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How Much Does Anticipation Matter? Evidence from Anticipated Regulation and Land Prices

Abstract

Land prices across administrative boundaries can be useful for estimating the causal effects of local policy. Market anticipation about potential boundary changes can confound identification, so studies often avoid markets where this may arise. We develop an approach to quantify anticipation by separately identifying the causal effect of local policy and the market's subjective beliefs that administrative boundaries will change. Using land prices and changes to land use regulation boundaries, our estimates indicate that anticipation does matter quantitatively: it increases the welfare cost of the policy by one-quarter and empirical analysis that omits anticipation underestimates this cost by nearly one-half.

JEL-Codes: D840, L500, R300.

Keywords: anticipation, local policy, land values, regulation, border discontinuity.

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1 Introduction

A growing body of empirical research uses land prices to estimate the causal effects of local policies, such as land use regulations or the quality of public schooling. Understanding the magnitude of these effects can ultimately be used for evaluating and improving policy. A common identification strategy is to ensure the market does not anticipate the policy will change. Absent such expectations, price differences between affected and unaffected land can reflect the causal effect of the policy.

Yet anticipation effects may be important on their own for at least two reasons. First, by responding to anticipation about potential policy changes, market participants may incur real costs or benefits. Understanding whether these costs or benefits are meaningful requires measuring their magnitudes. Second, it may be impossible to eliminate anticipation altogether. To continue using land prices to estimate causal effects, researchers need to deal with the presence of anticipation. While expectations and anticipation are fundamental parts of economic theory, there is little research quantifying anticipation because distinguishing anticipation effects from the effects of existing policy is challenging.[1]

In this paper, we propose an identification strategy for estimating the effect of anticipation about changes to the scope of regulation – where the regulation is applied – on the value of land.[2] Using this approach, we estimate the market's subjective beliefs that currently unregulated land will become regulated in the future. The strategy allows us to measure not only the cost of anticipation but also the cost of existing regulation. It also allows us to quantify the bias from failing to empirically account for anticipation.

We base our estimation strategy on a standard model of land prices and land use regulation. We adapt the model to allow for possible rezoning, 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 market participants will incorporate their beliefs

[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 implicit price of air quality."

[2]Though our focus is on an anticipated change in the scope of regulation, our approach, which entails accounting for which entities may face a future change in regulation, can also be applied to anticipation about a change in the stringency of regulation.

that rezoning will occur by capitalizing the expected costs of anticipated regulation into the price of affected parcels.

To identify anticipation effects requires observing where rezoning can realistically occur. This allows us to categorize land as regulated or unregulated, with a subset of land that may be rezoned. After controlling for factors affecting the value of land, we identify the effect of anticipation by comparing the price of unregulated land to the price of land that is anticipated for rezoning. If the cost of regulation is constant, the effects of anticipated and existing regulation differ only by the average subjective beliefs that rezoning will occur, allowing us to identify the market's beliefs about rezoning.

The discontinuous change over space in the regulatory status of a parcel – being either regulated, unregulated, or anticipated for rezoning – motivates a regression discontinuity (RD) framework with multiple borders. We follow Dell (2010) by using a multidimensional RD approach that controls for the geographic location of land parcels to identify the effects of anticipation and regulation on land prices. However, if the market expects an immediate change in the boundary, there might not be a discontinuity in land values at the current boarder. Being able to address this possibility distinguishes our work from the previous literature.

We apply this approach to Canadian data on oil lease prices and land use regulations. The regulations aim to protect the local environment by imposing development restrictions in geographic zones. A key feature of these regulations is that the zones have been gradually expanding over time and we can observe where it is realistic that rezoning can and cannot occur. Altogether, this information allows us to categorize leases as being either regulated, anticipated (i.e., currently unregulated but might be rezoned in the future), or unregulated now and in the foreseeable future.

Using information on more than 4,000 oil leases sold between 2003 and 2016 and mid-sample boundary changes to the regulatory zones, we find that the price per hectare for an anticipated lease is 23% lower on average than an unregulated lease that is not at risk of being rezoned. This price discount increases with a lease's proximity to existing regulation boundaries and over time, consistent with the regulation's history of gradual zone expansion. In contrast, the price discount for regulated leases is 30% on average.

Based on our estimates, we calculate average beliefs that rezoning will occur. Although we impose no structure on these beliefs and allow them to vary freely, we find they typically lie between 0 and 1, as probabilities should, and are statistically significant at conventional levels. Hence, even without imposing any structure on the magnitude of beliefs, our empirical analysis yields highly sensible results. More specifically, our results suggest that the market anticipates rezoning with an average probability of 0.71 – as high as 0.98 just outside existing boundaries – supporting the prediction that the market saw an expansion of the regulation zones as likely and imminent.

Using our estimates, we quantify whether anticipation matters in two ways. First, we find that anticipation increases the aggregate cost of the regulation by 24%. Second, we find that the bias from not accounting for anticipation yields an underestimate of 30% of the aggregate cost of existing regulation and 44% of the aggregate cost of existing and anticipated regulation. Together, these estimates suggest that anticipation has a substantive effect on land prices and on empirical analyses that omit it.

A nascent literature estimates anticipation effects from policy changes (see Malani and Reif (2015) and Coglianese et al. (2016)). Much like our paper, this literature finds that anticipation effects are large and omitting them econometrically leads to biased estimates of the effects of existing policy. Using the timing of policy announcements and implementation, this literature exploits variation in expectations over time. In contrast, by using uncertainty about where future policy may be applied, we are the first to exploit variation in expectations over space.

We are also, to the best of our knowledge, the first to estimate how expectations about changes to regulation boundaries may be capitalized into land values. This contribution extends beyond the context of land use regulation to research that uses discontinuities in treatment across administrative boundaries to estimate causal effects.[3] If boundaries in those contexts are known to change over time, then expectations that boundaries may again change will confound identification of the effects of existing treatment.[4] Our study shows that when anticipation effects are present, outcome differences across existing boundaries do

[3]Exploiting administrative boundaries has been used to study, among the ones cited in this paper and many others, the effect of local taxes on the location of firms (Duranton et al. (2011)), the cost of endangered species regulation (Bošković and Nøstbakken (2017)), the benefit of common language to international trade (Egger and Lassmann (2015)), and the effect of particulate matter on life expectancy (Chen et al. (2013)).

[4]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)). The redrawing of school zone boundaries over time is a well-known 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; only by accounting for anticipation about boundary changes will the willingness to pay for school quality be identified.

Real estate agents often caution clients against living near boundaries which may change and suggest searching for housing strategically within neighborhoods or blocks in order to maximize the chance of being in a desired school zone. For an example of this advice, see `http://juliekinnear.com/blogs/school-boundaries-toronto`.

not reflect the effect of existing treatment. By observing where market participants believe boundaries may change, we show how anticipation effects can be identified along with the effect of the existing treatment.

Research inferring the valuation of local amenities from land 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) find that expectations about the negative effects of a local incinerator siting decreases nearby land 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; Bayer et al., 2016). We contribute to this literature on how market participants capitalize information into land prices by estimating firms' subjective beliefs regarding a possible policy change.

We also contribute to the literature investigating how zoning causes 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.

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 quantifies the magnitude of anticipation in terms of the aggregate cost of regulation and quantifies the bias from omitting anticipation in the empirical analysis. We then provide concluding remarks.

2 Stylized 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.[5] Adapted from hedonic models of land prices, such as the seminal paper by Rosen (1974), the purpose of the model is to illustrate how to identify anticipation

[5]Although our empirical specification takes account of the two-dimensional nature of geographic location, we use a one-dimensional model for ease of exposition which is sufficient to provide insights for the empirical specification.

about potential regulatory changes from land prices.

Land parcels lie on the real line and the location of a parcel is denoted by x. The value of 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 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.[6]

It is possible that rezoning may occur, such that 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 of a parcel x are described by the probability function $F(x)$. The status of currently regulated parcels as well as unregulated parcels to the left of $\underline{x}$ is not anticipated to change; that is, $F(x) = 1$ for parcels $x \geq \overline{x}$, and $F(x) = 0$ for $x < \underline{x}$. For unregulated parcels located between the existing regulation boundary and the boundary under potential rezoning, the probability of rezoning is between zero and one: $F(x) \in [0, 1]$ for $x \in [\underline{x}, \overline{x})$. Finally, we assume that $F(x)$ is continuous over the area that may be rezoned.

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. In general, we can express the price of a parcel as: $p(x) = V(x) - cF(x)$. For parcels that are not regulated and for which there is no anticipation that status will change, i.e., $x < \underline{x}$, this simplifies to $p(x) = V(x)$. 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 $x \geq \overline{x}$. Finally, parcels that are not regulated but may be subject to regulation, $x \in [\underline{x}, \overline{x})$, will have the expected cost of anticipated regulation, $cF(x)$, capitalized into their prices.

[6]Our model easily generalizes to the case of regulation that brings subsidies, and hence added value rather than a cost for the land owner. For example, water quality regulation can improve the value of agricultural land.

[7]If the zone contracts, so that the boundary shifts to the right, the identification arguments are much the same.

Summarizing the price of land, we have:

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

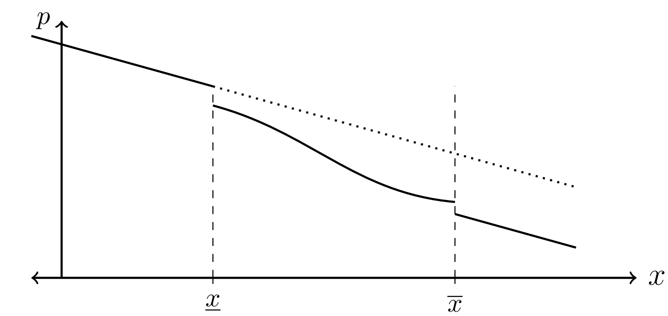
Figure 1 depicts a version of this model. The top panel, Figure 1a, plots land values exclusive of the cost of regulation. For the purposes of illustration, we have depicted $V(x)$ as linearly decreasing along the real line. The second panel, Figure 1b, depicts the price of land by solid lines while the dotted line represents the counterfactual price of land if there was no cost of complying with regulation. Finally, the third panel, Figure 1c shows the expected cost of anticipated regulation, given by the distance between the dotted and solid lines in Figure 1b.

In practice, rezoning often occurs gradually; Figures 1b and 1c depict a case where parcels nearest to the current boundary are anticipated as more likely to be rezoned than parcels farther away. Parcels lying just to the left of the zone boundary $\overline{x}$ face a probability of being rezoned that is close to 1, so that the expected cost of anticipated regulation is just less than the cost of regulation. As depicted, there is a smaller discontinuity in prices around $\overline{x}$ than at the other end of the potentially rezoned area. At that boundary, $\underline{x}$, the probability of being rezoned is closer to 0 than to 1, so expected costs are much smaller than for parcels closer to the existing boundary. 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 counterfactual prices under no regulation, depicted as the dotted line.

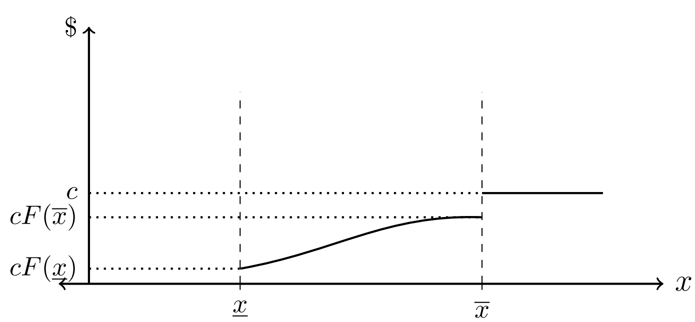
To see how anticipation can be identified from prices, it is useful to first examine how the cost of regulation is identified when there is no anticipation of regulatory change. In this case, the price for parcels between $\underline{x}$ and $\overline{x}$ is given by the dotted line. The discontinuity in regulatory status as one moves across the regulation boundary causes a discontinuity in prices, the difference being the cost of regulation, c. The common approach to identify the cost of regulation is to compare prices on either side of the regulation boundary (see Turner et al., 2014).

When there is anticipation that the boundary will shift leftward, the difference in prices around the boundary $\overline{x}$ will no longer equal the cost of regulation. This is because the expected cost of anticipated regulation will be capitalized into the price of parcels between $\underline{x}$ and $\overline{x}$, as illustrated in the two lower panels of Figure 1. For strong enough beliefs, there may be no price discontinuity whatsoever at the existing regulation boundary.

(a) Land values excluding regulatory costs



(b) Land prices when rezoning is anticipated



(c) The expected cost of anticipated regulation

Figure 1: Anticipated rezoning and the price of land

With $V(x)$ (and $F(x)$) being given by an unknown continuous function, we can instead estimate the anticipation and identify the cost of regulation by controlling for geographic location. That is, we control for continuous, smooth functions of x, along with an indicator for whether the parcel lies in the regulation zone and another indicator for whether the parcel lies in the potentially rezoned area. Geographic location proxies for the value function, while the regulation zone indicator identifies the cost parameter and the ratio of the regulation zone and potentially rezone indicators identify the probability of rezoning.

In short, after controlling for $V(x)$ – the case depicted in Figure 1c, with $[p - V(x)]$ represented on the vertical axis – we can identify the average cost of anticipated regulation, $\overline{cF(x)}$, by comparing the price of of unregulated to anticipated parcels. In comparing unregulated and regulated parcels, we obtain the cost of regulation, c. The ratio of these two quantities yields $\overline{F(x)}$, the average belief that parcels between the two boundaries will be rezoned. Identifying F for all x would require comparing the average net price for parcel x to the average net price of regulated parcels for all $x \in [\underline{x}, \overline{x})$. Note that we disregard timing effects and discounting in the above illustration. Our framework easily extends to including time as well as spatial effects. In this case, the function $F(\cdot)$ captures the anticipated discounted cost of potential regulation.

Our analysis shows that under the assumptions that (1) the researcher can observe the potential future boundary $\underline{x}$, and (2) the value of land, gross of regulatory costs, is continuous, one can identify the cost of existing regulation as well as the beliefs that unregulated land may be rezoned. As we describe in the following sections, we follow the prescriptions of the model to estimate these quantities empirically.

3 Data

Based on the stylized model, estimating the effects of anticipation and regulation on land prices requires a context where there exists anticipation – not based on a regulator's announcement, but from perceptions based on other information – that regulation boundaries may change. We use such a context from the Canadian province of Alberta. Specifically, we use oil lease prices and a change in the boundaries of land use regulations aimed at protecting the environment.

The market for oil production in Alberta is developed and competitive, as fossil fuel development has been the main industry there for several decades.[8] Though mineral rights

[8]Watkins (1975) and Watkins and Kirby (1981) found that competition for the right to development oil

are publicly owned, the government sells the right to extract fossil fuels through first-price, sealed bid auctions. Auctions for leases are announced 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.

We focus on lease prices for so-called oil sands, a type of formation which produces heavy crude oil. The prevalence of oil sands puts Alberta as having the third largest oil reserves in the world (AER (2017)). Auction sales and royalty payments generate billions in government revenue annually.

The development of oil sands significantly damages the environment. Though known primarily for its high greenhouse gas emissions, oil sands production creates immense land disturbances. Because of the remote location of the deposits – in the mostly uninhabited northern part of the province – the disturbances impact ecosystems and wildlife. The most salient and critically affected species is the woodland caribou, to which oil sands has caused and continues to cause severe population declines. The population decline has led to the caribou's designation as an endangered species (Boutin et al. (2012)). To protect the species from continued risk, the Albertan government in the 1990s imposed land use regulations within geographic zones. The zones impose restrictions on production, implying that lease holders incur costs from complying with the regulation that would not be occurred outside the zones.[9]

The zones are determined by the critical habitat of the endangered species. They are subsets of ranges, the areas containing critical habitat and the species' migration routes.[10] Since their inception, the zones have gradually increased in size, thereby containing more of each herd's range.[11] The regulation zones have always expanded and never contracted, so there would be good reason for producers to anticipate further expansion.

Between 2003 and early 2013, there were 31 geographically distinct zones, which are depicted by the darker shade in Figure 2. In 2013, the zones were abruptly expanded

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and gas in Alberta is competitive; the industry has only grown since the time of these studies.

[9]Examples include reduced clear-cutting of forests, diverting roads and pipelines from caribou routes and habitats, limiting seismic disturbances from drilling, and restoring seismic lines and cleared areas to original conditions as soon as possible.

[10]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.

[11]The zones were initially created in 1991, a map of which we provide in the Appendix. The 1991 zones were clearly smaller than the zones we consider in this paper. The zones underwent expansions in 1994 (twice), 1996, 2003, and 2013. This expansion is well-documented in government reports; see Dzus (2001) and ASRD and ACA (2010). Paper maps of the pre-2003 zones are available, but they are drawn too imprecisely for statistical analysis, which we discuss in the Appendix.

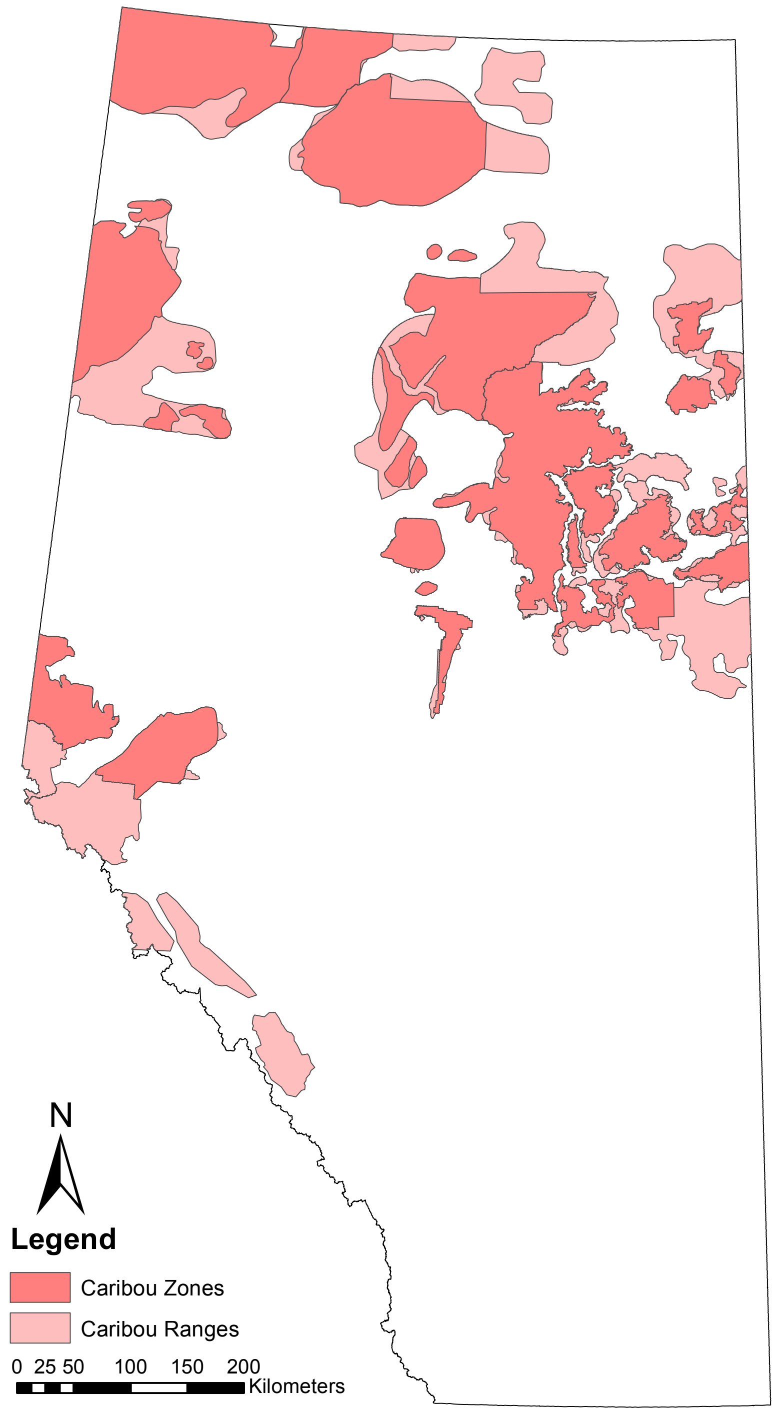


Figure 2: Location of wildlife protection zones in Alberta, 2003–2016

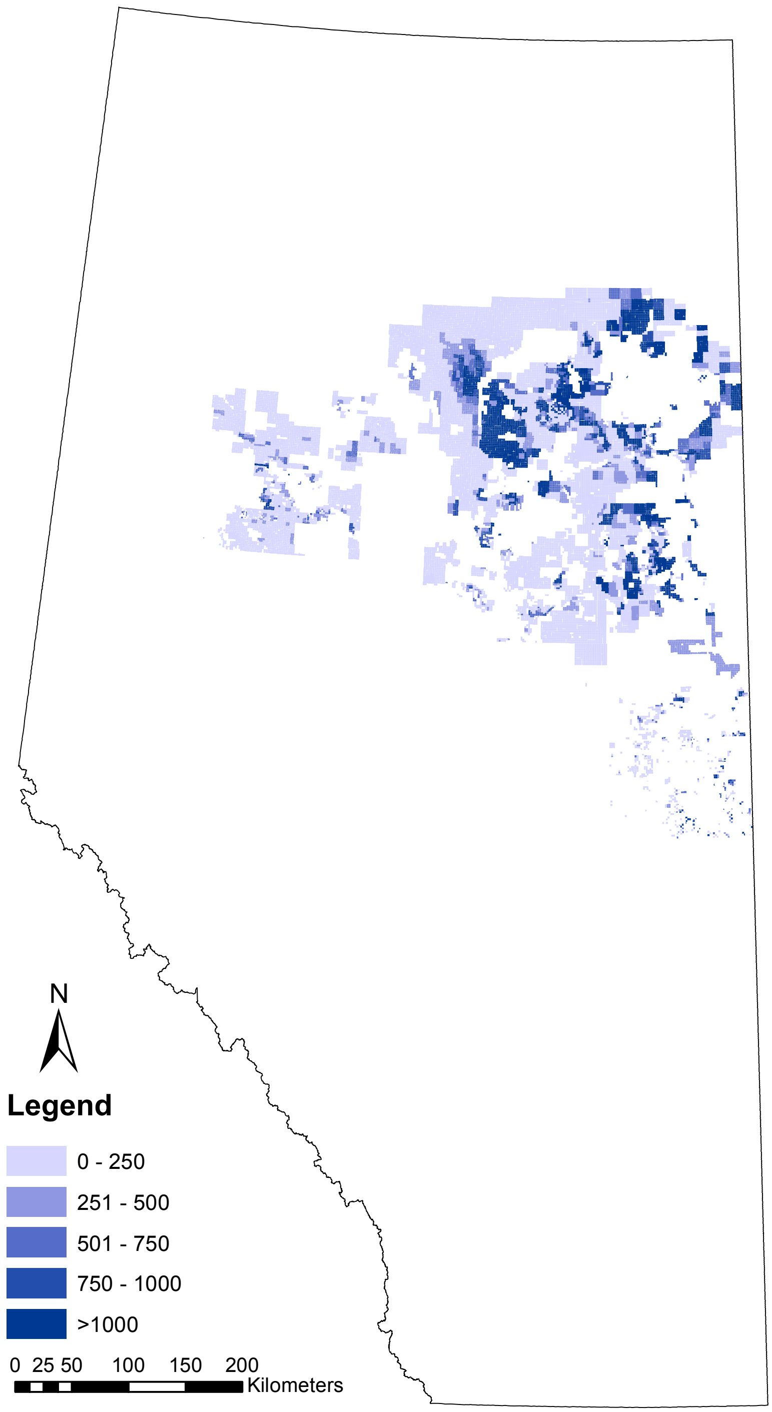


Figure 3: Price per hectare, in 2017 Q1 Canadian dollars, of oil sands leases sold during 2003–2016

without much prior notice to where they coincided everywhere with range boundaries. The expansion resulted in 13 regulation zones; these are depicted by the outer boundaries of the shaded areas in Figure 2. There is little chance that the regulation boundaries will be further expanded, since they now include the geographic outer limits of caribou activity. This new boundary represents the potential new boundary $\underline{x}$ from our theoretical model.

Any leases sold between 2003 and May 2013, the date of the expansion, located within the darker region in Figure 2 are subject to the regulation over the course of our sample, and so are categorized as regulated. Similarly, any leases located in any shaded area that were sold after May 2013 are regulated, so these are also categorized as regulated to indicate that, at the time of their purchase, they are subject to the regulation.

Any leases purchased in the lighter shade areas – outside the regulation zones but within the ranges – before the expansion would not be regulated at the time of their sale. However, we categorize these leases as being "anticipated" for potential rezoning. Essentially, our analysis will ask whether unregulated leases that were rezoned following the boundary expansion were anticipated to be rezoned by testing whether such anticipation was capitalized into their lease prices. For convenience, we will refer to these as being "anticipated" leases.

Leases that are located outside the shaded areas are unregulated before and after the expansion. Because the range boundaries form the outer limits of caribou activity and because this species is sensitive to relocation, there is little chance the boundaries will shift beyond the range boundaries. We categorize them as being unregulated.

Table 1 reports sample means and standard deviations of the characteristics of the 4,139 oil sands leases sold during 2003–2016. Of these, 483 leases face anticipated rezoning, 1,555 leases are located within regulation zones and are thus regulated, and 2,101 leases are unregulated. The first row reports statistics for the auction price per hectare of leases, measured in the first quarter of 2017 Canadian dollars. The average price for anticipated leases is $1,112, more than the price of regulated leases and even more than the price of unregulated leases. Though unregulated leases are surprisingly the least valued, within a 10 kilometer band around regulation boundaries this pattern changes: unregulated leases have a mean price of $1,374 per hectare, while anticipated and regulated leases have mean prices of $1,136 and $723 per hectare, respectively. The different price patterns suggest that controlling for geographic location is important.

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.[12] The total number of firms

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

in the sample equals 148. Sixty-one of these firms own anticipated leases, while 84 and 135 of the firms own leases that are regulated and unregulated, respectively.

Table 1: Summary statistics of leases by regulatory status

	Regulatory status:			
	Anticipated	Regulated	Unregulated	Total
Price/hectare	1112.4	918.6	641.7	800.7
	(2891.8)	(1861.1)	(2046.0)	(2104.4)
Number of joint owners	1.149	1.132	1.060	1.098
	(0.458)	(0.382)	(0.282)	(0.348)
Surface mining area	0.0124	0.00386	0.0224	0.0143
	(0.111)	(0.0620)	(0.148)	(0.119)
Latitude	-110.0	-111.1	-93.80	-102.2
	(18.67)	(17.16)	(54.48)	(41.60)
Longitude	54.20	54.90	35.85	45.15
	(18.96)	(17.23)	(54.28)	(41.68)
Distance to regulation boundary	8.287	33.25	58.36	43.08
	(9.332)	(40.44)	(48.08)	(45.76)
Special access area			0.0842	0.0428
			(0.278)	(0.202)
Key wildlife area	0.122	0.0714	0.222	0.154
	(0.328)	(0.258)	(0.416)	(0.361)
Number of unique firms	61	84	135	148
Observations	483	1555	2101	4139

Notes: Price/hectare is measured in Canadian dollars from the first quarter of 2017. Latitude and longitude are measured in degrees. Distance is in kilometers.

The third row reports summary statistics for whether a lease is located in the surface mining area. Oil sands which can be extracted by surface mining, as opposed to *in situ* drilling, are typically larger in scale and more profitable. Most of the deposits that can be surface mined were purchased prior to 2003; as a result, only 1.4% of our sample is located within the surface mining area.

The next two rows report latitude and longitude, in degrees, which we use to measure the geographic location of a lease. While the anticipated and regulated leases possess similar geographic coordinates, which is not surprising given they are located within or near the regulation zones, the unregulated leases are relatively farther east and south.

Distance to the regulation boundary measures, in kilometers, how far a lease is to the nearest regulation boundary, regardless of its regulatory status. Anticipated leases are on average 8 kilometers from the nearest regulation boundary, which is unsurprising given the

the main owner and the one we use to count the number of unique firms.

map of zones and ranges in Figure 2. On average, leases are about 43 kilometers from the nearest boundary, with unregulated leases being the farthest.

The final two rows report statistics on binary variables describing whether the lease is located in areas where other forms of regulation are applied. These areas, known as key wildlife and special access area, impose different land use regulations to protect biodiversity.[13] The special access area is outside the area of caribou ranges, so no anticipated or regulated leases are located within this area. The key wildlife area overlaps considerably with the unregulated area, so more than 22% of unregulated leases are located in this area, whereas only 12% and 7% of anticipated and regulated leases overlap this area.

4 Empirical specification

Our goal is to test the extent to which anticipation about potential changes to regulation boundaries is capitalized into land prices. The theoretical model prescribes controlling for the regulatory status of a parcel and for its geographic location. We achieve the former by controlling for whether a lease is regulated, anticipated, or unregulated. As for the geographic location, we observe the geographic coordinates – the latitude and longitude – of a lease and estimate a function of the coordinates to control for geographic location. Doing so, along with controlling for the identify of the nearest regulation zone, amounts to a multidimensional regression discontinuity, first used by Dell (2010).[14]

Based on these prescriptions, we estimate the following equation as the baseline specification for lease i purchased in quarter-year t:

$$p_{it} = \beta \text{anticipated}_i + \delta \text{regulated}_i + g(\text{location}_i) + X_i \Gamma + \lambda_t + \varepsilon_{it}. \qquad (2)$$

The dependent variable, p_{it}, is the logarithm of the price per hectare for lease i. The variable anticipated_i indicates whether i is an 'anticipated' lease – unregulated but which may be regulated in the future – which takes on the value 1 if it is an anticipated and equals 0 otherwise. The variable regulated_i describes whether lease i is located within an existing regulation zone. By construction, if $\text{anticipated}_i = 1$ then $\text{regulated}_i = 0$, and *vice versa.* A

[13]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.

[14]The multidimensionality is from using the coordinates, as opposed to the one-dimensional distance of a parcel to the regulation boundary. The coordinates contain more information on geographic location than distance, since the latter is a one-dimensional function of the former. This is especially useful in controlling for the unobserved resource quality associated with a parcel of land (see Bošković and Nøstbakken (2017)).

lease for which the value of both indicator variables is zero is an unregulated lease.

The unknown function g controls for functions of geographic location that affect the profitability of land, such as the underlying resource stock and distances to hubs where producers obtain their inputs. We specify $g(\text{location}_i)$ as being equal to the function $f(\text{lat}_i, \text{lon}_i) + \lambda_{z(i)}$. f is a smooth function of parcel i's latitude, lat_i, and longitude, lon_i, while $\lambda_{z(i)}$ is a fixed effect for the nearest regulation zone to i, regardless of i's regulatory status. Given f is unknown, we specify it, again following Dell (2010), as a polynomial in the coordinates.[15]

The vector X_i contains several variables affecting the underlying value of the lease along with a constant. In particular, the vector contains the variables listed in Table 1 (excluding the coordinates and distance), along with a fixed effect for the identity of the main owner of lease i. The parameters λ_t are quarter-year fixed effects that control for factors affecting lease prices across each quarter-year, such as the price of crude oil. The variable ε_{it} is the error term.

The parameters β and δ are the parameters of interest. The parameter δ captures the effect of being located in a regulation zone. If the cost of regulation is capitalized into the price of land, then the lifetime costs of complying with the regulation, net of any tax liabilities, will be reflected in the magnitude of this parameter; the parameter is proportional to the cost of regulation, represented by c in the model.[16] The parameter β captures the average effect of being located in an unregulated area for which there is anticipation that it may be regulated in the future. Again, if markets capitalize this information into lease prices, then we expect that this parameter will reflect the price effect of anticipated regulation. In Section 6, we use estimates of δ to calculate the expected cost of anticipated regulation, which in the model is represented by $\overline{F(x)}c$.

Since δ reflects the cost of regulation and β reflects the product of the cost of regulation and the beliefs of rezoning, it should be the case that $\beta \leq \delta$. Further, by estimating β and δ, we can calculate β/δ, which represents, according to the model, the average belief that anticipated leases will be regulated in the future. A more structural approach would put restrictions on the range of β/δ, but we will instead allow it to take on any value and

[15] We use a quadratic polynomial for our baseline specifications, as this is the highest degree polynomial we can use before encountering collinearity problems. A quadratic polynomial in latitude and longitude is $\text{lat}_i^2 + \text{lon}_i^2 + \text{lat}_i \times \text{lon}_i$. We also report results from using lower degree polynomials; the results are virtually the same as our baseline estimates.

[16] To see this, suppose the corporate tax rate is denoted by α, where $0 < \alpha < 1$. A regulated lease with lifetime real revenue R that incurs a cost of regulation, c, generates PV after-tax profits equal to $(1-\alpha)(R-c)$. The difference in prices between a regulated and unregulated but otherwise identical lease is equal to $(1-\alpha)c$. In Section 6, we perform such calculations to obtain the cost of anticipated and existing regulation.

test whether the estimate of β/δ is consistent with the model's prediction that it represents average beliefs.

Our baseline specification, equation (2), identifies the average effect of anticipation. Yet as we showed in Figure 1b, the structure of beliefs may be such that the anticipation effect varies with a lease's proximity to the regulation boundary. Testing for this in a simple way amounts to interacting anticipated_i with the distance of a lease to the regulation boundary.[17] Thus we augment our baseline specification as follows:

$$p_{it} = \sum_{k=0}^{K} \beta_k \text{distance}_i^k \times \text{anticipated}_i + \delta \text{regulated}_i + g_i(\text{location}_i) + X_i\Gamma + \lambda_t + \varepsilon_{it}, \qquad (3)$$

where distance_i measures the distance, in kilometers, of lease i to the nearest regulation boundary. For a linear interaction, $K = 1$, so that the effect on the price of a lease located in the anticipated area is equal to $\beta_0 + \beta_1 \text{distance}_i$. If anticipated leases closer to the regulation boundary are perceived as being more likely to be rezoned than a lease farther away, then we expect that $\beta_1 > 0$ so that the effect has a smaller negative effect on lease prices the farther is a lease from the boundary. Because we do not have a large number of observations in the anticipated regulation area, we are limited in the number K that we can employ.

Given the specification in equation (3) and the model's predictions, based on Figures 1b and 1c, the ratio of $\sum_{k=0}^{K} \beta_k \text{distance}_i^k$ and δ reflect the belief that a lease of distance equal to distance_i will be regulated in the future. As we mentioned above, we will test whether this ratio of estimated parameters is consistent with the predictions of the model, i.e., that the value lies between 0 and 1 and that its value is increasing the closer the lease is to the regulation boundary.

Note that anticipation about regulatory change may differ not only by the proximity of a lease to existing regulation boundaries, but also over time. To account for this, we can augment our baseline specification (3) by interacting our anticipated variable with a time variable. We estimate such a specification and the results, reported in the Appendix, corroborate our baseline results. Another way to enhance our model specification is by accounting for the distances to multiple regulation boundaries. While our baseline estimates use the proximity to the nearest regulation boundary, some leases lie in close proximity to multiple boundaries. In such cases, bidders for such a lease may anticipate that one or more of these boundaries may shift in the future so that the lease will be rezoned. For such leases,

[17] An approach that is more difficult to interpret is interacting the anticipated variable with polynomials in latitude and longitude, then depicting the estimates on a map.

the likelihood of being rezoned in the future may be greater than a lease near to only one boundary; the resulting price discount for leases near several boundaries should be greater than for leases near one boundary. In the Appendix, we test this by accounting for the distances to the nearest and second-nearest regulation boundaries. Accounting for distance to multiple boundaries strengthens our findings that anticipation affects lease prices.

Identification

The identification strategy premised on equations (2) and (3) attributes, after controlling for geographic location, firm-specific and time-varying heterogeneity, and lease-specific differences, any difference in prices between anticipated and unregulated leases to be caused by market anticipation that regulation is likely forthcoming. Similarly, after incorporating our full set of controls, we attribute any price difference between regulated leases and unregulated leases to be caused by the existing regulation. Several issues affect the identification and interpretation of the effects of anticipated and existing regulation, such as: (1) selection of leases by firms; (2) externalities caused by regulation, and; (3) the determination of regulation boundaries. We discuss each of these in turn.

A potential identification issue is whether leases are chosen based on regulatory status; the ability to manipulate the regulatory treatment would, in most scenarios, confound identification. However, in our application, regardless of a lease's regulatory status, bidders will in equilibrium pay for the value of owning that land. A firm that anticipates future regulation of an unregulated parcel can fully compensate itself for the expected cost of complying with future regulation by decreasing its bid by an amount equal to that expected cost. This behavior does not pose an identification issue, but is what we rely on to identify the effects of anticipation and regulation.[18]

A similar issue is whether some leases that would have been purchased in the absence of anticipation or 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 anticipation and regulation on leases for which the net present value of owning the lease, including the expected cost of regulation, is non-negative.[19]

The second identification issue is externalities arising from the regulation. The presence

[18] 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 anticipated or regulated leases. However, assuming auctions are competitive, we are able to control for producer identity, and thus our identification strategy is robust to this issue.

[19] 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.

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 generate similar price paths as depicted in Figures 1b.

We do not suspect externalities to pose an identification problem for two reasons. The first reason is due to our data and identification strategy. As depicted in Figure 2, not all unregulated leases are buffered by an anticipated area; some unregulated areas are adjacent to regulation boundaries. If externalities exist, then the leases in these unregulated areas will also be subject to them. To identify the effect of anticipation, we compare the prices of anticipated and unregulated leases. If both types of leases are subject to externalities, then the difference in their prices will identify the effect of anticipation net of any externalities. Therefore, our identification of the effect of anticipation is robust to this issue. The second 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 third identification issue is the determination of boundaries. An implicit identification assumption we are making is that the regulation boundaries are determined independently of the underlying oil sands resource. If that were not the case, any estimated price differences may be due to differences in unobserved resource quality across the boundaries. However, as discussed in detail in Bošković and Nøstbakken (2017), the regulation boundaries were drawn without consideration of the underlying resource and it is a coincidence that oil sands deposits lie below caribou ranges and critical habitats in Alberta.

5 Empirical estimates

Table 2 reports results from estimating the baseline equation (2). Each column includes progressively more controls than the previous column. Robust standard errors, adjusted for clustering across a regulation zone region, are reported in parentheses.

In the first column, we report estimates from a regression that controls only for whether the lease is anticipated for rezoning or is regulated. The estimates are of the opposite sign predicted by the model and, without any additional controls, reflect the pattern of unconditional average prices per hectare reported in Table 1.

Column (2) reports estimates from the specification that includes the controls for geographic location – the polynomial in latitude and longitude and the zone region fixed effects, the latter controlling for the identity of the nearest regulation zone to the lease – which decrease the estimates relative to column (1) so much that they are now of the predicted sign. The third column adds the firm fixed effects, which accounts for, among other things, the different cost structures across firms. These fixed effects control for a significant amount of variation in the price per hectare of leases, which can be seen from the substantial increase in the R^2 value. The coefficient estimates in this column are of the predicted relative magnitude – the anticipated coefficient estimate is smaller in magnitude than the regulated coefficient estimate. This prediction is further supported by the results from the remaining specifications.

The fourth column adds quarter-year fixed effects, which control for the volatility in the industry and the price of oil, and also captures a significant amount of variation in prices. The coefficient estimates for anticipated and regulation in this column are both statistically significant at conventional levels and remain stable even after controlling for the remaining lease-specific controls, the results of which are reported in the final column. The coefficient estimates indicate that a lease that is located in an area anticipated to be rezoned imposes a negative effect on the price of that leases but, as predicted, is not as large as the effect on a lease that is currently regulated. These results are consistent with the prediction that the anticipated costs of potential regulation are capitalized into land prices.

The preferred coefficient estimate for being in an anticipated area, -0.2562, indicates that a lease that is unregulated (thus bearing no costs from complying with current regulation) but for which there is anticipation of rezoning has a price per hectare that is 22.6% lower on average than a lease that is unregulated and for which there is no anticipation of rezoning. To put this price discount into context, the average price of a lease is \$800 per hectare, so anticipated leases are on average discounted by about \$180 per hectare. In contrast, the coefficient estimate for a regulated lease indicates that such leases are discounted by about 30% relative to unregulated leases, which amounts to a discount of \$240 per hectare for the average lease price.

To give these numbers more context, the minimum lifetime for an oil sands facility is about 20 years. At the average price for leases in our sample, these price discounts imply that the maximum effect of regulation on regulated leases is about \$12 per hectare per year, whereas for anticipated leases the effect of potential regulation is about \$9 per hectare per year.

Toward the bottom of Table 2, we report the estimate of the ratio of coefficient estimates for anticipated and regulated leases. Recall that, based on the model, this ratio reflects the average belief of the likelihood that leases in the anticipated area will be rezoned. Below each estimate, we report the standard error in parentheses. Like the coefficient estimates on which this estimate is derived, the estimates in the first two columns are nonsensible. However, after controlling for firm fixed effects in column (3), the estimates are fairly similar in value, statistically different from zero at conventional levels and, most notably, are between 0 and 1. The value of these estimates is consistent with the prediction that the ratio of the estimates reflects the market's belief that the area will be rezoned. The estimate in column (5) suggest that the market anticipates the area will be rezoned with an average probability of 0.714. We take these results to support the prediction that the market believed that an expansion of the regulation zones was quite likely.

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

	(1)	(2)	(3)	(4)	(5)
Anticipated	0.4257	-0.2988	-0.1939	-0.2474**	-0.2562**
	(0.2707)	(0.1816)	(0.1248)	(0.0958)	(0.0908)
Regulated	0.3759	-0.1000	-0.2466*	-0.3420**	-0.3588**
	(0.2601)	(0.1278)	(0.1229)	(0.1189)	(0.1303)
Number of joint owners					0.2424*
					(0.1340)
Surface mining area					0.1922
					(0.3057)
Special access area					0.0617
					(0.1609)
Key wildlife area					-0.1574
					(0.1251)
Anticipated/Regulated	1.133*	2.988	0.786**	0.724***	0.714***
	(0.657)	(3.394)	(0.358)	(0.241)	(0.227)
Quad. poly. in coordinates	N	Y	Y	Y	Y
Zone region fixed effects	N	Y	Y	Y	Y
Firm fixed effects	N	N	Y	Y	Y
Quarter-year fixed effects	N	N	N	Y	Y
R^2	0.01	0.16	0.38	0.47	0.47
Observations	4139	4139	4139	4139	4139

Notes: The dependent variable is the price per hectare of a lease, in Q1 2017 Canadian dollars. Robust standard errors, adjusted for clustering by regulation zone region, in parentheses. *, **, and *** denote estimates statistically different from zero at the 10%, 5%, and 1% significance levels.

In Table 3, we report results from estimating equation (3), which allows the effect of anticipated regulation to vary for a lease by the distance to the nearest existing regulation boundary. Table 3a reports the coefficient estimates from the regressions. Since the estimates from higher-order polynomials are difficult to interpret, Table 3b reports the estimated effects for several distances as well as the ratio of anticipated to regulated estimates by distance to the regulation boundary. The specifications in all columns include the full suite of controls that we used and reported in column (5) of Table 2; the only difference across columns in Table 3 is the degree of polynomial in distance. Since we have only 483 leases that are anticipated regulation leases, we use a maximum of a third-degree polynomial to avoid overfitting.

The pattern from the results in Table 3 is that the effect of anticipation is largest in magnitude for leases nearest to the regulation boundary and dissipates the farther away is a lease. This evidence supports the notion that anticipation, and the expected cost of potential regulation, is higher for leases that are nearer to the existing boundary, as we depicted in Figure 1b. In the context of oil sands leases, this perception for this time period makes sense, since the history of this regulation was a gradual expansion of the regulation zones over time.

Consider column (1) of Table 3, which reports estimates from an interaction of anticipated status with distance to the boundary. According to the coefficient estimate in the first row of Table 3a, -0.33826, the average effect on anticipated leases is negative and statistically significant. The coefficient estimate on the interaction term, 0.01002, is positive and indicates that the average effect of anticipation increases in value – the price discount becomes smaller – the farther a lease is from the boundary. Based on these coefficient estimates, the estimated effect of being a lease anticipated to be rezoned that is 5 kilometers from the regulation boundary, reported in the first row of Table 3b, is statistically significant and equal to -0.2881. The estimated effect indicates being anticipated for rezoning and 5 kilometers from the regulation boundary reduces the price per hectare of that lease by 25% on average, which is a price discount that is nearly 3 percentage points larger in magnitude than the average effect based on the baseline estimate of -0.2562 in Table 2. For leases farther away, the effect dissipates: at 10 kilometers from the boundary, the statistically significant estimate of -0.2380 implies a price discount of 21%, while the estimate for a lease 15 kilometers away is statistically insignificant and implies a price discount of 17% on average.

The ratio of the anticipated effect to the effect of being located in a regulation zone also differs by distance. Focusing still on column (1), the estimate for a lease that is 5 kilometers from the boundary is statistically significant and is consistent with the notion

Table 3: Anticipation effects dissipate with distance from regulation boundary

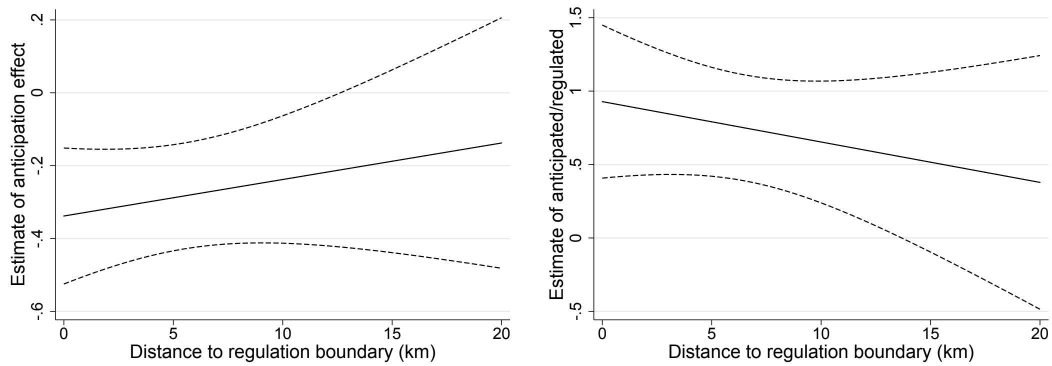
(a) Coefficient estimates

	(1)	(2)	(3)
Anticipated	-0.33826***	-0.45221***	-0.30290**
	(0.1076)	(0.1250)	(0.1242)
Anticipated×Distance	0.01002	0.03671**	-0.02220
	(0.0124)	(0.0156)	(0.0195)
Anticipated×Distance^2		-0.00061**	0.00263***
		(0.0003)	(0.0007)
Anticipated×Distance^3			-0.00003***
			(0.0000)
Regulated	-0.36426**	-0.35530**	-0.35761**
	(0.1293)	(0.1346)	(0.1331)

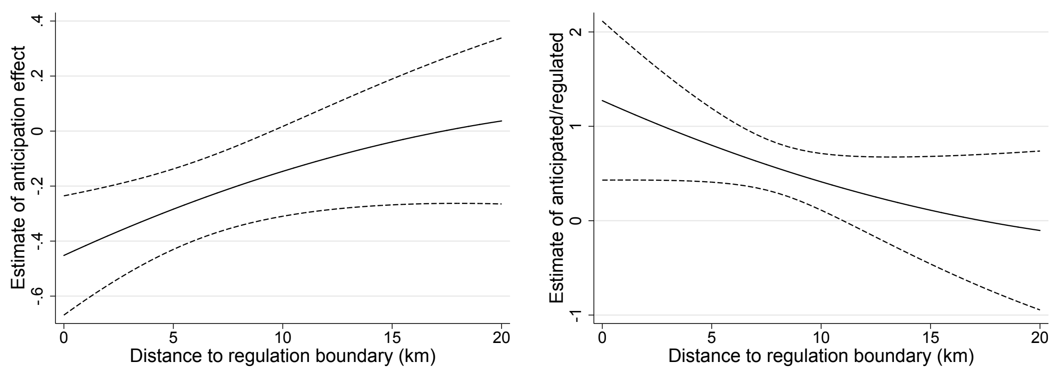
(b) Estimated effects by distance to regulation boundary

	(1)	(2)	(3)
Anticipated:			
5 km from boundary	-0.2881***	-0.2840***	-0.3525***
	(0.0840)	(0.0844)	(0.0911)
10 km from boundary	-0.2380**	-0.1464	-0.2966**
	(0.1009)	(0.0941)	(0.1095)
15 km from boundary	-0.1879	-0.0395	-0.1606
	(0.1447)	(0.1319)	(0.1476)
Anticipated/Regulated:			
5 km from boundary	0.791***	0.799***	0.986***
	(0.225)	(0.238)	(0.281)
10 km from boundary	0.653***	0.412**	0.829***
	(0.252)	(0.182)	(0.237)
15 km from boundary	0.516	0.111	0.449
	(0.372)	(0.347)	(0.352)

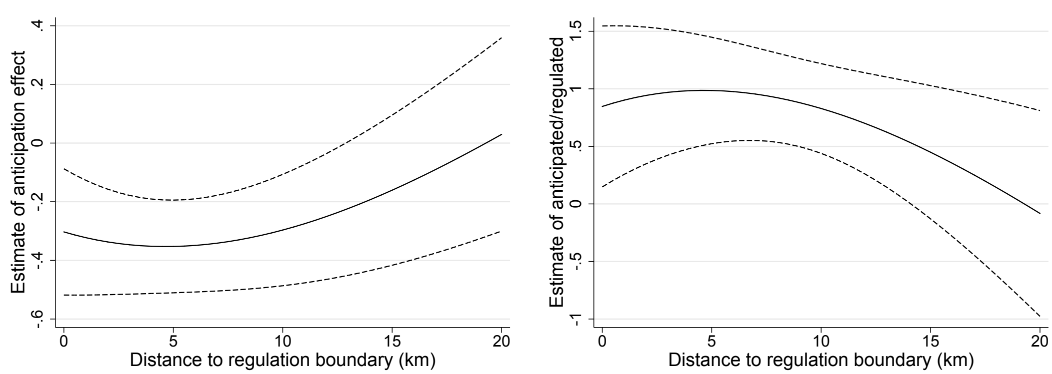
Notes: The dependent variable is the price per hectare of a lease, in Q1 2017 Canadian dollars. All specifications include a quadratic polynomial in latitude and longitude, zone region fixed effects, firm fixed effects, quarter-year fixed effects, and lease-specific controls. Robust standard errors, adjusted for clustering by regulation zone region, in parentheses. *, **, and *** denote estimates statistically different from zero at the 10%, 5%, and 1% significance levels.



(a) First-degree polynomial in distance



(b) Second-degree polynomial in distance



(c) Third-degree polynomial in distance

Figure 4: Estimates of the effect of anticipated regulation and the ratio of anticipated to existing regulation using polynomials in distance to regulation boundary

that the market anticipates such a lease would be rezoned with a probability of 0.791 on average. For a lease 10 kilometers from the boundary, the estimate falls to 0.653, while the estimate at 15 kilometers is lower in value and statistically not different from zero. Assuming that the effect of regulation is constant, these estimates are consistent with the notion that the market believed that leases nearer to the existing regulation boundary faced a stronger prospect of being rezoned than leases farther away. Such beliefs make sense based on the historical practice of the regulator.

The estimates derived from a specification of a quadratic interaction with anticipated status are much the same. The estimates from column (3), based on the third-degree polynomial interaction, are slightly different. The estimated effect of being an anticipated lease 5 kilometers from the boundary is a statistically significant -0.3525, which is virtually the same as the coefficient estimate for being regulated, in the final row of column (3) in Table 3a. This is reflected in the ratio of the estimated effects, equal to 0.986 and statistically significant. The estimate is consistent with the notion that leases 5 kilometers away were expected with near certainty to be rezoned in the near future. For leases farther away, the effect, as with the other specifications, dissipates. For a lease 10 kilometers away, the anticipated effect implies a price discount of nearly 26% on average, while the estimated effect dissipates sharply for leases just farther away.

To visualize the pattern in these estimates, we plot the estimated anticipation effects for leases up to 20 kilometers from the regulation boundary, as well as the ratio of anticipated to regulated effects, for the three different specifications. For each subfigure, the diagram on the left is the estimated effect of anticipation by distance to the regulation boundary, and the diagram to its immediate right is the ratio of anticipated and regulated effects by distance. Though the estimates are noisy, given we have less than 500 observations of anticipated leases, the pattern is clear regardless of polynomial: the effects of anticipated rezoning are largest in magnitude the closer is a lease to the boundary and the effects become negligible the farther is a lease from the existing regulation boundary. Similarly, the ratio of estimates – the figures on the right – are all higher in value the closer is a lease to the regulation boundary and decrease in value the farther is a lease.

Robustness checks

We investigate how our estimates change when (1) we use different degree polynomials in latitude and longitude, and (2) we restrict our sample by proximity to the regulation boundaries. We discuss each in turn.

For our baseline specification, we specified the unknown function f as a quadratic polynomial in latitude and longitude; here we investigate whether our estimates are robust to different polynomial specifications. Table 4 reports the results from using a linear polynomial and no polynomial in latitude and longitude.[20] Both specifications employ, except for the polynomial in latitude and longitude, the same set of controls as the preferred specification. As a result, the estimates are directly comparable to the estimates in column (5) of Table 2.

Table 4: Estimates using alternative specifications of polynomials in latitude and longitude

	Linear polynomial	No polynomial
Anticipated	-0.2431***	-0.2034**
	(0.0807)	(0.0773)
Regulated	-0.2823***	-0.2921***
	(0.0913)	(0.0901)
Anticipated/Regulated	0.861***	0.696***
	(0.292)	(0.220)
R^2	0.47	0.46
Observations	4139	4139

Notes: The dependent variable is the price per hectare of a lease, in Q1 2017 Canadian dollars. All specifications include zone region fixed effects, firm fixed effects, quarter-year fixed effects, and lease-specific controls. Robust standard errors, adjusted for clustering by regulation zone region, in parentheses. *, **, and *** denote estimates statistically different from zero at the 10%, 5%, and 1% significance levels.

The coefficient estimate for anticipated leases when using the linear polynomial, reported in the first column, is virtually identical to our baseline estimate of -0.2562. The estimate when using no polynomial is slightly smaller in magnitude. The ratio of anticipated and regulated estimates under either polynomial specification is quite similar to the estimate in Table 2, all of which suggest that the market believed anticipated leases would be rezoned with a high probability.

We also estimate equation (3) using the different polynomials. The results, reported in the Appendix, possess the same pattern as our baseline estimates: anticipated leases in closer proximity to the existing regulation boundary incur greater price discounts relative to those farther away.

Altogether, these estimates suggest that our choice of polynomial does not affect our finding that anticipation about regulatory change is capitalized into lease prices.

[20] As we mentioned in Section 4, we cannot use polynomials of degree greater than two due to collinearity problems.

Our second robustness check concerns lease proximity to regulation boundaries. If the multidimensional RD approach is valid, the estimates should not drastically change if we restrict the sample of leases to those located nearer to the regulation boundary. Table 5 reports estimates from using subsamples of leases, regardless of regulatory status, located within 20 and 10 kilometers from the existing regulation boundary.[21] Each set of estimates is from a specification using the same set of controls as our preferred specification, so the estimates are directly comparable to those in column (5) of Table 2.

The estimates indicate that anticipated leases incur a price discount that is statistically different from zero and similar in magnitude to the estimate from using the full sample. In particular, the 10-kilometer sample estimate, -0.1930, implies a price discount of 18%, within a few percentage points of our full sample estimate. The ratio of anticipated and regulated estimates in the 10-kilometer sample, 0.606, is fairly similar to our full sample estimate.

Table 5: Estimates using samples of leases by proximity to regulation boundaries

	Leases within:	
	20 km	10 km
Anticipated	-0.1948**	-0.1930*
	(0.0678)	(0.0968)
Regulated	-0.4304***	-0.3184*
	(0.1491)	(0.1823)
Anticipated/Regulated	0.453***	0.606
	(0.152)	(0.404)
R^2	0.53	0.59
Number of anticipated leases	446	324
Number of regulated leases	879	738
Observations	1935	1450

Notes: The dependent variable is the price per hectare of a lease, in Q1 2017 Canadian dollars. All specifications include a quadratic polynomial in latitude and longitude, zone region fixed effects, firm fixed effects, quarter-year fixed effects, and lease-specific controls. Robust standard errors, adjusted for clustering by regulation zone region, in parentheses. *, **, and *** denote estimates statistically different from zero at the 10%, 5%, and 1% significance levels.

We also estimate equation (3) using the restricted samples. The results, reported in the Appendix, also possess the same pattern as our baseline estimates, indicating that price

[21] We choose 20 kilometers because this contains about half of our full sample. Each lease typically covers a large area, so restricting the smaller sample to a distance below 10 kilometers would severely reduce the sample, particularly among the anticipated leases.

discounts for anticipated leases are largest for those leases closest to the regulation boundary.

Overall, these robustness checks suggest that our multidimensional RD approach is robust to alternative functional form specifications and is not driven by outlying leases in terms of proximity to existing regulation boundaries.

6 How much does anticipation matter?

Our estimates indicate that anticipation about potential regulatory change has an economically and statistically significant effect on land prices. There are two ways to quantify the extent to which anticipation matters. The first way is to aggregate the effects across all leases to determine whether anticipation matters in the aggregate, particularly in comparison to the aggregate cost imposed on regulated leases. Second, anticipation may in many contexts be difficult to observe. For researchers estimating the cost of existing regulation, does not accounting for anticipation matter? Our estimates allow us to quantify this.

Calculating the aggregate cost of anticipation is fairly straightforward. We need to compute leases under the counterfactual scenario where there is no anticipation and then calculate the cost, after accounting for taxes, by subtracting observed prices from counterfactual prices. If we denote the observed price of a lease as p, then by using the baseline estimate in column (5) of Table 2 of -0.2562, the price discount is equal to 22.6%, so the counterfactual price of an anticipated lease is equal to $p/(1-0.226)$. Similarly, the price discount for a regulated lease is 30% on average, so the counterfactual price of a regulated lease is $p/(1-0.30)$. For unregulated leases, their prices remain the same.

The difference between a lease's observed price and its counterfactual price describes only the loss of auction revenue from regulation. To calculate the present value (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 regulated lease with lifetime real revenue R that incurs a cost of regulation, c, generates PV after-tax profits equal to $(1-\alpha)(R-c)$. These 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%.[22]

In Figure 5, we plot the estimates for the aggregate costs of anticipated regulation and existing regulation, the latter we label 'regulated' for consistency with its use in the previous sections, as well as their sum. The aggregate cost of anticipated regulation for leases sold during 2003–2016 is equal to $424.70 million. In contrast, the aggregate cost of existing regulation – for leases located within the regulation zones – is equal to $1,772.15 million. Together, these estimates imply that anticipation increases the cost of regulation by 24% over the cost imposed on regulated leases. As the figure demonstrates, this finding suggests that anticipation about potential regulatory change does increase aggregate costs significantly.

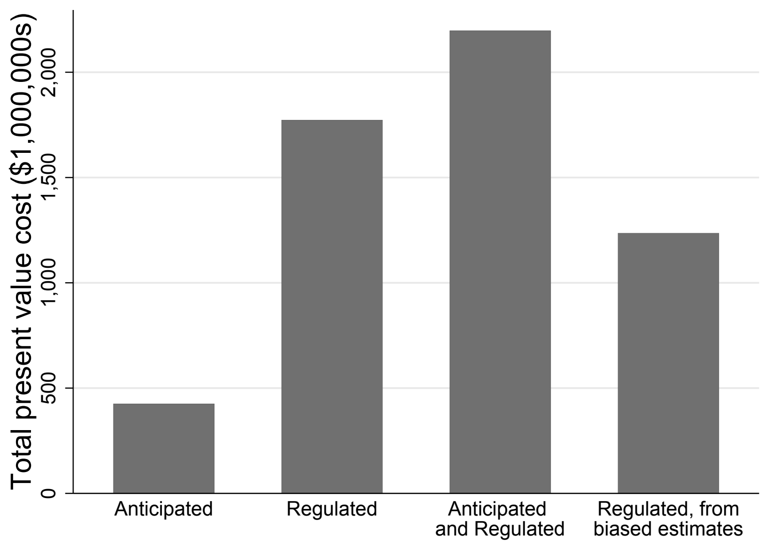


Figure 5: Aggregate cost estimates for leases sold during 2003–2016

The second way to quantify the importance of anticipation is in its absence from empirical analysis. Often, it may be difficult to measure or be aware of market anticipation of regulatory change. In this case, anticipation may be omitted in analyses estimating the cost of regulation. While it is straightforward to calculate the bias from implicitly setting the cost of anticipation to zero, we ask whether there is a bias in estimating the cost of existing regulation when anticipation is omitted.

[22]The maximum rate is 40%. While using this rate generates the largest aggregate cost estimates, the relative difference, as a percentage, of anticipated and regulated costs remains the same. As a result, we use the minimum rates for a conservative estimate.

In not accounting for anticipation, parcels that are anticipated for rezoning will be categorized by the researcher as unregulated. An identification problem arises because treatment and control groups are misspecified: being unregulated (at least in our context), 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.[23]

To quantify the size of this omitted variables bias using our data, we estimate equation (2) but exclude the anticipated variable. In doing so, there are only two types of leases in the specification: regulated and unregulated. Anticipated leases, not being regulated, fall into the latter category. This is equivalent to not observing anticipated rezoning of unregulated leases in estimating the effect of the existing regulation. We report the estimation results in Table 6, which has the same structure as Table 2, so the estimates are directly comparable to the baseline estimates.

Table 6: Estimates of the effect of regulation when not accounting for anticipation

	(1)	(2)	(3)	(4)	(5)
Regulated	0.2963	0.0109	-0.1744*	-0.2520**	-0.2621**
	(0.2403)	(0.1110)	(0.0949)	(0.1087)	(0.1208)
Quad. poly. in coordinates	N	Y	Y	Y	Y
Zone region fixed effects	N	Y	Y	Y	Y
Firm fixed effects	N	N	Y	Y	Y
Quarter-year fixed effects	N	N	N	Y	Y
Lease controls	N	N	N	N	Y
R^2	0.01	0.16	0.38	0.47	0.47
Observations	4139	4139	4139	4139	4139

Notes: The dependent variable is the price per hectare of a lease, in Q1 2017 Canadian dollars. Robust standard errors, adjusted for clustering by regulation zone region, in parentheses. *, **, and *** denote estimates statistically different from zero at the 10%, 5%, and 1% significance levels.

The estimates in Table 6 differ from the same-column estimates in Table 2. Though the coefficient estimates for a regulated lease are of the predicted sign after controlling for firm fixed effects, the estimates are consistently smaller in magnitude than the baseline estimates. This supports the prediction that not accounting for anticipation leads to an underestimate of the effect of existing regulation.

[23]Not accounting for anticipation that regulated parcels may become unregulated will similarly lead to underestimates of the cost of existing regulation.

The coefficient estimate in column (5), -0.2621, implies that the price per hectare of a regulated lease is on average 23% lower than the price of an unregulated lease. This estimated effect is 7 percentage points smaller in magnitude than the estimated effect based on the estimate in column (5) of Table 2. To put these differences into context, the sample average price per hectare is \$800. The estimated effect that accounts for anticipation indicates that a regulated lease is priced \$240 per hectare less than a regulated lease. The estimated effect that does not account for anticipation underestimates this amount by 23%, or \$56 per hectare.

These estimates, which support the prediction that omitting expectations biases the regulation effect estimates toward zero, are quite similar to the findings in Malani and Reif (2015) and Coglianese et al. (2016). In those studies, which exploit variation in expectations over time, omitting expectations from the econometric analysis biases the estimates in predictable ways. Our results, which we obtain from exploiting variation in expectations over space, reinforce their findings that incorporating anticipation of changing policy matters for identifying the effect of existing policy.

We can use these estimates to contrast the aggregate cost of regulation when anticipation is accounted for to the biased aggregate costs of regulation when anticipation is omitted. We depict the biased cost of regulation as the final bar in Figure 5. The total cost of existing regulation when anticipation is omitted is equal to \$1,235.13 million. The difference between the aggregate cost of existing regulation when anticipation is accounted for, the second bar in the figure, and when it is not is equal to \$537.01 million. This represents a 30% underestimate of the cost of existing regulation and suggests that accounting for anticipation matters for accurately estimating the costs of existing regulation, let alone the costs of anticipation.

When anticipation is not accounted for, its cost is implicitly set equal to zero. The total bias from omitting anticipation – the difference between the aggregate cost of regulation that includes the cost of anticipated and existing regulation and the biased aggregate cost – is \$961.71 million. This implies that not accounting for anticipation generates a cost estimate of regulation that is only 56% of the aggregate cost of anticipated and existing regulation. This significant difference in estimates reinforces the evidence that accounting for anticipation does matter in accurately estimating the costs of regulation.

7 Concluding remarks

The purpose of this paper is to quantify the effect of anticipation about potential regulatory change on land prices. We have proposed an empirical approach to separately identify the causal effect of existing regulation and anticipation effects when the market believes regulation boundaries will change.

Using data on oil lease prices and changing land use regulations from Canada and employing a multidimensional regression discontinuity framework, we estimate both the costs of anticipated and existing regulation. Our empirical results indicate that anticipation matters. While the aggregate costs of existing regulation are significant, anticipation increases the cost of regulation considerably. Further, analysis that omits anticipation severely underestimates the causal effect of existing regulation on lease prices and the aggregate cost of regulation.

Our paper therefore offers important lessons for policymakers and researchers that go beyond land prices, land use regulation, or administrative boundaries. Our results indicate that evolving policies generate anticipatory behavior by the market which in turn increases the cost of those policies. Accordingly, policymakers should carefully consider how any signals they send or do not send causes market anticipation. For researchers, our results suggest that anticipation can be an influential behavioral phenomenon that is worth measuring, both on its own and for accurately estimating the causal effects of existing policy.

There are several possibilities for extending this work. One possibility is to use our framework to quantify the government's tradeoff between credibility through commitment and flexibility. To reduce anticipation costs, the government can commit to existing regulations. However, the government may value flexibility should anything unexpected happen. A key part of this tradeoff is quantifying the effects of anticipation caused by a flexible regulatory approach.

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A Appendix

This appendix reports supplementary data and estimation results. Section A.1 provides additional historical data on the regulations. Section A.2 provides robustness checks in addition to those provided in Section 5. Section A.3 tests whether anticipation grows over time. Section A.4 tests whether anticipation effects increase with the proximity of a lease to multiple regulation boundaries.

A.1 Historical data on regulations

The regulations were first implemented in 1991. To illustrate how much smaller the regulation zones were in 1991 compared to the 2003 and 2013 zones, Figure A1 displays the 1991 zones from the original regulation document.[24] Comparing this figure to Figure 2, the total area of the 1991 zones was much smaller than the zones during 2003-2013 or after the final expansion. Although not displayed in this document, the subsequent boundary changes – twice in 1994, in 1996, and in 2003 – all involved expansions of some kind with no contractions.

The regulation zones were provided in digital shapefiles starting in the mid-2000s. Prior to this time, the regulation zones were all printed in the same documents outlining the regulations. The maps were drawn, according to one civil servant with whom we spoke, with a "thick pencil," implying the exact location of the boundary was imprecise on those maps. Without shapefiles, there were two ways for one to determine whether a particular parcel was located in a zone: (1) it was flagged as such when it went up for auction, or (2) one could ask the Ministry of the Environment. Because the printed maps were drawn without sufficient detail, we cannot use them for our empirical analysis.

A.2 Results from additional robustness checks

Section 5 reported robustness checks of our baseline estimate by re-estimating equation (2) with (1) alternative degrees of polynomials in latitude and longitude, and (2) using samples of leases that are near regulation boundaries. In this section, we report results from re-estimating equation (3) under similar robustness checks.

Table A1 reports estimates from re-estimating equation (3) using lower-degree polynomials in latitude and longitude than the quadratic polynomial we used for our baseline

[24] Though the legend states that these are "caribou ranges," the shaded areas depict the regulation zones. Historically the phrases zone and range are used interchangeably to denote the regulation zones.

ATTACHMENT 2 TO INFORMATION LETTER 91-17

Figure A1: The regulation zones in 1991

specification. The first three columns report estimates from using a linear polynomial; the remaining three columns report estimates from omitting any controls for latitude and longitude. Table A1a reports coefficient estimates, while Table A1b reports estimated effects by proximity to regulation boundaries. But for how the polynomial in latitude and longitude is specified, all specifications employ the full set of controls.

The coefficient estimates across Table A1a are all similar in value and statistical significance to the coefficient estimates in Table 3a. Similarly, the estimated effects are similar in value and statistical significance. Regardless of the polynomial specification, anticipated leases that are nearer to regulation boundaries incur greater price discounts than those farther away. The pattern of the ratio of anticipated and regulated estimates for each distance is similar to the estimates in Table 3b and suggest the market anticipated leases nearer existing boundaries to be more likely to be rezoned than those farther away. Unlike the estimates in Table 3b, some of these estimates are greater than 1; this suggests that controlling for a sufficiently high degree polynomial in latitude and longitude is important for obtaining reasonably-valued estimates.

Figures A2 and A3 plot the estimated anticipation effects and the ratio of anticipated to regulated estimates by distance to the regulation boundary using a linear polynomial and no polynomial in latitude and longitude, respectively. These estimated effects follow the same pattern as our estimates obtained from using a quadratic polynomial in latitude in longitude, depicted in Figure 4.

Overall, we take these results as evidence that the heterogeneous effect of anticipation by distance to regulation boundaries is robust to alternative polynomials in latitude and longitude.

Table A2 reports estimation results from re-estimating equation (3) using restricted samples of leases by proximity to regulation boundaries. The first three columns report estimates using leases within 20 kilometers of regulation boundaries; the remaining three columns report estimates from the sample of leases within 10 kilometers of regulation boundaries. Table A2a reports coefficient estimates, while Table A2b reports estimated effects by proximity to regulation boundaries. All specifications employ the full set of controls.

The coefficient estimates in Table A2a are fairly similar to the coefficient estimates in Table 3a, as well as the estimated effects and the estimated ratio of anticipated and regulated effects in Table A2b. A notable exception is the 10 kilometer subsample, which generates estimates that do not possess the same pattern of results as all of the other estimates in the paper. This is likely due to the fact that the sample is too small and with a specification that controls for geographic location and distance to the boundary (for leases that are already close to the boundary), we are overfitting the data.

Figures A4 and A5 plot the estimated anticipation effects and the ratio of anticipated to regulated estimates by distance to the regulation boundary using the 20-kilometer and 10-kilometer sample of leases, respectively. The 20-kilometer estimated effects follow the same pattern as our estimates using the full sample. The 10-kilometer estimates are unwieldy due to the reasons stated above.

Overall, we take these results as evidence that, for a sufficiently large sample of leases, the heterogeneous effect of anticipation by distance to the boundary is robust to outlying leases.

Table A1: Anticipation effects by distance to regulation boundaries, using alternative polynomials in latitude and longitude

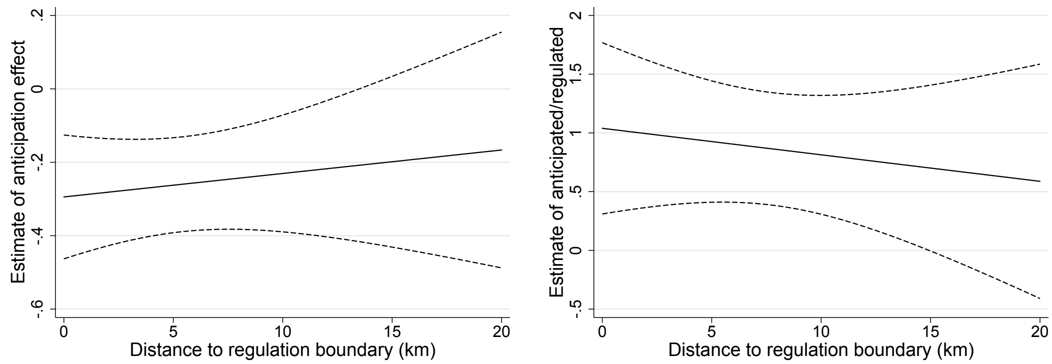
(a) Coefficient estimates

	Linear polynomial:			No polynomial:		
	(1)	(2)	(3)	(4)	(5)	(6)
Anticipated	-0.29442***	-0.38652***	-0.24262*	-0.27236***	-0.36689***	-0.22315*
	(0.0972)	(0.1110)	(0.1231)	(0.0933)	(0.1028)	(0.1108)
Anticipated×Distance	0.00639	0.02823*	-0.02844	0.00844	0.03074*	-0.02571
	(0.0116)	(0.0158)	(0.0212)	(0.0118)	(0.0158)	(0.0204)
Anticipated×Distance^2		-0.00050*	0.00261***		-0.00052**	0.00258***
		(0.0003)	(0.0008)		(0.0002)	(0.0007)
Anticipated×Distance^3			-0.00003***			-0.00003***
			(0.0000)			(0.0000)
Regulated	-0.28333***	-0.27284**	-0.27426***	-0.29318***	-0.28257***	-0.28375***
	(0.0910)	(0.0967)	(0.0951)	(0.0897)	(0.0957)	(0.0942)

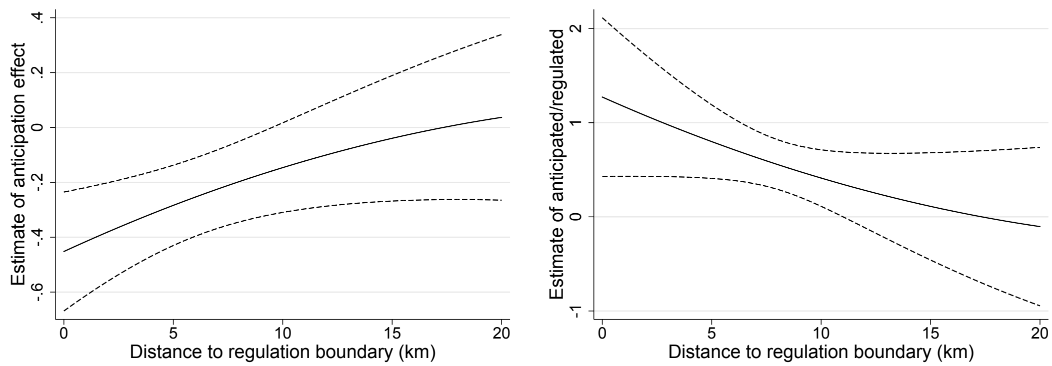
(b) Estimated effects by distance to regulation boundary

	Linear polynomial:			No polynomial:		
	(1)	(2)	(3)	(4)	(5)	(6)
Anticipated:						
5 km from boundary	-0.2625***	-0.2580***	-0.3237***	-0.2302***	-0.2261***	-0.2912***
	(0.0746)	(0.0702)	(0.0738)	(0.0697)	(0.0672)	(0.0722)
10 km from boundary	-0.2305**	-0.1547*	-0.2992***	-0.1879**	-0.1111	-0.2546**
	(0.0917)	(0.0871)	(0.0997)	(0.0890)	(0.0916)	(0.1048)
15 km from boundary	-0.1985	-0.0767	-0.1936	-0.1457	-0.0219	-0.1378
	(0.1341)	(0.1301)	(0.1471)	(0.1338)	(0.1376)	(0.1528)
Anticipated/Regulated:						
5 km from boundary	0.926***	0.946***	1.180***	0.785***	0.800***	1.026***
	(0.314)	(0.343)	(0.390)	(0.233)	(0.253)	(0.297)
10 km from boundary	0.814***	0.567**	1.091***	0.641**	0.393*	0.897***
	(0.307)	(0.221)	(0.283)	(0.251)	(0.231)	(0.239)
15 km from boundary	0.701	0.281	0.706*	0.497	0.077	0.486
	(0.429)	(0.411)	(0.415)	(0.405)	(0.467)	(0.440)

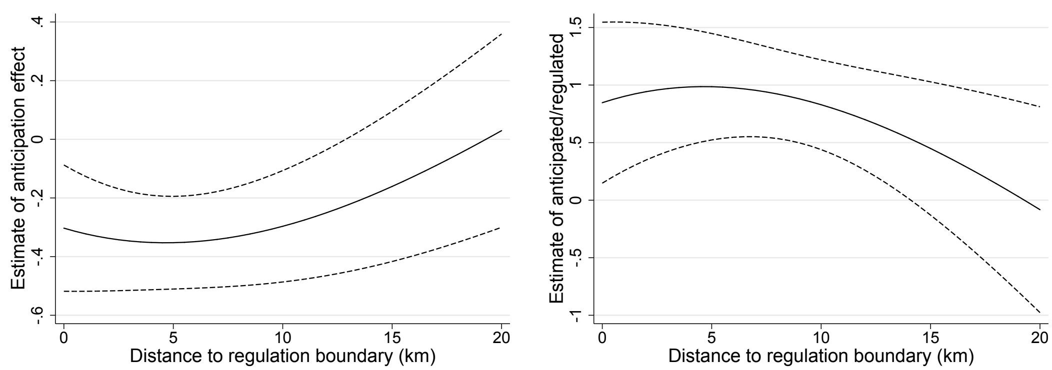
Notes: The dependent variable is the price per hectare of a lease, in Q1 2017 Canadian dollars. All specifications include the specified polynomial in latitude and longitude, zone region fixed effects, firm fixed effects, quarter-year fixed effects, and lease-specific controls. Robust standard errors, adjusted for clustering by regulation zone region, in parentheses. *, **, and *** denote estimates statistically different from zero at the 10%, 5%, and 1% significance levels.



(a) First-degree polynomial in distance

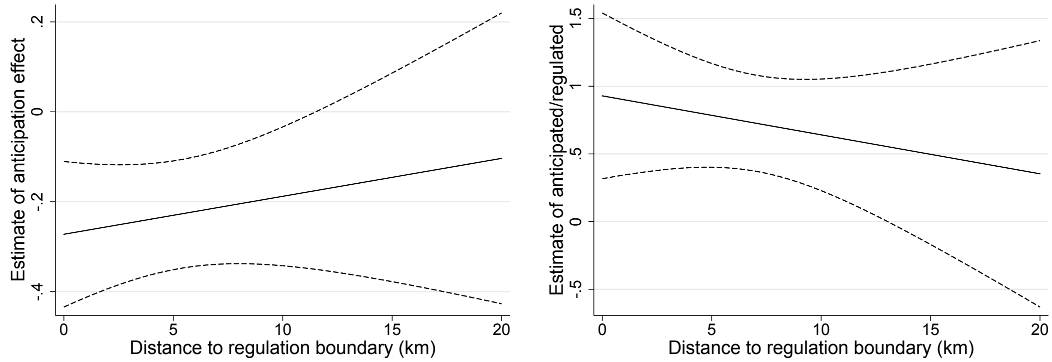


(b) Second-degree polynomial in distance

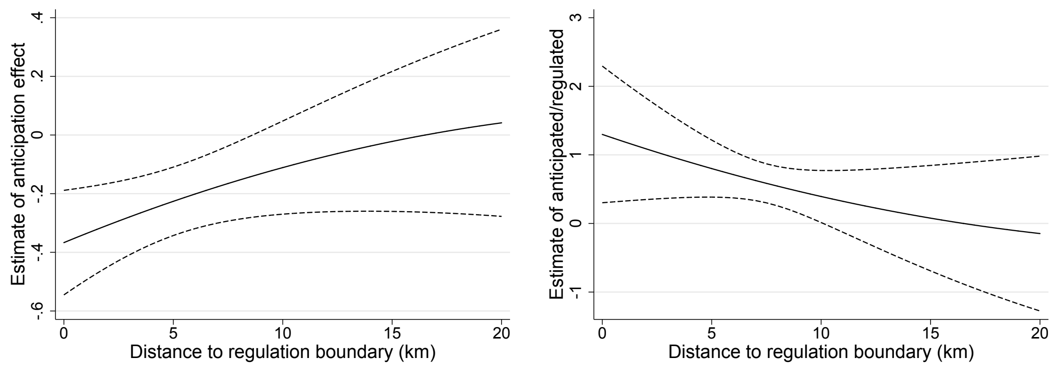


(c) Third-degree polynomial in distance

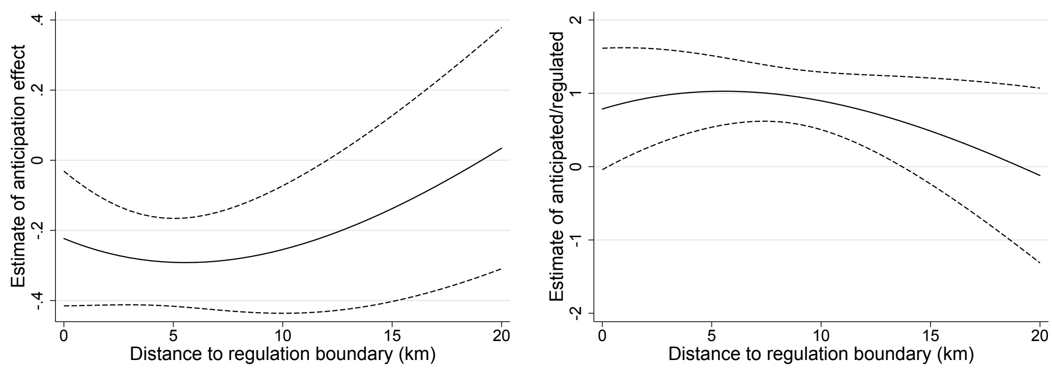
Figure A2: Estimates of the effect of anticipated regulation and the ratio of anticipated to existing regulation using polynomials in distance to regulation boundary and a linear polynomial in latitude and longitude



(a) First-degree polynomial in distance



(b) Second-degree polynomial in distance



(c) Third-degree polynomial in distance

Figure A3: Estimates of the effect of anticipated regulation and the ratio of anticipated to existing regulation using polynomials in distance to regulation boundary and no polynomial in latitude and longitude

Table A2: Anticipation effects by distance to regulation boundaries, using restricted samples based on distance to boundary

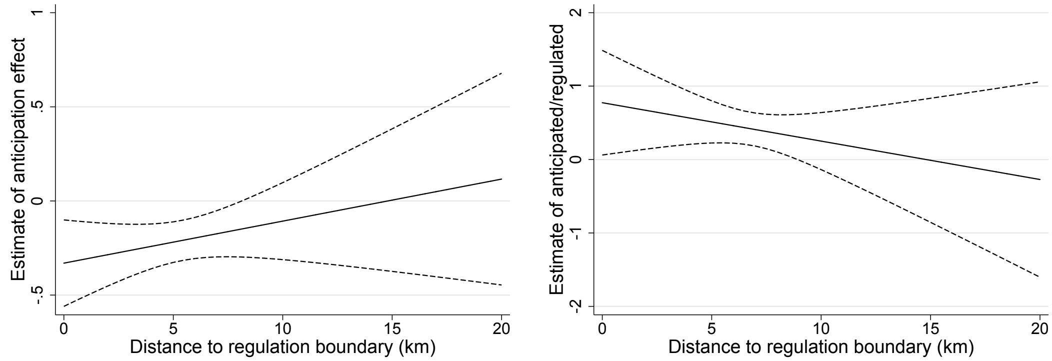
(a) Coefficient estimates

	Sample within 20 km:			Sample within 10 km:		
	(1)	(2)	(3)	(4)	(5)	(6)
Anticipated	-0.33038**	-0.06282	-0.05036	0.00982	0.08226	-0.02179
	(0.1324)	(0.1264)	(0.1480)	(0.1190)	(0.1314)	(0.1101)
Anticipated×Distance	0.02232	-0.11382**	-0.12657	-0.06398	-0.13170	0.05771
	(0.0218)	(0.0462)	(0.0883)	(0.0520)	(0.1073)	(0.1268)
Anticipated×Distance^2		0.00815***	0.01005		0.00773	-0.04641
		(0.0028)	(0.0118)		(0.0161)	(0.0378)
Anticipated×Distance^3			-0.00007			0.00386
			(0.0004)			(0.0032)
Regulated	-0.42669**	-0.40631**	-0.40588**	-0.30613	-0.30572	-0.30614
	(0.1543)	(0.1525)	(0.1529)	(0.1778)	(0.1766)	(0.1782)

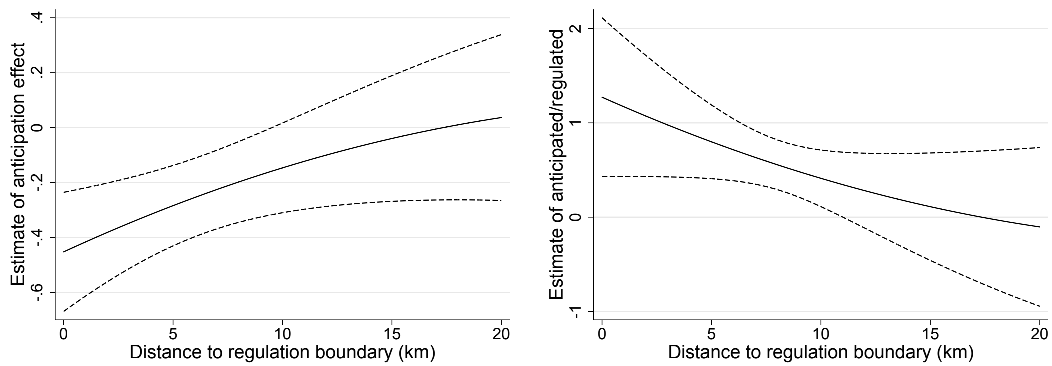
(b) Estimated effects by distance to regulation boundary

	Sample within 20 km:			Sample within 10 km:		
	(1)	(2)	(3)	(4)	(5)	(6)
Anticipated:						
5 km from boundary	-0.2188***	-0.4281***	-0.4406***	-0.3101*	-0.3831***	-0.4111***
	(0.0621)	(0.0949)	(0.1132)	(0.1677)	(0.1012)	(0.1012)
10 km from boundary	-0.1071	-0.3857***	-0.3808**	-0.6299	-0.4621	-0.2267
	(0.1179)	(0.1310)	(0.1425)	(0.4210)	(0.7244)	(0.8332)
15 km from boundary	0.0045	0.0643	0.0766			
	(0.2184)	(0.1856)	(0.2308)			
Anticipated/Regulated:						
5 km from boundary	0.513***	1.054**	1.086*	1.013	1.253	1.343
	(0.175)	(0.514)	(0.575)	(0.826)	(0.811)	(0.869)
10 km from boundary	0.251	0.949*	0.938*	2.058	1.512	0.741
	(0.236)	(0.503)	(0.508)	(1.971)	(2.608)	(2.779)
15 km from boundary	-0.011	-0.158	-0.189			
	(0.514)	(0.491)	(0.607)			

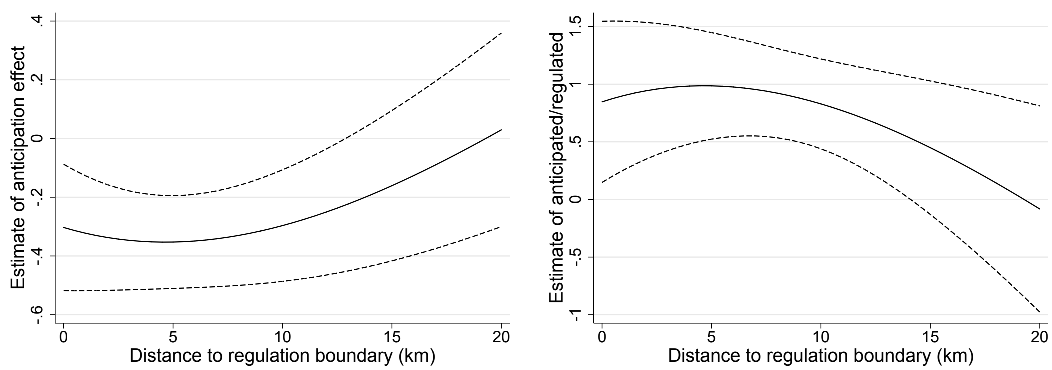
Notes: The dependent variable is the price per hectare of a lease, in Q1 2017 Canadian dollars. All specifications include a quadratic polynomial in latitude and longitude, zone region fixed effects, firm fixed effects, quarter-year fixed effects, and lease-specific controls. Robust standard errors, adjusted for clustering by regulation zone region, in parentheses. *, **, and *** denote estimates statistically different from zero at the 10%, 5%, and 1% significance levels.



(a) First-degree polynomial in distance

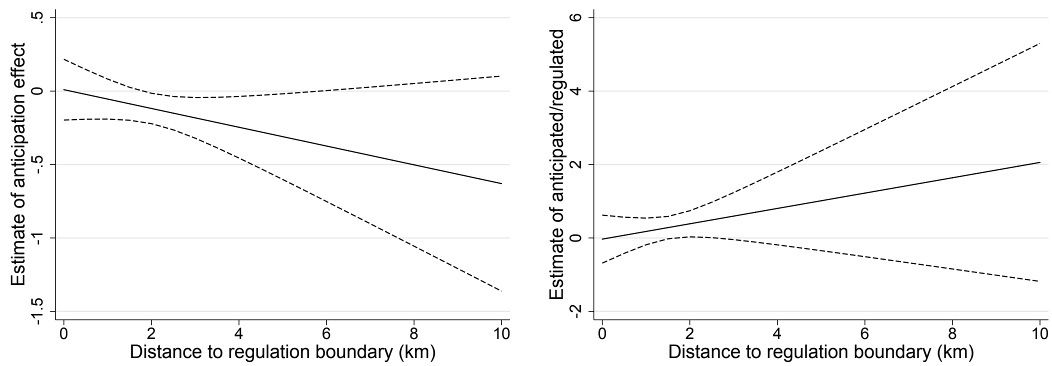


(b) Second-degree polynomial in distance

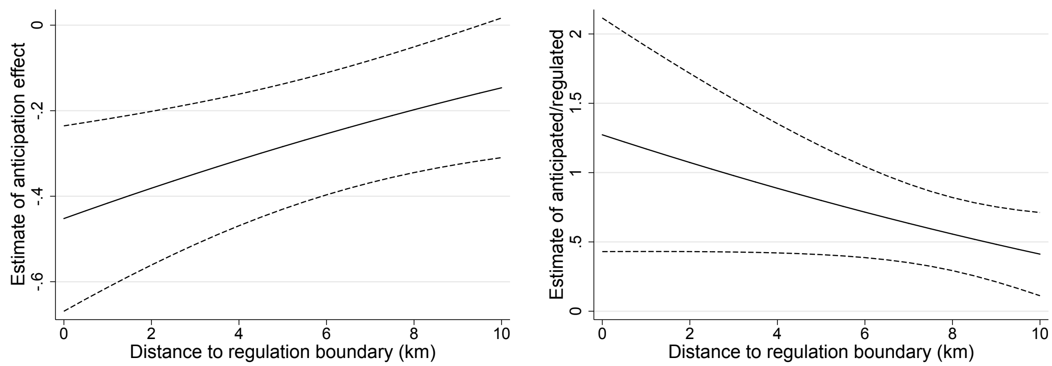


(c) Third-degree polynomial in distance

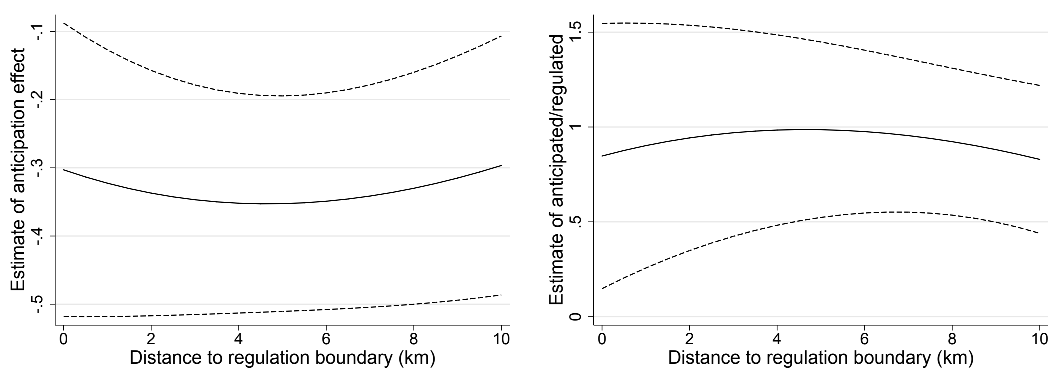
Figure A4: Estimates of the effect of anticipated regulation and the ratio of anticipated to existing regulation using sample of leases within 20 kilometers of regulation boundaries



(a) First-degree polynomial in distance



(b) Second-degree polynomial in distance



(c) Third-degree polynomial in distance

Figure A5: Estimates of the effect of anticipated regulation and the ratio of anticipated to existing regulation using sample of leases within 10 kilometers of regulation boundaries

A.3 Does anticipation change over time?

Just like how anticipation about regulatory change may differ by the proximity of a lease to existing regulation boundaries, anticipation may change over time. Given the history of expansion of these regulations, it may be the case that anticipation about regulatory change grew over time. To test this possibility, we augment our baseline specifications by interacting our anticipated variable with a linear time trend:

$$\begin{aligned} p_{it} &= \sum_{k=0}^{K} \beta_k \text{distance}_i^k \times \text{anticipated}_i + \sum_{k=0}^{K} \alpha_k \text{distance}_i^k \times \text{anticipated}_i \times t \\ &\quad + \delta \text{regulated}_i + g(\text{location}_i) + X_i \Gamma + \lambda_t + \varepsilon_{it}, \end{aligned} \tag{4}$$

where t is the numerical quarter between 2003 and 2016. If anticipation does change over time, then according to this specification the interaction with the time trend will shift the effect of anticipation up or down for a lease of a given distance to the boundary. If anticipation is growing over time such that the price discount of anticipated leases increases over time, then the effect of anticipation should increase in magnitude for larger values of t.

We report results from estimating equation (4) without any distance effects, i.e., $K = 0$, in Table A3. For convenience, we report only the estimates from our preferred specification that includes the full set of controls. The coefficient estimate for the interaction term is negative and statistically significant, supporting the prediction that anticipation about regulatory change increases over time.

To put these estimates into perspective, the estimated effect on an anticipated lease in the first quarter of 2005 is equal to 0.01, with a p-value of 0.99. In contrast, for leases sold in the first quarter of 2009, the estimated effect is equal to -0.4846, is statistically significant at the 1% level, and implies an average price discount of 37%.

We report the results from estimating equation (4) with $K = 1, 2$ and 3 in Figures A6a, A6b, and A6c, respectively. For each polynomial in distance, we plot the estimated effect of anticipated and the ratio of this estimate to the coefficient estimate for regulated leases. To depict how time affects anticipation, we plot the estimates evaluated at the first quarter of 2005 and the first quarter of 2012. The estimates for the former and the 90% confidence interval are plotted as the thinner lines, whereas the estimates for the latter and the confidence interval are plotted using thicker lines.

Regardless of the distance polynomial, the pattern of the effect of anticipation over distance is the same as our baseline estimates, depicted in Figure 4: the closer is a lease to the

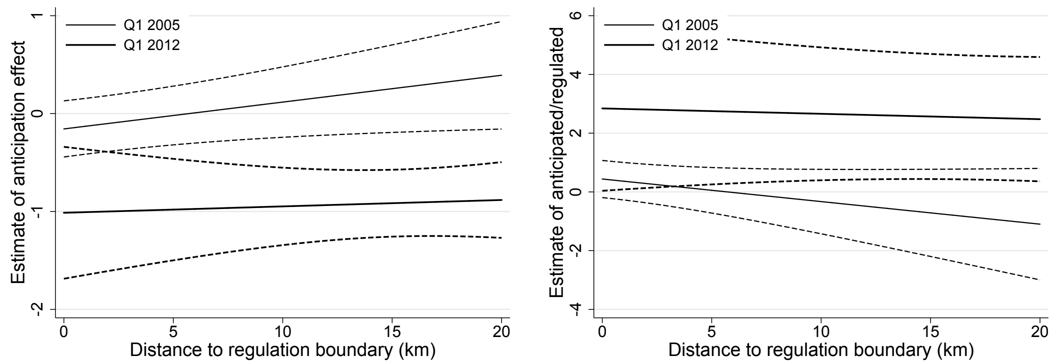
Table A3: Estimates of the effect of anticipated regulation over time

	(1)
Anticipated	0.27434
	(0.2749)
Anticipated×Quarterly time trend	-0.03036**
	(0.0124)
Observations	4139

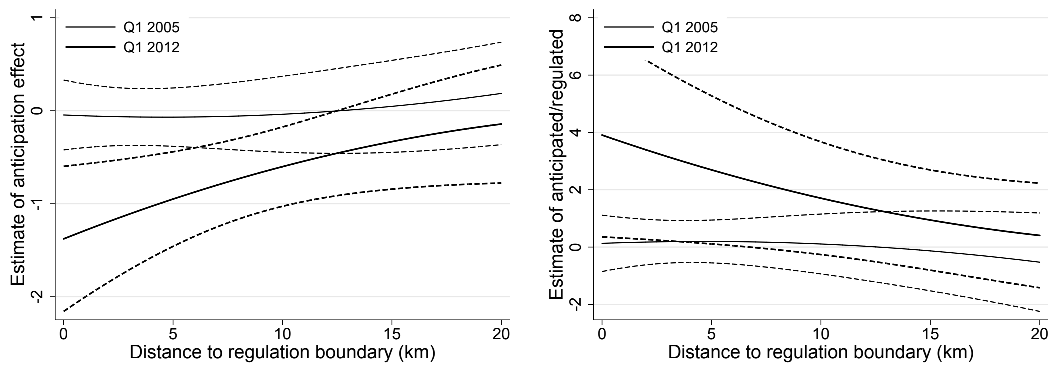
Notes: The dependent variable is the price per hectare of a lease, in Q1 2017 Canadian dollars. The specification includes all controls, including a quadratic polynomial in latitude and longitude. Robust standard errors, adjusted for clustering by regulation zone region, in parentheses. *, **, and *** denote estimates statistically different from zero at the 10%, 5%, and 1% significance levels.

regulation boundary, the greater is the price discount. As for whether anticipation effects change over time, the estimates at Q1 2005 are above the estimates at Q1 2012, indicating that the value of the estimated effect of anticipation by proximity to the regulation boundary decreases the further along in time a lease is sold. This is consistent with the prediction that anticipation grows over time.

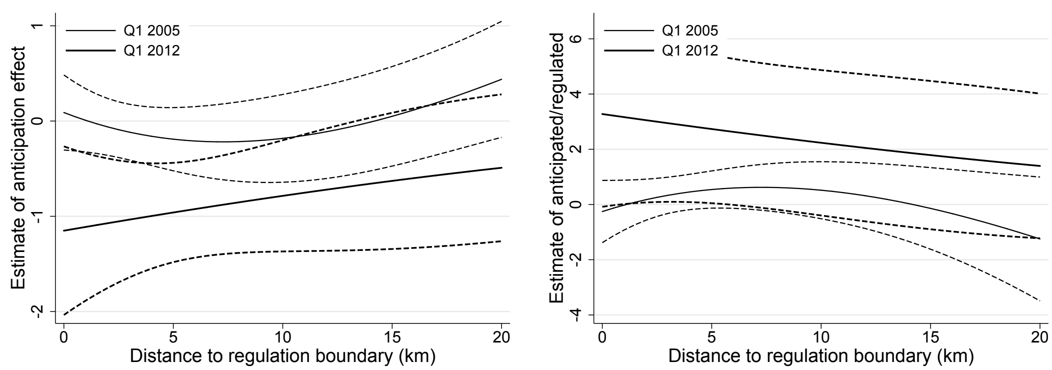
Altogether, the estimates reported in this section indicate that the effect of anticipation lowers the price of anticipated leases at an increasing rate over time. Given the occurrence of several boundary expansions since 1991, it is reasonable that the market anticipated the boundaries would shift outward and that such anticipation increased as time passed by.



(a) First-degree polynomial in distance



(b) Second-degree polynomial in distance



(c) Third-degree polynomial in distance

Figure A6: Estimates of the effect of anticipated regulation using polynomials in distance interacted with a time trend

A.4 Does anticipation change in proximity to multiple regulation boundaries?

In estimating equation (3), we test whether the effect of anticipation changes with the proximity of a lease to the nearest regulation boundary. The results reported in Table 3 and Figure 4 support the prediction that it does and, as predicted, that price discounts of anticipated leases increase in magnitude the nearer is a lease to the boundary. In this section, we investigate further how anticipation may differ by the proximity of a lease to regulation boundaries. While our baseline estimates used the proximity to the nearest regulation boundary, some leases lie in close proximity to multiple boundaries. In such cases, bidders for such a lease may anticipate that one or more of these boundaries may shift in the future so that the lease will be rezoned. For such leases, the likelihood of being rezoned in the future may be greater than a lease near to only one boundary; the resulting price discount for leases near several boundaries should be greater than for leases near one boundary.

To test this prediction, we still use the distance to the nearest regulation boundary and also calculate the distance to the second-nearest regulation boundary. For anticipated leases, the mean second-nearest distance is 24 kilometers with a standard deviation equal to just over 13 kilometers. To test whether the proximity to the second-nearest regulation boundary has an effect on anticipated lease prices, we augment equation (3) as:

$$\begin{aligned} p_{it} \;=\; & \sum_{k=0}^{K} \beta_k \text{distance}_i^k \times \text{anticipated}_i + \sum_{j=0}^{J} \alpha_j \text{distance}_i^j \times \text{anticipated}_i \times \text{distance}_{2i} \quad (5) \\ & + \delta \text{regulated}_i + g(\text{location}_i) + X_i \Gamma + \lambda_t + \varepsilon_{it}, \end{aligned}$$

where distance_{2i} is the distance of lease i to the second-nearest regulation boundary.[25] We expect the effect of the second-nearest distance to be similar to the effect of the nearest distance, though perhaps at a smaller magnitude because the proximity of the nearest boundary leads to a greater likelihood of being rezoned. For example (though in most of our estimations we will consider cases where $K = J$), if $K = 1$ and $J = 0$ then the effect of anticipation is equal to $\beta_0 + \beta_1 \text{distance}_i + \alpha_0 \text{distance}_{2i}$, which depends on both the nearest and second-nearest distances. We expect in this case that $\beta_1 > 0$ and $\alpha_0 > 0$ as well as $\beta_1 > \alpha_0 > 0$.

In Table A4, we report results from estimating equation (5) for the case of $K = 1$

[25] Note that we are not employing higher-degree polynomials of the second-nearest distance, but instead using a linear interaction. We have too few anticipated lease observations to explore higher degree polynomials of a second distance variable with any statistical precision.

and $J = 0$. For convenience, we only report estimates from our preferred specification that includes the full set of controls. The coefficient estimates for the interactions of the distance of nearest- and second-nearest regulation boundary are of the predicted sign. To put the estimates into perspective, if the nearest boundary is 5 kilometers from the lease and the second-nearest boundary is 10 kilometers away, then the estimated effect of being an anticipated lease is equal to -0.3361, which is statistically significant at the 5% level. Increasing the distance of the second-nearest boundary leads to an estimated effect equal to -0.2982, statistically significant at the 1% level. For increasing values of the distance to the second-nearest boundary, the estimated effect continues to decrease in magnitude.

Table A4: Anticipation and proximity to nearest and second-nearest boundaries

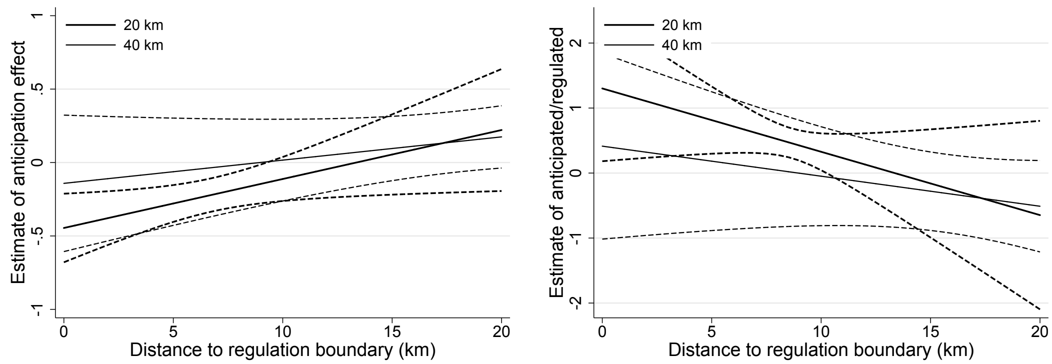
	(1)
Anticipated	-0.46363**
	(0.1936)
Anticipated×Distance	0.01038
	(0.0120)
Anticipated×Distance to second-nearest boundary	0.00757
	(0.0106)
Observations	4038

Notes: The dependent variable is the price per hectare of a lease, in Q1 2017 Canadian dollars. The specification includes all controls. Robust standard errors, adjusted for clustering by regulation zone region, in parentheses. *, **, and *** denote estimates statistically different from zero at the 10%, 5%, and 1% significance levels.

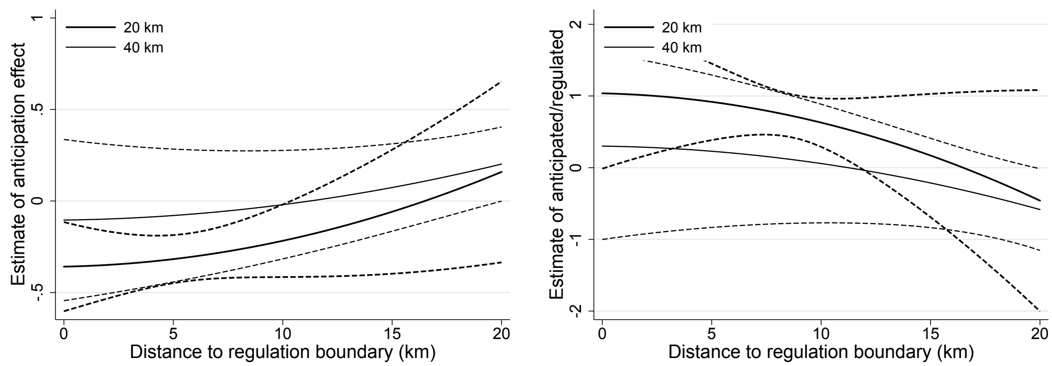
We report results from estimating equation (5) for $K = J = 1, 2$ and 3 in Figures A7a, A7b, and A7c, respectively. To depict how the second-nearest distance affects anticipation, we plot the estimates evaluated at distance values of the second-nearest boundary equal to 20 kilometers and 40 kilometers. We pick 20 kilometers as the smallest value because it allows us to plot estimates of the effect of anticipation for distances of the nearest regulation boundary up to 20 kilometers. The estimates using the 20 kilometer second-nearest distance and the 90% confidence interval are plotted using the thicker lines, whereas the estimates using second-nearest distance equal to 40 kilometers and the associated confidence interval are plotted using thinner lines.

Similar to the results in the previous sections of this appendix, the pattern of the effect of anticipation over distance is the same as with our baseline estimates: the nearer is an anticipated lease to the closest regulation boundary, the greater is the price discount. And more relevant to the tests in this section, the effect of the distance to the second-nearest boundary increases the price discount. In particular, for a given distance to the nearest regulation boundary, the effect of anticipation on a lease that is 20 kilometers from the second-nearest boundary is greater in magnitude than an anticipated lease that is 40 kilometers from the second-nearest boundary, all else being equal. This supports the prediction that the market anticipates leases that lie near more than one regulation boundary are more likely to be rezoned than leases located near only one regulation boundary.

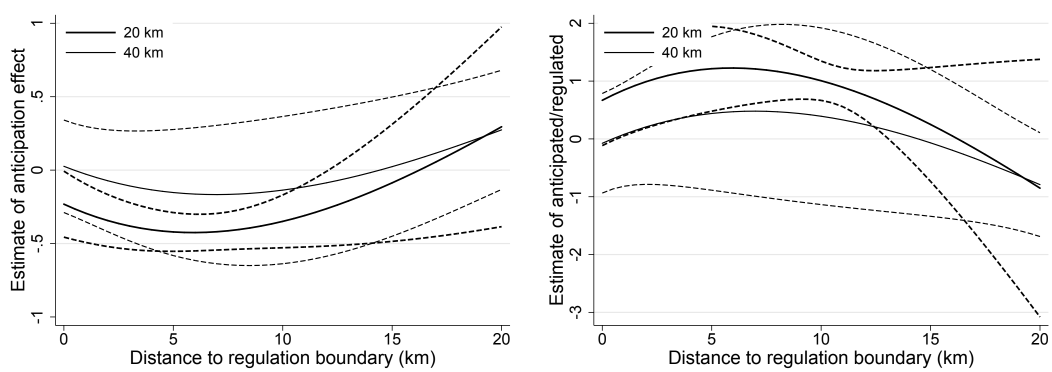
Altogether, the estimates in this section indicate that price discounts for anticipated leases are greater the closer the leases are located to one or more existing regulation boundaries. We take this as further evidence that the market anticipates regulatory change, since leases near several boundaries are more likely to be rezoned from a change to one or more boundaries than a lease located near only one boundary.



(a) First-degree polynomial in distance



(b) Second-degree polynomial in distance



(c) Third-degree polynomial in distance

Figure A7: Estimates of the effect of anticipated regulation using polynomials in distance interacted with distance to second-nearest regulation boundary