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Land Use Regulation, the Redevelopment Premium and House Prices

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Land Use Regulation, the Redevelopment Premium and House Prices

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Abstract

The right 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 residential structure, comparatively little research has focussed on how land use regulations (LURs) interact with these characteristics to affect redevelopment premia. In this paper we study the effect of upzoning (i.e., a relaxation of restrictions on site development) on the redevelopment premium and house prices using a rich dataset of residential sales transactions. To study the effects of this policy intervention, 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 – intensity (i.e., the ratio of improved value to the total value of the property). We find that upzoning significantly increases the redevelopment premium and generates a substantial increase in the price of underdeveloped properties relative to properties that were already intensively developed.

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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 the property's 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 house 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 a 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 – *intensity*, which is the ratio of the value of improvements to the total value of the property (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. We find that upzoning significantly increased the hedonic estimate of the redevelopment premium, and generated a significant increase in the price of underdeveloped (i.e., low intensity) properties relative to both highly developed (i.e., high intensity) properties and properties that were not upzoned.

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 intensity as an empirical proxy for the value of

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

the redevelopment option embedded in a property. Intuitively, the opportunity cost in terms of foregone rent from tearing down a large block of apartments (with a correspondingly high intensity ratio) is much higher than the opportunity cost of tearing down a small, freestanding house on a large plot of land (with a correspondingly low intensity ratio). 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 decreasing in the intensity ratio in a sample of properties from different towns in Connecticut. We follow these authors and adopt the intensity ratio as an empirical proxy for the redevelopment premium.

Our empirical model is built around a rich and detailed dataset of residential sales transactions from Auckland, New Zealand, that spans 2010 to 2017, inclusive. Auckland is the largest metropolitan region in New Zealand, with a population of approximately 1.5 million people as of 2017. Recent policy changes also mean that Auckland provides a unique opportunity to analyze the impact of LURs on a variety of outcomes, including property prices. In 2013, the Auckland City Council announced plans to rezone much of the land in the city to support more intensive forms of housing and thus higher 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 quasi-control for studying the effects of LURs on a variety of outcomes, including house prices. In section 3 below we provide a detailed description of the policy intervention, 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 the intensity ratio (measured prior to the policy announcement). Estimated coefficients on these interaction terms thereby inform us about any change in the hedonic estimate of the redevelopment premium of the properties located in a given residential zone after the policy is announced. Our dataset offers some unique advantages that assist in identifying this effect. First, it contains the geographic location of the dwelling (longitude-latitude), which allows us to match the transacted property to its residential planning zone. This significantly aids the identification of the upzoning effect because we can pinpoint both when and where the new residential planning zones applied in our sample of transactions. In contrast, researchers must often use statistical methods to indirectly infer when zoning changes were implemented (e.g., Dalton and Zabel, 2011). Second, there is a unique identifier for each property, which allows us to use repeat sales to analyze the effect of the policy intervention on house prices. Third, the dataset 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 in the different residential zones, such as the number of bedrooms and bathrooms, 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 intensity ratio variable. Finally, as we describe below in more detail, variation in the intensity ratio between different observations within the new planning zones also mitigates potential endogeneity of the upzoning treatment in the empirical model.[2]

[2]If the intensity ratio was binary instead of continuous, our model would follow a triple difference-in-differences

Our findings provide strong support for LURs having a material effect on both the redevelopment premium and house prices. The estimated model implies that residential properties with an intensity ratio of zero (equivalent to an undeveloped plot of land) that were rezoned to the permit the most site development appreciated by 14.7% per annum, on average, over the period spanning the upzoning announcement. Meanwhile properties with an intensity ratio of one (i.e. no relative land value) located in the same planning zone appreciated by only 9.3% per annum, on average, over the same period. The difference in appreciation rates is statistically significant. Meanwhile, properties that were not upzoned appreciated by between 10.9% to 11.3% per annum, over the same period, depending on the intensity ratio of the property.[3] Interestingly, the model therefore implies that upzoned properties that were already very intensively developed *decreased* in value relative to similar houses that were not upzoned. In our sample, this occurs for properties that have an intensity ratio above the 95th percentile. The depreciative effect of upzoning may reflect anticipated disamenities from increased population density, or anticipated supply effects from future construction of intensive forms of housing.

The remainder of the paper is organized as follows. The following section discusses the relevant literature, while section three provides a detailed description of the institutional background underlying our dataset. In section four we present a simple real option 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. They therefore recommend extending the hedonic regression framework of Rosen (1974) to include measures of the redevelopment option, such as the intensity ratio. 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 intensity ratio and building age as empirical proxies

structure, since the treatment group would be upzoned, low intensity properties, and both upzoned, high intensity properties and non-upzoned, low intensity properties would act as quasi-controls.

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

for the redevelopment premium. Although real option theory predicts a nonlinear relationship between the value of the premium and intensity, a linear specification typically provides a first order correction in conventional applications, such as hedonic regressions. The 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 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.

The intensity ratio 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 its institutional history. This provides the contextual backdrop to recent policy interventions with respect to changes in 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 outside the 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. These high population density areas are in the CBD.

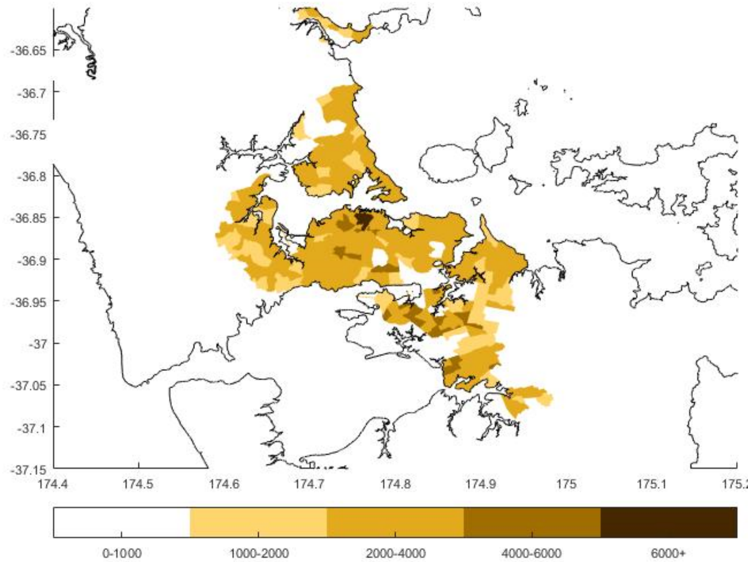


Figure 1: Population densities (persons/km^2) across Area Units in Auckland. Authors' calculations based on 2013 census.

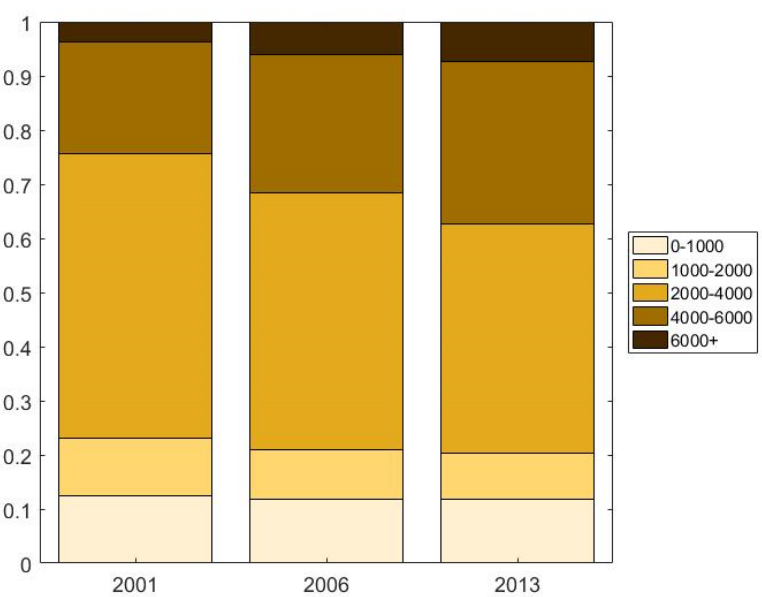


Figure 2: Proportion of population living at different population densities (persons/km^2). Source: Authors' calculations based on 2013 census.

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. 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 (AUP).

The key milestones in the development and implementation of the AUP are summarized below:

- On 15 March 2013, AC released the 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 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 2016, 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. However, the abolition of minimum lot sizes for existing parcels was maintained. 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.[4]

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.[5]

[4] 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.

[5] The 'Capacity for Growth Studies' provide estimates of how many additional dwellings can be constructed in Auckland under various assumptions. Upper estimates of this capacity increased from 338,007 additional dwellings in

The amount of development permitted on a given site is restricted by the residential planning 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 Use Suburban; Mixed Use Urban; and Single House. (For expositional purposes we will refer to these as 'Zone 4', 'Zone 3', 'Zone 2' and 'Zone 1', respectively, in places throughout the text.) Thus 'Terrace Housing and Apartments' permits the most site development, 'Single House' permits the least. The LURs that apply within each zone are listed in Table 14 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. For example, between five to seven storeys and a maximum site coverage ratio of 50% is permitted in 'Terrace Housing and Apartments', whereas only 2 storeys and a coverage ratio of 35% is permitted in 'Single House'. 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 Use Suburban' is the largest zone by area, closely followed by 'Mixed Use 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 least amount of land.

Our empirical design treats the AUP as a quasi-natural experiment. All versions of the AUP ('draft', 'proposed', 'decisions' and 'final') announced changes to LURs that would potentially change 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 uniform zoning rules for the city would soon be 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 mid August 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. In section 5.5 we present evidence indicating that upzoning was not

the 2012 Capacity for Growth Study (Fredrickson and Balderston, 2012) to 417,043 in the 2013 capacity for growth study (Balderston and Fredrickson, 2014) – after the first draft AUP is announced. 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.

priced into properties by 2012, suggesting that the market did not anticipate the scale and extent of rezoning prior to March 2013. Our post-treatment sample is September 2016 to December 2017, which is immediately after the final 'decisions' version of the AUP is released. Note that we do explore several other time periods in our robustness checks (see section 5.4).

4 Real Option 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. 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

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

The term in the brackets is the redevelopment premium. If $q_n = q_0$ it disappears. Clapp and Salavei (2010) solve for the optimal date of redevelopment, which we will refer to as T. By rearranging equation (5) in Clapp and Salavei (2010) we have

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

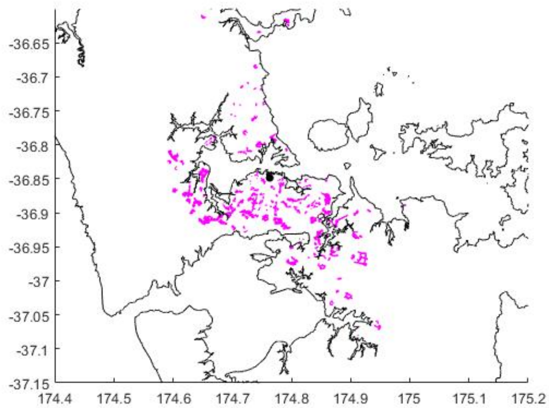
and thus

$$V_0 = \upsilon' q_0 + \left(\upsilon' \left(q_n - q_0 \right) - k \right) \left(\frac{\upsilon' q_n - k}{\upsilon' q_0} \right)^{\frac{\rho}{\delta}} \left(\frac{\rho}{\rho+\delta} \right)^{\frac{\rho}{\delta}} \tag{2}$$

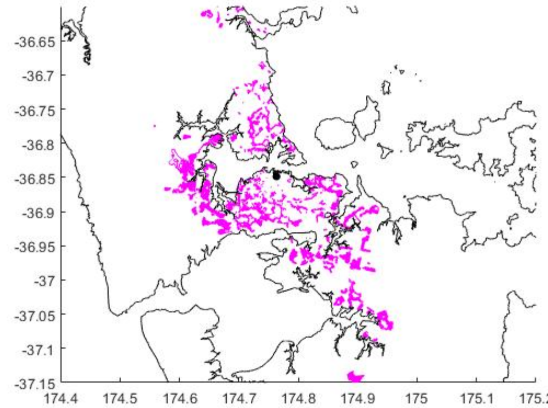
where we let $\upsilon = \frac{p}{\rho+\delta}$.

Next we consider what happens to V_0 in (2) when the local authority increases q_n, so that the value of the property will be modelled as a function of q_n, i.e. $V_0(q_n)$. For instructive purposes, we will focus on the case where q_n is a scalar that represents an overall measure of development intensity. Thus we can think of upzoning as an exogenous increase in q_n. 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

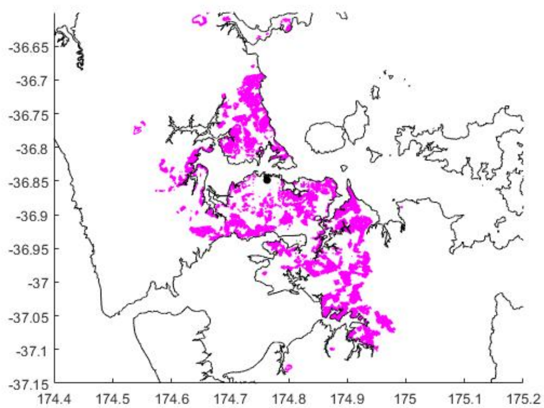
Figure 3: Location of Specific Residential Zones



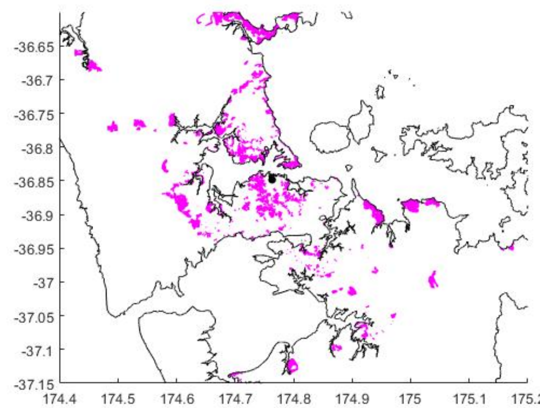
Terrace Housing and Apartments (Zone 4)



Mixed Use Urban (Zone 3)



Mixed Use 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.

$k(q_n) > 0$ and $k'(q_n) \geq 0$, i.e. improvement costs are positive and increasing in q_n. We have

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

where the inequality holds provided that $\upsilon - k'(q_n) \geq 0$, the marginal benefits to improvement at q_n exceed the marginal cost of improvement. The above result indicates that an increase in permitted development intensity q_n increases the value of the property.

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 decreasing in q_0, meaning that the property with a lower initial level of site development q_0 will experience a larger increase in value after upzoning. This key prediction from the model will be examined in our empirical specification.[6]

In summary, we have two key predictions from the real option model that we will evaluate in the empirical section: (i) upzoning increases the price of the house, and (ii) houses with a lower level of site development will experience a greater increase in price after upzoning. Taken together, these imply that it is important to condition on the existing extent of site development when examining changes in house prices to estimate the effect of upzoning on the redevelopment premium.

5 Empirics

In this section we first describe our dataset and empirical regression, before proceeding to our main results and robustness checks.

5.1 Data

Our primary dataset consists of all residential property sales in Auckland between 2010 and 2017 (inclusive). The dataset contains various information on transacted property, including: 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 (in square meters) of the residential building; whether the property is freehold or leasehold; dwelling type (house, flat, apartment or vacant land); the Area Unit (AU) in which the property is located[7]; number of bedrooms and bathrooms; the decade in which the

[6] Although it is not germane to our empirical analysis, the model also suggests that upzoning brings forward the optimal date of redevelopment. Letting $T(q_n)$ denote the optimal date of redevelopment as a function of q_n, 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.

[7] 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 persons, 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

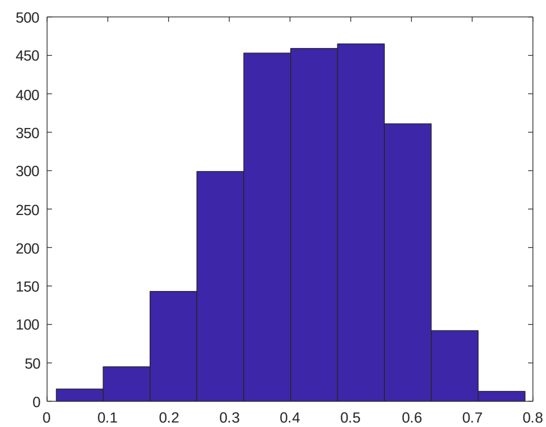


Figure 4: Histogram of Intensity Ratio. See (3) for the construction of the ratio.

dwelling was built; and the latitude and longitude of the property. The dataset also includes a unique identifier for each property. We can also identify properties with exclusive ownership of the underlying land in the title, since many real estate titles in our sample carry joint ownership of the land underlying the structure, such as apartments and cross-leased parcels.[8]

The intensity ratio plays a significant role in our empirical method, and it is constructed from the assessment information in our transaction dataset as follows:

$$intensity := \frac{IV}{AV} = 1 - \frac{LV}{AV} \tag{3}$$

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. Assessed values are based on local government valuations made for the purpose of levying property taxes. By construction the ratio lies between zero and one. Figure 4 presents a histogram illustrating the empirical distribution of the intensity ratio used in estimation of our preferred empirical specification (described in the following subsection). Evidently, the ratio does not exceed 0.8 in our sample.

The intensity ratio described in (3) 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 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 intensity ratio, on the other hand, is indicative of a high opportunity cost of redevelopment.[9]

[8]Cross-leasing was an inexpensive alternative to subdivision in New Zealand, whereby two or more title holders jointly own the land underlying the residential structures, and lease use of the land back to one-another. Although it clearly was not equivalent to subdivision, cross-leasing circumvented many of the administrative costs of subdividing existing residential parcels.

[9]Because it is based on local government assessments, it is likely that the intensity ratio will be measured with error. As illustrated below in Section 5.3, the upzoning effect is statistically significant despite this potential source

We add some additional variables to the transaction dataset. We use the longitude and latitude 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 Use Suburban' ('Zone 3'); 'Mixed Use Urban' ('Zone 2'); and 'Single House' ('Zone 1'). We also use the longitude and latitude coordinates to calculate the distance of the property to downtown Auckland.[10] We assign the median household income for the Area Unit (AU) in which the property is located. These data are obtained from the 2006 New Zealand census.[11] AUs are a geographic measure roughly corresponding to large suburbs in urban areas, comprising between 3,000 and 5,000 residents. By comparing the floor area to the site footprint, we generate a dummy variable for houses with two or more storeys. 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.[12]

We clean the data in order to remove transactions that appear to have had information incorrectly coded or omitted, that appear to be non-market transactions, or that are not relevant to our empirical analysis. 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 meters or more than 500 square meters were removed. Fourth, transactions with a land size of more than 10 hectares were removed. Fifth, transactions with a coverage ratio (site area to land area) greater than one were removed. Sixth, transactions on properties without exclusive land ownership are omitted, thereby restricting our attention to properties that can more easily be redeveloped by a single title holder (we do, however, include these properties in a robustness check exercise). 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.

5.2 Econometric Model

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

$$\frac{1}{T_i}\left(p_{i,t_1} - p_{i,t_{-1}}\right) = \beta_1 + \sum_{s=2}^{m} \beta_s zone_{s,i} + \delta_1 intensity_{i,t_{-1}} + \sum_{s=2}^{m} \delta_s zone_{s,i} \cdot intensity_{i,t_{-1}} + \gamma' X_{i,t_{-1}} + \varepsilon_i \tag{4}$$

where:

- $i = 1, \ldots, n$ indexes the transactions (houses) in the sample.

of attenuation bias.

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

[11] The next census after 2006 occurs in 2013, which is during our observation period. Median incomes above \$100,000 are truncated in the census dataset. Thus, for 19 of the approximatelty 340 AUs in Auckland, median household income is recorded as \$100,000.

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

- $p_{i,t_{-1}}$ is log sales price of house i in period $t_{-1} < t_0$ (i.e., before the announcement). We remove the reported value of chattels from the sales price. Similarly, p_{i,t_1} is log sales price (excl. chattels) of house i in period $t_1 > t_0 > t_{-1}$. This means that a property is included in our sample if it was sold in period t_{-1} and in period t_1. If a house was sold more than once within t_{-1} (or t_1), we use the first transaction and omit the remaining transactions within the period. In our baseline empirical specification, we use the years 2010 through 2012 (inclusive) for t_{-1} and 1 September 2016 to 31 December 2017 for t_1. This pre-treatment period precedes the draft AUP, and the post-treatment period occurs after the final 'decisions' version of the AUP. 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.

- 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. Because we use the month of sale, T_i is expressed as a fraction of 12. For instance, if the sales occurred five years and 7 months apart, $T_i = 5 + \frac{7}{12}$. Table 11 in the Appendix provides summary statistics on T_i, and shows that the average number of years between transactions is 5.64.

- $zone_{s,i}$ 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 Use Urban* (Zone 3), and *Mixed Use 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; a dummy variable indicating two or more storeys; number of bedrooms; number of bathrooms; approximate age of building; the (log) distance to downtown; and the (log) median household income for the suburb in which the house is located. We report regression results both with and without these controls.

We are left with 2340 observations for our preferred empirical specification. Table 1 below illustrates the sample statistics for all variables in the model, including the mean, median, and the 1st, 5th, 95th and 99th percentiles. Tables 6 through 9 in the Appendix contain these descriptive statistics stratified by residential zone. These Tables show that sales in zones that permit more intensive development also tended to be closer to downtown, and to be in suburbs with lower incomes, on average. Interestingly, there is no discernible relationship between the average intensity ratio of the properties and residential planning zone, as the average intensity ratio is remarkably similar across all four zones.

Table 2 provides a breakdown of the sample into the four residential zones. Approximately a quarter of the transactions (25.5%) fall into the Single House zone, which acts as our quasi-control. Only 5% of the transactions fall into the Terrace Housing and Apartments zone, which permits the most amount of site development.

Table 1: Summary Statistics

	mean	median	std. dev.	skew	1st perc	5th perc	95th perc	99th perc
Price Appreciation	0.12	0.11	0.03	-0.8	0.04	0.07	0.18	0.21
Intensity	0.43	0.44	0.13	-0.25	0.10	0.21	0.63	0.70
Land Area (hectares)	0.07	0.07	0.03	4.84	0.02	0.03	0.12	0.18
Floor Area (sq meters)	154.58	140	62.30	1.02	70	80	274.0	340.9
Coverage Ratio	0.21	0.19	0.09	0.76	0.06	0.09	0.37	0.45
Bedrooms	3.48	3	0.74	0.41	2	3	5	5
Bathrooms	1.65	2	0.74	1.04	1	1	3	4
Building Age (years)	38.74	40.0	26.42	0.64	1	2	92	102
Dist to Dntown (km)	17.89	14.37	11.43	1.25	2.24	4.47	41.91	51.29
Suburb Income ($000)	64.61	61.60	15.53	0.58	36.90	42.0	95.5	100.00

Note: Price appreciation is the average annual change in log prices and is based on repeat sale residential transactions between the pre-treatment sample (January 2010 to December 2012) and the post-treatment sample (September 2016 to December 2017). Suburb Income is median household income in the Area Unit of the transactions and is obtained from the 2006 census. 'skew' denotes "skewness", while 'perc' denotes 'percentile'.

Table 2: Sample Characteristics of Residential Zones

	Zone 1	Zone 2	Zone 3	Zone 4	All Zones
	Single House	Mixed Use Suburban	Mixed Use Urban	Terrace Housing & Apartments	
Observations	597	1199	428	116	2340
Proportion	0.255	0.512	0.183	0.050	1

Several features of the empirical model (4) 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 the intensity ratio 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 the intensity ratio. Similar statements can be made about δ_2 and δ_3 for the 'Mixed Use Suburban' and 'Mixed Use Urban' zones ('Zone 2' and 'Zone 3').

(*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 approach adopted by 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 confounding factors can be controlled for to the extent that they are time invariant.

(*iii*) It is certain that the observed geographic variation in LURs is driven by unobserved variables that affect house prices. Such confounding 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 intensity ratio between observations within each residential zone identifies 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 between t_{-1} and t_1. Pakes (2003) argues that hedonic models should permit these prices to change over time and presents a straightforward empirical methodology to accommodate this variation. In our present application, we allow the hedonic price of housing attributes (such as the number of bedrooms and bathrooms) 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 through more bedrooms and bathrooms.

(*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.[13] Note that the standard errors are robust to any heteroskedasticity induced by different holding periods across $i = 1, \ldots, n$.

5.3 Regression Results

Table 3 illustrates the estimated coefficients of the empirical model. We also present results when the controls are omitted and when the controls related to the immediate neighborhood (household income and distance to downtown) are omitted.

The coefficients on the three upzoning dummy variables interacted with the intensity ratio 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), and that the redevelopment premium depends on the existing extent of site development. Our findings therefore corroborate the key predictions of the real option model introduced in Section 4. Furthermore, note that the magnitude of these coefficients correspond to the ordinal ranking of permissible site development under each zone. That is, for $m = 2, 3, 4$,more intensive development is permitted under Zone m than under Zone $m-1$, and we correspondingly observe that the coefficient for Zone m is larger in magnitude than that of Zone $m-1$. (For example, the coefficient for Zone 3 is -0.048, while that for Zone 2 is -0.026). This is consistent with our ordinal ranking of the planning zones according to permissible site development.

Interestingly, the coefficient on intensity (not interacted) is statistically indistinguishable from zero. This suggests that there was no change in the redevelopment premium for the quasi-control group after the announcement.

Next, to illustrate how the effect of upzoning on overall house prices depends on the intensity of existing site development, we use the estimated regression model to construct predicted changes in house prices conditional on both the residential zone and the intensity ratio. For each of the four zones, Figure 5 plots the expected annualized price appreciation conditional on the intensity ratio, which exists between zero and one.[14] For the purpose of this exercise we set the control variables in $X_{i,t_{-1}}$ to their sample means when constructing these predicted values.

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 14.7% (intensity = 0) and 9.3% per year (intensity = 1). Consistent with the predictions of the real option model, properties that had relatively little site development (reflected in a low intensity ratio) experienced substantially higher rates of inflation compared to properties with a lot of site development (reflected in a high intensity ratio).

However, as illustrated above in Figure 4, intensity does not exceed 0.8 in our sample. We therefore also consider what the model implies for houses with an intensity at either end of the empirical distribution of the variable – specifically at the 1st and 99th percentile. Across all zones,

[13] These are Newey-West standard errors with Euclidean distance (rather than time) as the measure of distance between observations.

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

Table 3: Estimated Regression Coeffcients

	(A)	(B)	(C)
Constant	0.324***	0.214***	0.129***
Zone 4	0.037***	0.042***	0.042***
Zone 3	0.032***	0.034***	0.034***
Zone 2	0.020***	0.021***	0.015***
Intensity	0.003	0.003	-0.044***
Zone 4 × Intensity	-0.057***	-0.064***	-0.056**
Zone 3 × Intensity	-0.048***	-0.050***	-0.044***
Zone 2 × Intensity	-0.027**	-0.029***	-0.017
ln(land)	0.001	-0.002	
ln(floor)	-0.025***	-0.026***	
bedrooms	0.002	0.002	
bathrooms	0.003**	0.003**	
2+ storey dummy	-0.000	0.005	
ln(age)	0.003***	0.003***	
ln(distance)	-0.004**		
ln(neighborhood income)	-0.009**		
R-squared	0.147	0.143	0.092
Adjusted R-squared	0.141	0.138	0.089
Observations	2340	2340	2340

Notes: OLS estimates of the regression equation (4) with various sets of controls: (A) denotes the full model with all control variables; (B) omits control variables related to the neighborhood; (C) omits all control variables. The dependent variable is annualized percent change in repeat sale residential transactions between the pre-treatment sample (January 2010 to December 2012) and the post-treatment sample (September 2016 to December 2017). ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively. Conley (1999) robust standard errors using a 10km radius. Zone 4 is the most intensive residential zone under the new LURs; Zone 1 is the least intensive.

the 1st and 99th percentiles of the intensity ratio are 0.103 and 0.705 (see Table 1). The model implies that properties at the 1st percentile appreciated by 14.1% on average, whereas properties at the 99th percentile appreciated by 10.9%.

Next we consider houses located in Zone 1, which is the residential zone that permits the least site development. The coefficient on intensity is close to zero, which implies very little variation in expected house price appreciation conditional on intensity. For example, the model implies that a house with an intensity of zero appreciated by 11.0% per year, on average, while a dwelling with an intensity of one appreciated by fractionally more – 11.3% per year. The difference in appreciation rates at the 1st and 99th percentile of intensity is smaller – the former is 11.0%, while the latter is 11.2%. In fact, the model implies that a house with an intensity ratio in excess of 0.63 (that is, above the 95th percentile; see Table 1) appreciated by more when located in Zone 1 compared to Zone 4.

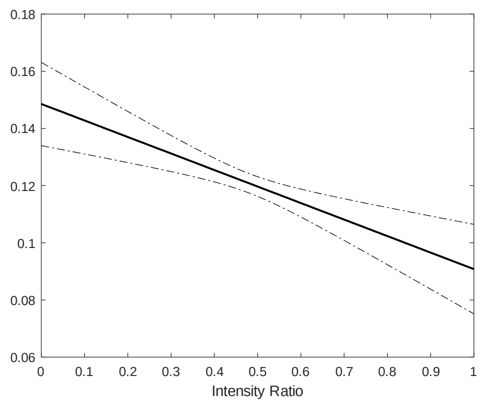
The model therefore implies that upzoning to the most intensive residential zone generated a premium of approximately 22.2% in properties that are equivalent to vacant land. Houses with an intensity ratio of zero located Zone 4 (Terrace Housing and Apartments) appreciated by 3.7% (= 14.7 – 11.0) more, per annum, than houses located in Zone 1 (Single House). This equates to approximately 22.2% over the six years spanning the announcement (2010-2012 to 2017). The upzoning premium declines as intensity increases.

Predicted price changes in Zones 2 and 3 further corroborate the predictions of the real option model. The fitted regression 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 14.1% (intensity = 0) and 9.7% (intensity = 1). Houses with an intensity ratio at the 1st percentile appreciated by 13.7%, while houses with an intensity ratio at the 99th percentile appreciated by 11.1%. Houses located in Zone 2 (which permits more site development than Zone 1, but less that Zones 3 and 4) appreciated by between 13.0% (intensity = 0) and 10.6% (intensity = 1) per year. Houses with an intensity ratio at the 1st percentile appreciated by 12.7% on average, while houses with an intensity ratio at the 99th percentile appreciated by 11.3%.

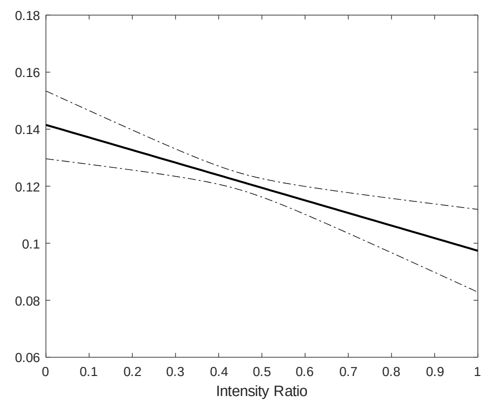
A consistent pattern therefore emerges from the estimated model. Houses with a low intensity ratio experienced higher rates of appreciation relative to houses that were not upzoned. As the intensity ratio increases, the impact of upzoning on price diminishes, and can even be negative for sufficiently high levels of intensity. The negative effect of upzoning on the price of properties that are already intensively developed could reflect concurrent effects of upzoning in the immediate area, such as disamenities from crowding, or anticipated construction of high intensity housing.

The estimated coefficients on the controls given in Table 3 also merit comment. The coefficient on distance is negative and statistically significant at the ten percent level, 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

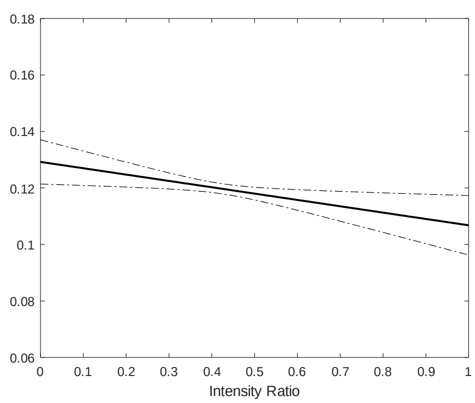
Figure 5: Expected Price Appreciation conditional on Intensity Ratio and Residential Zone



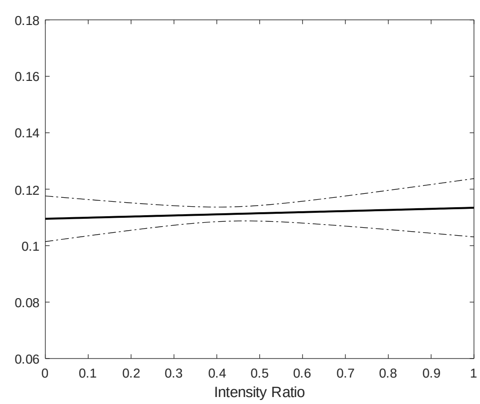
Terrace Housing & Apartments (Zone 4)



Mixed Use Urban (Zone 3)



Mixed Use Suburban (Zone 2)



Single House (Zone 1)

Notes: Conditional expectations are based on OLS estimation of (4). See Table 3 for the estimated coefficients. Dashed lines represent 95% confidence intervals. Standard errors are robust to spatial dependence and heteroskedasticity.

use of untreated 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. Our results may indicate that this discount increased over the 2010 to 2017 period. Next, the coefficients on the number of bedrooms and the number of bathrooms is positive and statistically significant, indicating that price appreciation was greater for houses that could accommodate more people. This is perhaps consistent with the well-documented increase in population pressures in Auckland over the sample period. In contrast, the coefficient on floor area is negative and statistically significant. Holding all else constant, including the number of bedrooms and bathrooms, larger homes appreciated by less over the sample period. Finally, the coefficients of land area and the dummy for two or more storeys are insignificant.

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.[15] For example, areas rezoned to Terrace Housing and Apartments may already be in areas of the city that already had LURs that permitted intensive development. 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 find evidence of the upzoning effect on the redevelopment premium despite this potential form of misspecification.

Nonetheless, to investigate the extent to which this attenuation bias is a valid concern, we examine whether there are significant differences in population density in the immediate neighborhood of the transacted properties across the four residential zones. To do this, we use the 2013 census to calculate the population density of the *meshblock* in which the transacted property is located.[16] Table 10 in the Appendix provides summary statistics on the population densities associated with our sample of residential transactions. While the median population density is similar across all four residential zones, transactions from Terrace Housing and Apartments (Zone 4) do have a higher average population density.

Furthermore, in a robustness check we expand the sample to include transactions on real estate titles without exclusive ownership of the underlying land (such as apartments and cross leased sections). Our main findings are largely unaffected by this expansion in the sample, and here we do find that the empirical distribution of population densities is very similar across the four residential zones (see Table 13). In particular, difference(s) in the mean average population density of the transactions across the different residential zones is quite small. Based on this robustness check, we do not anticipate that our results are significantly affected by this form of attenuation bias.

5.4 Robustness Checks

We explore alternative empirical designs and a different regression specification as robustness checks.

[15] Doing this would be very difficult because there was no uniform set of planning rules for the region. Prior to amalagmation into Auckland (see section 3 above), each of the seven authorities implemented their own residential planning rules.

[16] The meshblock is the smallest geographic unit for which statistical data is collected and processed by Statistics New Zealand. A meshblock is a defined geographic area, varying in size from part of a city block to large areas of rural land. See http://datainfoplus.stats.govt.nz/Item/nz.govt.stats/011d668f-1fe2-4820-8957-837aae2bf575

First we explore the extent to which our results are sensitive to the selected pre-treatment and post-treatment periods. In Table 12 in the Appendix we consider the baseline empirical specification (4) under three 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 2017, which substantially increases the number of observations.

In these robustness checks our qualitative conclusions remain the same. The coefficients on the upzoning dummies interacted with intensity are negative and statistically significant at the 10% level (except in two cases, they remain significant at the 1% level). Interestingly, the coefficient on 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.

Next we estimate a model that includes sales of properties that do not carry exclusive ownership of the underlying land on the title. This includes many apartments and units, as well as houses on cross-leased sites. We include a dummy variable in the model to account for these kind of properties. The dummy is effectively interacted with (log) land area and the coverage ratio, because our dataset only contains land area information for houses with exclusive ownership of land on the title. We can, however, still construct the intensity ratio for these properties without exclusive ownership, because the assessment data contain the assessed value of land. We also include a dummy variable for apartments and units.

One notable feature of this larger sample is that the distribution of local population density associated with the transactions appears rather uniform across the four residential zones – see Table 13 in the Appendix.

Table 4 presents the results. Note that we also include the regression estimated without the controls, and without the distance and neighborhood income controls. Our results remain largely the same. The coefficients on the zones interacted with site intensity are negative and highly statistically significant, and the relative magnitude of the coefficients corresponds to the amount of site development permitted.

We also construct predicted price appreciation conditional on intensity and residential zone in Figure 6 in the Appendix. The patterns are very similar to those exhibited in Figure 5 above. However, the model implies that a larger proportion of upzoned houses decreased in value relative to houses that were not upzoned. Specifically, houses with an intensity ratio above the 80th percentile (an intensity ratio above 0.55) appreciated by less when located in Zone 4 compared to Zone 1. Thus approximately a fifth of the most highly developed properties that were upzoned to the most intensive residential planning zone *decreased* in value relative to properties that were not upzoned.

This is a larger proportion of the sample than under the baseline model and sample.

5.5 Placebo Tests

As a further robustness check we estimate the same model over pre- and post -treatment periods that altogether precede the announcement of the AUP altogether. These placebo tests serve two purposes.[17] 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: 2005 to 2007 (pre) and September 2011 to 2012 (post); 2004 to 2006 (pre) and September 2010 to 2011 (post); and 2003 to 2005 (pre) and September 2009 to 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 5.

In all placebo samples the coefficients on the upzoning dummies interacted with intensity are by and large statistically insignificant. The single exception is the coefficient on the Zone 3 dummy in the 2003-2005 to September 2009-2010 sample, which is positive and significant at the 5% level. From this we may conclude that there is no differential effect of 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 3 dummy in the 2003-2005 to September 2009-2010 sample, which is negative and significant at the 5% 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 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 significant at a one percent level in the 2005-2007 to September 2011-2012 sample, which would indicate a decline in the redevelopment premium across the metropolitan area over this period.

[17] We adopt the nomenclature of Chetty, Looney and Kroft (2009) in describing this exercise as a “placebo test”.

Table 4: Robustness Checks on Regression Results

	(A)	(B)	(C)
Constant	0.360***	0.189***	0.126***
Zone 4	0.027***	0.033***	0.033***
Zone 3	0.026***	0.029***	0.028***
Zone 2	0.018***	0.020***	0.014***
Intensity	-0.003	0.005	-0.034***
Zone 4 × Intensity	-0.050***	-0.059***	-0.056**
Zone 3 × Intensity	-0.039***	-0.041***	-0.036***
Zone 2 × Intensity	-0.026***	-0.030***	-0.017*
land dummy × ln(land)	-0.002	-0.001	
land dummy	0.002	0.003	
ln(floor)	-0.020***	-0.023***	
bedrooms	0.003***	0.003***	
bathrooms	0.002**	0.002*	
2+ storey dummy	-0.001	-0.001	
apartment dummy	-0.005	-0.006	
ln(age)	0.004***	0.004***	
ln(distance)	-0.002**		
ln(neighborhood income)	-0.016***		
R-squared	0.127	0.120	0.067
Adjusted R-squared	0.123	0.116	0.065
Observations	3695	3695	3695

Notes: OLS estimates of the regression equation (4) fitted to a larger sample that includes sales transactions on properties without exclusive ownership of the land underlying the structure (such as apartments and houses on cross-leased parcels). (A) denotes the full model with all control variables; (B) omits control variables related to the neighborhood; (C) omits all control variables. We include dummy variables for properties with exclusive land titles and apartments in models (A) and (B). The dependent variable is annualized percent change in repeat sale residential transactions between the pre-treatment sample (January 2010 to December 2012) and the post-treatment sample (September 2016 to December 2017). ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively. Conley (1999) robust standard errors using a 10km radius. Zone 4 is the most intensive residential zone under the new LURs; Zone 1 is the least intensive.

Table 5: Placebo Tests

	pre: 2005-2007 post: Sept 2011-2012	pre: 2004-2006 post: Sept 2010-2011	pre: 2003-2005 post: Sept 2009-2010
Constant	-0.040	-0.050	0.055
Zone 4	0.005	-0.023	-0.013
Zone 3	0.005	-0.001	-0.015**
Zone 2	0.007	-0.003	-0.001
Intensity	0.025***	0.008	0.008
Zone 4 × Intensity	-0.003	0.047	0.015
Zone 3 × Intensity	-0.007	0.006	0.028**
Zone 2 × Intensity	-0.008	0.009	0.005
ln(land)	0.001	0.006	0.004
ln(floor)	-0.011***	-0.015***	-0.017***
bedrooms	0.000	0.003***	0.003***
bathrooms	0.001**	0.000	0.001
2+ storey dummy	-0.001	-0.001	-0.001
ln(age)	0.004***	0.002**	0.001**
ln(distance)	-0.014***	-0.008***	-0.004***
ln(income)	0.012***	0.014***	0.007***
R-squared	0.139	0.077	0.031
Adjusted R-squared	0.137	0.074	0.027
Observations	4827	3736	3595

Notes: OLS estimates of the regression equation (4) 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. "pre" refers to the placebo pre-treatment period; "post" referees to the placebo post-treatment period

6 Concluding Remarks

In this paper we provide empirical evidence of the effect of LURs on the redevelopment premium and house prices. We exploit a rich dataset of individual residential property transactions from Auckland, New Zealand, that spans the announcement of a spatially heterogenous relaxation of LURs. We find that upzoning significantly increased the redevelopment premium of affected properties, and generated a significant increase in the price of low intensity properties relative to both high intensity properties and to properties that we not upzoned. Interestingly, our estimated model implies that properties with a sufficiently high intensity ratio could decrease in relative value after upzoning. This may reflect anticipated disamenities from crowding or anticipated construction of high intensity housing.

Our findings demonstrate that changes in land use policies can have vastly different effects on the value of individual properties depending on the redevelopment potential of the site. These heterogenous effects should be taken into consideration when evaluating the effect of an urban intensification policy of housing unit prices. For example, relaxing LURs in order to enhance housing affordability may initially *increase* sales prices of underdeveloped properties that have been upzoned. Transactions involving such properties should be disregarded or downweighted when evaluating the effectiveness of the policy. Instead, policymakers could focus on tracking the prices of the more intensive forms of housing that the policy is designed to encourage (e.g. apartments or terraced housing).

7 Appendix

7.1 Descriptive Statistics by Planning Zone

Table 6: Summary Statistics for Terrace Housing and Apartments (Zone 4)

	mean	median	std. dev.	skew	1^{st} perc	5^{th} perc	95^{th} perc	99^{th} perc
Price Appreciation	0.13	0.12	0.03	0.74	0.08	0.09	0.18	0.21
Intensity	0.42	0.42	0.13	0.01	0.11	0.22	0.62	0.71
Land Area (hectares)	0.06	0.06	0.04	5.06	0.01	0.02	0.10	0.24
Floor Area (sq m)	131.26	119.50	46.75	1.25	67	76.8	238.3	284.04
Coverage Ratio	0.23	0.21	0.10	0.43	0.05	0.10	0.42	0.46
Bedrooms	3.29	3	0.76	0.66	2	2	5	5
Bathrooms	1.43	1	0.65	1.41	1	1	3	3
Building Age (years)	47.86	52.0	30.47	-0.00	1.66	10	92	101
Dist to Dntown (km)	12.24	11.78	6.48	1.88	2.38	4.38	22.83	41.53
Hhold Income ($000)	58.8	55.1	15.1	0.99	36.29	40.16	95.3	96.56

Note: Price appreciation is the average annual change in log prices and is based on repeat sale residential transactions within Terrace Housing and Apartments (Zone 4) between the pre-treatment sample (January 2010 to December 2012) and the post-treatment sample (September 2016 to 2017). Suburb Income is median household income in the Area Unit of the transactions and is obtained from the 2006 census.

Table 7: Summary Statistics for Mixed Use Urban Zone (Zone 3)

	mean	median	std. dev.	skew	1^{st} perc	5^{th} perc	95^{th} perc	99^{th} perc
Price Appreciation	0.13	0.13	0.03	0.12	0.04	0.08	0.18	0.21
Intensity	0.41	0.41	0.12	-0.00	0.12	0.22	0.59	0.69
Land Area (hectares)	0.06	0.06	0.03	2.68	0.02	0.03	0.11	0.14
Floor Area (sq m)	134.68	120.00	50.0	1.26	76.77	80	230.15	287.76
Coverage Ratio	0.21	0.18	0.09	0.91	0.07	0.1	0.39	0.47
Bedrooms	3.32	3	0.69	0.34	2	2	5	5
Bathrooms	1.53	1	0.70	1.12	1	1	3	3
Building Age (years)	42.15	42	24.02	0.37	2	10	90.15	101
Dist to Dntown (km)	13.71	12.63	6.57	1.29	3.31	4.98	28.18	30.78
Hhold Income ($000)	59.33	57.2	13.10	0.87	36.9	40.91	87.2	95.75

Note: Price appreciation is the average annual change in log prices and is based on repeat sale residential transactions within Mixed Use Urban (Zone 3) between the pre-treatment sample (January 2010 to December 2012) and the post-treatment sample (September 2016 to 2017). Suburb Income is median household income in the Area Unit of the transactions and is obtained from the 2006 census.

Table 8: Summary Statistics for Mixed Use Suburban Zone (Zone 2)

	mean	median	std. dev.	skew	1st perc	5th perc	95th perc	99th perc
Price Appreciation	0.12	0.11	0.04	-1.67	0.06	0.08	0.18	0.22
Intensity	0.43	0.44	0.13	-0.26	0.10	0.22	0.63	0.70
Land Area (hectares)	0.07	0.07	0.03	5.12	0.03	0.03	0.11	0.17
Floor Area (sq m)	157.48	147	60.68	0.94	79.47	86.35	269.30	331.53
Coverage Ratio	0.21	0.19	0.09	0.60	0.06	0.09	0.38	0.44
Bedrooms	3.51	3	0.73	0.50	2	3	5	5
Bathrooms	1.64	2	0.71	0.83	1	1	3	3
Building Age (years)	35.11	32.00	22.39	0.51	1	2	72	92
Dist to Dntown (km)	18.34	15.25	10.59	1.04	4.42	6.43	41.48	44.96
Hhold Income ($000)	65.87	57.60	12.05	0.63	41.63	48.4	95.3	100.00

Note: Price appreciation is the average annual change in log prices and is based on repeat sale residential transactions within Mixed Use Suburban (Zone 2) between the pre-treatment sample (January 2010 to December 2012) and the post-treatment sample (September 2016 to 2017). Suburb Income is median household income in the Area Unit of the transactions and is obtained from the 2006 census.

Table 9: Summary Statistics for Single House Zone (Zone 1)

	mean	median	std. dev.	skew	1st perc	5th perc	95th perc	99th perc
Price Appreciation	0.11	0.11	0.03	0.52	0.03	0.06	0.16	0.21
Intensity	0.45	0.47	0.14	-0.48	0.10	0.19	0.63	0.68
Land Area (hectares)	0.08	0.07	0.04	4.52	0.03	0.03	0.14	0.21
Floor Area (sq m)	167.57	151	71.01	0.81	50	80	300.75	360
Coverage Ratio	0.21	0.19	0.10	1.04	0.05	0.07	0.35	0.42
Bedrooms	3.59	3	0.79	0.19	2	3	5	5
Bathrooms	1.80	2	0.81	1.17	1	1	3	4
Building Age (years)	41.81	32	32.85	0.64	2	2	101	102
Dist to Dntown (km)	21.09	18.07	14.80	0.82	1.94	2.36	50.25	64.79
Hhold Income ($000)	66.98	67.30	18.51	0.28	36.90	37.6	100	100

Note: Price appreciation is the average annual change in log prices and is based on repeat sale residential transactions within Single House (Zone 1) between the pre-treatment sample (January 2010 to December 2012) and the post-treatment sample (September 2016 to 2017). Suburb Income is median household income in the Area Unit of the transactions and is obtained from the 2006 census.

Table 10: Local population densities for sales transcations

	mean	median	std. dev.	skewness	5th perc.	95th perc.
All Zones	4014	3401	6502	10.09	978	6312
Terrace Housing and Apartments (Zone 4)	5219	3512	10137	5.92	689	8236
Mixed Use Urban (Zone 3)	3839	3390	5539	9.64	351	6121
Mixed Use Suburban (Zone 2)	3825	3389	4917	8.86	593	6183
Single House (Zone 1)	4285	3415	8667	9.71	523	6468

Note: Population densities (persons per km^2) are based on the Census 2013 meshblocks where the transacted house is located. For each transaction, we assign the population density of the meshblock in which the property is located.

Table 11: Years between Repeat Sales Transactions by Residential Zone

	mean	median	std. dev.	skewness	5th perc.	95th perc.
All Zones	5.64	5.58	0.94	0.22	4.25	7.25
Terrace Housing and Apartments (Zone 4)	5.72	5.67	0.88	0.04	4.25	7.14
Mixed Use Urban (Zone 3)	5.62	5.50	0.90	0.25	4.25	7.69
Mixed Use Suburban (Zone 2)	5.65	5.58	0.95	0.19	4.17	7.33
Single House (Zone 1)	5.61	5.58	0.95	0.29	4.25	7.33

Note: Number of years between repeat sales transactions in the baseline sample.

7.2 Robustness Checks

Table 12: Robustness Checks on Regression Results

	pre-treatment: 2007-2009 post-treatment: Sept 2016-2017	pre: 2007-2012 post: Sept 2016-2017	pre: 2010-2012 post: 2014-2017
Constant	0.207***	0.292***	0.486***
Zone 4	0.032***	0.026***	0.048***
Zone 3	0.025***	0.029***	0.035***
Zone 2	0.018***	0.017***	0.038***
Intensity (I)	-0.015	-0.033***	-0.012
Zone 4 × I	-0.042***	-0.040***	-0.089***
Zone 3 × I	-0.036***	-0.050***	-0.036***
Zone 2 × I	-0.024*	-0.026***	-0.058***
ln(land)	0.002	-0.001	-0.002
ln(floor)	-0.014***	-0.015***	-0.038***
bedrooms	0.002***	0.002**	0.008***
bathrooms	0.003***	0.003***	0.005***
2+ storey dummy	0.001	0.001	0.001
ln(age)	0.002***	0.001	0.000
ln(distance)	-0.011***	-0.007***	-0.011***
ln(income)	-0.004	-0.010***	-0.017***
R-squared	0.262	0.129	0.111
Adj. R-squared	0.257	0.125	0.109
Observations	2139	3974	7686

Notes: OLS estimates of the regression equation (4) for various pre- and post-treatment samples. The dependent variable is annualized percent change in repeat sale residential transactions between the pre-treatment sample (January 2010 to December 2012) and the post-treatment sample. ***, **, * denote significance at the 1%, 5%, and 10% levels respectively. Conley (1999) robust standard errors based on 10km radius.

Table 13: Population densities for by Residential Zone

	mean	median	std. dev.	skewness	5th perc.	95th perc.
All Zones	3991	3368	6560	9.78	469	6232
Terrace Housing and Apartments (Zone 4)	4280	3367	8229	7.76	480	6227
Mixed Use Urban (Zone 3)	3849	3326	5598	9.76	359	6517
Mixed Use Suburban (Zone 2)	3975	3373	6124	8.99	491	6095
Single House (Zone 1)	4073	3388	7761	10.75	523	6400

Note: Population densities (persons per km^2) are based on the Census 2013 meshblocks where the transacted property is located. For each transaction, we assign the population density of the meshblock in which the property is located.

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.

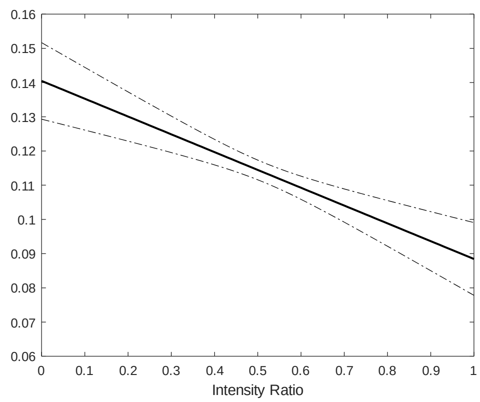
Approximately 222,234 unique properties underlying the transaction dataset were matched to an AUP zone prior to the filtering described in the Data section above. The matching process is as follows:

(*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.

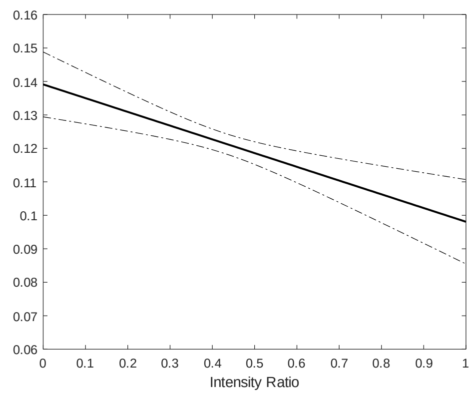
(*ii*) Approximately 5% of the longitude-latitude coordinates fall exactly on the boundary of two or more polygons, resulting in an unmatched zone for the property. Another 40% or so fall just outside a lot, usually on the road frontage of the property, resulting in a returned AUP zone of 'road' or 'public'. 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

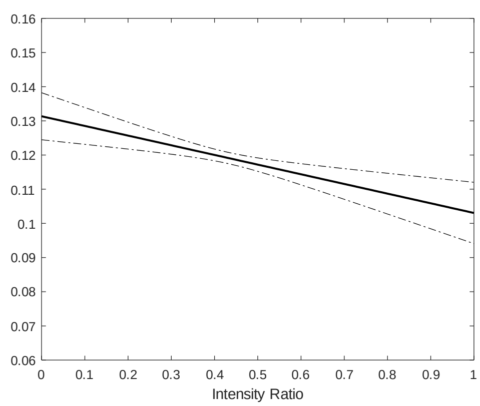
Figure 6: Expected Price Appreication conditional on Intensity Ratio and Residential Zone



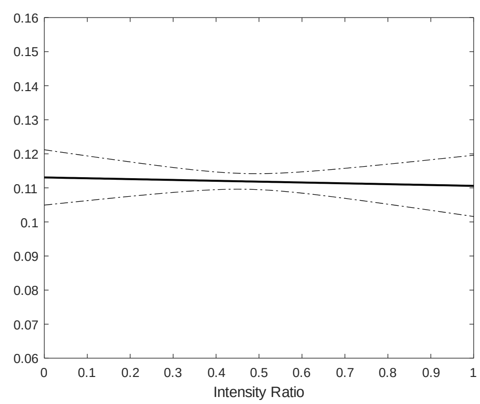
Terrace Housing & Apartments (Zone 4)



Mixed Use Urban (Zone 3)



Mixed Use Suburban (Zone 2)



Single House (Zone 1)

Notes: Conditional expectations are based on OLS estimation of (4) augmented with a dummy variable for exclusive land ownership. See Table 4 for the estimated coefficients. Dashed lines represent 95% confidence intervals. Standard errors are robust to spatial dependence and heteroskedasticity.

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 14: Summary of Land Use Regulation by Residential Planning Zone

Land Use Regulation	Terrace Housing & Apartments	Mixed Use Urban	Mixed Use 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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