Master's Thesis

The impact of the Auckland Unitary Plan on the spatial arrangement of land values

by

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1 Introduction

Rapidly rising housing costs in cities across the globe has led to the emergence of the Yes-In-My-Back-Yard (YIMBY) movement, which argues that cutting land use regulations (LURs) will boost housing supply and bring prices down. This movement has the broad support of mainstream economists such as Moretti (2019) and Glaeser & Gyourko (2005). But emerging voices, such as Murray & Gordon (2021) and Condon (2020), argue that relaxing land use regulations simply grants windfall profits to the owners of upzoned properties, and doesn't necessarily increase the subsequent supply of dwellings or ease the underlying burden of urban land rents.

To examine these opposing perspectives, this paper asks the research question *"what impact do land use regulations have on the spatial arrangement of urban land values"*. We search for answers in the context of the Auckland Unitary Plan (AUP), which significantly relaxed height and density limits across broad swathes of Auckland, New Zealand in 2016.

We set the scene in Section 2 by describing the background context in which the AUP was designed and passed into law. Next, Section 3 surveys the the economic literature and identifies three key pathways through which LURs influence land values, and core challenges faced by the empirical literature in proving the size and scale of these mechanisms. Section 4 embeds these three mechanisms within the canonical open- and closed-city models, providing a clear set of predicted effects of LURs under different assumptions.

We then proceed to an empirical evaluation of the AUP's impact on land values in Auckland. Section 5 describes the key datasets, including a novel measure of LUR stringency available at a high level of granularity. Our two identification strategies follow, with Section 6 deploying a boundary discontinuity design, and Section 7 using a first-difference approach. We tie these findings together with a concluding discussion in Section 8.

2 Background to the Auckland Unitary Plan

Auckland is New Zealand's largest city, comprising 1.7 million residents as of 2021 (NZ, 2021). Prior to 2010 the city was administered by seven different local councils, each of which conducted their own spatial planning via separate district plans. In late 2010, these local authorities were merged into the unitary Auckland Council, which retained the legacy district plans. What followed was a multi-year process of planning for Auckland's future, including the creation of a 'unitary plan' that would govern land use regulations across the city.

Discussions with the public took place in 2012, and the first draft of the plan was released in early 2013. After multiple iterations and three years of public hearings, the decisions version of the Auckland Unitary Plan (AUP) became operative on 15 November 2016. Our analysis below therefore relies on observations from 2011 for pre-announcement measures of LURs and land values, and data from 2021 to observe post-treatment effects.

Crucial to this study, the AUP made a significant effort to increase housing supply by relaxing land use regulations within the city. House prices in Auckland had more than doubled in real terms in the two decades before 2013, reaching a median price that was 7 times the median household income (Housing and Development, 2022; Chaston, 2022). An emerging narrative held that strict land use regulations were to blame for these rising house prices (Lawrie, 2011).

Under the legacy district plans, land use had been tightly regulated by so-called 'single family zoning', which required that most residential land parcels only host a single dwelling, with height limits of 8-11 metres (2-3 storeys) and 'setbacks' requiring space to be left between boundaries and the street/neighbouring properties (Fredrickson and Balderston, 2013; A. D. Council, 1999). Rare exceptions were limited to the 'town centres' dotted throughout the city. Housing construction had fallen to below 5,000 dwellings per year, equal to around only 1% of the city's stock (NZ, 2022).

In response, and after several years of bitter public debate over density, sprawl, and the need to protect neighbourhood character, the AUP introduced several residential zones with much less restrictive regulations. Significant portions of the city were subject to 'upzoning', where developers were permitted taller height limits, smaller setbacks, and more intensive site coverage ratios relative to the legacy plans. Table 1 summarises the four key residential zones.

Table 1: Residential zones in the Auckland Unitary Plan:

Zone	**Dwelling controls**	**Max height limit**	**Max site coverage**	**Boundary Setbacks**
Single House Zone (SHZ)	1 per site	2 storeys	35%	1m
Mixed Housing Suburban (MHS)	min $45m^2$	2 storeys	40%	1m
Mixed Housing Urban (MHU)	min $45m^2$	3 storeys	45%	1m
Terraced Housing & Apartment Buildings (THAB)	min $45m^2$	5-7 storeys	50%	0m

The THAB zone permits construction with 5 to 7 storeys and site coverage ratios of up to 50%. This reflects a significant increase in the number of dwellings that can legally be built, compared to the past as well as other residential zones within the AUP. While a typical land parcel of 750 square metres was previously restricted to building a single standalone house, being zoned for THAB grants a landowner the legal right to build an apartment building containing around 12 units. The remaining sections of this paper seek to examine the predicted and observed impact of this upzoning on the spatial arrangement of land values within Auckland.

3 Literature Review

Land regulations are theorised to influence urban land values through three distinct pathways: the amenity effect; the profit effect; and the scarcity effect. We describe each in turn. In Section 4, we will proceed to parametreise these three effects within open- and closed-city models.

3.1 Amenity Effect

Urban space is riddled with spatial externalities: from positive amenities such as knowledge spillovers, thick labour markets and economies of scale; to disamenities such as noise, congestion and shadowing from neighbouring properties (Ciccone and Hall, 1993; Glaeser et al., 1992). Land use regulations which successfully maximise amenity value will increase the utility delivered by those locations, resulting in greater willingness-to-pay for access to those locations, ultimately raising land rent (Atkinson-Palombo, 2010; Brueckner, 1990). LURs can therefore either raise or lower land values in a particular location, depending on the direction of their net impact on utility. A benevolent social planner would seek to implement LURs which efficiently balance positive and negative externalities such that the aggregate value of land across the entire economy is maximised (McDonald & McMillen, 2012).

Amenity effects were the historical justification for the introduction of LURs. During the AUP public hearings, much of the public debate around upzoning centred on the impact that apartments would have on shading of neighbours, traffic congestion, competition for street parking, and the overall 'character' of the neighbourhood (Wilson, 2016).

3.2 Scarcity Effect

Perhaps the most common refrain within the public debate around LURs is the argument that upzoning will expand the supply of housing, ultimately reducing house prices. In the economic literature this story is carried-through to land values, where binding LURs are thought to reduce the supply of residential land within a given city, resulting in land values rising for all parcels which are zoned for housing (Cheshire and Vermeulen, 2009; Quigley and Rosenthal, 2005). This is often referred to as the 'supply effect' but we adopt the term 'scarcity effect' as it makes it clear that the key mechanism is a scarcity of housing capacity. Through this scarcity effect, LURs are expected to burden tenants with higher rents, but generate windfall gains for the existing owners of residential property (Brueckner, 1990; Ellickson, 1977; Greenaway-McGrevy et al., 2021).

Fischel (2001) explains that 'homevoters' rationally recognise that upzoning will reduce the value of their properties, and lobby aggressively against upzoning as a result. Indeed, the AUP public hearing process featured significant lobbying by homeowners' organisations against upzoning in their neighbourhoods (Wilson, 2016).

3.3 Profit Effect

McDonald & McMillen (2012) use a model of land-use intensity to characterise what we describe as the profit effect. Every parcel of land faces an exogeneous market price and construction cost to produce housing floorspace, which yields a profit-maximising density of floorspace that an unconstrained landowner would provide on a given parcel of land. Regulations which force the permitted density of housing below this optimal point will therefore lower the value of the land itself.

We refer to this as the profit effect: LURs can lower land values by limiting the quantity of housing that can legally be supplied there. It is observed most clearly at Auckland's urban growth boundary: properties just inside the boundary sell for 10 times more than those which do not have permission to build housing because they are zoned for rural use (Grimes and Liang, 2009).

There is also an element of spatial competition within the profit effect. Locations are, to varying extents, substitutes for one another. LURs which ban certain types of housing at one location may cause demand to spill-over to nearby locations where such activity is permitted, causing land values to rise in those alternative locations (Brueckner, 1990).

Section 4 below explores the shape of these three effects in the case of both an open- and closed-city model.

3.4 Empirical Research

The scarcity effect is the central focus of much of the empirical literature on LURs and property prices. Early correlational studies mostly found that areas with more strict LUR tended to have higher property prices (Katz and Rosen, 1987; Beaton, 1991; Malpezzi, 1996; Quigley and Raphael, 2005a) and faster growth in house prices over time (Pollakowski and Wachter, 1990; Green, 1997).

However, estimating the scarcity effect as a causal relationship has been plagued by identification issues, largely due to endogeneity in the process of setting LURs (Fischel, 1990; Quigley and Raphael, 2005b). Areas with high property prices tend to have high income residents who are highly motivated to lobby for strict land use regulations, either to prevent their neighbourhoods from changing or to protect their property values (Fischel, 2001). Similarly, an issue that we confront in the analysis below is that upzoning may be targeted at areas which are already primed for growth, such that observed appreciation in land values is caused by these unobserved factors rather than by upzoning itself.

Instrumental variables have commonly been used to overcome this endogeneity, by identifying exogeneous variation in land use regulations through factors such as historic density, political predispositions and traffic congestion (Ihlanfeldt, 2007; Saiz, 2010; Mayer and Somerville, 2000; Quigley et al., 2008). Freemark (2020) utilises a difference-in-difference strategy to find that properties which were upzoned around transit stations in Chicago grew by 15-23% more than a control group, a measure of the profit effect. Similar to our study, Greenaway-McGrevy et al. (2021) use data on repeat sales in Auckland and find that properties which were upzoned to THAB grew at an annual rate up to 3% faster than comparable properties in the Single House Zone. Zhou et al. (2008) use a boundary discontinuity design to analyse a 1957 downzoning in Chicago and found that the positive amenity effect was sufficient to outweigh any negative profit effects from lost option to develop. We deploy the latter two methods below.

One significant challenge faced by studies of this nature is the difficulty of measuring LURs in a manner which can be readily compared across jurisdictions with wildly differing regulatory regimes. Common methods include indices identifying the presence of different regulations (Deakin, 1989; Jackson, 2016; Mayer and Somerville, 2000; Pendall, 2000) and surveys asking developers about the ease of building, such as the Wharton Index (Gyourko et al., 2008; Kok et al., 2014; Mayer and Somerville, 2000; Quigley et al., 2008). However, these methods may be imprecise or biased by subjective factors (Lewis and Marantz, 2019).

In this study we deploy a novel measure of LURs, using the outputs of a model which calculates the maximum number of dwellings that can be legally built on every individual parcel in Auckland, given the active regulations in place (Balderston and Fredrickson, 2014). With repeat observations on both LURs and land values at multiple points in time, our datasets enable a panel set-up and the use of first-difference estimates. Finally, while most previous studies operate at the level of whole neighbourhoods or cities, our data measures the stringency of regulations at the individual parcel level, enabling a relatively new level of granularity.

4 Models

Before proceeding to our empirical analysis, we begin by developing the theoretical basis of the relationship between LURs and the spatial arrangement of land values, using an Alonso-Muth-Mills (AMM) monocentric city model (Alonso, 1964; Muth, 1969; Mills, 1967). For each of the three effects discussed above, we characterise their impact on land values near the city centre, in suburban locations, and at the edge of the city. We also consider these relationships in the case of both open- and closed-city assumptions, as these two extremes generate quite different predictions.

4.1 Basic Set-Up

We follow the standard set-up of the AMM model (Brueckner, 2011). Consumers enjoy utility from consumption of a numeraire good c with price normalised to 1, and housing services q which costs p per unit, generating utility $u = u(c, q)$. All households earn income y and commute distance x kilometres (km) to the city centre, with costs of t per km. Their budget constraint is therefore: $y - tx = c + pq$. Spatial equilibrium requires that utility be the same everywhere, meaning that the price of housing declines with distance to the central business district (CBD) ($\frac{\partial p}{\partial x} < 0$) and the quantity of housing consumption rises with distance to the CBD $\frac{\partial q}{\partial x} > 0$.

We assume the price of agricultural land outside of the city to be zero, which determines the city's edge. Our analyses below consider the case of an open city, where utility is fixed at $\bar{u}$ and the city's population N is determined endogeneously, and a closed city, where utility is endogeneous and the city's population is fixed at $\bar{N}$. Colloquially, in the open city model, LURs cannot change any individuals' utility, and there exists an infinite population of people waiting to move into or out of the city in order to maintain utility at $\bar{u}$, whereas in the closed city model, the population are trapped inside our city, and consumer utility can be improved or reduced by LURs.

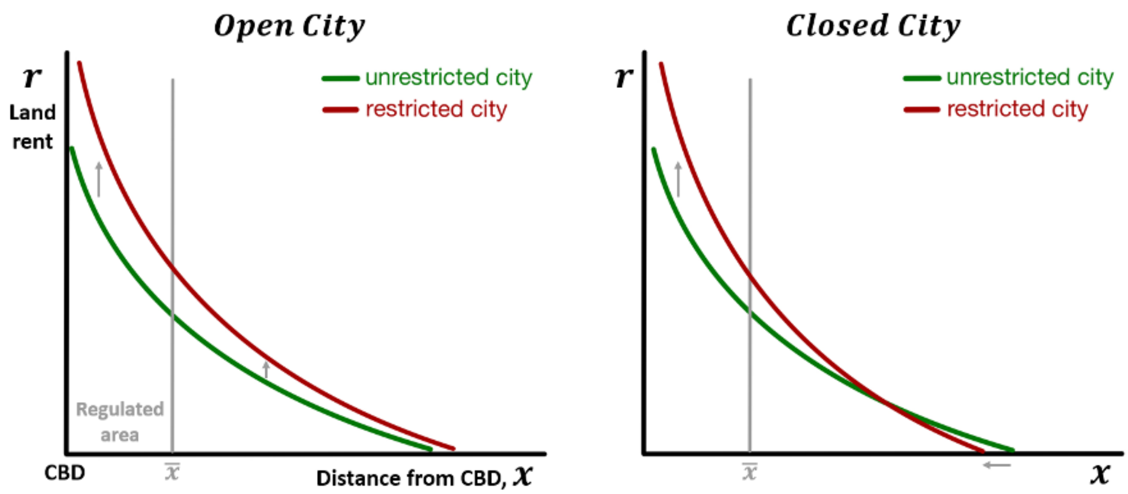
Housing services are constructed by a constant-returns technology where $q = h(S)$ represents the housing services produced per square meter of land, and S represents the capital-to-land ratio ('structural density'). We normalise the price of capital to 1, such that profits are $p \times h(S) - S - r$ where r is the rental price of land in each location, which determines land values. Because competition drives profits to zero, land rent is $r = p(x, u) \times h(S) - S$, which declines with distance to the CBD.

We are interested in how LURs will change the shape of this bid-rent curve for land, through the amenity, profit and scarcity effects. Following the example of Bertaud & Brueckner (2005), we consider the case of a binding height restriction enacted on all land located between 0 and $\bar{x}$ km of the city centre.

4.2 Amenity Effect

Turner, Haughwout & van der Klaauw (2014) demonstrate a simple model which demonstrates how positive amenities spill-over to properties on either side of a LUR boundary, but they do so using homogeneous space. To demonstrate the amenity effect within our AMM model, let us assume that tall buildings generate a disamenity for nearby properties, possibly due to shading, noise or loss of privacy. Implementing a height limit between 0 and $\bar{x}$ therefore generates a positive externality which increases amenity levels within the regulated area, along with spillover benefits decline with distance to the edge of the regulated area (similar to Rossi-Hansberg et al., 2010). The impact of these positive amenities is depicted in Figure 1 below, which plots land rents r by distance to the city centre x.

Figure 1: Amenity Effect



With utility fixed at $\bar{u}$ in the open city model, the increased amenity value attracts new residents to the city and enables landowners in all parts of the city to raise their prices. Because a small amount of the positive amenity value spills over to the edge of the city, the height restriction also raises rent there, expanding the city outwards. Conversely, in the closed city model, increased amenity within the regulated area is able to raise utility for all members of the city. With central locations made relatively more attractive, land rents rise there, while areas at the city edge have become relatively less attractive, lowering land rents there. The bid-rent curve therefore becomes more steep, and the edge of the city moves inwards.

Because amenity effects operate by raising the utility generated by a given location, LURs which increase the aggregate sum of land values throughout the economy, via the pathway of amenity effects, can be interpreted as welfare-enhancing.

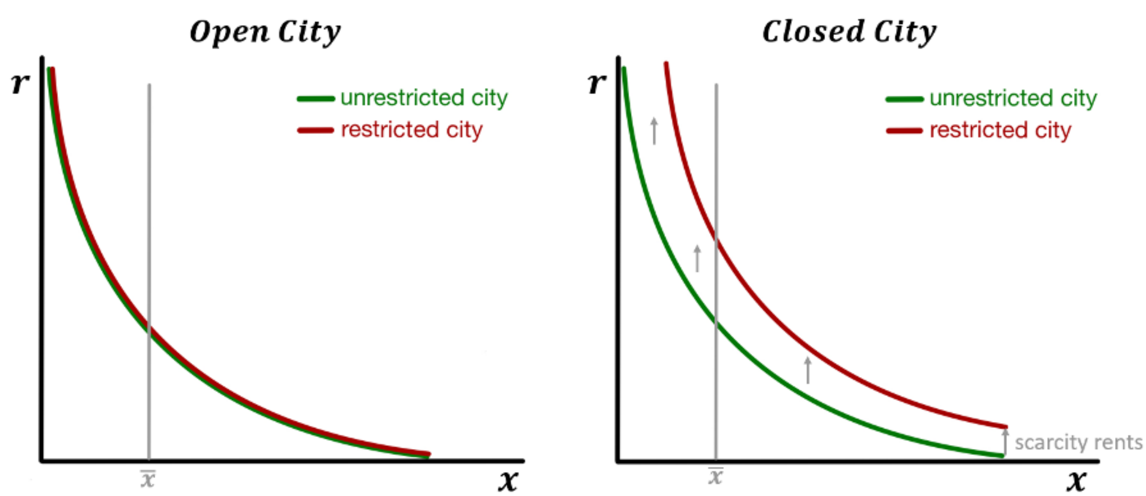
4.3 Scarcity Effect

Despite representing one of the central claims made by upzoning advocates and being heavily investigated within the empirical literature, there has been relatively little theoretical modelling of the pathway through which LURs are anticipated to raise land values across an entire city.

Parker (2021) develops one such model to describe the impact of New Zealand urban growth boundaries using a closed AMM model. We adapt that model here, whereby a height limit within the regulated area reduces the supply of housing below efficient levels, putting upwards pressure on the price of housing services, reducing utility for all residents of the closed city, which ultimately drives up land prices upwards throughout the city.

It is this upward-shifting of the bid-rent curve for land that characterises the scarcity effect, visible in the right-hand panel of the figure below: a reduction in the available capacity for residential land increases the value of all residential land throughout the city, generating scarcity rents for all landowners in the closed city.

Figure 2: Scarcity Effect

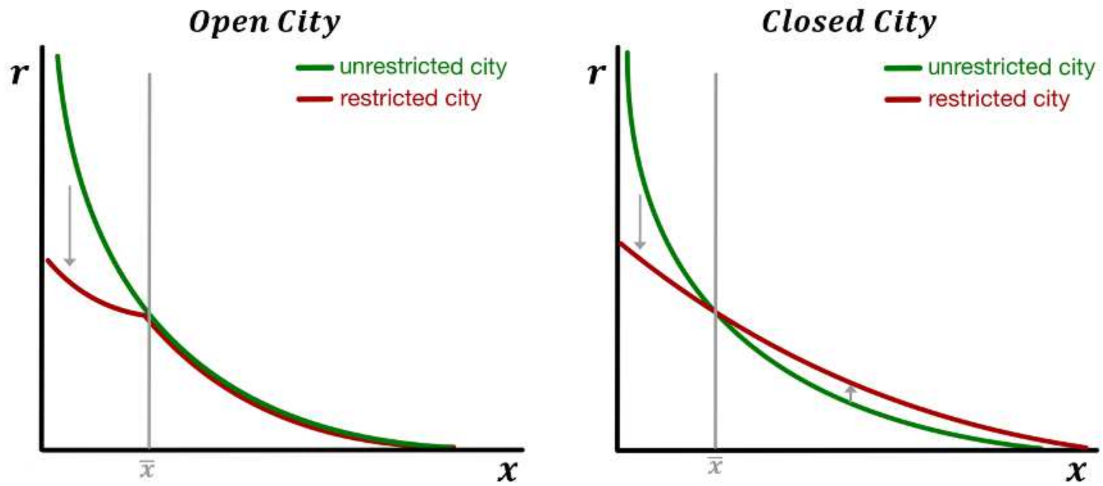


In the open city, however, the scarcity effect cannot exist. The availability of alternative locations outside the city which provide the same level of utility, means that LURs simply displace urban residents. This process leaves utility and rents unchanged within the city, such that no scarcity effect exists.

4.4 Profit Effect

Finally, we consider the impact of a height restriction on the profitability of developing housing at different locations in the city. Bertaud & Brueckner (2005) provide a full treatment of the profit effect within a closed city, demonstrating that a limit on building heights close to the city reduces the profitability of land in those locations, driving land rents downward. It also forces residents to live in locations farther from the CBD than is optimal, which reduces utility for all members of the city, increasing the price of housing services, ultimately raising land rents in the unregulated part of the city, and pushing the edge of the city outwards. This is depicted in the right-hand panel of Figure 3 below.

Figure 3: Profit Effect



Not considered by Bertaud & Brueckner (2005) however, is the impact of LURs within the context of an open city model. In this case, LURs have a similar impact within the regulated area, forcing developers to build a density of housing that is suboptimal, ultimately capitalising into lower land rents. However, because utility is unchanged, the bid-rent curve for housing is unchanged outside of the area where the height limit is binding. Thus, the land rent curve is unaffected in that area. Individuals who would have lived within the regulated area are forced out of the city, reducing the city's population.

It is the profit effect which is the primary focus of our empirical analyses in Sections 6 and 7 below, where we look for discontinuities in land rents at the boundaries between different zones of LUR, and estimate the change in land values arising on properties where permission for more intensive housing was granted by the AUP.

We focus on the profit effect for a few reasons. Amenity effects are difficult to identify with our two empirical strategies, as they operate on neighbouring properties and vary rather smoothly over space. In addition, the net impact of amenity effects from the AUP is ambiguous, as they involve the combination of both positive and negative effects such as agglomeration economies and shadowing respectively. The scarcity effect operates at the level of entire urban areas, and we only utilise data from Auckland. Event-study methods are difficult due to the long timespan of the AUP's implementation and the difficulty in constructing a credible counterfactual for Auckland had the AUP not passed. Identification of the scarcity effect is a key challenge for continued empirical research on this subject.

4.5 Interpretation

LURs which force residents to relocate to suboptimal locations, such as the height limit discussed above, operate on land values by reducing the utility of residents. Thus, when LURs reduce aggregate land values through the profit effect, this can be considered welfare-reducing, as they reflect the loss of utility for the city's residents. For example, Brueckner &

Sridhar (2012) show that a binding height limit reduces welfare through increased commuting costs, where the loss of welfare to each city resident can be measured by the increase in commuting costs for residents at the edge of the city.

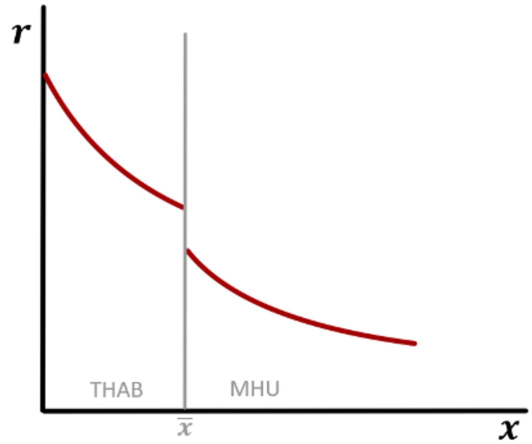
Therefore, the overall effect of height limits and other LURs on land values in different parts of the city is highly ambiguous. Strong claims about the existence of scarcity rents must be tempered by the endogeneity that besets much of the empirical literature (Murray and Phibbs, 2022) and must be sensitive to the availability of substitute locations to which residents are willing to relocate (Ohls et al., 1974). The net effect of LURs will differ between central and peripheral locations, and will depend on the relative sizes of amenities generated, how binding the regulation is on the density of construction, whether housing is made scarce by the regulation, and whether the system in question better reflects the characteristics of an open or closed city model.

While it may seem implausible for any real-world city to exhibit the characteristics of a true open-city, it is notable that rising house prices in Auckland have been accompanied by rapid relocation of Auckland households to nearby cities such as Hamilton and Tauranga, both of which have experienced elevated rates of growth in both population and house prices in recent years (Housing and Development, 2022). Conversely, many households are tied to their current city by both sentimental ties and the costs involved in relocating. Reality will therefore always lie somewhere between the open and closed city extremes.

4.6 The Case of Two Regulated Zones

Applying the above models to the real-world context, we note that the AUP regulates land use on every parcel in Auckland. Rather than comparing the cases of an unregulated and regulated city, we are therefore interested in what happens over space when there are two adjacent zones facing differing regulations. Consider a scenario where the area closer to the city center is granted the more permissive THAB zoning, while the area further from the CBD is given the more restrictive MHU zoning. If these regulations are binding in both areas, we would expect that the profit effect would produce the pattern of land rents depicted in Figure 4 below.

Figure 4: Two Regulated Zones



While THAB zoning may depress land values close to the city centre, the more strict restrictions on construction within the MHU zone substantially reduces the volume of housing that can be legally built in this area, relative to neighbouring parcels within the THAB zone. This results in a discontinuous shift downward in the land rents that can be earned on the MHU side of the boundary. This is similar to the pattern observed by Koster, van Ommeren & Volkhausen (2021), who find a discontinuous reduction in house prices at the border of areas where AirBnb listings are banned. We apply a similar identification strategy in our first empirical strategy in Section 6.

4.7 Rents and Values

While these theoretical models are specified in terms of the land rents at a given point in time, the following analysis is based on land values. We connect these two concepts with the asset price formula for land value LV_0 where $E[r_t]$ represents the land rent expected in future period t, and i is the discount rate:

$$LV_0 = \sum_{t=1}^{T} \frac{E[r_t]}{(1+i)^t} \tag{1}$$

We would therefore expect that changes in LURs will rapidly capitalize into land values, as the market anticipates the rearrangement of future land rents. Predictions from the above models should therefore generalise to our analysis of land values Indeed, our analysis relies on land values from 2021, which was five years after the AUP had passed into law, and more than enough time for the profit effect to be captured in the underlying data. However, this also means that even in areas where LURs are not currently binding, land values may still be affected through expectations that the regulations will become binding in the future. Likewise, if the market anticipates that LURs will change in future periods, this information may be incorporated into current-period land values.

5 Datasets

Before launching into our empirical investigation of the profit effect, this section describes the key datasets utilised in this analysis. Because each data is used for different purposes in each of our two empirical strategies, we describe data preparation and present summary statistics in subsequent sections.

5.1 Rates Assessments

Every property in New Zealand periodically has its value assessed for the purposes of levying local property taxes (called 'rates'). We rely on Auckland Council's rates assessment database to obtain our key dependent variable for the purposes of this study.

Values are estimated using a combination of traditional valuation and hedonic modelling techniques. For every property, recent sales in the vicinity are combined with factors such as property type, location, land size, zoning, and floor area, to derive a valuation. These are strictly controlled by the Rating Valuations Act 1998, and the model is subject to an audit process by the Office of the Valuer General. The model separately estimates each parcel's land value (LV) as well as the value of the buildings and other improvements on top of the land (IV), which sum to total capital value (CV). We are interested in the impact of LURs on land rents, so our analysis primarily considers the LV variable. Supplementary variables also track each property's land area, zoning, and a number of built characteristics such as the amount of built floorspace and exterior façade materials.

We rely on the 2011 valuations to measure land value prior to the announcement of the draft AUP, and use 2021 as an observation that was a sufficient period of time after the operative AUP had come into force, such that the policy changes would have fully capitalised into land values by this point in time.

While it would be preferable to use market transaction data, these were not available for the purposes of this study. One advantage of the valuation dataset is that it contains observations for every property in Auckland, rather than being limited to the subset of properties which have sold within a given timeframe. This increases sample size and averts selection bias in the types of properties which transact more frequently. However, valuation data does have the drawback of being sensitive to the particular specification of the valuation model (Bourassa et al., 2009). For example, if land value assessments are modelled based on the transacted prices of nearby properties, the model may 'smooth' valuations over space, which would result in both of our empirical methods underestimating the size of the true effect.

5.2 Capacity for Growth Study

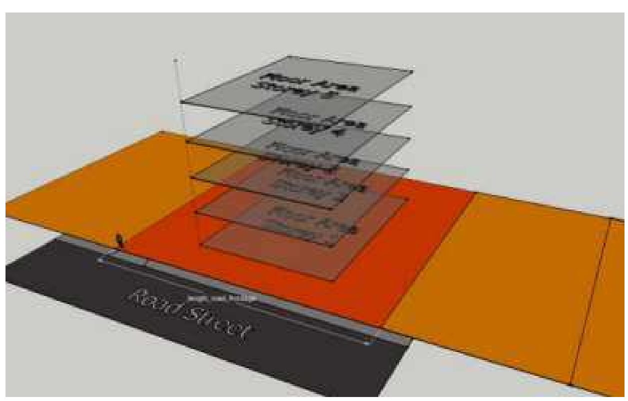
Our second key dataset derives from Auckland Council's Capacity for Growth Study (CfGS). This is a geospatial model which seeks to estimate the 'plan-enabled' capacity for dwellings on every individual parcel within Auckland city at a given point in time. We refer to this measure as 'legal capacity', defined as the maximum number of housing units that a developer is rightfully permitted to build on a land parcel according to the operative planning regime.

For example, under the legacy district plans, most residential parcels in Auckland were limited to a single standalone dwelling. Thus, prior to 2012, a typical 750 square metre plot of land would often have legal capacity for only one dwelling. After the AUP, parcels upzoned to THAB were instead allowed to build between 5-7 storeys with smaller setbacks, meaning that a typical parcel could now support around 12 apartments. For this example, the AUP upzoning has increased legal capacity on our hypothetical parcel from 1 to 12 dwellings.

For our measure of legal capacity before the AUP, we rely on the 2012 installation of the CfGS model. The methodology for this early version of the model is outlined in Fredrickson & Balderston (2013), but summarised here. In 2012, most legacy district plans allowed only a single dwelling on each residential parcel. Thus, this early installation of the CfGS model calculated the legal capacity for each parcel by dividing the land area by the minimum lot size and rounding the result down to the nearest integer. This value represents the upper limit on how many whole dwellings could be built on a parcel (even if it were subdivided), and is our legal capacity measure for prior to the AUP.

By the time the new AUP became operational, the CfGS had been updated to reflect the new types of residential zoning that had been introduced, especially to accommodate terraced housing and apartments (full details available in Balderston and Fredrickson, 2014). The new version of the model takes the physical area of each individual parcel, applies the AUP rules around boundary setbacks, height-to-boundary recession planes, and maximum site coverage ratios, to generate a three-dimensional 'planning envelope' which represents the physical space in which floorspace can legally be built. This area is then divided by the height of one storey (typically 3.5 to 4.0 metres) to return the maximum floorspace that could legally be built within the parcel. This process is graphically represented in Figure 5 below. Finally, the total floorspace is divided by the minimum dwelling size (typically 45 square metres) and rounded down to return an integer representing the maximum number of dwellings that could legally be built on a given parcel, which is our measure of legal capacity after the implementation of the operative AUP.

Figure 5: Calculation of Developable Floorspace in the CfGS model, Operative AUP



Source:Balderston and Fredrickson, 2014

6 Boundary Discontinuity Analysis

6.1 Empirical Strategy

Our first strategy for identifying the profit effect relies on a boundary discontinuity design (BDD). We follow a similar set-up to Koster, van Ommeren & Volkhausen (2021), Harari & Wong (2018), and Turner, Haughwout & van der Klaauw (2014) in analysing the effects of a treatment which are discontinuous over geographic space. Residential properties in Auckland are designated with one of four zones, each of which permit a different level of housing development (see Section 2 above). Boundaries between properties with different zones therefore represent a discontinuity in the legal treatment of neighbouring properties.

Hahn, Todd, and van der Klaauw (2001) and Imbens and Lemieux (2008) describe the two identifying assumptions underlying this BDD set-up. First, the regression discontinuity (RD) assumption requires that the probability of treatment be a continuous function of distance to the boundary z on either side of the treatment boundary z_0, and discontinuous at the boundary.

RD Assumption:

$$where\; x^+ = \lim_{z \to z_0^+} E[x_i|z_i = z] \; and \; x^- = \lim_{z \to z_0^-} E[x_i|z_i = z]\;,\; x^+ \neq x^- \tag{2}$$

In our study, the RD assumption is met at the boundary between properties with different zones, as treatment is deterministic either side of the boundary. This study is therefore a sharp RDD.

Our second assumption requires that all unobserved property characteristics α_i vary smoothly as they approach and subsequently cross the treatment boundary, such that properties on either side of the boundary are otherwise identical.

Continuity Assumption:

$$E[\alpha_i|z_i = z] \; is\; continuous\; in\; z\; at\; z_0 \tag{3}$$

We cannot claim ex ante that the second assumption holds at all of the relevant treatment boundaries in our study. For example, it may be the case that some boundaries between residential zones have been deliberately drawn along geographic features that create a divergence in property prices (the "wrong-side-of-the-tracks"). Our robustness checks will therefore also involve including various property characteristics as control variables, and testing whether a discontinuity in these features exists at the relevant boundary.

If both of the above assumptions are met, BDD will identify the causal impact of land use regulation on land values. One limitation of BDD is that it only estimates the average treatment effect at the precise boundary location, whereas our model anticipates that zoning will have a different impact on land values in different parts of the city. We therefore estimate the effect at boundaries in different parts of the city, which will provide insight into the impact of the upzoning over space.

6.2 Data Preparation

We focus on the boundary between the Mixed Housing Urban (MHU) and Terraced Housing and Apartment Buildings (THAB) zones. As described above, this boundary represents a significant discontinuity in the volume of housing which can legally be built, which we anticipate should be observable in our BDD analysis. In locations where LURs are binding, we expect that a property with THAB zoning will be worth more than a neighbouring property with MHU zoning, all else equal.

Our BDD analysis requires well-defined boundary lines between clusters of properties which have THAB zoning on one side ('treated') and MHU zoning on the other ('untreated'). These clusters must have significant depth moving away from the boundary, such that there are sufficient observations to establish a polynomial trend between price and distance to the boundary. The boundary itself must also have sufficient width such that there are sufficient observations within each distance bin. As a final complication, neighbouring properties are sometimes contiguous and sometimes separated by a road. These complexities meant that it was not possible to draw treatment boundaries algorithmically, so we instead proceeded to manually draw boundaries that satisfied the above requirements, following either the shared edge of contiguous parcels, or the centerline of the road between them. Figure 6 presents examples of such a drawn boundary, for the study area around Mangere, in South Auckland and near the airport. Parcels coloured orange are zoned MHU and red parcels are designated THAB.

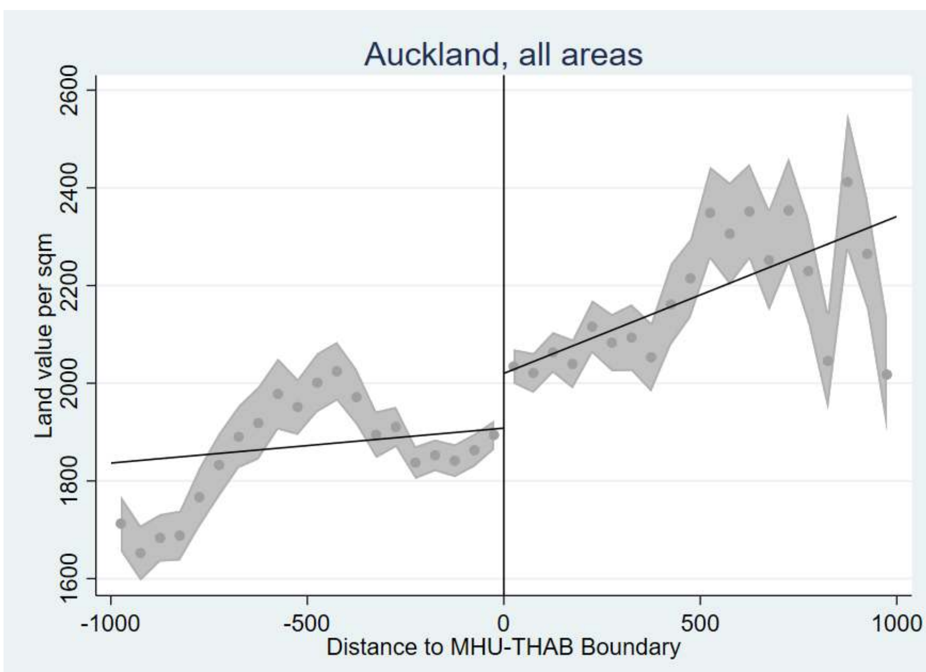
Figure 6: Mangere BDD data

With these boundaries in place, we calculate the distance in metres between each boundary and the centroid of surrounding MHU and THAB properties (using centroids prevents a distance of 0 being returned for properties which are contiguous with the boundary). Properties on the MHU side of the boundary have their distances flipped to negative values, to reflect their untreated status. These boundary distances will subsequently be used as the running variable z_i in our BDD regressions.

As our dependent variable, we draw on the 2022 residential valuation dataset described above. We obtain land value per square metre by dividing each property's LV by the land area of its parcel. This variable represents our dependent variable, LV_i. In Figure 6 above, each dot is coloured to reflect the land value per square metre, with more valuable land being a deeper shade of red. Even a visual inspection indicates that properties in the THAB zone appear to be discontinuously more valuable than those zoned for MHU. Data of this type has been prepared for each of the 30 boundaries identified throughout the Auckland area, and is summarised along with descriptive characteristics of the properties within each study area.

Based on this data, Figure 7 gives us our first glimpse of the discontinuity we are estimating, by plotting the average land value of properties within distance bands on either side of the MHU-THAB boundary (with the MHU zone to the left of the boundary). This figure uses IMSE-optimal distance bins, and fits a linear trendline on either side of the boundary, with shaded areas representing 5% confidence intervals. As we are aggregating across a wide number of study areas, the slope of these trendlines is not of importance, although the positive slope may indicate that THAB areas tend to be located closer to the centre of Auckland than MHU zones.

Figure 7: BDD plot for all Auckland



This plot displays a striking discontinuity at the MHU-THAB boundary. Despite having similar locational characteristics, properties on the THAB side of the boundary appear to be worth over $100 more per square metre more than neighbouring properties with a MHU designation. In the next section, we explicitly estimate this discontinuity using the following set-up:

$$LV_i = \beta_0 + \beta_1 THAB_i + \beta_2 z_i + \beta_3 THAB_i z_i + \epsilon_i \tag{4}$$

Where $THAB_i$ is a dummy variable set to 1 for observations in the THAB area and 0 on the MHU side of the boundary, and z_i is our running variable, the distance to the MHU-THAB boundary. This model replicates what is presented visually in the previous figure: it fits a linear trend on either side of the MHU-THAB boundary, where β_1 captures the vertical discontinuity in land values at the boundary. If our continuity assumption holds, then ϵ_i is uncorrelated with a parcel's $THAB_i$ status and β_1 will reflect the causal impact of THAB zoning relative to MHU zoning for a given study area. Later, we test this assumption by looking for discontinuities in property characteristics, by replacing LV_i with alternative dependent variables α_i. Ultimately, we test the sensitivity of our estimated β_1 by adding these α_i as control variables to the above specification.

For each of the study areas, we replicate Figures 6 and 7 in Appendix A. Eyeballing these charts, we might expect to identify positive discontinuities in Avondale, Botany, Flat Bush, Greenlane East, Howick, Kelston, Mangere, Panmure, Papakura, Sunnyvale, and Te Atatu. Many of these discontinuities also appear to be in the range of $150 to $200 per square metre. Contrary to expectations, we observe a negative discontinuity at St Lukes.

6.3 Results

Here we present the findings from our empirical BDD analysis. In Table 2 we begin by conducting pooled regressions which draw upon data from all study areas and estimate the average profit effect at the MHU-THAB boundary across all of Auckland. Later we will examine how these findings differ across our study areas.

Table 2: BDD Results, Pooled for all of Auckland

	(1) Constant Slope	(2) Slopes Vary by Area	(3) with Controls	(4) Excl. Failed. Cont. Assump.	(5) Only Positive Areas
β_1, Discontinuity in LV per sqm ($/sqm)	133.6***	256.7***	179.4**	256.7***	184.9**
	(14.0)	(99.0)	(84.7)	(97.1)	(82.5)
β_2, Boundary distance (m) (THAB=0)	0.08***	0.4***	-0.1**	0.43***	-0.12**
	(0.02)	(0.06)	(0.05)	(0.06)	(0.05)
β_3, Boundary distance (m) (THAB=1)	0.1***	-2.3***	-0.9	-2.3***	-1.0***
	(0.03)	(0.7)	(0.6)	(0.7)	(0.6)
Built before 1980			31.6***		-58.3***
			(8.5)		(9.4)
Made of weatherboard			89***		79.0***
			(6.4)		(7.0)
Built floorspace (sqm)			0.3***		0.02
			(0.06)		(0.07)
Land area (sqm)			-1.3***		-1.2***
			(0.01)		(0.01)
β_0 (Constant)	2168.9***	1714.3***	2376.4***	1714.3***	2162.8***
	(8.9)	(32.9)	(31.0)	(32.2)	(30.6)
Observations	33534	33534	29926	11598	24291
R^2	0.026	0.470	0.461	0.388	0.645
F	301.6	248.5	435.2	189.28	444.3

Standard errors in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Specification (1) simply estimates equation (4) above and finds an average land value discontinuity of $134 per square metre at the boundary between parcels with MHU and THAB zoning, across all of the areas studied. This effect is statistically significant at the 1% level. Because the average Auckland property has a land area of 750 square metres, this would suggest that being zoned to THAB generates a windfall profit effect that is very close to $100,000 of additional property value, relative to being granted MHU zoning.

In specification (2), we allow the slope of the relationship between distance and land value to vary not just on either side of the boundary, but also by study area. This is achieved by including an interaction term between study area dummies and $\beta_2 z_i$ and $\beta_3 THAB_i z_i$ respectively. This reflects the fact that some study areas are oriented with the THAB area closer to the city centre (where we may expect a negative relationship between distance and land value), while other study areas have different orientations. This adjustment results in a sizeable increase in R^2, suggesting that it much better captures the variation in the underlying data. Our coefficient of interest nearly doubles to $257 per square metre and remains strongly significant. This estimate suggests a profit effect that is close to $200,000 for properties given THAB zoning instead of MHU.

Before proceeding to specification (3), we test our continuity assumption by looking for discontinuities in various property characteristics at the MHU-THAB boundary. We do so by estimating equation (4) above, but with four different property characteristics as the dependent variable. First, land area may indicate differences in the physical size of properties designated with MHU and THAB zoning. Next, we test for discontinuities in the dwelling's built floorspace, the material used for classing the dwelling, and whether the dwelling was built before 1980. While we would not necessarily expect these latter factors to influence land value, they may be indicative of the relative attractiveness of a given neighbourhood or the potential for household sorting along demographic lines (Bayer et al., 2007).

The results of these estimates are presented in Table 7 in Appendix A and show that across Auckland there are no statistically significant discontinuities in the built characteristics of dwellings at the MHU-THAB boundary. There is some evidence that parcels in the THAB zone are around 80 square metres smaller than neighbouring sites zoned for MHU, although this effect is only weakly statistically significant.

To test the sensitivity of our pooled estimates to these control variables, specification (3) above adds these characteristics as control variables α_i to equation (4). This reduces our coefficient of interest to \$179 and weakens its significance somewhat. This suggests that the smaller parcel sizes within the THAB zone may have been biasing estimates upwards in specification (2).

In the following section, we examine the profit effect across each study area, including testing the continuity assumption within each area. For now, specification (4) above repeats specification (2) but excluding study areas which failed at least two tests of the continuity assumption. This returns estimates that are very similar to those in specification (2).

Finally, there are several study areas which return a negative discontinuity coefficient, suggesting that MHU parcels are more valuable than THAB parcels in that area. As we discuss below, this result is hard to explain and may reflect unique characteristics of the location of the boundary in that study area. To exclude the effects of these areas, specification (5) presents pooled results with control variables but excluding study areas where statistically significant negative results were found. This specification finds a profit effect of \$185 at the MHU-THAB boundary, an effect which is statistically significant at the 5% confidence level.

All of the estimates from these above specifications are positive and statistically significant. Given the likelihood that the relationship between boundary distance and land value will differ by study area, and because inclusion of the control variables did shift our coefficient of interest, we consider specification (3) to be the best estimate of the average profit effect across the entirety of Auckland city, suggesting that the best estimate of this effect is \$179 per square metre (with a standard error of \$85). In the next section, we seek to disentangle this effect across the different study areas.

6.4 Results by Study Area

We proceed to separately estimate this profit effect within each of our study areas. Table 3 sorts these study areas by their euclidean distance from Auckland CBD, including the number of observations for each study area. Specification (1) applies an identical slope on either side of the MHU-THAB boundary, while specification (2) allows this slope to vary on either side. Specification (3) adds control variables.

Table 3: Discontinuity in LV per square metre at the MHU-THAB border, by study area

	N	Distance from CBD (km)	(1) Constant Slope	(2) Slope Differs	(3) with Controls
Morningside	646	3.9	68	28	9
			(102)	(108)	(95)
St Lukes	1645	4.3	-520***	-454***	-511***
			(41)	(44)	(40)
Northcote	967	5.6	-70	-38	-270***
			(124)	(124)	(98)
Greenlane East	1230	5.7	1,237***	1,237***	1,217***
			(92)	(92)	(91)
Takapuna	1546	6.2	-1,040***	-1,099***	-149
			(215)	(238)	(171)
Mt Roskill	1755	6.7	-23	-20	-66***
			(39)	(39)	(28)
Three Kings	1023	7.0	-197**	-120	98
			(99)	(100)	(78)
Avondale	1704	8.2	143**	124***	21
			(57)	(57)	(48)
Glenfield	589	8.3	261**	269***	178
			(110)	(110)	(118)
Onehunga	2298	8.4	13	80***	68***
			(28)	(33)	(34)
Waipuna	1377	9.1	-36	84	99
			(67)	(67)	(62)
Glen Innes	3616	9.2	49	5	182***
			(54)	(57)	(40)
Te Atatu	2033	9.9	83	232***	245***
			(54)	(56)	(46)
Panmure	1870	10.0	287***	308***	303***
			(49)	(55)	(46)
Kelston	4376	10.8	397***	365***	312***
			(36)	(37)	(35)
Te Atatu South	3595	11.4	49	176***	231***
			(37)	(43)	(39)
Lincoln	3123	12.4	184***	-112***	-29
			(39)	(44)	(41)
Glen Eden	3376	12.4	145***	151***	130***
			(34)	(34)	(33)
Pakuranga	555	12.5	178	71	434***
			(150)	(151)	(119)
Sunnyvale	1003	13.3	434***	441***	-575***
			(101)	(102)	(88)
Westgate	1422	13.4	-12	257***	202***
			(34)	(55)	(38)
Mangere	1254	14.4	257***	291***	265***
			(22)	(27)	(22)
Ranui	1122	14.5	353***	0	-98
			(83)	(101)	(87)
Howick	810	14.5	440***	460***	286***
			(79)	(80)	(74)
Otara	448	15.4	-8	-44	-21
			(31)	(44)	(37)
Botany	2328	16.6	902***	589***	260***
			(57)	(66)	(36)
Papatoetoe	993	17.0	123	179***	108*
			(85)	(87)	(74)
Flat Bush	696	18.3	689***	997***	336***
			(48)	(61)	(35)
Papakura	1063	29.7	341***	349***	263***
			(53)	(53)	(41)
Manurewa	1893	29.9	142***	220***	246***
			(28)	(35)	(30)

Standard errors in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Specifying a constant slope on either side of the boundary, specification (1) finds a positive and statistically significant profit effect at the MHU-THAB boundary in 15 of our 30 study areas. Allowing this gradient to differ on either side of the boundary raises this figure to 18 of the study areas, including all of the areas where we anticipated a positive result from a visual inspection of the figures in Appendix A. Close to half of the statistically significant effects are land value discontinuities of between \$150 and \$300 per square metre, similar to the range of results identified in our pooled specifications. The largest positive effect is consistently observed in Greenlane East, an attractive area located 6km from Auckland's city center and very close to the popular greenspace at One Tree Hill.

Surprisingly, negative and statistically significant discontinuities are observed in both the St Lukes and Takapuna study areas. Because these odd results may be caused by unobserved factors which influence land value and which are also discontinuous at the MHU-THAB boundary. We therefore test for discontinuities in our control variables, with the results by area presented in Table 8 in Appendix A. These results are much less consistent than the results for the profit effect, with different study areas sporadically returning statistically significant results. For example, the results for St Lukes indicate that houses tend to be smaller and less likely to be made of weatherboard on the THAB side of the boundary than in the MHU zone. Some areas indicate discontinuities in several of the tested variables. For example, 16 of the 30 areas return significant results for at least three of the four variables tested.

As these results may threaten the continuity assumption, specification (3) in Table 3 examines the impact of including these control variables in our profit effect estimates. Most results are not significantly affected. Notably, the large negative effect at Takapuna has been substantially reduced and lost statistical significance. There remains a significant negative discontinuity at St Lukes, of close to \$500 per square metre. This is possibly because many properties on the THAB side of the St Lukes boundary are located along the busy arterial of Sandringham Road, which may cause some negative externalities due to traffic noise and pollution. However, several study areas within 10 kilometres of the CBD fail to return statistically significant results, including Morningside and Northcote.

While the size of many effects have been reduced somewhat, 16 areas finding positive profit effects that are statistically significant at the 1% confidence level. Among these areas, the majority continue to produce results within the range of \$150 to \$300 per square metre. We therefore adopt this range as a generalised estimate of the profit effect of a property obtaining THAB zoning (relative to MHU) across Auckland city.

In contrast to the expectations of our theoretical model, none of our specifications reveal a consistent pattern of larger profit effects closer to Auckland CBD. This may be explained by Auckland being a relatively polycentric city, with employment hubs spread over the 10 'metropolitan centres' across the city. Alternatively, housing supply may be so tightly constrained even under the AUP that allowances to build additional housing are valuable regardless of where they are in the city. This is consistent with the theoretical predictions of the profit effect within a closed city, whereby strict land use regulation within the central historic suburbs of Auckland may be pushing land value outwards into the suburbs, especially into areas where THAB zoning has been granted.

7 First Difference Analysis

7.1 Panel Set-Up

While the previous section simply estimated the cross-sectional difference in the value of properties with different zoning designations, our second analytical strategy shifts to a panel structure and seeks to estimate the intensive effects of additional legal capacity on the change in land values over time.

Recall from Section 5 that our Capacity for Growth Study (CfGS) dataset considers all of the zoning regulations in place at a given point in time, and calculates the maximum number of dwellings that could be built on each parcel if it were put to its maximum legal use. This returns an integer indicating the 'legal capacity' of every parcel in Auckland. We are interested in the marginal impact that every additional unit of legal capacity has on land values.

While we might consider estimating this effect within a simple hedonic price analysis, we know that the selection of sites to be given permissive zoning has not been done at random. Indeed, the AUP process specifically sought to enable more intensive forms of housing in locations that were proximate to employment centres and public transportation (A. Council, 2012). It is therefore highly likely that a hedonic price analysis will have omitted locational attributes which are correlated with both high land values and legal capacity, which would bias our estimates upwards.

Instead, this analysis exploits the fact that we have multiple observations on each property, recording the land value and legal capacity before the AUP was announced, using data from 2011, and well after the final AUP had made it into law, using CfGS data from 2017 and land value data from 2021 (to allow the new regulations to capitalize into property values). This enables us to construct a panel dataset, and calculate changes in the above variables over time. Appendix B details the technical aspects of the preparation of this dataset, and Table 4 presents summary statistics for all observations in 2021.

Table 4: Summary Statistics for the First Difference Panel

	N	Mean	Median	Std.Dev.	Min	Max
Area of the parcel (sqm)	171733	764	694	339	152	25809
Zone: Single House Zone	171733	0.14	0.00	0.34	0.00	1.00
Zone: Mixed Housing Suburban	171733	0.54	1.00	0.50	0.00	1.00
Zone: Mixed Housing Urban	171733	0.26	0.00	0.44	0.00	1.00
Zone: THAB	171733	0.06	0.00	0.25	0.00	1.00
Valuation, land only ($)	171733	1417404	1240000	822974	210000	44000000
Valuation, improvements ($)	171733	282790	175000	359580	0	10150000
Valuation, total ($)	171733	1700194	1450000	1018464	460000	52000000
# dwellings on the site (#)	171733	1.1	1.00	0.5	0.0	45.0
# dwellings legal capacity (#)	171733	2.7	2.00	2.9	0.0	42.0
Change in land value ($)	171733	1056579	950000	584213	40000	28500000
Change in improvement value ($)	171733	47868	-10000	230884	-2700000	8810000
Change in total value ($)	171733	1104448	950000	630862	-780000	30000000
Change in legal capacity (#)	171733	1.4	1.00	2.7	-4.0	15.0
Change in dwellings (#)	171733	0.0	0.00	0.2	-20.0	28.0

By 2021, the average residential property in our sample was worth \$1.70m, an increase of \$1.10m compared to 2012. Land values were responsible for 90% of this growth, which motivates our interest in unravelling the role played by zoning capacity. Here we can observe that land parcels were legally allowed to build an average of 2.7 dwellings in 2021, with this figure having increased by 1.4 as a result of the AUP upzoning process. Among our studied residential parcels, there was no change in the number of dwellings over the past decade, likely because redeveloped properties may have experienced changes in the land title which selected these parcels out of our matched database (see Appendix B for more details). 6% of the study sample is zoned THAB, 80% is zoned for mixed housing (urban and suburban) and the remaining 14% of parcels are zoned only for a single dwelling (i.e., have not experienced upzoning).

7.2 Empirical Strategy

Our basic econometric set-up is as follows. We anticipate that land values at a point in time are a function of various physical attributes $f(PHI)$ (such as the parcel's size, shape and slope), locational attributes $f(LOC)$ (proximity to the city centre, water, employment), zoned capacity CAP_it, and an idiosyncratic error term:

$$LV_{it} = \beta_0 \ + \ \beta_1 CAP_{it} + f(PHI_i) + f(\mathrm{LOC}_i) + \varepsilon_{it} \tag{5}$$

Where we are seeking to identify the marginal effect of a change in zoned capacity (CAP) on land values (LV). This specification will return an unbiased estimator of β_1 only when the error term is uncorrelated with LV_{it}. However, we cannot reasonably expect this assumption to be met, as we know that upzoning was targeted at specific areas within Auckland based on their locational attributes. We therefore proceed to calculate the first difference between land values in 2021 and 2011, which we write simply as

$$\begin{aligned} \Delta LV_i &= LV_{i,2021} \ - \ LV_{i,2011} \\ &= \beta_{0,2021} + \beta_1 CAP_{i,2021} + f\left(PHI_i\right) + f\left(\mathrm{LOC}_i\right) + \varepsilon_{i,2021} \\ &- \beta_{0,2011} - \beta_1 CAP_{i,2011} - f\left(PHI_i\right) - f\left(\mathrm{LOC}_i\right) - \varepsilon_{i,2011} \end{aligned} \tag{6}$$

If both physical and locational attributes remain constant over time, they are differenced-out and the above equation can be written as:

$$\Delta LV_i = \Delta\beta_0 + \beta_1 \Delta CAP_i + \Delta\varepsilon_i \tag{7}$$

Where all observations reflect changes between 2011 and 2021. This is the baseline regression presented as specification (1) in the results table below.

For the estimator β_1 to be unbiased, it must be the case that the estimator $\Delta\varepsilon_i$ is uncorrelated with the change in land values. The most significant threat to this assumption is that the locational characteristics of properties are not fixed over time, but rather that properties that were selected for upzoning lie within parts of Auckland that were also increasing in attractiveness more rapidly than areas which were not selected for upzoning. This would result in an unobserved ΔLOC_i which would be correlated with the error term in model (7) above. We attempt to control for some of these potentially-changing locational characteristics in specifications (2) below, by including postcode fixed-effects. Thus, while certain postcodes may be becoming more desirable over time, specifications (2) isolates the impact of changes in capacity on land values within postcodes.

It may be the case that additional zoned capacity exhibits declining marginal returns for land value, for example because the returns that can be generated from being granted the right to turn a single family house into three townhouses may exceed the returns from being allowed to build 12 rather than 10 apartments on a site. We investigate this possibility in specifications (3), which includes a squared capacity term to estimate changes in the marginal impact of capacity on land value.

Finally, specification (4) attempts to control explicitly for changes in the built characteristics of each parcel, by including the change in the number of built dwellings on each site. Table 5 presents the results from these specifications. To account for the possibility that error terms may be correlated between properties which are proximate or which have the same zoning, all specifications cluster standard errors at the level of zone-postcode interactions.

7.3 Results

Table 5 presents the results of the above specifications.

Table 5: FD Regressions

	(1) Baseline	(2) Postcode FE	(3) Non-Linear	(4) With Control
Change in capacity (#)	31773***	35828***	49373***	31766***
	(7762)	(4432)	(7075)	(7767)
Change in capacity squared			-1426**	
			(560)	
Change in dwellings (#)				-5267
				(18031)
Constant	1.013e+06***	1.007e+06***	1.002e+06***	1.013e+06***
	(44408)	(9534)	(10235)	(44467)
Observations	171722	171722	171722	171722
R^2	0.022	0.498	0.499	0.022
F	16.756	65.347	41.768	9.270

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

In the baseline specification (1), we estimate that properties gained an additional $31,800 of land value for every additional unit of zoned capacity that they were granted by the AUP upzoning. This effect is statistically significant at the 1% level. Surprisingly, this marginal effect increases to \$35,800 after controlling for postcode fixed-effects, providing some evidence against the idea that our estimated effect has been biased-upwards by properties were granted additional capacity in locations that were already becoming more attractive.

In specification (3) we do indeed find some evidence that windfall gains in land value are stronger for the first few units of capacity (such as an upzoning from a single family house to terraced housing) than at larger levels of initial capacity (such as an upzoning from terraced housing to allow apartments). Finally, specification (4) indicates that controlling for changes in the number of dwellings on a property does somewhat reduce the estimated benefits of upzoning, which is consistent with the predictions of option-value models, where the profit to be earned from developing a vacant parcel is larger than for sites on which a dwelling has already been built.

To put these estimates in context, we note that this final estimate suggests that every additional unit of legal capacity increases land value by \$31,800. Within our sample, we find that the average THAB parcel has legal capacity for 8.6 dwellings compared to 1.9 units on MHU parcels, a difference of 6.7. If each of these additional units of legal capacity raises land value by \$31,800, then being zoned for THAB generates a windfall profit effect of \$213,000 relative to MHU parcels. This is equivalent to 14.2% of a typical THAB parcel's land value, and 12.6% of its expected market sale price. We divide this windfall gain by the average parcel size of 750 square metres to obtain an estimated profit effect of \$284 per square metres, which is well within the range of estimates obtained in our BDD analysis above.

7.4 Interaction with Location

We now proceed to add a spatial dimension to the above analysis by exploring whether the estimated profit effect differs across different parts of Auckland. Recall from our theoretical considerations in Section 4 that we would expect that additional units of legal capacity would raise land values by much more on land close to the city centre than on land at the outskirts of the city. We therefore borrow a similar specification as Brueckner & Singh (2020) and let x represent the euclidean distance of each parcel from Auckland CBD in the following:

$$\Delta LV_i = \Delta\beta_0 + \beta_1\Delta CAP_i + \beta_2 x_i + \beta_3 x_i \Delta CAP_i + \Delta\varepsilon_i \tag{8}$$

Here, the marginal profit effect now differs by distance to the center of Auckland, being equal to $\beta_1 + \beta_3 x_i$. Below, we replicate Table 5 using the alternative specification from equation (8), again clustering all standard errors at the level of zoning and postcode interaction terms.

Table 6: FD Regressions with Distance interactions

	(1) Baseline	(2) Postcode FE	(3) Non-Linear	(4) With Control
β_1, Change in capacity (#)	21724	29837***	13643	21664
	(19386)	(11116)	(17453)	(19388)
β_2, Distance from CBD (km)	-45604***	-55961***	-55816***	-45625***
	(6104)	(8192)	(8236)	(6107)
β_3, Distance × Change in capacity	901	537	1118	909
	(1480)	(845)	(1160)	(1481)
Change in capacity squared			1396	
			(1121)	
Distance × Change in Sq Capacity			-52.4	
			(96.0)	
Change in dwellings (#)				21134
				(16027)
Constant	1579675***	1703844***	1703378***	1579633***
	(91842)	(103334)	(103871)	(91853)
Observations	171722	171722	171722	171722
R^2	0.239	0.511	0.512	0.239
F	31.56	46.00	27.48	23.69

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Some striking results emerge. First, we consistently find a negative and statistically significant coefficient β_2 indicating that land parcels closer to Auckland's city centre have experienced faster growth in their location value over the past decade. For example, specification (4) suggests that land values decline by $46,000 for every additional kilometre of distance from the centre of Auckland (the median observation is located 12km away). This can be visualised as a steepening of the bid-rent curve discussed in Section 4, possibly due to improving amenities in the centre of Auckland or increasing transportation costs due to motorway congestion.

Second, while the average profit effect from an additional unit of legal capacity remains positive, we observe that controlling for distance has reduced β_1 somewhat relative to the results in Table 5, such that it is only statistically significant in specification (2). This suggests that even after including postcode-fixed effects above, our estimates may have been biased upwards by the omission of Aucklanders' rising demand for central locations.

Somewhat surprisingly, in all four models we observe a positive relationship between the interaction between distance and change in capacity β_3, although this effect is not statistically significant. This would suggest that the profit effect from obtaining additional legal capacity may be the same regardless of how far a property is from Auckland CBD, which was not anticipated from our theoretical modelling. However, this is consistent with the finding from our preceding BDD analysis, where discontinuities remained large even within study areas located a large distance from Auckland central. Together, these results suggest that despite market prices signalling a rising appreciation for central locations, profit effects from additional zoned capacity remain high even in suburban locations.

The coefficients on squared capacity in specification (3) and on the change in built dwellings in specification (4) have lost significance. We therefore adopt specification (2) as our preferred estimate, such that the marginal effect of one additional unit of legal capacity on a parcel's land value is equal to $\$29,837 + \$537x$. This suggests that for the median Auckland dwelling, which is located 12km from the city centre, adding a unit of zoned capacity will increase its value by \$36,230. For every additional kilometre of distance that a land parcel is from the city centre, we anticipate this profit effect will increase by a further \$540.

8 Discussion

This exploration has made a number of meaningful contributions to the discourse on the impact of LURs on the spatial arrangement of land values. We have fully characterised the amenity, profit and scarcity effects of LURs into open- and closed- city models, which provide a useful tool for assessing the likely impact of regulations under different conditions of mobility and spatial substitution. Our empirical strategies draw on a novel measure of LURs which calculates the legal capacity for new dwellings, and we utilise parcel-level data to estimate the impact of LURs on land value at highly-localised levels and in different parts of Auckland.

Both of our empirical strategies provide evidence that the Auckland Unitary Plan generated windfall profit effects for the owners of upzoned land. Using our BDD strategy we find that properties zoned for THAB accrued a profit effect which averaged $179 per square metre across the Auckland region. Likewise, our first difference analysis indicates that every additional dwelling that is legally permitted on a property, land value increases by $31,800. Combined, these two estimates suggest that for the owner of a typical 750 square metre parcel, being granted THAB zoning adds 6.7 units of legal capacity relative to receiving a MHU designation, and raises land value by between $134,000 to $213,000.

These observations are consistent with our theoretical predictions and have a number of practical implications. While YIMBY advocates for upzoning typically make lofty predictions about reducing house prices via the scarcity effect, they should be aware that many properties targeted for upzoning will immediately rise in value as the land capitalizes the value of increased profit potential. This explains the findings of studies such as Freemark (2020), which found that upzoning around Chicago's transit stations increased rather than decreased property prices.

Planners who wish to know what to expect from a change in LURs should be aware of the extent to which their city exhibits characteristics of the open or closed cities. In areas which are closer to the closed model, the profit effect will involve a political struggle between the owners of tightly regulated land in desirable locations and suburban homevoters. Strict regulation in more closed cities will drive up house prices through the scarcity effect, resulting in extractive rents that transfer wealth from tenants to landowners, with net welfare losses through lost consumption of other goods.

Municipalities facing tight budgets may find it appealing to capture some of the profit effects through 'rezoning windfall taxes' (Prosper Australia, 2021). Sometimes called betterment capture or value-uplift taxes, these mechanisms seek to capture the windfall gains which would otherwise flow to private landowners as the result of public planning decisions (Alterman, 2012). Conversely, restrictive land use regulations also generate rents for a different set of landowners; our closed-city model suggested that height limits raise land values in suburban locations through both the profit and scarcity effects. Annual taxes on land value can capture these rents on an ongoing basis, simultaneously discouraging 'homevoters' from lobbying for restrictive zoning (Fischel, 2001), encouraging more rapid construction (Murray, 2022), and giving municipalities the incentives to engage in efficient land use planning which maximises the provision of public goods (Brueckner, 1979).

In contrast to theoretical predictions, we did not find evidence that the profit effect was larger in more central areas of Auckland, but was instead fairly flat across the city. This may indicate that Auckland is highly polycentric, with multiple employment hubs spread across the city's metropolitan centres, a congested road network, and high natural amenity at the city edge. However, this explanation is challenged by our panel dataset revealing that land values grew much more quickly in central locations over the past decade. Alternatively, it may be the case that strict heritage protections within very central suburbs (such as Grey Lynn and Mount Eden) has pushed land value out to more suburban locations that were upzoned, consistent with the pattern of profit effects under a closed city model.

Our empirical methods are beset by a few notable weaknesses. In the BDD analysis, St Lukes returned a negative result that could not be explained with the available data on property characteristics. This may suggest the existence of unobserved components of land value that may also be discontinuous at the MHU-THAB boundary, threatening causality. Likewise, the FD estimates will be biased if there are unobserved time-variant components of land value which are correlated with the legal capacity from zoning. Difficulty in matching observations over time in the panel dataset may also have resulted in selection-bias in the characteristics of the properties retained.

Crucially, our measure of land value relies on a valuation model used for assessing property taxes, meaning that our results will be highly sensitive to the model's specification. For example, if the model values properties by taking nearby sales, this method will smooth land value over space, biasing estimates downwards in both of our analyses. Detailed information about the model was not available so is to some extent a 'black box'. Finally, our data did not enable estimation of the amenity or scarcity effects.

Given these weaknesses, we can observe that the methodology would have been significantly improved with access to property sales data. Results from the valuation dataset could have been validated against data from market transactions, and the addition of repeat-sales data could have improved the precision of the first difference estimates, similar to Greenaway-McGrevy (2021). The addition of data from other cities in New Zealand may also have provided some insight into the extent to which LURs in Auckland causes spillovers into other cities, as the open city model would predict. For example, Parker (2021) argues that New Zealand can be considered a closed system at a national level, where scarcity effects of LURs are determined by the binding-ness of restrictions in the least-regulated city.

Future research on this topic should focus on causal identification of the scarcity effect, as this is the key pathway through which LURs can harm welfare. While existing research has struggled to overcome endogeneity, estimation could be improved through quasi-experimental methods such as large-scale event studies around periods of upzoning, especially if suitable control areas can be identified. These methods may be improved by datasets which measure LURs as the legal capacity for additional dwellings. Theoretical research should seek to model land rents across a closed system of open cities, to better reflect the urban structure of most real-world countries.

9 Conclusions

Land use regulations such as height and density maximums influence the spatial arrangement of urban land rents through three key pathways: managing externalities to create amenity value, enabling landowners to maximise profits by developing the optimal level of capital-intensity, and through the overall scarcity of housing. The direction of these effects will differ in central and suburban locations and will depend on the mobility of households and the availability of substitute locations. Upzoning as part of the Auckland Unitary Plan created substantial legal capacity for new dwelling supply, but in the process generated windfall profits in the order of $134,000 to $213,000 per parcel for the owners of properties where apartments were permitted. Municipal policymakers may look to windfall gains taxes or land taxes as mechanisms for capturing the land rents created through efficient land use regulation.

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A Appendix: Boundary Discontinuity

A.1 Pooled BDD: Testing Continuity Assumption

The following table presents the results of a BDD regression that pools observations from all study areas and tests the continuity of various control variables at the boundary between MHU and THAB zoned areas. Distance slopes are allowed to vary on either side of the boundary, as well as by each study area.

Table 7: Pooled BDD Regressions: Testing property characteristics at MHU-THAB boundary

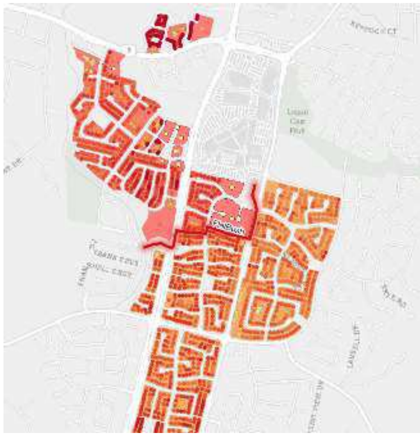
	(1) Before 1980	(2) Weatherboard	(3) Built floorspace	(4) Land area
THAB	-0.05	0.05	-5.7	-83.5*
	(0.08)	(0.08)	(8.9)	(46.7)
Observations	46978	49558	49115	32994
R^2	0.200	0.095	0.125	0.119
F	98.2	43.5	58.9	37.2

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

A.1.1 Avondale

Figure 8: Avondale BD

A.1.2 Botany



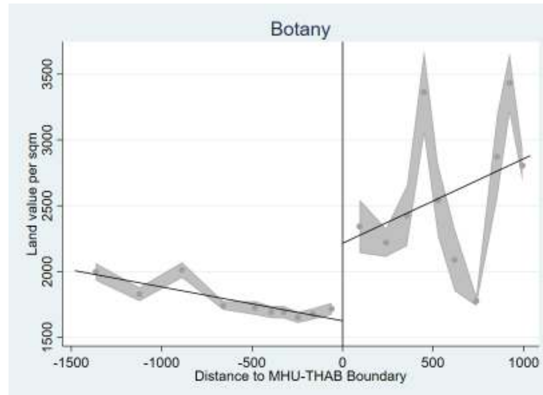


Figure 9: Botany BD

A.1.3 Flat Bush

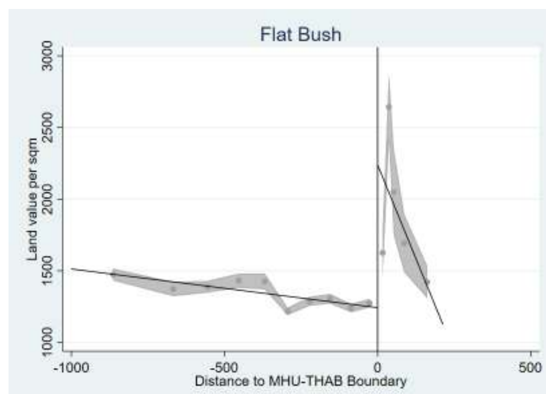


Figure 10: Flat Bush BD

A.1.4 Glen Eden

Figure 11: Glen Eden BD

A.1.5 Glen Innes

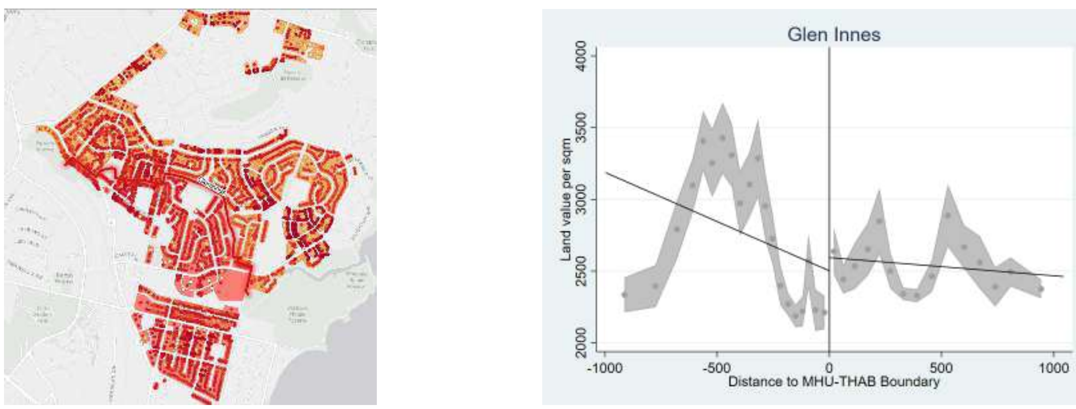


Figure 12: Glen Innes BD

A.1.6 Glenfield

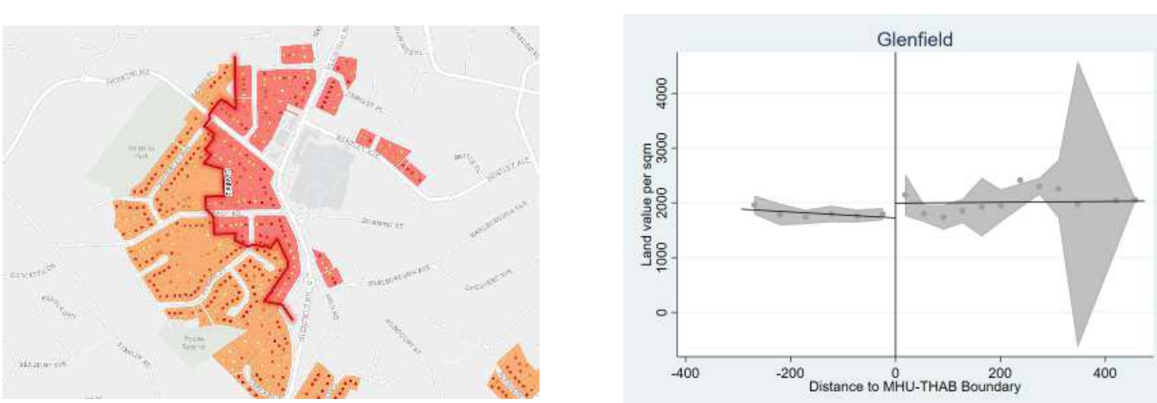


Figure 13: Glenfield BD

A.1.7 Greenlane East

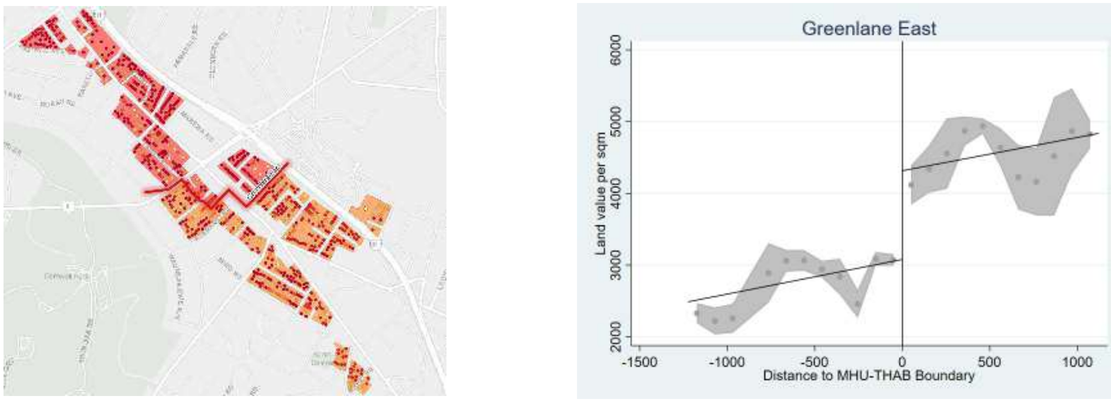


Figure 14: Greenlane East BD

A.1.8 Howick

Figure 15: Howick BD

A.1.9 Kelston

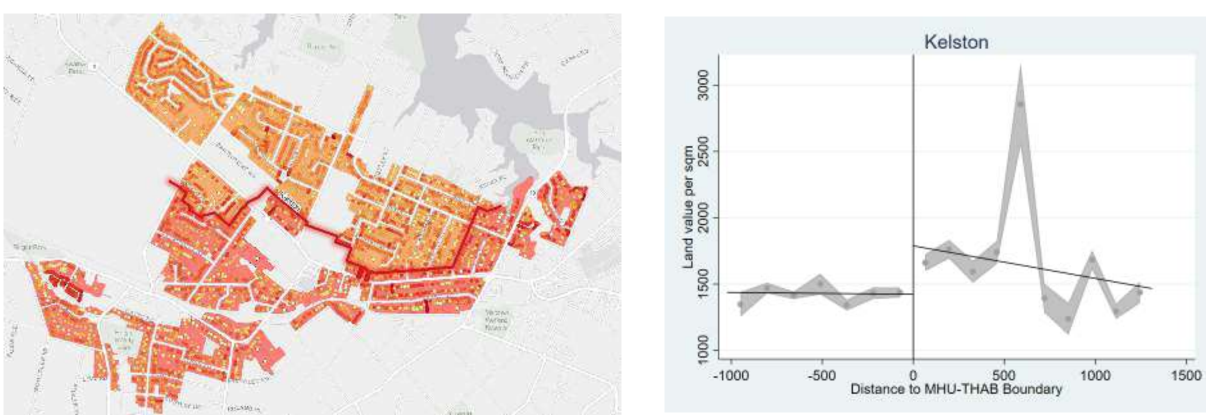


Figure 16: Kelston BD

A.1.10 Lincoln

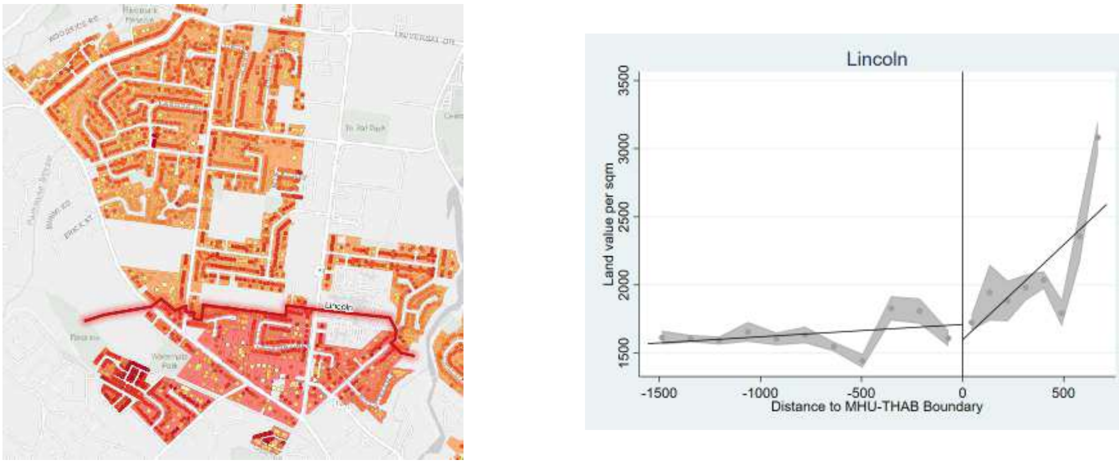


Figure 17: Lincoln BD

A.1.11 Mangere

Figure 18: Mangere BD

A.1.12 Manurewa

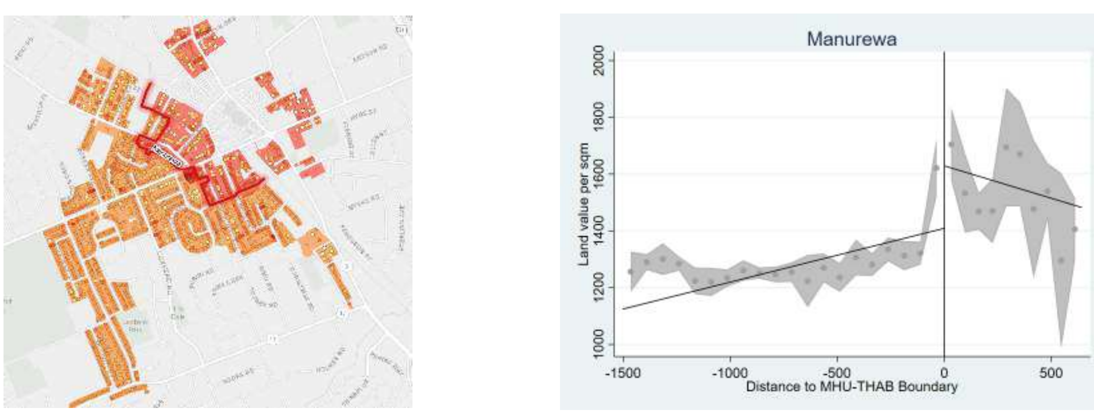


Figure 19: Manurewa BD

A.1.13 Morningside

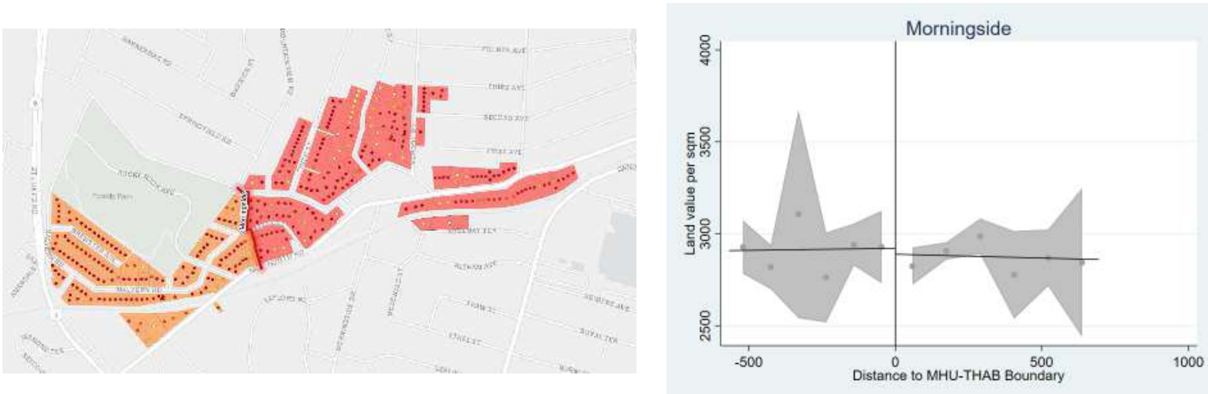


Figure 20: Manurewa BD

A.1.14 Mt Roskill

Figure 21: Mt Roskill BD

A.1.15 Northcote

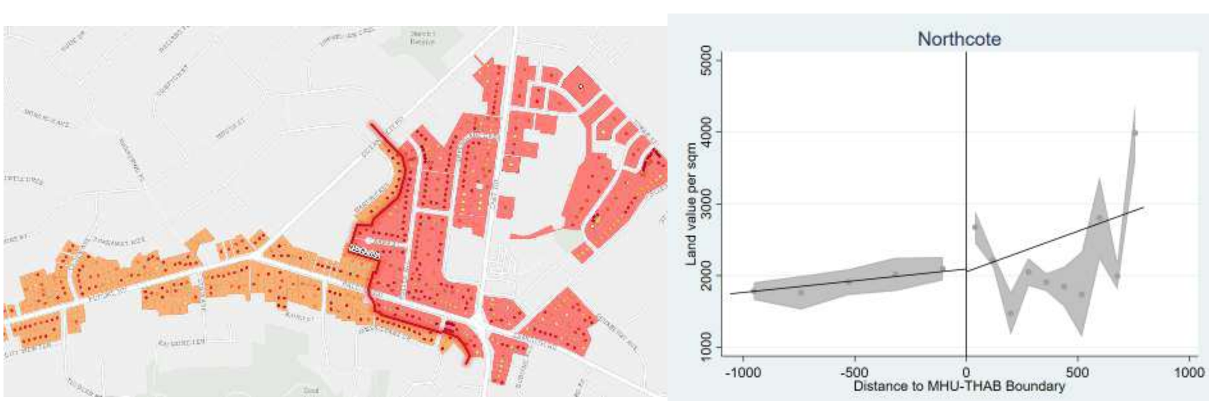


Figure 22: Northcote BD

A.1.16 Onehunga

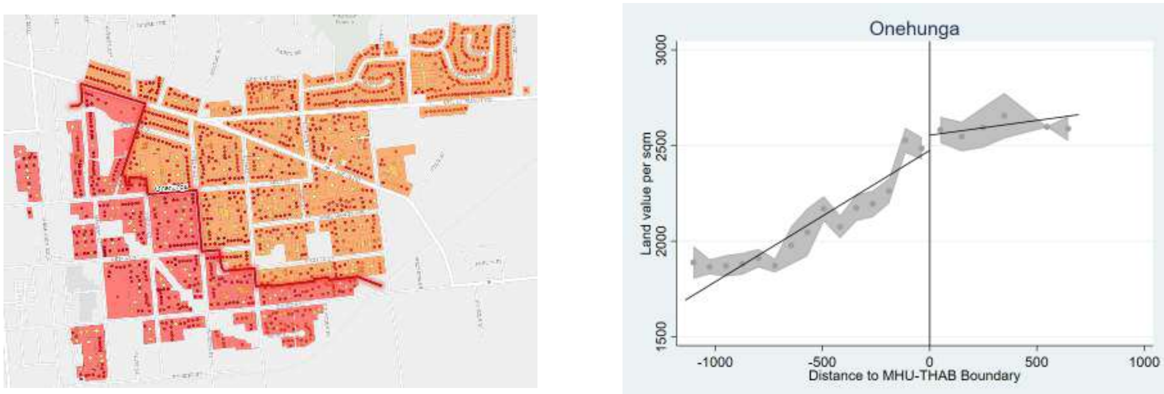


Figure 23: Onehunga BD

A.1.17 Otara

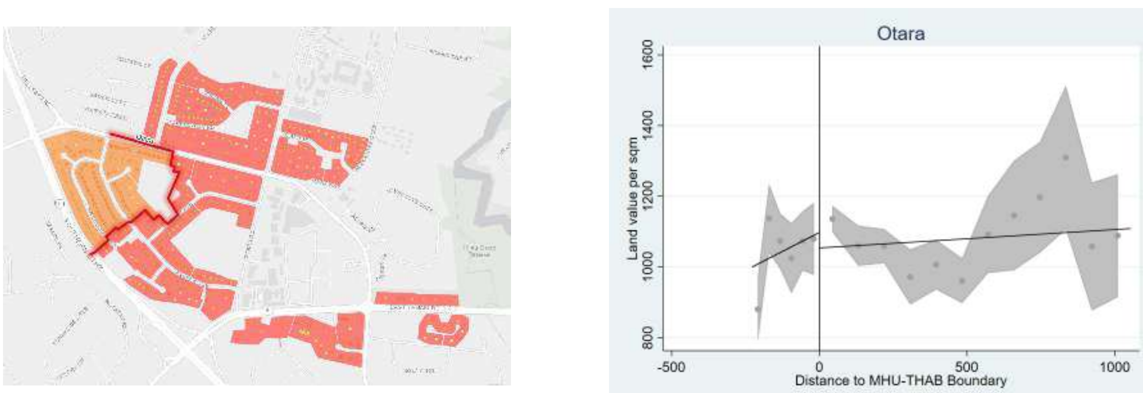


Figure 24: Otara BD

A.1.18 Pakuranga

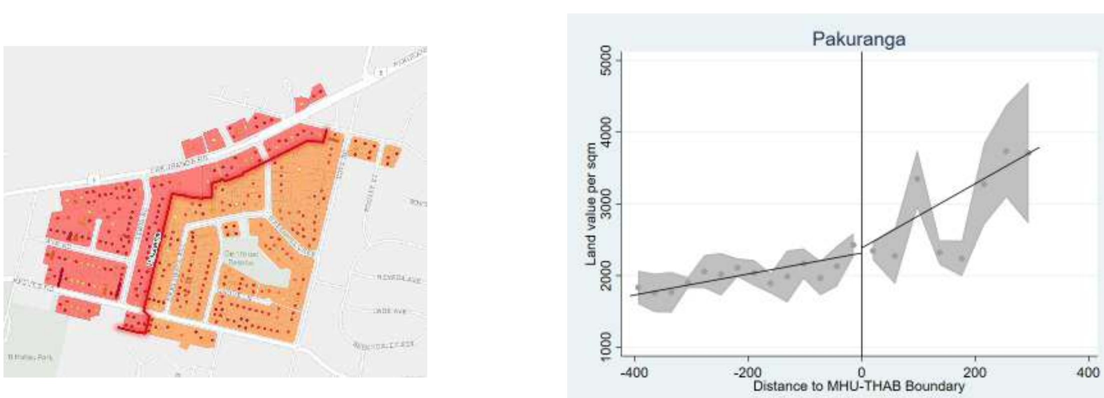


Figure 25: Pakuranga BD

A.1.19 Panmure

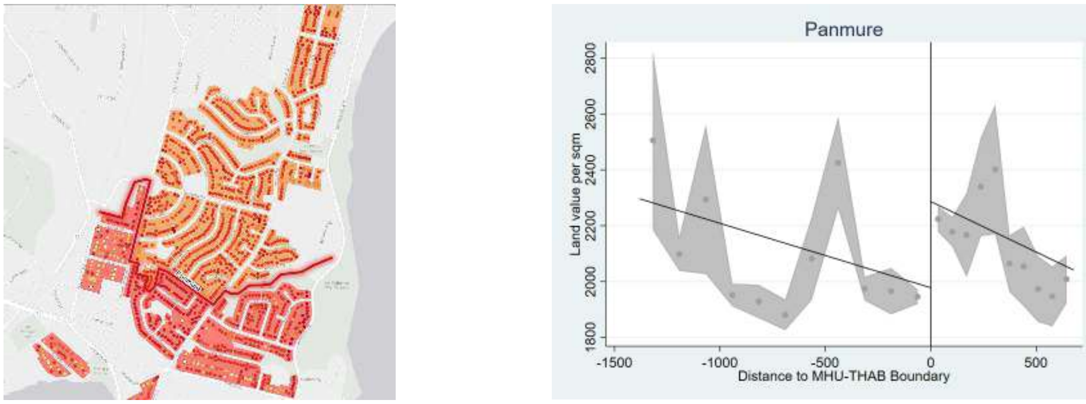


Figure 26: Panmure BD

A.1.20 Papakura

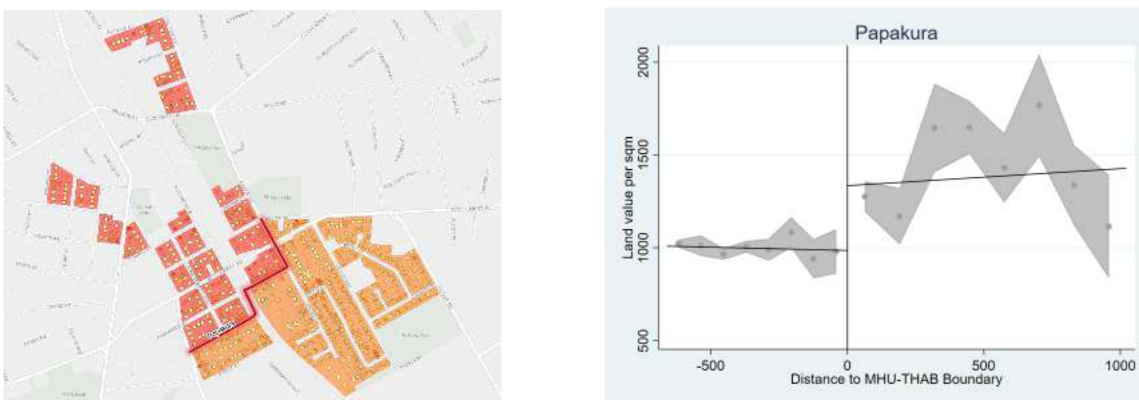


Figure 27: Papakura BD

A.1.21 Papatoetoe

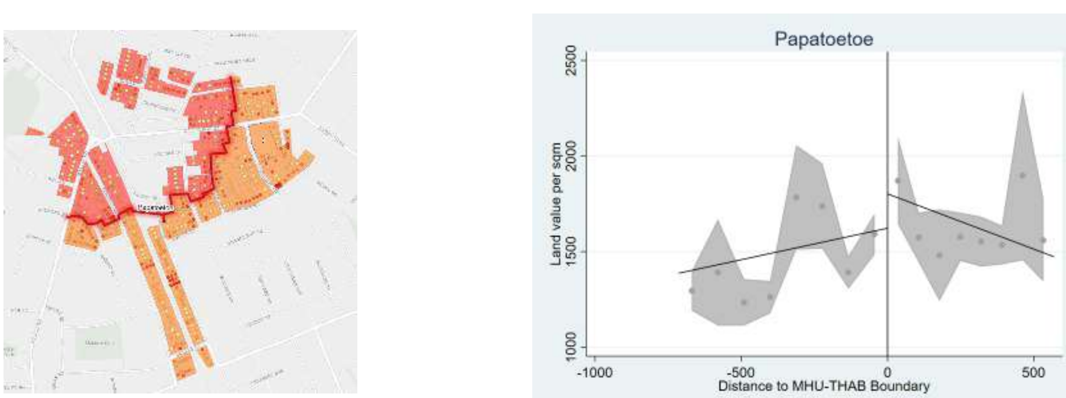


Figure 28: Papatoetoe BD

A.1.22 Ranui

Figure 29: Ranui BD

A.1.23 St Lukes

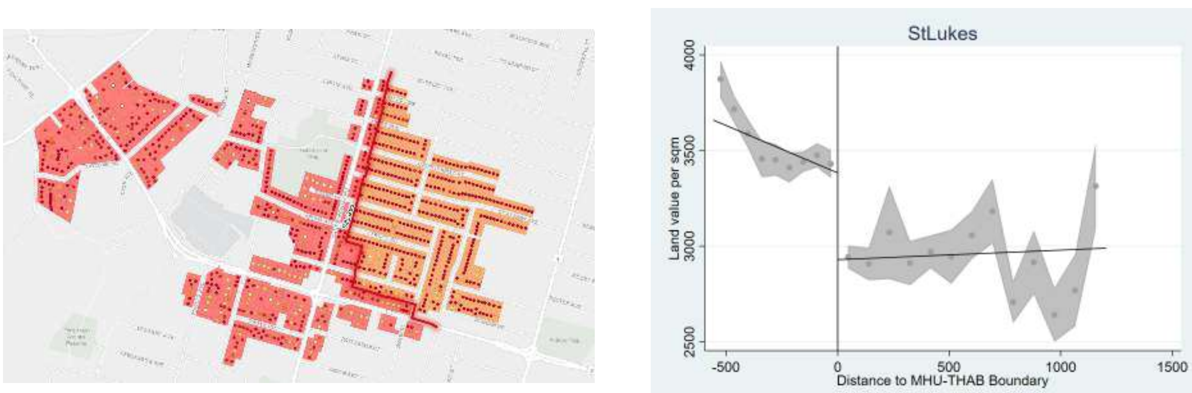


Figure 30: St Lukes BD

A.1.24 Sunnyvale

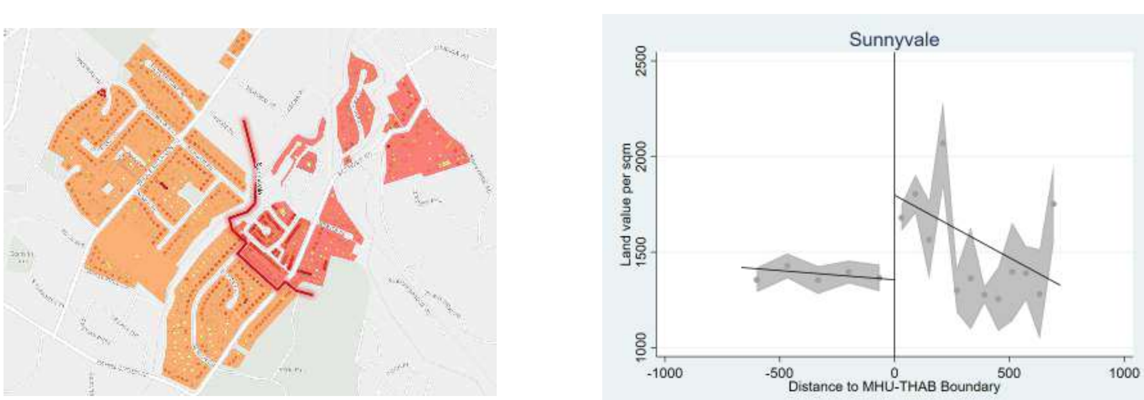


Figure 31: Sunnyvale BD

A.1.25 Takapuna

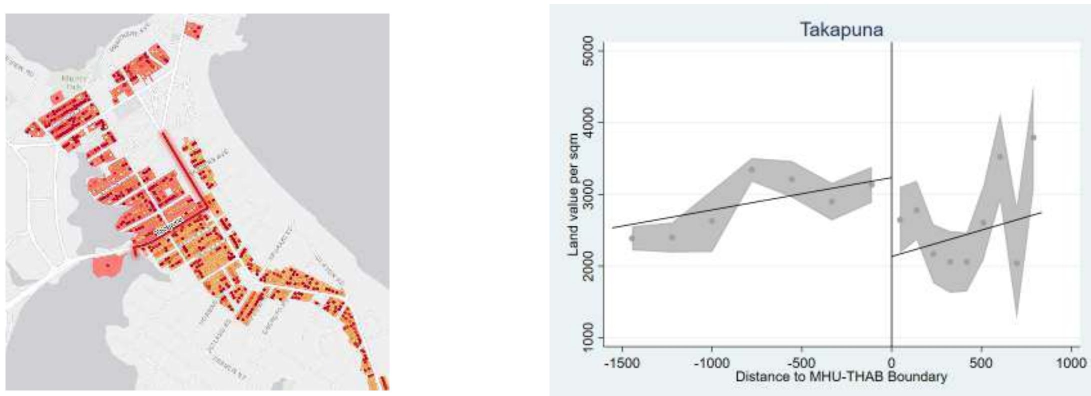


Figure 32: Takapuna BD

A.1.26 Te Atatu

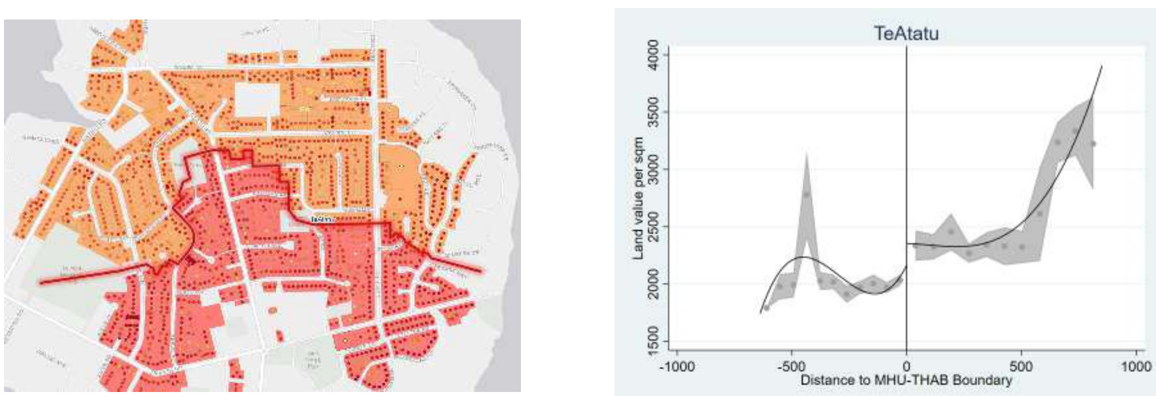


Figure 33: Te Atatu BD

A.1.27 Te Atatu South

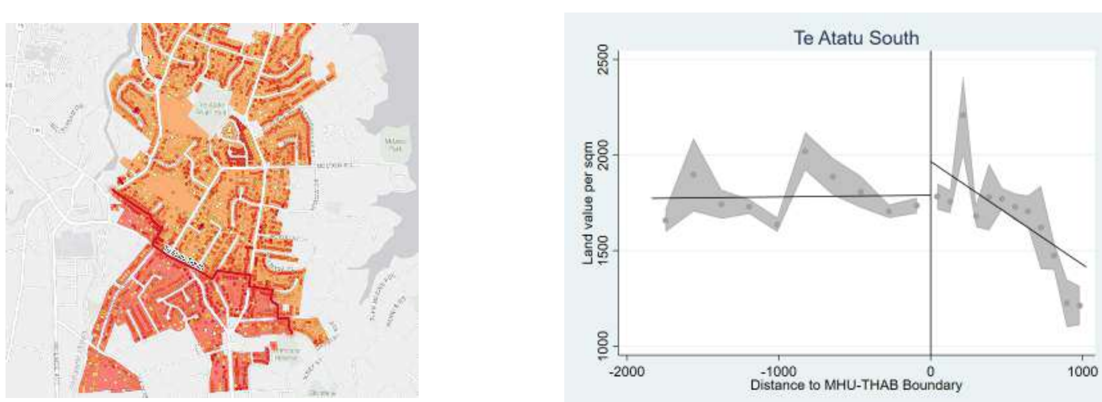


Figure 34: Te Atatu South BD

A.1.28 Three Kings

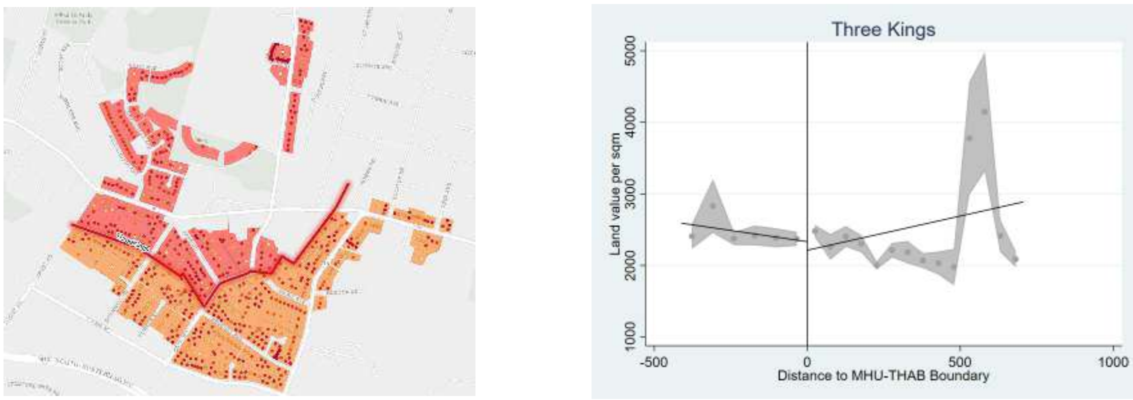


Figure 35: Three Kings BD

A.1.29 Waipuna

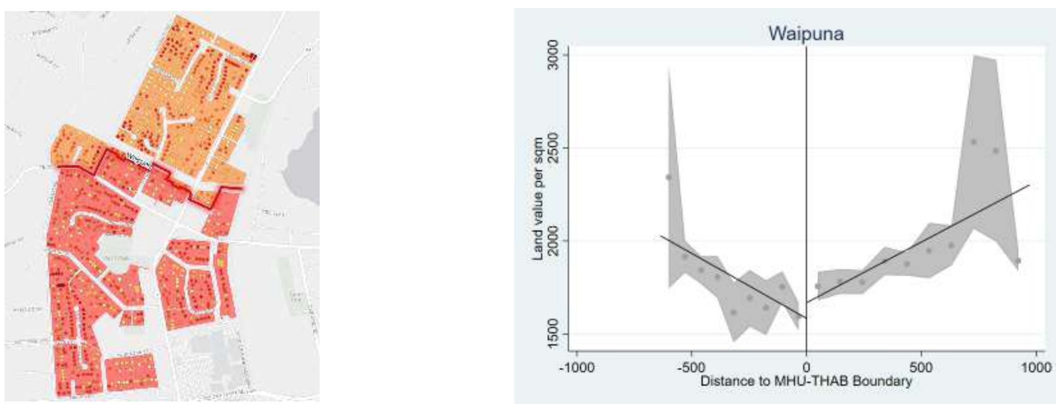


Figure 36: Waipuna BD

A.1.30 Westgate

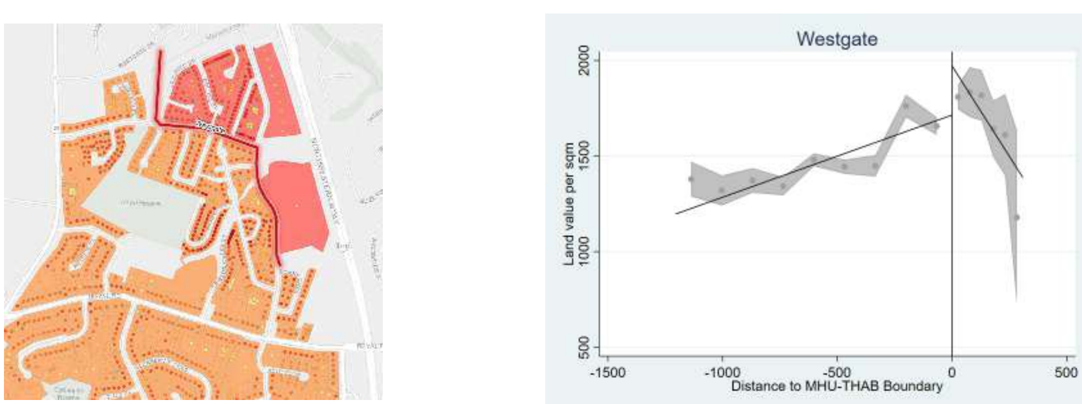


Figure 37: Westgate BD

A.2 Testing Continuity Assumption by Area

Table 8: Pooled BDD Regressions: Testing property characteristics at MHU-THAB boundary

	(1) Before 1980	(2) Weatherboard	(3) Built floorspace	(4) Land area
Morningside	0.151**	-0.026	-6.4	-16.6
	(0.076)	(0.085)	(9.8)	(48.4)
StLukes	-0.054	-0.403***	-20.9***	-23.3
	(0.036)	(0.04)	(5.3)	(25.4)
Northcote	-0.055	0.237***	-45.3***	-140.8***
	(0.055)	(0.058)	(6.8)	(55.5)
GreenlaneEast	-0.087*	-0.103**	-12.4**	-69.7*
	(0.046)	(0.046)	(5.9)	(40.6)
Takapuna	0.146***	-0.036	-27.3***	314.5***
	(0.048)	(0.042)	(6.4)	(65.1)
MtRoskill	0.002	-0.137***	-13.9***	-25.8
	(0.033)	(0.045)	(4.5)	(22.9)
ThreeKings	0.244***	-0.088*	14.3**	114.4***
	(0.053)	(0.052)	(6.8)	(43.1)
Avondale	0.117**	0.093**	-18.8***	-34.5
	(0.047)	(0.046)	(5.1)	(34.5)
Glenfield	-0.127**	-0.012	9.0	-110.5**
	(0.064)	(0.067)	(7)	(47.8)
Onehunga	0.277***	0.089***	2.2	-22.9
	(0.031)	(0.033)	(3.3)	(22.7)
Waipuna	0.182***	-0.05	5.8	-9.2
	(0.049)	(0.045)	(5.5)	(42.2)
GlenInnes	0.134***	-0.079**	-15.6***	48.7**
	(0.031)	(0.031)	(3.1)	(20.3)
TeAtatu	0.041	-0.01	6.9	14.5
	(0.042)	(0.04)	(5.1)	(21.2)
Panmure	-0.186***	-0.183***	-21.8***	2.4
	(0.034)	(0.037)	(3.5)	(23.3)
Kelston	0.021	-0.047*	-12.7***	-68.1***
	(0.028)	(0.026)	(2.7)	(22)
TeAtatuSouth	-0.072**	0.101***	-2.0	57.7**
	(0.034)	(0.032)	(3.9)	(23.1)
Lincoln	0.17***	0.129***	-5.9	121***
	(0.039)	(0.038)	(3.9)	(24.3)
GlenEden	-0.13***	-0.096***	-6.7**	-129***
	(0.028)	(0.027)	(2.8)	(24.5)
Pakuranga	0.286***	0.032	16.0*	192.2***
	(0.073)	(0.071)	(9.2)	(62.3)
Sunnyvale	-0.362***	0.193***	7.3	-453.6***
	(0.052)	(0.045)	(4.5)	(31.2)
Westgate	-0.053	0.046	-5.7	-83.5**
	(0.072)	(0.076)	(8.9)	(35)
Mangere	-0.021	0.063	-1.2	-47.7**
	(0.033)	(0.048)	(3.8)	(19.7)
Ranui	0.19***	0.079	-28.6***	-18.2
	(0.055)	(0.052)	(4.9)	(38.7)
Howick	-0.206***	-0.122***	5.9	-131.5***
	(0.067)	(0.033)	(6.7)	(32.6)
Otara	0.040	0.039	40.1***	163.1***
	(0.044)	(0.098)	(11.5)	(59.8)
Botany	0.000	0.516***	-68.7***	-83.7***
	(0.000)	(0.019)	(3.2)	(14.5)
Papatoetoe	0.030	0.011	-19.4***	73.8
	(0.047)	(0.034)	(5.4)	(63.8)
FlatBush	-0.002	0.065***	43.0***	-205.7
	(0.006)	(0.015)	(5.0)	(17.5)
Papakura	0.005	0.098**	1.2	-122.8**
	(0.052)	(0.047)	(4.7)	(53.1)
Manurewa	0.115***	-0.219***	2.8	72.3**
	(0.036)	(0.037)	(4.0)	(31.5)

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

B Appendix: First Differences Panel Dataset

To construct our panel data for use in the first differences analysis in Section 7 we must combine four datasets: land values from the 2011 and 2021 valuations datasets; pre-AUP legal capacity from the 2012 CfGS; and post-AUP legal capacity from the 2016 CfGS. For all datasets, we retain only the parcels which are zoned for residential use.

The two valuation datasets contain a shared variable which identifies unique parcels, called '_valuation". We merge the two datasets on this variable. Close to 17,000 parcels are dropped from the 2011 dataset and 51,000 from the 2021 dataset, due to parcels being amalgamated or subdivided making them non-comparable over time. We focus on the remaining 341,892 parcels that are observed in both 2011 and 2021.

Next, we seek to join the 2011 valuation data to the 2012 CfGS. While there are no unique identifiers to connect the two datasets, we have geospatial information identifying the location and shape of each parcel. We use the QGIS function to 'join attributes by location' and connect each polygon from the valuation dataset to the corresponding CfGS polygon with the largest shared overlap. For matches, we compare the land area recorded in each dataset, to ensure that matches correspond to the same physical property.

Of the nearly 390,000 matched observations, 255,000 are uniquely matched with parcel areas within 2% of each other. We drop 64,000 observations which have land areas that differ by more than 2%, as their underlying measured attributes may diverge in ways that bias our results. We also drop 70,000 observations which are within 2% error but have multiple rows of valuation data. Visual inspection suggests that these are mostly multi-unit titles, which may have shared ownership of the underlying land title, making them difficult to deploy for our purposes.

After restricting this sample to our study area, we are left with 245,608 observations which match between the 2011 valuation data and the 2012 CfGS. Repeating these exact steps for the 2021 valuation data and 2016 CfGS, returns 194,856 matched parcels.

We then merge these two datasets using the '_valuation" variable from the valuation datasets, which returns a panel dataset which contains 174,186 parcels with both land values and legal capacity observed both before and after the passage of the AUP. This is the dataset summarised and used in Section 7.