Land Use Regulation, the Redevelopment Premium and House Prices

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Abstract

The option to redevelop a residential property can carry a significant positive premium. Although the existing literature has examined how this redevelopment premium is affected by the inherent characteristics of a property, comparatively little research has focussed on how land use regulations (LURs) interact with these characteristics to affect property values. In this paper we study the effect of upzoning (i.e., a relaxation of restrictions on residential density) on property values using a rich dataset of residential sales transactions. To study the effects of this policy change, we embed a difference-in-differences structure within a hedonic pricing function, wherein the upzoning quasi-treatment is interacted with a commonly-used empirical proxy for the opportunity cost of redevelopment – site intensity (i.e., the ratio of improved value to the total value of the property). We find that upzoning significantly increased the redevelopment option and inflated the price of under-developed properties. But we also find that upzoning deflated the price of properties that were already intensively developed, suggesting that the increase in the redevelopment option was offset by concurrent effects of upzoning, such as disamenities from increased population density.

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1 Introduction

The option to improve, augment or teardown and replace a residential structure can carry a significant positive premium (Clapp and Salavei, 2010; Clapp, Salavei Bardos and Wong, 2012). The size of this redevelopment premium is influenced by a variety of property attributes, such as the existing extent of site development and the age of the structure (Clapp and Salavei, 2010). Additionally, the regulatory environment should affect the size of the redevelopment premium, since land use regulations (LURs) such as minimum lot sizes and building coverage ratios are designed to limit the scope of site development. Holding all else equal, a relaxation of LURs within a residential zone should increase the value of the redevelopment option embedded in the affected housing, since the land underlying the structure has been upzoned to support additional dwellings (Williams, 1991).

In this paper we empirically examine the effect of LURs on the redevelopment premium embedded in individual property prices. While theoretical treatments of the redevelopment option imply that a relaxation (tightening) of LURs can increase (decrease) the redevelopment premium (Williams, 1991; Jou and Lee, 2007), comparatively little work has confirmed these predictions in an empirical setting. To date, much of the empirical work on the redevelopment option has focussed on how the inherent characteristics of the residential structure affect the premium (Clapp and Salavei, 2010; Clapp, Salavei Bardos and Wong, 2012; Clapp, Jou and Lee, 2012). Meanwhile, although a substantial amount of empirical research has examined the effects of LURs on average house prices across cities (see Quigley and Rosenthal, 2005; or Gyourko and Molloy, 2014, for recent surveys), comparatively little work has examined the effect of LURs on individual house prices. Our goal in this paper is to fill this gap in the extant literature by providing empirical evidence of the impact of LURs on the redevelopment premium.

This study is based on a large dataset of residential sales transactions from a single metropolitan jurisdiction, where policy intervention resulted in the relaxation of LURs within targeted areas of the city. To study the effects of this policy change, we embed a difference-in-differences structure within a hedonic pricing function, wherein the upzoning quasi-treatment is interacted with a commonly-used empirical proxy for the redevelopment premium – site intensity (Clapp and Salavei, 2010).[1] The estimated model suggests that LURs have a substantial impact on the value of the redevelopment option in our sample. Upzoned properties experienced a significant increase in the redevelopment premium compared to properties that were not upzoned. Moreover, depending on the scale of upzoning and the existing extent of site development, the model indicates that the increase in the redevelopment premium in our sample can be sufficiently large so as to offset any decline in property value due to other concurrent effects from the change in LURs, such as disamenity effects from crowding or anticipated supply effects from future redevelopment and construction.

Our approach is heavily influenced by the recent theoretical and empirical work of Clapp and Salavei (2010), Clapp and Salavei Bardos and Wong (2012) and Clapp, Jou and Lee (2012) on the redevelopment premium. These papers use both site intensity – the ratio of the value of

[1] In fact we have several upzoning treatments depending on the scope of site development permitted under the new LURs.

improvements to the total value of the property – and building age as empirical proxies for the value of the redevelopment option embedded in a property. Intuitively, the opportunity cost in terms of foregone rent from tearing down a large and newly-constructed block of apartments is much higher than the opportunity cost of tearing down a small, depreciated building. The former should therefore carry a smaller redevelopment premium compared to the latter. Consistent with this intuition, Clapp, Salavei Bardos and Wong (2012) show that house prices are increasing in site intensity and decreasing in age in a sample of properties from different towns in Connecticut. We follow these authors and adopt site intensity as an empirical proxy for the redevelopment premium.[2]

Our empirical model is built around a rich and detailed dataset on residential sales transactions from Auckland, New Zealand, that spans 2010 to 2016, inclusive. Auckland is the largest metropolitan region in New Zealand, with a population of approximately 1.5 million people as of 2017, and has experienced a substantial rise in its property prices over the past decade (Greenaway-McGrevy and Phillips, 2016). From 2010 onwards the entire metropolitan region has fallen under the jurisdiction of a single local government (namely the Auckland City Council). Recent events in Auckland also mean that it provides a unique opportunity to analyze the effects of LURs. In 2013 the Auckland City Council announced plans to rezone much of the land in the city to support greater population density. However, the changes in LURs were not uniform – regulations were relaxed to varying degrees in targeted areas of the metropolitan region – so that houses that were not upzoned provide a potential control for studying the effects of LURs on a variety of outcomes, including house prices. We can pinpoint both when and where the new residential planning zones applied in our sample of transactions, significantly aiding the identification of the upzoning effect. In section 3 below we provide a detailed description of the policy change, including a timeline.

The empirical model is based on a regression of the change in the sales price of individual houses on a collection of upzoning dummy variables interacted with our site intensity indicator (which is the site intensity of the property prior to the policy announcement). Estimated coefficients on these interaction terms thereby inform us about any change in the redevelopment premium of the properties located in a given residential zone after the policy is announced. The dataset also offers some other unique advantages when identifying this effect. More specifically, our data includes information on an array of property attributes, which enables us to control for numerous potential confounding factors that may have also affected price appreciation, such as the number of bedrooms in the dwelling, the distance to the central business district (CBD), and the average household income in the immediate neighborhood. These attributes also include assessed valuations of the property, which permits us to construct the site intensity variable. Variation in site intensity across different observations within each planning zone is also used to mitigate potential endogeneity of the upzoning treatment in the empirical model.[3] Importantly, our dataset also contains the geographic location of the dwelling (longitude-latitude), which allows us to match the transacted property to

[2]We do not use age as an empirical proxy as it is a poor indicator of depreciation in Auckland. We refer the reader to Section 3 for details.

[3]If the site intensity variable was binary instead of continuous, then our model would follow a triple difference-in-differences structure, with high site intensity properties acting as a control for low site intensity properties.

its residential planning zone. There is also a unique identifier for each property, which allows us to use repeat sales to analyze the effect of the policy intervention on house prices.

Our findings provide strong support for LURs having a material effect on the redevelopment premium. The estimated model implies that properties with a site intensity ratio of zero (equivalent to an undeveloped plot of land) that were rezoned to the highest level of residential density appreciated by 18.1% per annum, on average, over the five year sampling period spanning the upzoning announcement. Meanwhile properties with a site intensity ratio of one (i.e. no land value) located in the same planning zone appreciated by only 10.5% per annum, on average, over the same period. The difference in appreciation rates is statistically significant. Properties that were not upzoned appreciated by approximately 13.5% per annum (regardless of the site intensity of the property) over the same period.[4] Interestingly, the model therefore implies that intensively developed properties rezoned for increased density depreciated in value relative to intensively developed properties that were not upzoned. This result is consistent with disamenities from population density or anticipated supply effects from future construction of high density housing.

The remainder of the paper is organized as follows. The following section discusses the relevant literature, while section three provides a detailed summary of the institutional background underlying our dataset. In section four we present a simple model based on Clapp and Salavei (2010) that provides the theoretical motivation for our empirical regressions. Empirics are contained in section five, while Section six concludes.

2 Related Literature

Our work builds directly on previous research on the option to redevelop real estate. While purely theoretical treatments of redevelopment date back to Williams (1991), there has been a more recent literature that has focussed on establishing and, in some cases, measuring the redevelopment premium in empirical contexts. Clapp and Salavei (2010) argue that hedonic regressions that do not control for the redevelopment option are likely to be misspecified. Estimated coefficients on attributes that are related to the size of the structure, such as floor area or number of bedrooms, are likely to be biased towards zero as such attributes are negatively correlated with the value of the redevelopment option. Clapp, Salavei Bardos and Wong (2012) estimate the size of the redevelopment premium in a sample of fifty-three towns in Connecticut that spans 1994 to 2007, showing that the premium is positive for at least one fifth of the towns in the sample. Within these towns, properties that were most similar to vacant land sold for a 29-34% premium. Clapp, Jou and Lee (2012) provide additional empirical evidence of the redevelopment premium in a sample of residential transactions in Berlin. These empirical papers often use the site intensity ratio and building age as empirical proxies for the redevelopment premium. Although real-option theory predicts a non-linear relationship between the value of the premium and site intensity, a linear specification typically provides a first order correction in conventional applications, such as hedonic

[4] There was significant house price appreciation Auckland between 2010 and 2015. See Greenaway-McGrevy and Phillips (2016) for further discussion.

regressions. The site intensity ratio is the value of improvements to the total value of the property, and it is typically based on assessed valuations made by local government for the purpose of levying property taxes. We follow this literature and use site intensity ratio as an empirical proxy for the redevelopment premium in Auckland. However, we eschew using building age in our application for two reasons. First, age is a poor indicator of quality in the Auckland housing stock due to the 'leaky building' crisis associated with housing constructed in the late nineties and early 2000s. Rehm (2009) showed that suspected leaky buildings sold for between 5-10% less, implying that the relationship between building age and price in Auckland is not monotonic. Second, the assessed value of improvements should take building condition into account, which encompasses the effects of depreciation.

Site intensity is related to several other measures that capture the relative value of land and capital in housing. It is equal to one minus the "land leverage" ratio (the ratio of land value to total value) proposed by Bostic, Longhofer and Redfearn (2007) and employed by Bourassa et al. (2009) and Bourassa et al. (2011). Davis and Heathcote (2007) also use a measure that is equivalent to land leverage.

Our work also draws on a substantive literature that examines the relationship between LURs and housing markets across cities. Cities with more restrictive LURs tend to have higher housing costs on average (see Quigley and Rosenthal, 2005; or Gyourko and Molloy, 2014, for recent surveys and evidence on this front). LURs constrain housing supply, pushing up house prices and suppressing new construction in growing cities. Ihlanfeldt (2007) examines the effects of regulation on individual parcels using a cross-section of 112 jurisdictions in Florida. He instruments for the potential endogeneity of regulations, and finds that cities with tighter LURs in Florida have higher house prices. Dalton and Zabel (2011) examine the effects of estimated changes in minimum lot sizes (MLS) on individual house prices across 471 residential zones (and 178 towns) in Eastern Massachusetts. They employ cross-section fixed effects in a panel data framework to control for potential endogeneity of local regulation, and find that increases in MLS over time pushed house prices up. Jackson (2014) also employs a fixed effects approach in a sample of Californian cities, and finds similar positive effects of regulation of house prices, albeit of a smaller magnitude.

A related literature has documented an opposite relationship between land prices and LURs. For instance, Ihlanfeldt (2007) shows that LURs decrease the price of vacant land in his sample of Florida jurisdictions. Gao, Asami and Katsumata (2006) show that land prices are cheaper in areas of Tokyo with tighter restrictions on floor area ratios (FARs), while Brueckner, Fu, and Zhan (2015) document a similar pattern between FARs and land lease prices in a sample of Chinese cities. More recently, Turner, Haughwout, and van der Klaauw (2014) also find that LURs reduce land values.

The long-run impact of LURs on metropolitan growth have also been well-documented. Positive shocks to labor demand lead to smaller increases in long-run employment and higher house prices costs in cities with tighter LURs (Saks, 2008; Zabel, 2012; Greenaway-McGrevy and Hood, 2016).

There are plenty of theoretical treatments of the option to redevelop residential property. Titman (1985), Williams (1991), Capozza and Li (1994), Gutherie (2007) and Clapp, Jou and Lee

(2012) solve for the optimal time to redevelop a site. The effect of LURs on redevelopment has also received significant attention in this literature. Turnbull (2002) examines the impact of regulations 'taking' on residential development; Cunningham (2006, 2007) examines the effect of urban boundaries on development; while Jou and Lee (2015) examine the effect of density controls on house prices and urban boundaries. Many empirical papers test and quantify the implications of real option approaches to housing. Quigg (1993) estimates the development premium on vacant land. Bulan, Mayer and Somerville (2009) quantify the impact of uncertainty on the timing of development. While related to our endeavours, our work differs from these empirical papers in that we are interested specifically in the value of the option to redevelop, not when redevelopment occurs per se.

Our paper also joins a wide body of research that examines LURs in the New Zealand context. Grimes and Liang (2007) document a significant disparity in land prices directly inside and directly outside the metropolitan urban limit (MUL) of New Zealand cities, while Grimes and Mitchell (2015) collect and tabulate the costs associated with satisfying LURs and administrative delays. Lees (2017) constructs the measures of regulatory distortions proposed by Glaeser and Gyourko (2003) and Glaeser, Gyourko and Saks (2005) for various New Zealand cities. This paper contributes to this work by examining how changes in LURs affect house prices within Auckland, using a framework that can easily be generalized to other cities.

3 Institutional Background

In this section we briefly describe the city of Auckland and the institutional history leading up to the changes in its LURs. We then discuss how these changes and the timing of announcements affects our empirical design.

Auckland is the largest city in New Zealand with an estimated population of approximately 1.5 million within the metropolitan region (as of 2017). It has a population-weighted density of approximately 4,310 people per km^2 (source: authors' calculations based on 2013 Census data), and the population is fairly evenly distributed within the immediate vicinity of the central business district (CBD), as demonstrated in Figure 1. Only in the CBD does population density exceed 6,000 people per km^2 (as indicated by the darkest area located at approximately latitude -36.85 and longitude 174.75 in the figure). The geographic distribution of density close to downtown is rather uniform, with much of the area within a 15 kilometer radius of the CBD having a density between 2,000 to 4,000 people per km^2.

The distribution of people across areas of different densities is also fairly uniform, as shown in Figure 2. Approximately 43% of the population live in areas with a density of 2,000 to 4,000 people per km^2, and a further 30% live in areas between 4,000 to 6,000. Only 8% of the population live in areas that are more dense than 6000 persons per km^2.

Recent changes to LUR under the 'Auckland Unitary Plan' make the city an ideal case study to investigate the effects of regulations on house prices within a metropolitan area. Prior to 2010, the Auckland metropolitan region comprised one regional council and seven city and district councils.

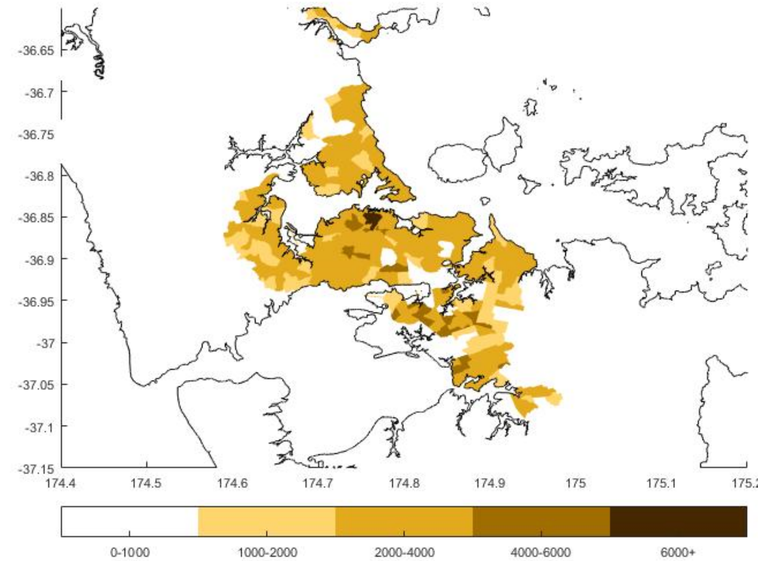


Figure 1: Population densities (persons/km^2) across Area Units in Auckland. Authors' calculations based on 2013 census.

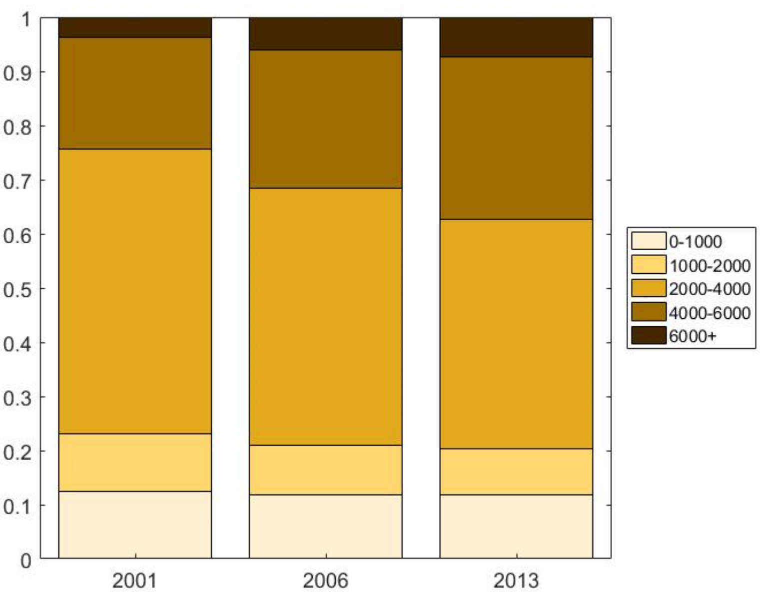


Figure 2: Proportion of population living at different population densities (persons/km^2). Source: Authors' calculations based on 2013 census.

The seven district councils used different land use zones and regulations. On 1 November 2010, Auckland Council (AC) was formed when the eight previous bodies in the region were amalgamated. Special legislation was also passed by the central government requiring AC to develop a consistent set of planning rules for the whole region under the Local Government Act 2010. This set of planning rules is embodied in the 'Auckland Unitary Plan'.

The key milestones in the development and implementation of the Auckland Unitary Plan (AUP) are summarized below:

- On 15 March 2013, AC released a draft AUP. The next 11 weeks comprised a period of public consultation, in which AC held 249 public meetings and received 21,000 pieces of written feedback.
- On 30 September 2013, AC released the Proposed AUP (PAUP) and notified the public that the PAUP was open for submissions. More than 13,000 submissions (from the public, government, and community groups) were made, with over 1.4 million separate submission points.
- Between April 2014 and May 2016, an Independent Hearings Panel (IHP) was appointed by the central government and subsequently held 249 days of hearings across 60 topics, and received more than 10,000 items of evidence.
- On 22 July 2016, the IHP's recommendations set out recommended changes to the PAUP. One of the primary recommendations was the abolition of minimum lot sizes for existing parcels. The AC considered and voted on the IHP recommendations over the next 20 working days. On 27 July the public was able to view the IHP's recommendations.
- On 19 August, AC released its 'decisions version' of the AUP, including zoning maps. Several of the IHP's recommendations were voted down, including a IHP recommendation to abolish minimum floor sizes on apartments. This was followed by a 20-day period for the public to lodge appeals on the 'decisions version' in the Environment Court. Appeals to the High Court were only permitted if based on points of law.
- On 8 November 2016, a public notice was placed in the media notifying that the AUP would become operational on 15 November 2016.[5]

Importantly, the AUP relaxed regulations in order to permit increased density within targeted areas of Auckland. For example, the 'Capacity for Growth Study' published by the Auckland City Council in 2014 quantified the additional housing that could be constructed under the draft AUP released in 2013. The study illustrates that there were "increased density provisions enabled by the AUP" (p. 21, Balderston and Fredrickson, 2014), and that the draft AUP altered LURs to allow a substantive increase in the number of dwellings able to built within the region.[6]

The amount of development permitted on a given site is restricted by the residential planning

[5] There were two elements of the AUP that were not fully operational at this time – (i) any parts that remain subject to Environment Court and High Court under the Local Government Act 2010, and (ii) the regional coastal plan of the PAUP that required Minister of Conservation approval.

[6] The Capacity for Growth Studies provide estimates of how many additional dwellings can be constructed in Auckland under various assumptios. Upper estimates of this capcity increased from 338,007 additional dwellings in the 2012 capacity for growth study (Fredrickson and Balderston, 2012) to 417,043 in the 2013 capaicty for growth study (Balderston and Fredrickson, 2014). The estimated number of existing dwellings was 485,013 in 2013. The significant increase in capacity between the two studies reflects changes in LURs under the draft AUP.

zone in which the site is located. In our empirical model we focus on four zones, listed in declining levels of permissible site development: Terrace Housing and Apartments; Mixed Housing Suburban; Mixed Housing Urban; and Single House. (For ease of exposition we will refer to these as 'zone 4', 'zone 3', 'zone 2' and 'zone 1', respectively, in places throughout the text.) The LURs that apply within each zone are listed in the Appendix, and support this ordinal ranking of permissible site development. These regulations include site coverage ratios, minimum lot sizes for new subdivisions, and height restrictions, among other things. Finally, these four zones comprise over 90 percent of the sales transactions in our sample.

Figure 3 depicts the geographic distribution of the four zones across the city. Evidently 'Mixed Housing Suburban' is the largest zone by area, closely followed by 'Mixed Housing Urban'. The 'Single House' zone is predominantly located either very close the to the CBD or at the outskirts of the city. 'Terrace Housing and Apartments' covers the smallest amount of land.

Our empirical design treats the AUP as a quasi-natural experiment. All announced versions of the AUP (draft, proposed, decisions and final) made changes to LURs that would potentially impact restrictions on the extent of site development, depending on where a site was located. These proposed changes were able to be viewed online, so that any interested member of the public could observe the specific LURs proposed for a given parcel of land. This means that it was relatively straightforward for interested individuals to determine whether a given parcel had been upzoned (and the proposed extent of that upzoning) prior to buying or selling a property.

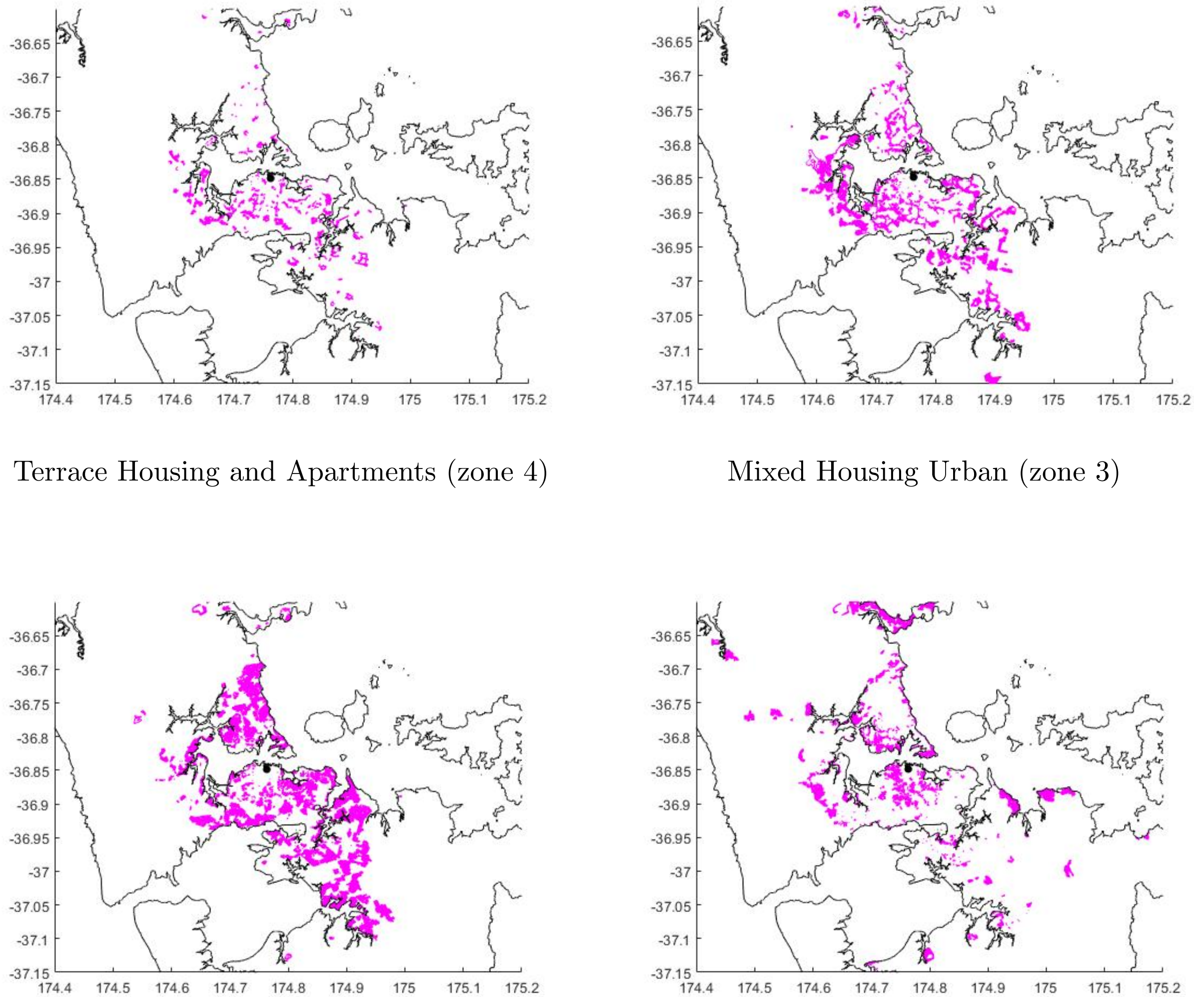
Our regression specification models house price appreciation over a period spanning the announcement of the change in LURs. We therefore must select a time period 'before' and 'after' the treatment has occurred. Unfortunately, as is clear from the timeline given above, there is no clean, singular announcement of rezoning. It first becomes apparent that changes to LURs are coming in 2010, after amalgamation of the distinct councils to create the Auckland City Council. However, the first draft plan detailing where and how LURs would change was not released until March 2013, at which point the public was able to observe the location and scale of intensification. Furthermore, it was not until July 2016 that the new residential zones were finalized.

In our main empirical specification, we take a somewhat conservative approach and take the years between 2010 and 2012 (inclusive) as the pre-treatment period. This period altogether predates the release of the (first) draft AUP, in which the first detailed maps of potential changes to LURs were made public. Our post-treatment sample is 2016, the year in which the 'decisions' version of the AUP is released. The final maps detailing the changes in LURs were made public with the release of the decisions version in July 2016. Note that we do explore several other time periods in our robustness checks (see Section 7.2 in the Appendix).

4 Economic Model

To motivate our empirical regression we adapt the model of residential redevelopment used by Clapp and Salavei (2010) to incorporate constraints on development imposed by a policymaker. We then examine the empirical predictions of the model when the policymaker relaxes these restrictions.

Figure 3: Location of Specific Residential Zones



Terrace Housing and Apartments (zone 4)

Mixed Housing Urban (zone 3)

Mixed Housing Suburban (zone 2)

Single House (zone 1)

Note: The dot located close to the center of the maps is the location of the 'Skytower' within the CBD.

The notation used in this section applies only within this section.

The set up is as follows. Each developed property has a vector of characteristics q_0 that earn rents p and depreciate at a constant rate δ. In the absence of redevelopment, the present value of the property is

$$V_0 = \int_0^{\infty} p' q_0 \cdot e^{-(\delta+\rho)s} ds = \frac{p' q_0}{\rho+\delta}$$

where ρ is the discount rate. Future rents p (and characteristics q_0) are known with certainty. The property owner is permitted by the local authority to redevelop the property to the standard given by q_n. In the absence of upzoning, we may think about setting $q_n = q_0$. The cost of redevelopment is k. If the property is redeveloped at time $\underline{T} > 0$ the present value of the property is

$$\begin{aligned} V_0 &= \int_0^{\underline{T}} p' q_0 \cdot e^{-(\delta+\rho)s} ds + \int_{\underline{T}}^{\infty} p' q_n \cdot e^{-(\delta+\rho)s} ds - k e^{\rho T} \\ &= \frac{p' q_0}{\rho+\delta} + \left[\frac{p'(q_n - q_0)}{\rho+\delta} e^{-\underline{T}(\rho+\delta)} - k e^{-\rho \underline{T}} \right] \end{aligned} \quad (1)$$

The term in the brackets is the redevelopment premium. If $q_n = q_0$ it disappears. Let T denote the date of optimal redevelopment. Straightforwardly we have

$$\begin{aligned} V_0 &= \int_0^{T} p' q_0 \cdot e^{-(\delta+\rho)s} ds + \int_{T^*}^{\infty} p' q_n \cdot e^{-(\delta+\rho)s} ds - k e^{\rho T} \\ &= \frac{p' q_0}{\rho+\delta} + \left[\frac{p'(q_n - q_0)}{\rho+\delta} e^{-T(\rho+\delta)} - k e^{-\rho T} \right]. \end{aligned} \quad (2)$$

Clapp and Salavei (2010) solve for the optimal date T to redevelop the property to q_n. By rearranging equation (5) in Clapp and Salavei (2010) we have

$$T = -\ln \left(\frac{\rho}{\rho+\delta} \frac{p' q_n - k}{p' q_0} \right) \frac{1}{\delta} \quad (3)$$

so that the optimal date of redevelopment is decreasing in q_n.

Next we consider what happens to V_0 in (1) when the local authority alters q_n. For instructive purposes we will focus on the case where q_n is a scalar that represents an overall measure of development intensity. We will also permit construction costs to be a function of $q_n \in \mathbb{R}_{>0}$. That is $k = k(q_n)$, where we will assume that $k(q_n) > 0$ and $k'(q_n) \leq 0$ (building costs are non-increasing with intensity).[7] We re-express V_0 as follows

$$V_0(q_n) = \frac{p q_0}{\rho+\delta} + \left[\frac{p(q_n - q_0)}{\rho+\delta} f(q_n) e^{\frac{\rho+\delta}{\delta}} - k(q_n) f(q_n) e^{\frac{\rho}{\delta}} \right]$$

where $f(q_n) = \frac{p q_n - k(q_n)}{p q_0}$ satisfies $f'(q_n) = \frac{p - k'(q_n)}{p q_0} > 0$ since $k'(q_n) < 0$. Thus we have

$$V_0'(q_n) = \left(\frac{p(q_n - q_0)}{\rho+\delta} - k(q_n) \right) f'(q_n) e^{\frac{\delta}{\rho}} + \left(\frac{p}{\rho+\delta} - k'(q_n) \right) f(q_n) e^{\frac{\delta}{\rho}} + \left(\frac{p}{\rho+\delta} - k'(q_n) \right) f(q_n) e \geq 0$$

provided that $\frac{p(q_n - q_0)}{\rho+\delta} - k(q_n) \geq 0$, i.e., the present value of improvements exceeds the cost of

[7] This assumption is not necessary for the property value to be increasing in q_n.

improvement.

The model also permits us to examine the impact of upzoning on two properties that exhibit different levels of site development. Note that $V_0'(q_n)$ is increasing in q_0, meaning that the property with the lower initial level of site development will experience a larger increase in value after upzoning. This key prediction from the model will be examined in our empirical specification.

Finally, the model can also be used to examine the impact of upzoning on the optimal date of redevelopment. Letting $T(q_n)$ denote the optimal date of redevelopment, we have

$$T'(q_n) = -\frac{1}{\delta}\frac{p-k'(q_n)}{pq_n-k(q_n)} < 0,$$

meaning that an increase in q_n will bring the optimal date of redevelopment forward in time.

5 Empirics

In this section we first describe our dataset and empirical regression, before proceeding to present and discuss our results.

5.1 Data

Our primary dataset consists of all residential sales in Auckland between 2010 and 2016 (inclusive). The transaction data are very detailed and include: the sales price; the value of any chattels included in the sale; the date of sale; the assessed value of improvements, land and total value of the property; the land area (in hectares) of the property; the floor area and site footprint (both in square metres) of the residential building; whether the property is leasehold or freehold; dwelling type (house, flat, apartment or vacant land); the Area Unit (AU) in which the property is located[8]; number of bedrooms and bathrooms; the decade in which the dwelling was built; and the latitude and longitude of the property. The dataset also includes a unique identifier for each property. Properties without an exclusive ownership of land on the title (such as apartments or cross-leased sites) are recorded as having zero land area in the dataset. Assessed values are based on local Council valuations made for the purpose of levying property taxes.

We add some additional variables to the transaction dataset. Using the longitude and latitude coordinates we calculate the distance of the property to downtown Auckland.[9] We also use these coordinates to identify the planning zone in which the property is located. The method for assigning the planning zone is described in detail in the Appendix. In our regressions we focus on the four main residential zones introduced in Section 3: 'Terrace Housing and Apartment Building' (or 'zone 4'); 'Mixed Housing Suburban' ('zone 3'); 'Mixed Housing Urban' ('zone 2'); and 'Single House' ('zone 1'). The site intensity ratio (which serves as an empirical proxy for the redevelopment

[8] Area Units are non-administrative geographic areas that are used for statistical purposes. They are similar to suburbs. For example, in urban areas they contain between 3,000 and 5,000 residents.

[9] We use latitude -36.84846 and longitude 174.763332, which is the approximate location of the Skytower in Auckland.

premium) is constructed as follows:

$$intensity := \frac{IV}{AV} = 1 - \frac{LV}{AV} \tag{4}$$

where AV is the total assessed value, LV is the assessed land value, and IV is the improved value (or capital value) of the property, where $IV = AV - LV$ holds as an identity. By construction the ratio lies between zero and one. Using the Area Unit (AU) of the transaction, we assign the median household income for the AU in which the property is located. AUs are a geographic measure roughly corresponding to large suburbs in urban areas, comprising between 3,000 and 5,000 residents.[10] We also create a dummy variable that is equal to one for properties that carry an exclusive land ownership rights on the title. Finally, we also construct the approximate age of the building as the difference between the date of sale and the decade in which the building was constructed.[11]

We clean the data in order to remove transactions that appear to have had information incorrectly coded or omitted, or that appear to be non-market transactions. First, any transactions with missing information on one of the variables was removed. Second, transactions for vacant lots or leasehold sales were removed. Third, transactions with a reported floor area of less than 10 square metres or more than 500 square metres were removed. Fourth, transactions with a land size of more than 10 hectares were removed. Fifth, transactions with a coverage ratio greater than one were removed. Finally, we remove transactions relating to properties that were bought and sold more than twice within a quarter as these transactions often appeared to occur at non-market prices. We end up with approximately 2,000 observations in our main empirical specification.

5.2 Econometric Model

Suppose that the policy announcement occurs in time period t_0. Our baseline econometric specification is as follows.

$$\frac{1}{T_i}\left(p_{i,t_1} - p_{i,t_{-1}}\right) = \beta_1 + \sum_{s=2}^{m} \beta_s zone_{s,i} + \delta_1 intensity_{i,t_{-1}} + \sum_{s=2}^{m} \delta_s zone_{s,i} \cdot intensity_{i,t_{-1}} + \gamma' X_{i,t_{-1}} + \varepsilon_i \tag{5}$$

where:

- $i = 1, \ldots, n$ indexes the transactions (houses) in the sample.
- $p_{i,t_{-1}}$ is log sales price of house i in period $t_{-1} < t_0$. We remove the reported value of chattels from the sales price. Similarly, p_{i,t_1} is log sales price of house i in period $t_1 > t_0 > t_{-1}$,

[10] Area units are non-administrative geographic areas defined and used by Statistics New Zealand. Within urban areas AUs are often a collection of city blocks or suburbs and normally contain 3,000-5,000 population, though this can vary due to such things as industrial areas, port areas, rural areas and so on within the urban area boundaries. For additional details see http://aria.stats.govt.nz/aria/#ClassificationView:uri=http://stats.govt.nz/cms/ClassificationVersion/cVYnMpeILgJRAY7E

[11] We use the beginning year of the decade, e.g. 1990 is used for a house built in the nineties.

where we again remove the value of chattels from the reported sales price. This means that a property is included in our sample if it was sold in period t_{-1} and in period t_1.

- T_i denotes the number of years between the sale of house i in period t_{-1} and period t_1, so that the dependent variable is an annualized rate of inflation. If for instance the sales occurred six years and 7 months apart, $T_i = 6 + \frac{7}{12}$.

- $zone_{s,i}$ is an upzoning dummy for residential zone under the AUP. We have dummies for three zones: *Terrace Housing and Apartments* (i.e., zone 4), *Mixed Housing Urban* (zone 3), and *Mixed Housing Suburban* (zone 2). Thus $m = 4$ in the above. The reference zone is *Single House*. In Table 2 below we tabulate the number of transactions in each zone.

- $intensity_{i,t_{-1}}$ is the ratio of assessed improvements value to assessed total value in period t_{-1}.

- $X_{i,t_{-1}}$ is a vector of controls. It includes: the (log) land area; the (log) floor area; the (log) site coverage (the coverage ratio is the footprint of the structure to total land area); number of bedrooms; number of bathrooms; approximate age of building; the (log) distance to downtown; and the (log) median household income in 2006 for the Area Unit in which the house is located. We report regression results both with and without these controls.

Several features of the empirical method are worth remarking on.

(*i*) The coefficients $\{\delta_s\}_{s=2}^{4}$ capture the effect of upzoning on the redevelopment premium. Recall that the coefficient on site intensity from hedonic regressions is used as an empirical measure of the redevelopment premium (Clapp et al, 2010; 2012a; 2012b). The coefficient δ_1 therefore captures the change in the redevelopment premium for the reference group in the regression – namely 'Single House' or 'zone 1', which was not subject to the upzoning treatment. In turn, the coefficient δ_4 captures the change in the redevelopment premium for houses located in 'Terrace Housing and Apartments' (or zone 4) relative to the change in the redevelopment premium for house located in 'Single House' (or zone 1). A priori we expect this coefficient to be negative since the redevelopment premium is declining in site intensity. Similar statements can be made about δ_2 and δ_3 for the 'Mixed Housing Suburban' and 'Mixed Housing Urban' zones.

(*ii*) Because the dependent variable is the change in *individual* house prices before and after the policy announcement, the empirical model controls for time-invariant confounding factors affecting inflation rates (unobserved individual heterogeneity). In this regard it is similar to the fixed effects approach of Dalton and Zabel (2011), who advocate the use of fixed effects to address potential endogeneity in the policy treatment. For example, wealthier or more expensive suburbs may be more effective at preventing upzoning in their neighborhoods (Quigley and Rosenthal, 2005). Such factors can be controlled for to the extent that factors such as these are time invariant.

(*iii*) It is probable that the observed geographic variation in LURs is driven by unobserved variables that affect house prices independently of upzoning. Such factors would therefore have to be adequately controlled for prior to causal inference. Suppose, for example, that the local authority chose to locate high density housing in areas close to transport networks, and that housing proximate to transport options appreciated in value during the sample period as traffic congestion in the city increased. However, such effects will be subsumed into the constants for each zone (i.e., $\{\beta\}_{s=2}^{m}$), and so variation in the site intensity ratio between observations within each residential zone can be used to identify the effect of upzoning on the redevelopment premium.

(*iv*) The vector of controls $X_{i,t_{-1}}$ is time-invariant. Thus the associated coefficients capture the change in the hedonic price of the attributes. Pakes (2003) argues that hedonic models should permit these prices to change over time and presents a straightforward empirical methodology to accommodate this time variation. In our present application, we allow the hedonic price of housing attributes – such as the number of bedrooms – to change over the sample period. This may be important if, for example, regulatory constraints on housing construction has led to a greater premium for existing houses that can accommodate more people.

(*v*) We permit spatial dependence and heteroskedasticity in the regression disturbances ε_i when constructing standard errors. We use the non-parametric approach suggested by Conley (1999) based on a 10km bandwidth and a triangular kernel.[12] Note that the standard errors are robust to any heteroskedasticity induced by different holding periods across $i = 1, \ldots, n$.

In our baseline empirical specification, we use the years 2010 through 2012 for t_{-1} and 2016 for t_1. Therefore, a house is included in the sample if (i) it was sold between 1 January 2010 and December 31 2012; and (ii) it was sold between 1 January 2016 and 31 December 2016. If a house was sold more than once within t_{-1} (or t_1) we use the first transaction and omit the remaining transactions. The post treatment sample period coincides with the year (2016) in which the final AUP is announced. Meanwhile, the pre-treatment sample spans six years before the draft AUP is announced. We use a relatively long pre-treatment sample in order to ensure that we have enough observations to obtain sufficient statistical precision. In the Appendix we present some robustness checks that examine the effect of altering the pre- and post- treatment sample periods. Our qualitative findings are by and large unaffected in these checks.

Our sample consists of residential dwellings that (a) have at least one transaction in t_{-1} and t_1; (b) are located in Auckland; and (c) carry exclusive land ownership on the title of the property. Many real estate titles carry joint ownership of land on the title, such as apartments and cross-leased sites. By focusing on properties with exclusive land ownership we restrict our attention to properties that can more easily be redeveloped by the owner. In the Appendix we run a robustness check in which we do not apply the exclusive land title filter, and instead introduce a dummy variable to indicate whether the property carries exclusive land ownership. This dummy variable is

[12] These are Newey-West standard errors with Euclidean distance as the measure of distance between observations.

Table 1: Summary Statistics

	mean	median	std. dev.	skewness	5th perc.	95th perc.
Average Annual Change in Log Prices	0.13	0.13	0.04	-0.03	0.08	0.20
Site Intensity	0.43	0.43	0.13	-0.25	0.21	0.62
Land Area (hectares)	0.07	0.07	0.03	6.45	0.03	0.11
Floor Area (sq meters)	155.41	140	64.20	1.10	80	279.5
Coverage Ratio	0.21	0.19	0.09	0.66	0.09	0.37
Bedrooms	3.51	3	0.77	042	3	5
Bathrooms	1.68	2	0.76	1.02	1	3
Building Age (years)	38.18	40.0	25.99	0.63	2	92
Distance to downtown (km)	16.96	14.10	10.30	1.29	4.42	40.60
Household Income ($000, 2006)	65.03	61.90	15.52	0.61	44.1	97.8

Note: Annualized price appreciation is based on repeat sale residential transactions between the pre-treatment sample (2010 to 2012) and the post-treatment sample (2016).

Table 2: Sample Characteristics of Residential Zones

	Zone 1	Zone 2	Zone 3	Zone 4	All Zones
	Single House	Mixed Housing Suburban	Mixed Housing Urban	Terrace Housing & Apartments	
Observations	405	1081	403	95	1984
Proportion	0.204	0.545	0.203	0.048	1

effectively interacted with the log land area and site coverage ratios, since we do not have a measure of land area for dwellings without exclusive land ownership in our dataset. Our main conclusions remain unchanged.

After these various filters are applied to the data, we are left with 1984 observations for our preferred empirical specification. Table 1 below illustrates the sample statistics for all variables in the model, while Table 2 provides a breakdown of the sample into the four residential zones.

Tables 5 through 8 in the Appendix contain descriptive statistics for the variables within each residential zone. There are some systematic differences across the variables. First, there is a monotonic relationship between density of the planning zone and distance from the city centre, with the zones that permit more intensive development being located closer to downtown, on average. Similarly, household income is declining with planning intensity, meaning that more intensive housing has been allocated to lower income areas. Houses located in ‘Single House’ or

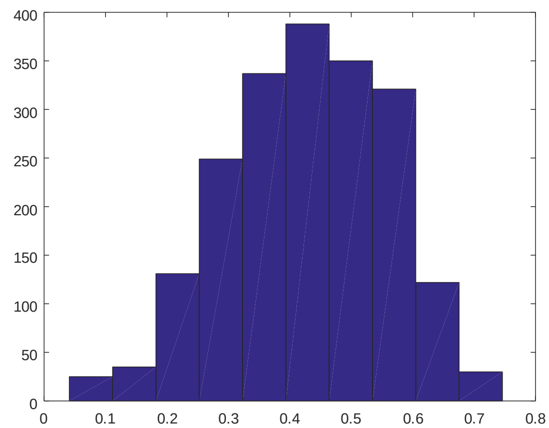


Figure 4: Histogram of Site Intensity. See (4) for the construction of the ratio.

'Mixed Housing Suburban' also tend to be larger, on average, and have appreciated by slightly less, on average, over the sample period. Interestingly, there is no discernible relationship between the average site intensity of the properties and residential planning zone, as the average site intensity is remarkably similar across all four zones.

Table 9 in the Appendix tabulates descriptive statistics for the population densities associated with the sample. Each transaction is allocated the population density of the meshblock that the dwelling is located. Remarkably, the transactions all exhibit similar median population densities.

The site intensity ratio plays a significant role in our empirics. It acts as a measure of the opportunity cost of teardown and replacement of the residential building on the property (Clapp and Salavei, 2010), and is often used in hedonic regressions as a proxy for the redevelopment premium (Clapp, Salavei Bardos and Wong, 2012; Clapp, Jou and Lee, 2012). A low site intensity ratio is indicative of a low opportunity cost – such properties are likely to be profitable to redevelop, provided that redevelopment is permitted under local planning constraints. A high site intensity ratio, on the other hand, is indicative of a high opportunity cost.

In discussing our results we will focus on two hypothetical values of the site intensity ratio: zero and one. A property with a site intensity ratio of zero is effectively identical to vacant land, since the value of assessed improvements is zero. On the other hand a property with a site intensity ratio of one has an assessed land value of zero, which would imply a massive amount of existing site development. Note, however, that we do not observe a site intensity ratio above 0.8 in our sample. We also parse our results in terms of properties with a site intensity ratio at the 5th and 95th percentile of the distribution, as well as the median level of site intensity (which is 0.43 in Table 1). Figure 4 presents a histogram illustrating the distribution of the site intensity ratio for the whole sample.

5.3 Regression Results

For instructive purposes all explanatory variables are demeaned when estimating the regression. This means that the estimated constant tells us the average annual rate of inflation for properties located in the 'Single House' zone ('zone 1'). Table 3 illustrates the results.

The coefficients on the three upzoning dummy variables interacted with site intensity are negative and statistically significant at the one percent level. This is strong evidence in favor of upzoning increasing the redevelopment premium (see Remark 1 in the preceding section). Furthermore, note that the magnitude of these coefficients correspond to the ordinal ranking of permissible site development under each zone. That is, more development is permitted under zone 3 than zone 2, and we correspondingly observe that the coefficient for zone 3 is larger in magnitude than that of zone 2 (-0.071 versus -0.042). This is consistent with our ordinal ranking of zones according to permissible site development.

Next we consider what the model implies about expected changes in house prices conditional on both the site intensity and the planning zone of the property. Figure 5 plots the expected house price appreciation conditional on site intensity for each of the four zones.

First we consider houses located in zone 4, which is the residential zone that permits the most site development. Holding all else equal, the model implies that houses located in this zone appreciated by between 18.1% and 10.5% per year depending on the site intensity of the property. A house in zone 4 with a site intensity of zero (i.e., equivalent to vacant land) appreciated by 18.1% (= 13.5 + 4.6) per year, one average, while a house with a site intensity ratio of one (i.e., the assessed value of land is zero) appreciated by 10.5% (= 13.5 + 4.6 + 0.1 – 7.7).[13] We also consider what the model implies for houses with a site intensity at either end of the empirical distribution of the site intensity variable – specifically at the 5th and 95th percentile. Within this zone, the 5th and 95th percentiles of the site intensity ratio are 0.21 and 0.635 (see Table 5 in the Appendix). The model therefore implies that properties at the 5th percentile appreciated by 16.6% on average (= 13.5 + 4.6 – (7.7 – 0.1) × 0.21), whereas properties at the 95th percentile appreciated by 13.2% ((= 13.5 + 4.6 – (7.7 – 0.1) × 0.65). Properties that had a low opportunity cost of redevelopment – reflected in a low site intensity ratio – experienced substantially higher rates of inflation compared to properties with a high opportunity cost of redevelopment. This is consistent with the predictions of the economic model. Meanwhile a house at the median level of site intensity (0.43) appreciated by 15.0% (= 13.5 + 4.6 – (7.7 - 0.1) × 0.41).

Next we consider houses located in zone 1, which is the residential zone that permits the least site development. The coefficient on site intensity is close to zero, which implies very little variation in expected house price appreciation conditional on site intensity for houses in this zone. For example, a house with a site intensity of zero appreciated by 13.5% per year, on average, while a dwelling with a site intensity of one appreciated by fractionally more – 13.6% (= 13.5 – 0.1) per year. Implied appreciation rates at the 5th and 95th percentile of site intensity are also 13.5% and

[13] A site intensity ratio of one does not occur in the sample, while a site intensity ratio of zero is very rare. These two bounds on the site intensity ratio are however instructive for understanding the predictions of model.

Table 3: Estimated Regression Coeffcients

Constant	0.135***	0.135***	0.135***
Zone 4	0.046***	0.052***	0.052***
Zone 3	0.043***	0.048***	0.050***
Zone 2	0.038***	0.040***	0.035***
Site Intensity	0.001	0.005	-0.043***
Zone 4 × Site Intensity	-0.077***	-0.085***	-0.072**
Zone 3 × Site Intensity	-0.065***	-0.072***	-0.067***
Zone 2 × Site Intensity	-0.055***	-0.060***	-0.048***
ln(land)	-0.009*	-0.010***	
ln(floor)	-0.017***	-0.018***	
ln(coverage)	-0.011***	-0.012***	
bedrooms	0.004**	0.005***	
bathrooms	-0.001	-0.001	
ln(age)	0.002	0.002*	
ln(distance)	-0.004*		
ln(neighborhood income)	-0.016***		
R-squared	0.153	0.148	0.108
Adjusted R-squared	0.147	0.142	0.104
Observations	1984	1984	1984

Notes: OLS estimates of the regression equation (5). The dependent variable is annualized percent change in repeat sale residential transactions between the pre-treatment sample (2010 to 2012) and the post-treatment sample (2016). ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively. Conley (1999) robust standard errors using a 10km radius. Zone 4 is the most dense residential zone under the new LURs; zone 1 is the least dense.

13.6%, respectively.

The model therefore implies that upzoning to the most intensive residential zone generated a premium of approximately 23% in properties that are equivalent to vacant land. Houses with a site intensity ratio of zero located zone 4 (Terrace Housing and Apartments) appreciated by 4.6% (= 18.1 − 13.5) more, per annum, than houses located in zone 1 (Single House). This equates to approximately 23% over the five years spanning the announcement (2010-2012 to 2016). The upzoning premium declines as site intensity increases, but remains positive provided that the site is sufficiently under-developed. The estimated coefficients imply that upzoned properties with a site intensity ratio less than 0.6 (= (18.1–13.5)/(7.6 + 0.1)) appreciated by more than properties located in zone 1.

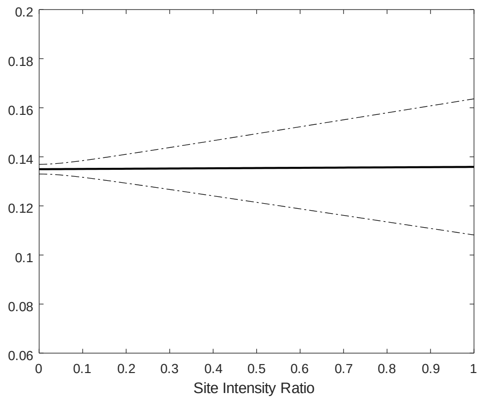
Expected price changes in zones 2 and 3 further corroborate the predictions of the model. The model implies that houses located in zone 3 (which permits more site development than zones 1 and 2, but less than zone 4) appreciated by between 17.8% and 11.4% per year depending on the site intensity ratio of the property. Houses with a site intensity ratio at the 5th percentile appreciated by 16.3%, while houses with a site intensity ratio at the 95th percentile appreciated by 13.9%. Houses located in zone 2 (which permits more site development than zone 1, but less that zones 3 and 4) appreciated by between 17.3% and 11.8% per year. Houses with a site intensity ratio at the 5th percentile appreciated by 16.1% on average, while houses with a site intensity ratio at the 95th percentile appreciated by 13.9%.

A consistent pattern therefore emerges from the model. Houses with a low site intensity ratio (and thus a low opportunity cost of teardown and replacement) experienced relatively higher rates of appreciation after being upzoned. Meanwhile, houses with a high site intensity ratio (and thus a high opportunity cost of teardown and replacement) experienced relatively lower rates of appreciation after being upzoned.

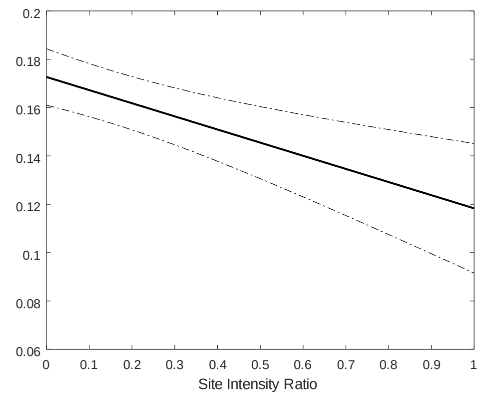
The empirical results are consistent with upzoning inflating the redevelopment premium, but it is clear that the overall effect of upzoning on house prices depends critically on the extent of existing site development. Compared to properties that were not upzoned, properties upzoned for increased density experienced a large increase in price provided that they were sufficiently under-developed (as indicated by a low site intensity ratio). But intensively developed properties (with a high site intensity ratio) upzoned for increased density experienced a decrease in price relative to properties that were not upzoned. Existing forms of intensive housing (such as apartment blocks) are less likely to be redeveloped, and thus changes in price may reflect anticipated effects of redevelopment on nearby parcels.

The estimated coefficients on the controls given in Table 3 also merit comment. The coefficient on distance is negative and statistically significant, indicating that price appreciation has been greater for houses located closer to downtown, all else equal. This is consistent with increased commuter traffic leading to greater demand for proximate housing. The coefficient on age of the building is slightly positive but statistically significant. This is consistent with the 'leaky building' stigma, which has been shown to reduce house prices by approximately 5-10% in New Zealand (Rehm, 2009). Various regulatory changes in housing construction (including the use of untreated

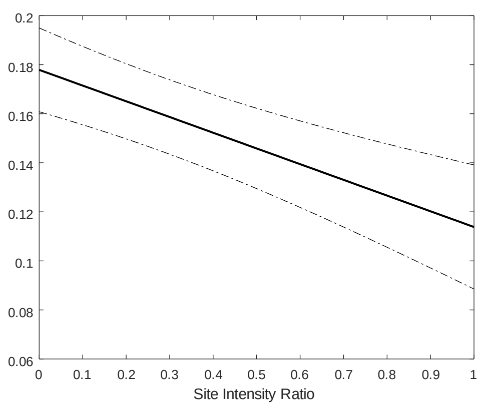
Figure 5: Expected Annual Change in Log House Prices conditional on Site Intensity Ratio



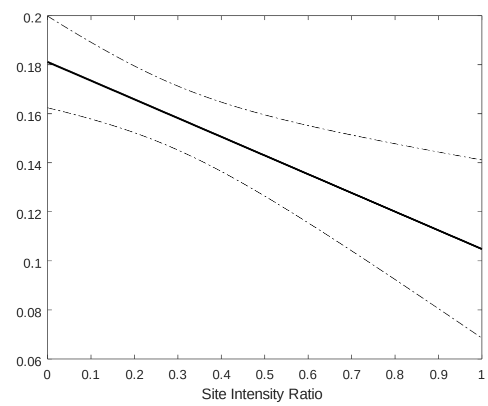
Single House (Zone 1)



Mixed Use Suburban (Zone 2)



Mixed Use Urban (Zone 3)



Terrace Housing and Apartments (Zone 4)

Notes: Dashed lines represent 95% confidence intervals. Standard errors are robust to spatial dependence and heteroskedasticity.

timber) in the late 1990s precipitated the leaky building crisis (May 2003; 2007). Houses built in the late 1990s through to the early 2000s are likely to sell at a discount due to an association with this period of poor construction. Finally, the coefficients on the number of bedrooms and the number of bathrooms are also statistically significant, and show that price appreciation was greater for houses with more bedrooms but fewer bathrooms. The former result is consistent with the well-documented increase in population pressures in Auckland over the sample period. It is less clear why an additional bathroom is associated with a lesser appreciation rate over the sample period.

One drawback of our approach is that we do not take into account what the residential zone of the transacted house was prior to the implementation of the AUP. For example, areas rezoned to Terrace Housing and Apartments may already be in areas of the city that are intensely developed. This would attenuate our estimates of the effect of upzoning, so that our estimates are biased towards zero. The fact that our point estimates retain statistical significance indicates that we have evidence of the effect upzoning on the redevelopment premium despite this potential misspecification. However, as shown in Table 9 (in the Appendix), the population densities across all four residential planning zones prior to the announcement of upzoning exhibit remarkably similar medians, suggesting that such effects, if present, are rather small.

5.4 Placebo Tests

As a further robustness check we estimate the same model over pre- and post -treatment periods *prior* to the announcement of the AUP altogether. These placebo tests serve two purposes. First, they tell us whether the geographic variation in upzoning is related to any omitted variables related to long-run variation in house prices. Second, they tell us whether the upzoning treatment was anticipated by the market prior to the announcement of the draft AUP in 2013.

We focus on three placebo pre- and post-treatment periods: 2006 to 2008 (pre) and 2012 (post); 2005 to 2007 (pre) and 2011 (post); and 2004 to 2006 (pre) and 2010 (post). These dates mimic the same pre- and post-treatment periods used in our preferred empirical specification, except that the relevant dates have been pushed back in time, so that the first announcement of the draft AUP in March 2013 is omitted altogether from the sample. Regression results are tabulated in Table 4.

In all placebo samples the coefficients on the upzoning dummies interacted with site intensity are by and large statistically insignificant. The single exception is the coefficient on the zone 3 dummy in the 2006-2008 to 2012 sample, which is positive and marginally significant at the 5% level. From this we may conclude that there is no differential effect of site intensity on house price inflation across the four zones prior to the announcement of the draft AUP in 2013. This suggests that the geographic variation in upzoning is unrelated to any omitted variables driving long-run variation in house prices, and that the market did not anticipate which areas of the city would be targeted for upzoning prior to the announcement of the draft AUP.

In addition, note that the coefficients on the upzoning dummies are by and large statistically insignificant. The single exception is the coefficient on the zone 2 dummy in the 2006-2008 to

2012 sample, which is marginally significant at the 10% level. Thus it appears that unconditional appreciation rates across the four zones are statistically indistinguishable from each other over the sample periods.

Finally, we note that the coefficient on site intensity (not interacted with residential zones) is insignificant in two of the three placebo samples. This indicates that there was little variation in the redevelopment premium of housing within Auckland over the time periods considered. Interestingly, the coefficient is positive and marginally significant at a ten percent level in the 2004-2006 to 2010 sample, which is consistent with a declining redevelopment premium across the metropolitan area over this period.

5.5 Robustness Checks

In the Appendix we explore alternative empirical designs and a different regression specification as robustness checks.

In Table 10 we consider the baseline empirical specification (5) under four different pre- and post-treatment periods. The first design is based on the assumption that market participants anticipated which areas would be targeted for upzoning soon after the amalgamation of Auckland in 2010 and the subsequent announcement that there will be a unified set of LURs (see section 3 for details). We therefore use 2007 to 2009 as our pre-treatment period. We also consider using 2007 to 2012 as the pre-treatment sample in order to expand the number of observations in the baseline model. The third design is based on the assumption that houses prices adjusted in full immediately after the announcement of the draft AUP in March 2013. For this design we expand the post-treatment sample to span 2014 to 2016, which substantially increases the number of observations to 6297. The final design uses only uses sales after the publication of the final 'decisions' version of the AUP in July 2016. Thus the post-treatment period is in this design is August 2016 to December 2016. This narrow post-treatment period leaves only 820 observations in our sample.

In Table 11 we also consider a second set of samples that includes dwellings that do not have an exclusive land title. In the associated regressions we include a dummy variable for this exclusive land title, since exclusive property rights to the land underlying a residential structure is likely to affect the value of the property. We consider the same four different pre- and post-treatment sample designs.

In all of our robustness checks our qualitative conclusions remain the same because the coefficients on the upzoning dummies interacted with site intensity are negative and generally statistically significant at the 10% level. We do, however, lose statistical significance in some of the regressions. For example, in the baseline regression model (5), we lose significance on the 'zone 4' dummy interacted with site intensity when August to December 2016 is the post-treatment sample, as well as on the 'zone 1' dummy interacted with site intensity when 2007 to 2009 is the pre-treatment period. The former result is accompanied by the caveat that there are only 39 transactions in this zone, and so it is perhaps unsurprising that the coefficient is imprecisely estimated. Interestingly, the

Table 4: Placebo Tests

	pre-treatment: 2006-2008 post-treatment: 2012	pre: 2005-2007 post: 2011	pre: 2004-2006 post: 2010
Constant	0.027***	0.021***	0.036***
Zone 4	0.016	-0.016	0.005
Zone 3	0.004	0.004	-0.013
Zone 2	0.009*	-0.003	0.002
Site Intensity	-0.008	0.012	0.023*
Zone 4 × Site Intensity	-0.023	0.028	-0.014
Zone 3 × Site Intensity	0.010	-0.006	0.028**
Zone 2 × Site Intensity	-0.016	0.006	0.001
ln(land)	0.006**	0.005	0.006*
ln(floor)	-0.013***	-0.017***	-0.018***
ln(coverage)	0.009***	0.008***	0.007***
bedrooms	-0.000	0.001	0.003***
bathrooms	0.004***	0.017	-0.000
ln(age)	0.003***	0.003**	0.002**
ln(distance)	-0.016***	-0.013***	-0.007***
ln(income)	0.010***	0.013**	0.023**
R-squared	0.187	0.103	0.061
Adjusted R-squared	0.183	0.099	0.056
Observations	3278	3069	2479

Notes: OLS estimates of the regression equation (5) for various treatment periods. *** indicates significance at 1% level; ** indicates significance at 5% level; * indicates significance at 10% level. Conley (1999) robust standard errors based on 10km radius.

coefficient on site intensity is negative and statistically significant in designs that include the 2007 to 2009 period in the pre-treatment period, perhaps indicating that the redevelopment premium was increasing across the city as a whole over the 2007 to 2009 time period.

6 Concluding Remarks

In this paper we provide empirical evidence of the effect of LURs on the redevelopment premium. We exploit a rich dataset of individual residential property transactions from Auckland, New Zealand, that spans a spatially heterogenous change in LURs. We show that low site intensity properties located in areas that were upzoned (as a result of the AUP being announced, which signalled a relaxation of LURs) experienced a significant increase in value when compared to properties that were not upzoned. For example, the model implies that upzoning to the most intensive residential zone generated a premium of approximately 23% in properties that had a site intensity ratio of zero (and were thus similar to vacant land). This is consistent with upzoning increasing the redevelopment premium. In addition, we found that high site intensity properties located in upzoned areas experienced a significant decline in value relative to comparable properties that were not upzoned. This may reflect anticipated effects of increased supply of high density dwellings, or a disamenity effect from crowding.

Disentangling and measuring the magnitudes of these offsetting price effects of LURs is important for a number of reasons. First, policy changes can have vastly different effects on individual properties depending on the redevelopment potential of the site. In addition to the regulatory environment, this potential depends on both the characteristics of the property (such as the size of the land parcel, the condition of the existing structure) and macroeconomic factors (such as the general level of house prices and interest rates). Second, these heterogenous effects must be taken into consideration when evaluating the price effects of an urban intensification policy. For example, relaxing LURs in order to enhance housing affordability may initially increase sales prices in areas that have been upzoned. In such circumstances, transactions involving such houses should be omitted when tracking longitudinal patterns in affordability, and policymakers should instead focus on tracking the prices of the more intensive housing that the policy is designed to encourage (See Greenway-McGrevy and Sorensen, 2016, for some prototypical price indices of this nature).

7 Appendix

7.1 Descriptive Statistics by Planning Zone

Table 5: Summary Statistics for Terrace Housing and Apartments (zone 4)

	mean	median	std. dev.	skewness	5th perc.	95th perc.
Average Annual Change in Log Prices	0.14	0.14	0.05	2.34	0.09	0.21
Site Intensity	0.42	0.41	0.14	0.04	0.21	0.65
Land Area (hectares)	0.06	0.06	0.05	4.51	0.02	0.11
Floor Area (sq m)	131	120	50.38	1.24	75	220
Coverage Ratio	0.22	0.18	0.11	0.67	0.09	0.42
Bedrooms	3.27	3	0.72	0.74	2	5
Bathrooms	1.58	1	0.79	1.54	1	3
Building Age (years)	43.64	51	29.42	0.15	10	91.75
Distance to Downtown (km)	11.37	11.39	5.39	2.05	4.66	18.24
Median Household Income ($000, 2006)	57.79	55.2	12.76	0.92	41.0	81.1

Note: Annualized price appreciation is based on repeat sale residential transactions within Terrace Housing and Apartments (Zone 4) between the pre-treatment sample (2010 to 2012) and the post-treatment sample (2016).

Table 6: Summary Statistics for Mixed Use Urban Zone (zone 3)

	mean	median	std. dev.	skewness	5th perc.	95th perc.
Average Annual Change in Log Prices	0.14	0.14	0.04	0.13	0.09	0.21
Site Intensity	0.42	0.42	0.12	-0.02	0.23	0.61
Land Area (hectares)	0.07	0.06	0.02	1.86	0.03	0.11
Floor Area (sq m)	135.05	120	51.27	1.47	80	231.4
Coverage Ratio	0.20	0.16	0.09	1.00	0.10	0.37
Bedrooms	3.43	3	0.69	0.70	3	5
Bathrooms	1.49	1	0.65	1.07	1	3
Building Age (years)	41.86	42.00	24.19	0.29	2	90
Distance to Downtown (km)	13.64	12.91	5.99	1.25	5.40	27.96
Median Household Income ($000, 2006)	58.65	57.60	12.05	0.77	40.76	79.12

Note: Annualized price appreciation is based on repeat sale residential transactions within Mixed Housing Urban (Zone 3) between the pre-treatment sample (2010 to 2012) and the post-treatment sample (2016).

Table 7: Summary Statistics for Mixed Use Suburban Zone (zone 2)

	mean	median	std. dev.	skewness	5th perc.	95th perc.
Average Annual Change in Log Prices	0.14	0.13	0.04	0.41	0.08	0.20
Site Intensity	0.43	0.43	0.13	-0.24	0.21	0.63
Land Area (hectares)	0.07	0.06	0.03	8.81	0.03	0.11
Floor Area (sq m)	158.70	146.00	62.99	0.97	85	273.55
Coverage Ratio	0.22	0.20	0.10	0.65	0.1	0.38
Bedrooms	3.55	3	0.77	0.45	3	5
Bathrooms	1.70	2	0.74	0.74	1	3
Building Age (years)	34.96	32	23.13	0.60	2	80.55
Distance to Downtown (km)	18.11	15.45	10.01	1.04	6.14	40.78
Median Household Income ($000, 2006)	66.34	64.0	14.76	0.61	48.3	95.3

Note: Annualized price appreciation is based on repeat sale residential transactions within Mixed Housing Suburban (Zone 2) between the pre-treatment sample (2010 to 2012) and the post-treatment sample (2016).

Table 8: Summary Statistics for Single House Zone (zone 1)

	mean	median	std. dev.	skewness	5th perc.	95th perc.
Average Annual Change in Log Prices	0.12	0.12	0.04	-1.96	0.07	0.19
Site Intensity	0.44	0.46	0.14	-0.55	0.19	0.62
Land Area (hectares)	0.07	0.07	0.03	1.51	0.03	0.13
Floor Area (sq m)	171.83	160.0	74.81	0.88	80	306.2
Coverage Ratio	0.21	0.2	0.09	0.22	0.08	0.35
Bedrooms	3.56	3	0.83	0.09	2.0	5.0
Bathrooms	1.84	2	0.86	1.21	1	3
Building Age (years)	41.81	40.0	32.25	0.66	1	101
Distance to Downtown (km)	18.51	15.53	13.66	0.99	2.27	47.48
Median Household Income ($000, 2006)	69.57	68.3	18.39	0.18	41.3	100.0

Note: Annualized price appreciation is based on repeat sale residential transactions within Single House (Zone 1) between the pre-treatment sample (2010 to 2012) and the post-treatment sample (2016).

Table 9: Population densities by Residential Zone

	mean	median	std. dev.	skewness	5th perc.	95th perc.
All Zones	3926	3395	5897	10.92	561	6183
Terrace Housing and Apartments (zone 4)	4953	3338	10253	6.29	760	7291
Mixed Housing Urban (zone 3)	3662	3448	3785	10.96	564	6091
Mixed Housing Suburban (zone 2)	3767	3408	4205	7.72	559	5997
Single House (zone 1)	4371	3372	9172	9.27	319	6316

Note: Population densities (persons per km^2) are based on the Census 2013 meshblocks where the transacted house is located.

7.2 Robustness Checks

Table 10: Robustness Checks on Regression Results

	pre-treatment: 2007-2009 post-treatment: 2016	pre: 2007-2012 post: 2016	pre: 2010-2012 post: 2014-2016	pre: 2010-2012 post: Aug-Dec 2016
Constant	0.085***	0.108***	0.130***	0.134***
Zone 4	0.033***	0.044***	0.054***	0.030***
Zone 3	0.032***	0.044***	0.038***	0.047***
Zone 2	0.016***	0.030***	0.045***	0.039***
Site Intensity (SI)	-0.028***	-0.036***	-0.012	-0.001
Zone 4 × SI	-0.046**	-0.079***	-0.104***	-0.049
Zone 3 × SI	-0.045**	-0.071***	-0.039*	-0.073***
Zone 2 × SI	-0.017	-0.042***	-0.069***	-0.064***
ln(land)	0.001	-0.011*	-0.014**	-0.007
ln(floor)	-0.013***	-0.007	-0.030***	-0.019***
ln(coverage)	0.001	-0.007	-0.013***	-0.012*
bedrooms	0.003**	0.003**	0.008***	0.005**
bathrooms	0.002	0.000	0.004***	0.003
ln(age)	0.03**	0.000	-0.001	0.001
ln(distance)	-0.012***	-0.009	-0.012***	-0.003
ln(income)	-0.006	-0.014**	-0.018***	-0.013**
R-squared	0.255	0.132	0.115	0.188
Adj. R-squared	0.249	0.128	0.113	0.173
Observations	1943	3530	6297	820

Notes: OLS estimates of the regression equation (5) for various pre- and post-treatment samples. ***, **, * denote significance at the 1%, 5%, and 10% levels respectively. Conley (1999) robust standard errors based on 10km radius.

Table 11: Robustness Checks on Regression Results

	pre: 2010-2012 post: 2016	pre: 2007-2009 post: 2016	pre: 2007-2012 post: 2016	pre: 2010-2012 post: 2014-2016	pre: 2010-2012 post: Aug-Dec 2016
Constant	0.134***	0.085***	0.107***	0.129***	0.133***
Zone 4	0.026***	0.017	0.026***	0.047***	0.023***
Zone 3	0.035***	0.025***	0.037***	0.032***	0.040***
Zone 2	0.031***	0.016***	0.028***	0.034***	0.031***
Site Intensity (SI)	-0.001	-0.024**	-0.027*	-0.011	0.001
Zone 4 × SI	-0.039**	-0.020	-0.041**	-0.088***	-0.038***
Zone 3 × SI	-0.054***	-0.035**	-0.061***	-0.037*	-0.058*
Zone 2 × SI	-0.048***	-0.019*	-0.044***	-0.048***	-0.050***
land title dummy	-0.032**	-0.017	-0.039***	-0.064***	-0.011
ln(land)×land title	-0.008**	-0.005*	-0.011***	-0.017***	-0.003
ln(floor)	-0.019***	-0.008***	-0.008***	-0.026***	-0.023***
ln(coverage)	-0.009***	-0.003	-0.007*	-0.015***	-0.006
bedrooms	0.006***	0.003***	0.004***	0.008***	0.005***
bathrooms	-0.001	0.001	0.000	0.003***	0.004
ln(age)	0.003**	0.005***	0.003**	0.002**	0.003**
ln(distance)	-0.002	-0.010***	-0.007	-0.009***	-0.003
ln(income)	-0.017***	-0.010***	-0.013*	-0.022***	-0.020***
R-squared	0.136	0.202	0.112	0.101	0.173
Adj. R-squared	0.131	0.198	0.110	0.100	0.162
Observations	3289	3280	5868	10175	1295

Notes: OLS estimates of the regression equation (5) including exclusive land title ownership in the set of control variables. ***, **, * denote significance at the 1%, 5%, and 10% levels respectively. Conley (1999) robust standard errors based on 10km radius.

7.3 Algorithm for matching transactions to planning zones

The method is the same as used in Greenaway-McGrevy and Sorensen (2017). For completeness, we re-state it here. The AUP master Geodatabase files were obtained from the Department of Geography at the University of Auckland. These represent the most up-to-date geospatial data on the AUP (published November 2016). We then project the data layers from New Zealand Transverse Mercator to decimal degrees formatting (WGS 1984) in order to match the longitude and latitude from the sales transaction dataset. The number of zone polygons within the AUP geospatial files was approximately 133,000.

Approximately 222,234 unique properties underlying the transaction dataset were matched to an AUP zone prior to the filtering described in the Data section above. The matching process is as follows:

(*i*) We allocate an AUP zone polygon to each unique property in the transaction dataset according to the property's reported longitude and latitude coordinates. We then take allocate the AUP zone (e.g. "Terraced Housing and Apartments") associated with the selected polygon to the property identifier.

(*ii*) Approximately 5% of the longitude-latitude coordinates fall exactly on the boundary of two or more polygons, resulting in an unmatched zone for the property. Another 40% or so fall just outside a lot, usually on the road frontage of the property, resulting in a returned AUP zone of 'road' or 'public'. We perform a second stage repair for these matches by searching for the nearest residential or commercial zone polygon in the immediate vicinity of the reported longitude-latitude coordinates. The procedure is as follows.

   (a) First, we identify all properties with either an unmatched zone or a matched zone that is non-residential or non-commercial (such as 'road' or 'public'). We generate an approximate circle around the original longitude-latitude coordinates of the property. This new polygon is based on a radius of 0.00001 decimal degrees ($\sim$ 1.11m) and has 50 sides - equivalent to 51 coordinates. One of the coordinates in the circle is directly north of the reported longitude-latitude coordinates of the property.

   (b) We match an AUP zone polygon to each of the 51 points. We then allocate the most frequently selected residential or commercial zone among these 51 matches to the property. If a residential zone is not among the 51 returned zones, the property is not allocated an AUP zone, and is filtered out of the dataset during the cleaning process described in the main text.

7.4 Algorithm for estimating average planning zone population densities.

Estimated population densities are based on usually resident population by Census 2013 meshblocks. The algorithm allocates an estimated population to each residential zone polygon by taking a weighted average of the populations from the meshblocks overlapping the polygon, where the weights are proportional to the area of intersection between the meshblock polygon and the residential zone polygon.

The specific details are as follows. For each zone polygon we calculate the total polygon area using an azimuthal projection. We then search for all meshblocks polygons that intersect with the zone polygon. If the residential zone polygon one is nested within a single meshblock, the zone is allocated the population density of the nesting MB. If the zone polygon intersects with two or more meshblock polygons, the process is as follows. For each intersecting meshblock polygon:

(*i*) We calculate MB density by square kilometers (hectares).

(*ii*) We calculate the area of intersection between the AUP zone polygon and the meshblock polygon.

(*iii*) The area of intersection is divided by the area of the residential zone polygon to obtain a weight for the meshblock polygon.

The density of the AUP zone polygon is then estimated by taking the weighted sum of the population densities of each intersecting meshblock. We then take a weighted average across all residential zone polygons to obtain an average density for the residential zone, where the weights are proportional to the area of zone polygon. Because we are interested in calculating urban density, we omit any residential zone polygons with a density less than 300 persons per square km, which approximates the density of countryside 'lifestyle' blocks.

7.5 Auckland Unitary Plan Zones

The Table below provides a brief summary of various land use regulations for each of the four residential zones considered.

Table 12: Summary of Land Use Regulation by Residential Planning Zone

Land Use Regulation	Terrace Housing & Apartments	Mixed Housing Urban	Mixed Housing Suburban	Single House
Height	between 16 to 22.5m (5 to 7 storeys)	11m + 1m roof (three storeys)	8m + 1m roof (two storeys)	8m + 1m roof (two storeys)
Height in relation to boundary	3m + 45° side & rear boundaries	2.5m + 45° side & rear boundaries	2.5m + 45° side & rear boundaries	2.5m + 45° side & rear boundaries
Site Coverage Ratio	50%	45%	40%	35%
Min. dwelling size (1 bedroom)	45m^2	45m^2	45m^2	n/a
Density	do not apply (DNA)	do not apply (DNA)	DNA for sites > 1000m^2 200m^2 otherwise	1 dwelling per site
Min. Lot Size (Vacant land)	1200m^2	300m^2	400m^2	600m^2

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