)	(0.1015)	(0.0899)
Range	-0.1444	-0.2055	
	(0.1381)	(0.1278)	
×Distance to zone boundary		0.0061	
		(0.0076)	
	C. No polynomial		
Zone	-0.3369***	-0.3409***	-0.2836***
	(0.1025)	(0.1012)	(0.0954)
Range	-0.1472	-0.2666*	
	(0.1301)	(0.1489)	
×Distance to zone boundary		0.0117	
		(0.0079)	
Observations	2918	2918	2918

Notes: The dependant variable is the logarithm of price per hectare at the lease level. All specifications include the specified latitude-longitude polynomial, zone region fixed effects, firm-year fixed effects, and lease-specific controls. Robust standard errors, adjusted for clustering by caribou zone, in parentheses. *, **, and *** denote estimates different from zero at the 10%, 5%, and 1% significance levels.

Panel B of Table 4 reports estimates from using a cubic polynomial in latitude and longitude. The zone coefficient estimates across the three columns are similar to the estimates in column (5) of Table 2. The coefficient estimates for the range variables in the first and second columns are smaller in magnitude than the corresponding Table 2 estimates (and estimates using different polynomials in this table), likely due to overfitting by the high-degree polynomial.

Finally, Panel C reports estimates from specifications that omit latitude and longitude. The coefficient estimates for the zone indicator variable are all similar to those in Table 2. The range coefficient estimate in the first column, using the baseline specification, is smaller in magnitude than the Panel A estimate in Table 2 and is more imprecisely estimated. The estimate in the second column, -0.2666, and the interaction term coefficient, 0.0117, are similar numerically and in statistical significance to the ones estimated using the quadratic polynomial, both of which suggest that firms anticipate that zones will be gradually expanded, which is consistent with historical practice.

Overall, we take the estimates in Table 4 as evidence that the estimates reported in Table 2 are not driven by our choice of a quadratic polynomial in latitude and longitude.

5.2 More on the bias from not accounting for anticipation

We can further explore the size of the bias due to not accounting for anticipated rezoning by exploiting the fact that for some zones the boundary coincides with or is close to the associated range boundary, while for other zones the boundaries are distant from one another. While still not accounting for anticipated rezoning by categorizing range leases as unregulated, we do this by estimating a specification of the following form:

$$p_{izjt} = \nu + \delta_1 \, \text{zone}_i + \delta_2 \, \text{zone}_i \times \text{size}_z + W_i \Pi + f(x_i, y_i) + \mu_z + \mu_{jt} + \epsilon_{izjt}, \tag{4}$$

where size_z is a measure of the size of a range associated with zone z. This estimating equation is similar to a version of equation (2) that omits range_i, but now the (biased) effect of lying in a zone is equal to $\delta_1 + \delta_2 \text{size}_z$. Our expectation is that larger range areas which may be rezoned in the future (and for which anticipated rezoning is unaccounted for), leads to greater bias in estimates of the price effect of being located inside a zone. The inclusion of the interaction term allows us to test this prediction, with the expectation that larger ranges are associated with greater bias, implying $\delta_2 > 0$.

We use two different measures for size_z. The first is the total count of leases sold in a range area near a given zone over the course of the entire sample. If there are a greater number of leases near a zone for which rezoning is anticipated and the expected costs of rezoning are capitalized into their lease prices, we expect the omission of their anticipated regulation status to dilute the effect of regulation than if there are no leases near a zone for which regulation is anticipated. The second measure is the distance of the lease in a range that is farthest from the given zone. Since there is a greater area for which regulation is anticipated, larger range areas may generate greater bias when range leases are unaccounted for in comparison to when there is no range area (i.e., the distance is zero because the zone and range boundaries coincide). Though these variables are similar, their correlation of approximately 0.5 implies that they are not perfect substitutes for one another.

Table 5: How the size of the bias from not accounting for anticipated rezoning is affected by the properties of potentially rezoned area

	(1)	(2)	(3)	(4)	(5)
A. Interacting zone with total number of leases in range					
Zone	-0.2695	-0.6242**	-0.2497	-0.2656*	-0.3166**
	(0.3009)	(0.2152)	(0.1901)	(0.1353)	(0.1363)
×Lease count in range	0.0042	0.0077***	0.0017	0.0001	0.0004
	(0.0031)	(0.0024)	(0.0016)	(0.0013)	(0.0014)
R^2	0.0051	0.1091	0.1539	0.5531	0.5539
B. Interaction zone with maximum distance from within range to zone boundary					
Zone	-0.6707	-0.6198	-0.5550	-0.4574*	-0.4587**
	(0.3968)	(0.4917)	(0.3224)	(0.2180)	(0.1971)
×Max. distance in range	0.0228	0.0153	0.0136	0.0066	0.0058
	(0.0151)	(0.0175)	(0.0112)	(0.0056)	(0.0057)
R^2	0.0116	0.0992	0.1554	0.5534	0.5541
Quad. poly. in lat/lon	N	Y	Y	Y	Y
Zone fixed effects	N	N	Y	Y	Y
Owner-Year fixed effects	N	N	N	Y	Y
Lease controls	N	N	N	N	Y
Observations	2918	2918	2918	2918	2918

Notes: The dependant variable is the logarithm of price per hectare at the lease level. Robust standard errors, adjusted for clustering by caribou zone region, in parentheses. *, **, and *** denote estimates different from zero at the 10%, 5%, and 1% significance levels.

We report coefficient estimates from estimating equation (4) using the two different measures of range size in Table 5. Panel A reports estimates from using the count of range leases as the size of a range, while Panel B reports estimates from using the maximum distance from a range lease.

Consider first the estimates in Panel A. The coefficient estimates for the zone variable, in the first row, are all negative in sign, statistically significant, and larger in magnitude than the estimates reported in Panel C of Table 2. The coefficient estimates for the interaction term, in the second row, are all positive. Together, the signs of the two sets of coefficient estimates indicate that the bias on the price effect for leases located in zones depends positively on the number of unaccounted for range leases. In particular, if there are no range leases associated with zones (which is the case for three zones), the coefficient estimate in column (5) is equal to -0.3166, which is numerically similar to the baseline estimate of -0.3536 in column (5) and Panel A of Table 2, where we do account for which leases are inside ranges. If the number of unaccounted for range leases is equal to the sample mean of range leases associated with a zone, 66, then the coefficient estimate for the effect of being in a zone is statistically significant at the 1% level and equal to -0.2890, which is virtually identical to the estimate in column (5) and Panel C of Table 2. If the total number of range leases is equal to the maximum we observe in our sample, 122, then the coefficient estimate of the effect of lying inside a zone is equal to -0.2696 and is statistically significant at the 5% level. Together, these estimates indicate that the greater the number of unaccounted for range leases, the greater is the bias on the estimated effect on existing regulation on lease prices.

The coefficient estimates using the maximum distance of a range lease to a given zone boundary, reported in Panel B, exhibit a similar pattern to those in Panel A. The coefficient estimates for the zone variable, in the first row, are negative, statistically significant, and larger in magnitude than the same-column estimates in Panel C of Table 2. The coefficient estimates for the interaction term, in the second row, are all positive, indicating zones with geographically larger range areas lead to greater bias in the estimated effect of regulation when not accounting for which leases lie in those range areas. If the maximum distance of range leases associated with a given zone is equal to the minimum, about 250 meters, then the coefficient estimate for the effect on the price of a lease inside a zone in column (5) is equal to -0.4571 and is statistically significant at the 5% level. If the maximum distance is equal to the sample average, about 31 kilometers, the coefficient estimate is equal to -0.2777, is statistically significant at the 1% level, and is virtually identical to the coefficient estimate in column (5) and Panel C of Table 2. If the maximum distance is equal to the maximum observed in the sample, about 68 kilometers, then the coefficient estimate is equal to -0.0623 with a standard error of 0.2346. Altogether, these estimates imply that the bias from failing to account for which leases are inside ranges, thus anticipating future rezoning, depends on the area of the range those leases fall into.

Overall, we take the results from Table 5 as further evidence supporting the prediction from the model in Section 2 that not accounting for which leases may be subject to potential rezoning will lead to underestimates of the effect of existing regulation on land prices.

6 The cost of existing and anticipated regulation

Based on our empirical strategy, we have identified the effect of existing and anticipated land use regulation on auction prices for oil sands leases. Furthermore, the analysis in Section 2 suggests that we can interpret this effect as the present value (PV) cost of complying with, depending on a lease's location, existing or anticipated regulation over the lifetime of the lease. Given our estimation results indicate that the protection zones and the anticipation of their potential expansion cause negative effects on oil sands lease prices, this section puts those estimates into context by calculating the aggregate PV of existing and anticipated regulation for all leases in our sample.

To quantify the total cost of regulation, we need to compute lease prices under the counterfactual scenario where there is no regulation and then calculate the cost, after accounting for royalties and taxes, by subtracting observed prices from counterfactual prices. To see this, suppose the observed price for a lease is p. For a lease inside a zone, the effect of lying in the zone, based on our baseline estimate from column (5) of Table 2, decreases the price by 30% on average. The counterfactual price in the absence of regulation, which we denote by $\widetilde{p}$, for a lease lying in a zone is therefore $\widetilde{p} = p/(1 - 0.30)$. Similarly for a lease lying in a range, the baseline estimate from column (5) of Table 2 yields a price discount of 16% on average, so $\widetilde{p} = p/(1 - 0.16)$. For unregulated leases, the absence of regulation has no effect on their prices, so $\widetilde{p} = p$ for any lease located outside of zones and ranges. We perform this calculation for each lease in our sample, and calculate the price, as opposed to price per hectare, by accounting for the geographic area of the lease.

The difference between a lease's observed price and its counterfactual price describes only the loss of auction revenue from regulation. To calculate the PV cost of regulation, we need to account for corporate taxes and royalties on profits because in Alberta any costs associated with complying with environmental regulations are deductible from these taxes. For example, if the sum of corporate and royalty tax rates is denoted by α, where $0 < \alpha < 1$, a lease with lifetime real revenue R that is inside the zone, thereby incurring a cost of regulation, c, generates PV profits equal to $(1 - \alpha)(R - c)$. The PV profits equal the value of holding the lease and thus equal the price the lease commands in a competitive, first-price, sealed-bid auction. The difference in prices between a regulated and unregulated but otherwise identical lease is equal to $(1-\alpha)c$. To calculate c, we then need to account for the sum of royalty and corporate tax rates, α, applied to oil sands leases. At their lowest, the provincial and federal tax rates during this time are 10% and 15%, respectively. Royalty rates in Alberta depend on several different factors, and the minimum royalty rate for oil sands operations during this period is 25%, while the maximum rate is 40%; we use both rates to provide a range of cost estimates.

We depict four different categories of aggregate PV cost from the regulation in Figure 5. The height of the bars indicate total PV cost in millions of 2012 Canadian dollars, for the specified category, for all leases sold during 2003-2012. For each category, we depict the cost under the minimum royalty rate in dark grey, while the cost under the maximum rate is the lighter color.

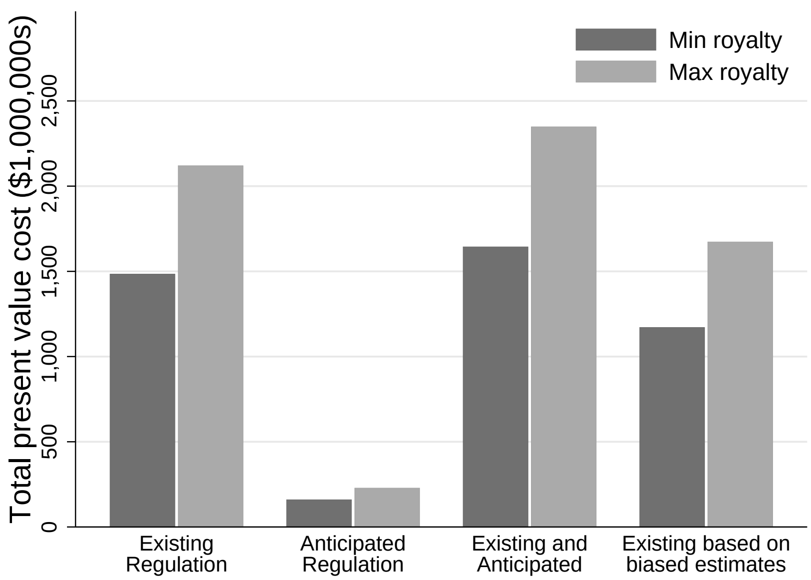


Figure 5: Total present value cost of regulation based on minimum and maximum royalty rates when anticipated rezoning is and is not accounted for in estimation

The first category is the PV cost of the regulation for all leases located in zones. Under the minimum royalty rate, the estimated total cost incurred for leases in the zones is $1.484 billion. The estimated total cost under the maximum royalty is $2.120 billion.

The second category is the cost imposed on the 320 leases that are outside zones – and thus are unregulated – but are located in ranges where regulation is not currently applied but where rezoning in the near future is plausibly anticipated. Based on the estimated price per hectare discount of 16%, the minimum PV cost imposed on these leases is $160 million and the maximum cost estimate is $228 million.

Because the regulation imposes costs on both leases that are regulated and leases that are unregulated but for which potential regulation in the future is anticipated, we calculate the total PV cost of the regulation as the sum of the costs to leases in the zones and the ranges. At a minimum, this cost is equal to $1.645 billion, while at a maximum the total cost is equal to $2.348 billion.

The cost of anticipated regulation accounts for nearly 10% of the total cost of regulation. Failing to account for anticipated regulation not only implicitly values those costs as being equal to $0, but also, as we found in Section 5, leads to underestimates of the effect of protection zones. Based on the biased estimates in column (5) and Panel C of Table 2, the price per hectare discount when omitting anticipation about rezoning is about 5 percentage points smaller than when anticipation is accounted for. The aggregate PV cost based on these biased estimates, depicted as the fourth category in Figure 5, is $1.170 billion at a minimum and a maximum of $1.673 billion. In comparison to the PV cost estimate for existing regulation when anticipated rezoning is accounted for in estimation, represented as the first category in Figure 5, these cost estimates understate the cost of existing regulation by about 22%. Relative to the total cost estimates which incorporate the cost of existing and anticipated regulation, the third category in Figure 5, the total cost estimates calculated from estimation that fails to account for anticipated regulation underestimates the total cost of regulation by 29%.

These estimates indicate that the prevailing approach to protecting endangered caribou in Alberta from the adverse effects of oil sands development is costly. Furthermore, all of the costs depicted in Figure 5 are borne entirely by the government: the costs from foregone auction revenues are incurred on the auction date, but the foregone royalty revenues are incurred during the production phase of each lease. And as Hervieux et al. (2013) find, caribou populations in Alberta are in continued decline and remain at ever greater risk of extirpation. Together with our finding that the regulation is costly and is incurred entirely by the government, this suggests that the regulation is ineffective.

7 Conclusion

This paper examines the effects of existing and anticipated regulation on the value of land. The conventional approach to identifying the effect of regulation, regression discontinuity

(RD), compares land values across administrative boundaries. In many settings, however, regulation boundaries can change over time, leading to potential identification issues. In a simple model of land use regulation and potentially changing boundaries, we show that comparing land values around existing regulation boundaries underestimates the effect of regulation if forward-looking agents anticipate a change in the boundaries. We show that by accounting for such anticipation, one can identify not only the cost of existing regulation, but also the cost of anticipated regulation.

We apply this approach to auction prices for oil sands leases and zoning regulations protecting endangered species that are plausibly anticipated to expand in the Canadian province of Alberta. We find that the existing regulation causes lease prices to decrease by 30% per hectare on average, while anticipated rezoning causes the price per hectare of unregulated leases to decrease by 16% on average. When allowing for heterogeneous anticipation effects, we find such effects to be most pronounced near existing regulation boundaries, where based on historical regulatory practice rezoning is perceived as most likely to occur, and the effect dissipates the farther is a lease from those boundaries.

The results in this paper provide several lessons. First, our model shows that accounting for anticipation effects caused by potentially changing administrative boundaries is critical to identifying the effect of regulation on land values. Not accounting for anticipation underestimates the effect of regulation. This phenomenon extends beyond land use regulation to any context where administrative boundaries defining where policy is applied, providing useful variation to identify the effect of the policy, can change over time. Second, our empirical results indicate that anticipation effects matter in practice: anticipation about potential rezoning significantly decreases the price of unregulated oil sands leases, resulting in a loss of government revenue exceeding $100 million. Furthermore, failing to account for anticipation effects underestimates the total cost of the regulation by nearly one-third. Given that we estimate the present value cost of the regulation to be in the billions of dollars, such a difference in cost estimates underscores the importance of accounting for anticipation when evaluating policy based on land values.

Our paper has broader lessons for policymakers. While delaying potential future regulation may have its benefits, the behavior by consumers or, in our case, firms caused by anticipating future regulation may come with considerable costs. In such a case, it is optimal for policymakers to weigh those costs, in addition to carefully considering how to signal future policy change, when designing public policy.

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A Appendix

Table A1 reports all coefficient estimates from column (5) for each panel in Table 2. The results for Panel A of Table 2 are reported in the first column, labelled “Baseline” to indicate our baseline specification. The results from Panels B and C are reported in the second and third columns, respectively. We report the coefficient estimates for the zone indicator variable, the range indicator variable, and the range variable interacted with distance to zone boundary for convenience.

Table A1: Full set of coefficient estimates from column (5) of Table 2

	Baseline	Heterogeneous	No anticipation
Zone	-0.3536***	-0.3604***	-0.2879***
	(0.0878)	(0.0850)	(0.0905)
Range	-0.1721	-0.2687*	
	(0.1174)	(0.1513)	
×Distance to zone boundary		0.0096	
		(0.0092)	
Number of joint owners	-0.1227	-0.1265	-0.1176
	(0.2685)	(0.2669)	(0.2598)
Key wildlife area	-0.1756***	-0.1737***	-0.1670***
	(0.0391)	(0.0396)	(0.0417)
Special access area	0.3183	0.3315	0.2904
	(0.4047)	(0.4052)	(0.4072)
Log(depth)	-0.2284	-0.2303	-0.2667
	(2.6386)	(2.6312)	(2.6577)

Notes: The dependant variable is the logarithm of price per hectare at the lease level. Robust standard errors, adjusted for clustering by caribou zone, in parentheses. *, **, and *** denote estimates different from zero at the 10%, 5%, and 1% significance levels.

The coefficient estimates across all specifications for the number of joint owners, listed in the fourth row, are all similar and indicate that the price per hectare for a lease decreases with the size of group ownership over a lease; this variable likely proxies for risk, as the practice in this industry is to share risk by entering into joint ownership. The coefficient estimates for the key wildlife area are negative and statistically significant, indicating that the price for a lease subject to the key wildlife land use regulations is lower than the price for a lease that is not in that area. The opposite is true for special access areas, though these are imprecisely estimated given few leases in our sample lie in these areas and the ones that do are all unregulated leases. The coefficient estimate for the logarithm of core depth is statistically insignificant, but being of negative sign is consistent with the notion that deeper deposits are costlier to extract. This variable is likely statistically insignificant for two reasons. First, oil sands are fairly similar within a given region, so there is likely little variation in depth. Second, shallower deposits are more lucrative and so leases are likely purchased in order of depth. As a result, leases purchased in a given year likely do not vary much in depth.