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Going it Alone: The Impact of Upzoning on Housing Construction in Lower Hutt

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Abstract

This paper studies a sequence of zoning reforms enacted in Lower Hutt, a constituent municipality of the wider Wellington metropolitan region of New Zealand. Beginning in the late 2010s, Lower Hutt independently implemented a sequence of widespread zoning changes to enable medium- and high- density housing in residential areas. Using a synthetic control to specify the policy counterfactual, we find that these zoning changes generated a three-fold increase in consents per capita and nearly tripled the number of housing starts over the six years subsequent to the onset of the reforms. Depending on how potential displacement effects are accounted for, the Lower Hutt reforms increased housing starts across the wider metropolitan region by approximately 10 to 18%. We also present evidence that the upzonings reduced rents by around 21% relative to the counterfactual.

Keywords: Zoning Reform, Upzoning, Housing Supply, Policy Spillovers

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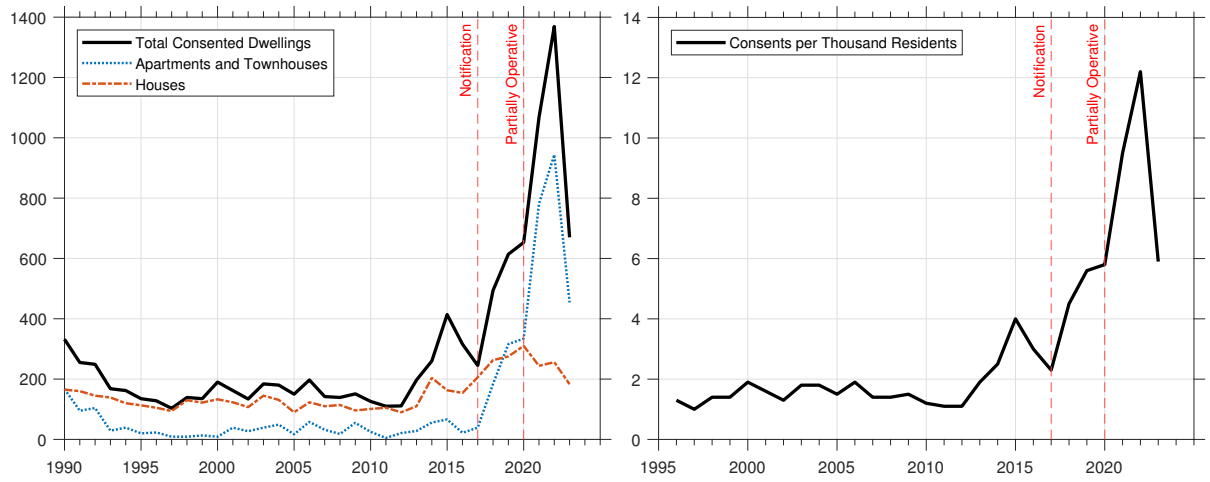
1 Introduction

Widespread upzoning is increasingly advocated to redress increasingly scarce and unaffordable housing in many cities around the world (Glaeser and Gyourko, 2003; Freeman and Schuetz, 2017; Been, Ellen, and O'Regan, 2019; Manville, Monkkonen, and Lens, 2020). However, there are few examples for policymakers to to learn from (Schill, 2005; Freeman and Schuetz, 2017), meaning that the limited number of cases of widespread upzoning are highly informative and useful to the ongoing policy discourse.

In this paper we consider a notable recent case: Lower Hutt. The city is one of several municipalities that constitute the larger Wellington metropolitan area of New Zealand. Beginning in the late 2010s, Hutt City Council implemented a sequence of widespread zoning changes to enable medium- and high- density housing in existing residential areas.[1] Housing construction subsequently boomed, with housing starts quintupling within a few years of the first medium density upzoning. See figure 1, which exhibits building consents for new dwellings (hereafter "consents") between 1990 and 2023.[2]

Figure 1: Consents for new dwellings in Lower Hutt, 1990 to 2023



Source: Statistics New Zealand (SNZ). Notes: "flats" and "units" are included under the same category as townhouses in SNZ classifications, and are therefore included under *Apartments and Townhouses*. Vertical dashed lines refer to notification and partial operationalized of *Plan Change 43*, the first widespread medium density upzoning implemented in a sequence of zoning changes between 2016 and 2023. See section 2 for further details on the significance of these milestones and a timeline of the various zoning changes. *Plan Change 56*, which was a more widespread medium- and high- density upzoning, superseded Plan Change 43. It was notified in August 2022 and made operative in September 2023.

[1] Hutt City Council is the name of the local government for Lower Hutt City. It does not include Upper Hutt City, which is governed by Upper Hutt City Council.

[2] Building consents are the leading indicator of housing starts in New Zealand. They are equivalent to building "permits" in the U.S. or "approvals" in Australia. Between 90 to 95% of consents result in a completed dwelling in New Zealand (see Appendix B).

The sequence of zoning changes is notable for several reasons, particularly when compared to other recent municipal zoning changes. First, the zoning changes were widespread, with the final upzoning to enable high- and medium- density housing affecting approximately 80% of residential-zoned land. Until recently, widespread upzonings were rare (Schill, 2005; Freeman and Schuetz, 2017), leaving policymakers with few empirical examples to learn from. Second, Hutt City Council independently initiated the sequence of reforms. Many recent reforms elsewhere have been top-down, with state, provincial or national governments passing legislation to require municipalities to upzone.[3] Third, the reforms relaxed restrictions on both dwelling density (such as minimum lot sizes) and floorspace (such as site coverage and height maximums). Although several municipalities in North America have also recently implemented widespread reforms to allow greater density, many did not substantially relax restrictions on floorspace, thereby only allowing housing intensification through the construction of smaller dwellings. Subsequent growth in housing starts in many of these cities currently appears sluggish compared to Lower Hutt.[4]

This paper describes the institutional and political background underpinning the sequence of zoning changes and evaluates their impact on housing construction. We find that the building boom from 2018 onwards illustrated in figure 1 is largely a causal effect from upzoning. Using a synthetic control to specify the policy counterfactual, the sequence of zoning changes generated more than a threefold increase in consents per capita, and almost tripled housing starts over the six years subsequent to the first medium density upzoning.

We also present evidence that the reforms increased housing starts by 10 to 18% across the wider Wellington metropolitan region, depending on whether and how spillovers from Lower Hutt to nearby areas are accounted for. Despite being home to approximately one-in-four residents, Lower Hutt accounted for only 13% of all new dwelling consents across the region over the ten years prior to the first medium density zoning change. Subsequent to that upzoning becoming operational, the city accounts for 36% (the plurality) of all starts.

We are careful to adopt an empirical design that addresses common pathologies asso-

[3]California, Oregon and Washington in the US, New South Wales in Australia, and British Columbia in Canada have recently passed zoning reform legislation. Meanwhile, the New Zealand government passed reforms to enable transit-oriented high density housing and widespread medium density housing in its largest cities. See section 2 below.

[4]For example, at the time of publication, Minneapolis has not experienced an increase building permits for plexes since abolishing single family zoning in 2020 (see https://minneapolisfed.shinyapps.io/Minneapolis-Indicators/ [accessed 1 October 2024]). Victoria initially only approved a handful of consent applications under its "Missing Middle" zoning changes, leading to further relaxations in height, setback and site coverage restrictions eleven months later (see https://engage.victoria.ca/missing-middle-housing [accessed 1 October 2024]). As of May 2024, Arlington, Virginia has approved permits for 126 units under its "Expanding Housing Option" program (see https://www.arlingtonva.us/Government/Programs/Housing/Housing-Arlington/Tools/Missing-Middle [accessed 1 October 2024]). Arlington is home to approximately 250,000 people.

ciated with the synthetic control method. First, we exclude other municipalities in the Wellington metropolitan region from the donor pool of the synthetic unit, as they could plausibly be affected by the changes in Lower Hutt via policy spillovers. Second, we implement a battery of other robustness checks, including alternative empirical specifications, leave-one-out validation, and backdated intervention timing. Finally, we consider other possible explanations for dwelling consent growth, for instance migratory patterns driven by the COVID-19 pandemic.

We also consider whether reforms in Lower Hutt displaced housing starts in other jurisdictions in the wider metropolitan area. We do so by estimating a synthetic control for each of these jurisdictions, using Hutt City's reforms as the intervention. Estimated displacement effects are modest and statistically insignificant. No displacement would imply that the Lower Hutt upzoning increased housing starts by 18.2% across the metropolitan Wellington region. If we instead ignore the lack of statistical significance and use point estimates of the policy spillover effects, region-wide consents increased by between 9.5 and 12.6%, depending on the specification adopted.

Finally, we also consider the effects of the upzonings on housing affordability by examining changes in rental price indexes. The synthetic control fitted to Lower Hutt indicates that rents would be 21% higher by 2023 under the counterfactual of no upzonings.

This paper makes several additional contributions to the zoning reform literature. First, it contributes empirical evidence to the debate on the effects of widespread zoning reform that is frequently characterized by entrenched positions, including supply skepticism from many (Been, Ellen, and O'Regan, 2019, 2023). While widespread zoning changes in Zurich, Sao Paulo, and Auckland have also been found to have a substantial impact on housing construction (Anagol, Ferreira, and Rexer, 2023; Greenaway-McGrevy and Phillips, 2023; Greenaway-McGrevy, 2023; Büchler and Lutz, 2024), the limited number of case studies rightly raises concerns about the external validity of these findings. Lower Hutt provides an additional data point supporting the effectiveness of widespread reform. Second, it also adds to extant evidence that widespread reforms can have vastly larger effects than localized (or "spot") upzonings, where supply responses range from non-existent (Freemark, 2020) to a sizable increase in the probability of development (Dong, 2021). This is consistent with widespread zoning reform enabling greater competition between landowners in the supply developable parcels to housing developers (Phillips, 2022). Third, it provides empirical evidence on how zoning reform in one jurisdiction affects other jurisdictions within the same metropolitan area. Our results suggest that zoning reform in one municipality can be an effective policy tool to increase housing supply across the wider area, and need not merely displace construction in nearby municipalities. Finally, it suggests an easily implemented empirical method to test for spatial displacement effects (and spillovers more

generally) by estimating a synthetic control for the units in close proximity to the treated unit.

The remainder of the paper is organized as follows. The following section discusses the institutional background of the reforms in Lower Hutt and New Zealand more generally. Section three discusses the data and our methodological approach. Section four exhibits our results, while section five contains robustness checks. Section six presents our results for rents. Section seven concludes.

2 Institutional background

2.1 New Zealand

Zoning reform has prominently featured in New Zealand's policy landscape over the past decade. The first significant upzoning occurred in Auckland, the nation's largest city. In March 2013, Auckland Council announced the first version of the Auckland Unitary Plan (AUP), which would enact planning reform across the recently amalgamated metropolitan area by upzoning three quarters of residential land (Greenaway-McGrevy and Jones, 2023). The plan was operative from November 2016 onwards and led to a significant increase in housing supply (Greenaway-McGrevy, 2023; Greenaway-McGrevy and Phillips, 2023).

The AUP provided a blueprint for subsequent nationwide reforms (West, 2024). In June 2020, the New Zealand government released the *National Policy Statement on Urban Development* (NPS-UD), which required the Territorial Authorities (TAs) within the most populous "tier one" metropolitan areas (Auckland, Hamilton, Tauranga, Wellington, and Christchurch) to zone for residential structures of up to at least six stories within walking distance of rapid transit stations and major commercial areas, and prevented local councils from requiring developers to provide car parking (Ministry of Housing and Urban Development, 2020).[5] Councils were required to implement these provisions over the following two years, but implementation was ultimately delayed beyond these deadlines.

In October 2021 the New Zealand government announced the *Medium Density Residential Standard* (MDRS), requiring tier one metropolitan areas to allow up to three dwellings and three storeys on residential parcels (Ministry of the Environment, 2022). This was initially a bipartisan proposal. Representatives of both the center-left Labour government and opposition center-right National Party featured in the media announcement (Greenaway-McGrevy, 2022). Both parties voted-in the legislation. However, the National Party subsequently pledged to repeal the MDRS as part of its campaign leading

[5]Territorial authorities (TAs) are the second tier of local government in New Zealand and are responsible for drafting and implementing spatial plans, zoning and land use regulations. They are governed by elected councils that consist of councilors and a mayor. TAs are analogous to municipalities.

up to the October 2023 election (Wilson, 2023), which it subsequently won. Most of the affected councils had drafted district plans compliant with the MDRS and NPS-UD, but all except Hutt City delayed implementation until after the election. The councils of Upper Hutt and Wellington City implemented compliant plans in 2024.

2.2 Lower Hutt

Lower Hutt is the sixth most populous city in New Zealand, with an estimated population of 114,000 as of June 2023 (Stats NZ, 2023). It is one of four major municipalities within the Wellington metropolitan area, along with Wellington City, Porirua and Upper Hutt.[6] Lower Hutt is located around 20 kilometers from the Wellington City CBD and it covers approximately 376 square kilometers of predominantly hilly terrain.

Lower Hutt has historically been zoned for low density housing. In 2017, 83% of the city's housing stock was situated in the *General Residential Activity Area*, which allowed for low density housing of up to two storeys (Hutt City Council, 2017). A maximum site coverage percentage of 35% and a minimum lot size of 400 square meters generally applied in most areas, although these were relaxed to 40% and 300 squares meters in specific locations. The first panel of figure 2 exhibits the geographic distribution of the *General Residential Activity Area* zone, which is classified as *low density* in the figure. The remaining residential land was either subject to more stringent minimum lot sizes or else fell under historic preservation restrictions, and is classified as *very low density* in the figure. Throughout the 2010s, Hutt City Council implemented spot upzonings and rezonings, largely converting recreational land to residential, and allowing for mixed-use development in and around commercial areas.[7]

2.2.1 Medium density upzoning under Plan Change 43

Widespread regulatory changes to enable housing intensification in Lower Hutt began with *Plan Change 39 ("Transport")*, which reduced the parking requirement for new dwellings from generally two spaces to one. The public were notified of this change in October 2016, before approval and operationalized in March 2018 (Hutt City Council, 2016).

The first significant zoning change then followed in November 2017, when Hutt City Council notified the public of *Plan Change 43 ("Residential and Suburban Mixed Use")*, which was proposed to "provide for greater housing capacity and a wider range of options

[6]The Wellington metropolitan area commuting zone also extends into a small part of the South Wairarapa district, which is a predominantly rural region.

[7]A full timeline of Plan Changes and spot upzonings throughout the 2010s can be found here: https://www.huttcity.govt.nz/council/district-plan/district-plan-changes/completed-district-plan-changes [accessed 1 October 2024].

for housing styles and sizes at medium densities within the existing urban area of the district" (Hutt City Council, 2023a). Plan Change 43 spent the following two years in public consultation, before being approved in November 2019. It was partially operative from April 2020 and was fully operative from February 2021.[8]

Plan Change 43 introduced two new zones to the district plan:

- *Suburban Mixed Use Activity Area*, which had a building height restriction of 12 meters (three to four storeys), and no site coverage restrictions. The zone allowed mixed use developments, including for apartments above commercial premises.

- *Medium Density Residential Area*, which had a building height restriction of 10 to 11 meters (three storeys) and a maximum site coverage of 60%. The zone allowed for terraced and clustered housing. Minimum lot sizes were removed and two dwellings per parcel permitted.

These zones were concentrated in eight areas throughout the city, chosen for "their proximity to shops, schools, public transport, and access to parks" (Hutt City Council, 2023a). Typically, each area consisted of a central *Mixed Use Activity Area* surrounded by *Medium Density Residential Area* zoning. The second panel of figure 2 exhibits the eight locations, which account for around 4.2% of residential land in Lower Hutt.[9]

The zoning changes introduced under Plan Change 43 were widespread because they also allowed for medium density housing even in the zone previously reserved for low density housing. Specifically, the *General Residential Activity Area* was altered to allow for medium density housing on sites larger than 1400 square meters, thereby permitting terraced and clustered houses on suitably large parcels in this previously low density zone. A height limit of 8 meters (two storeys) and a maximum site coverage of 60% applied to qualifying parcels. Minimum lot sizes were removed.

Restrictions on development of parcels less than 1400 square meters in the *General Residential Activity Area* were also relaxed. Minimum lot sizes were removed and a maximum site coverage of 40% uniformly applied. Due to the dependence of regulations on parcel-size in this zone, we classify *General Residential Activity Area* areas as *medium-low density* in the second panel of figure 2.

[8] All parts of Plan Change 43 that were not subject to an appeal from the public were made operative in April 2020. Three appeals were lodged after the plan change was approved in November 2019. These were "relatively narrow in focus, with a total of thirteen rules and one policy affected" (Hutt City Council, 2023a). The remainder of Plan Change 43 was operationalized in February 2021 after the three appeals were resolved.

[9] We omit the *Landscape Protection Activity Area* from residential areas as this zoning covers steep and undeveloped areas. The zone allows for very low density housing.

2.2.2 Medium and high density upzoning under Plan Change 56

Hutt City Council has also been an early adopter of national policy directives to enable housing intensification. In September 2020, it became the first city to remove minimum car parking spaces as required under the NPS-UD, superseding the impacts of Plan Change 39 (Hutt City Council, 2023c). It also operationalized the MDRS and NPS-UD in 2023 as part of *Plan Change 56 ("Enabling Intensification in Residential and Commercial Areas")* (Hutt City Council, 2023b).

Plan Change 56 introduced a new high density zone and re-defined the medium density zone:

- *High Density Residential Activity Area*, with a building height restriction of 22 meters, a maximum site coverage of 50%, and no minimum lot sizes.
- *Medium Density Residential Activity Area*, with a building height restriction of 10 to 12 meters (three storeys), a maximum site coverage of 50%, and no minimum lot sizes. Three dwellings per parcel are permitted.

The new medium and high density zones applied to the vast majority of residential land. The final panel of figure 2 exhibits the spatial distribution of residential zoning under Plan Change 56.

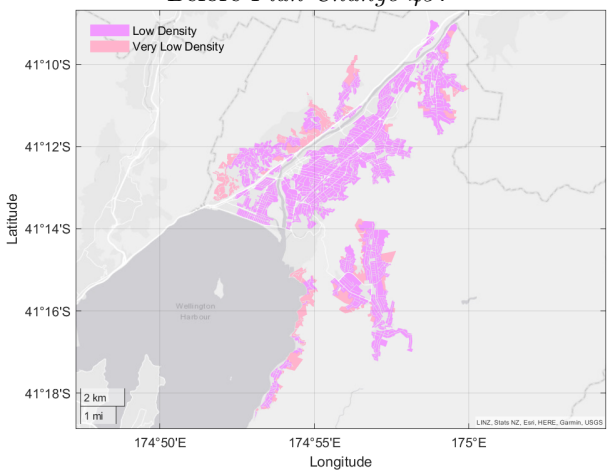
The *High Density Residential Activity Area* covers approximately 28.9% of all residential land, and is primarily located in the flat areas of the Hutt Valley floor. The *Medium Density Residential Activity Area* covers another 51.5%. The remaining areas are zoned for very low density housing under the *Hill Residential Activity Area*, which has an 8 meter height limit, a maximum site coverage of 35% and a minimum lot size of 1000 square meters.

Hutt City Council notified the public of Plan Change 56 in August 2022 and operationalized it in September 2023, becoming the only council to implement both the NPS-UD and the MDRS at the time.

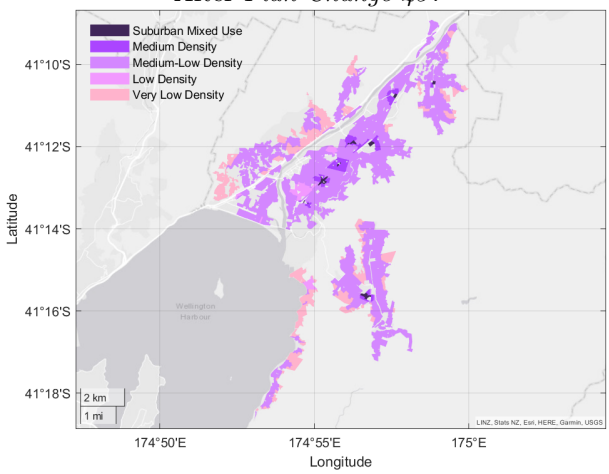
In summary, between 2016 and 2023, Hutt City Council implemented four sequential policy changes within a relatively short time frame: a reduction in parking minimums (Plan Change 39); a targeted medium density upzoning in central areas with a weaker but more widespread upzoning throughout remaining residential areas (Plan Change 43); an abolition of parking minimums; and a widespread high- and medium- density upzoning that supersedes the previous reforms (Plan Change 56). Figure 2 presents maps of residential zoning over time, with zones classified according to permitted housing density.

Figure 2: Residential zoning in Lower Hutt between 2017 and 2023

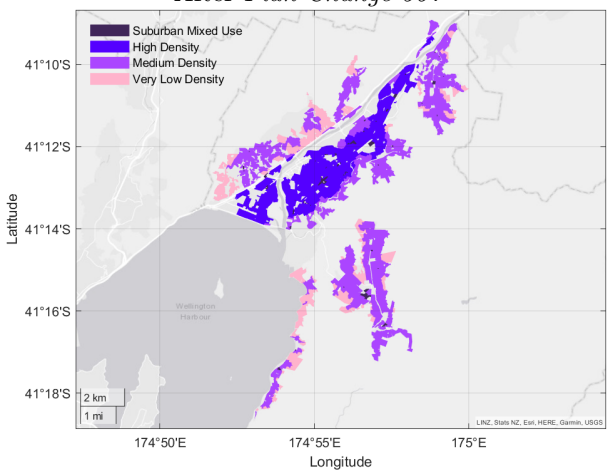
Before *Plan Change 43*:



After *Plan Change 43*:



After *Plan Change 56*:



Source: Hutt City Council. Notes: Residential zones are classified as either *Very Low*, *Low*, *Medium-Low*, *Medium* or *High Density* based on maximum height, site coverage, and minimum lot size restrictions that applied under the given version of the Hutt City District Plan. See table A1 in the Appendix for the classifications. For example, the *General Residential* zone is classified as *Low Density* before Plan Change 43, and as *Medium-Low Density* after Plan Change 43. Plan Change 43 was notified in November 2017 and partially operative in November 2019. Plan Change 56 was notified in August 2022 and operative in October 2023.

2.2.3 Changes in housing construction

Decomposing the extent to which new housing supply is attributable to each regulatory change is difficult. However, the medium- and high- density upzonings under Plan Changes 43 and 56 are likely to be primary enablers of increased housing supply. In low density areas, minimum lot sizes and site coverage restrictions are typically the binding constraints on the number of dwellings that can be fit on a given parcel of land. For example, the *General Residential Area* had a minimum lot size of 400 square meters prior to Plan Change 43. A relaxation of parking minimums would have little effect on dwelling density if this constraint was binding and remained in place. The relaxation of parking minimums likely amplified the impact of the subsequent medium- and high- density reforms, but they would have had a smaller impact if they had been implemented in isolation. In our empirical analysis, we therefore focus on Plan Change 43 because it was the first substantive medium density upzoning in the sequence of zoning changes.

Further complicating identification of policy effects is that plan changes are implemented gradually, not abruptly. Plan changes begin to be considered in the assessment of dwelling consent applications after public notification. The weight given to the new regulations is initially small but increases as the decision date approaches and as the likelihood of adoption rises. This means that development proposals that comply with the notified regulations may be approved prior to the plan becoming operative. Consequently, Plan Change 43 feasibly influenced applications from November 2017 onwards. Any influence would have initially been small, but gradually increased through to final approval in November 2019. The largest impacts are anticipated after Plan Change 43 became operational, as buildings compliant with the new regulations would not require specific permission from council.[10]

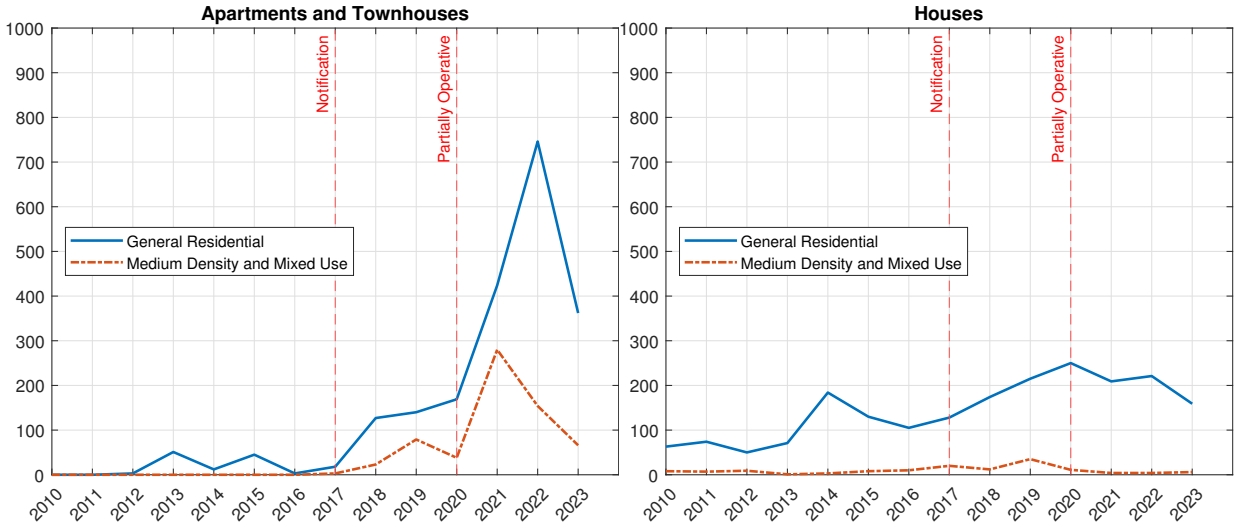
The time series depicted in figure 1 are consistent with this narrative. Consents are flat from the mid 1990s until 2012, after which there is moderate growth, consistent with increased spot rezonings over the early 2010s. The local peak in 2015 is due to a single retirement village development, which accounts for 44% (= 184/414) of the consent dwellings in that year. The growth rate in consents then increases significantly after 2017, consistent with Plan Change 43 having an increasing impact after notification. Attached housing accounts for the majority of the subsequent increase in consents, and becomes the majority of new construction by 2019. There is then another increase in the growth rate of consents after Plan Change 43 becomes partially operative in 2020. The increased growth rate lasts until 2023, when the national economy enters a recession after an unprecedentedly rapid rise in interest rates.[11]

[10] We thank current and former employees of Hutt City Council for providing insights into how milestones in the implementation of plan changes affect consent approvals.

[11] The central bank increased the official cash rate from 0.25% in October 2021 to 5.5% by May 2023. Meanwhile, GDP growth was negative in the December 2022, March, September and December 2023

To shed light on where the increase in housing construction is occurring, figure 3 presents consents decomposed by Plan Change 43 zones. We group the *Medium Density* and *Mixed Use* zones together, and decompose consents into two housing types: low density (*Houses*) and medium/high density (*Apartments and Townhouses).*[12] The increase in medium density housing construction begins in *General Residential* areas after Plan Change 43 is notified. After Plan Change 43 becomes partially operative, consents for this housing type increases rapidly in the newly-created *Medium Density* and *Mixed Use* zones, contributing to the second increase in consent growth between 2020 and 2022.

Figure 3: Dwelling consents by housing type and zone under Plan Change 43



Source: Authors' calculations from individual consent data supplied by Hutt City Council. Notes: Vertical dashed lines refer to the notification and partial operationalized of Plan Change 43. "Retirement Village Units" are not depicted separately for visual clarity. The *General Residential* zone allows medium density construction on parcels >1400m^2. "Granny flats", "flats" and "units" included under *Apartments and Townhouses*.

Much of the overall increase since 2017 has occurred in *General Residential*. This is unsurprising, as: (i) this zone covers the most land, while *Medium Density* and *Mixed Use* only cover 4.2% of residential land, and (ii) it was also subject to a relaxation in land use regulations to allow medium density housing on sufficiently large parcels, in excess of $1400m^2$ (see section 2.2.1).

quarters.

[12]Data for these figures are based on individual consent data supplied by Hutt City Council. See Appendix B for the method for assigning consents to zones.

2.2.4 Other residential development policies in Lower Hutt

Lower Hutt also implemented other development policies during the 2010s that plausibly affected housing construction. First, the *Development Stimulus Package*, which waived resource consent and building consent fees, ran from July 2012 to December 2018. Council figures suggest there were 294 consent applications under the policy over this period (Tso, 2019). Second, there was an increase in infrastructure contribution rates for developers in July 2021 to address the need for more infrastructure growth and upkeep (Tso, 2021).

These policies do not threaten our empirical design, and in most cases will likely result in us underestimating the impact of reforms on housing supply, in part because the development stimulus program ends in the first year after intervention. See section 3.4 for additional discussion.

2.3 Wellington Region

The Wellington Region occupies the southernmost part of the North Island of New Zealand and is home to approximately 543,000 people. Its four main cities of Wellington City, Lower Hutt, Upper Hutt, and Porirua account for around 79 percent of the population. The largest of these is Wellington City, the capital of New Zealand, with a population of around 212,000 (Stats NZ, 2023). An additional 10% of the population live in several towns and coastal settlements on the Kāpiti Coast.[13] Hereafter we refer to these five territorial authorities as constituting the "Wellington metropolitan area".[14]

Unlike Hutt City, the other constituent councils of the Wellington metropolitan area have not implemented widespread zoning changes until very recently. Wellington City released a draft district plan to comply with the MDRS and NPS-UD in late 2021, with the public notified of the proposed district plan in July 2022. The parts of the plan related to intensification under the MDRS and NPS-UD were originally scheduled to meet the required timelines, but were subsequently delayed until after the national election (Wellington City Council, 2023), and were finally approved in May 2024.[15] Upper Hutt Council and Porirua

[13]The remaining 10% of the population in the region live in the more rural Masterton, South Wairarapa, and Carterton Districts.

[14]Together the five TAs substantially overlap the Wellington "functional urban area" as defined by Statistics New Zealand. However, functional urban areas are defined based on commuting patterns rather than administrative boundaries. Kāpiti Coast constitutes its own commuting zone that is nonetheless contiguous to the Wellington commuting zone.

[15]Until final approval it was unclear whether the proposed zoning changes would be implemented. In February 2024, a council-appointed independent hearings panel (IHP) recommended significantly less upzoning than planned, stating that it was unclear to them that the MDRS would redress housing shortages or enhance housing affordability (see https://wellington.govt.nz/-/media/your-council/plans-policies-and-bylaws/district-plan/proposed-district-plan/files/decision-making-process-on-the-proposed-district-plan/briefing-1/ihp-recommendation-report-1a.pdf [accessed 1 October 2024]).Wellington City Council subsequently voted to reject many of the IHP's recommendations,

Council comply with the MDRS through their Intensification Planning Instruments (IPI), but both Councils sought and received permission to delay decisions to implement the plans.[16] Upper Hutt's IPI became fully operational in December 2023, while Porirua's IPI was implemented in November 2023. There is therefore a policy divergence between the constituent municipalities of the Wellington metropolitan area between 2017 and 2024, with only Hutt City Council independently implementing a sequence of regulatory changes to enable medium- and high-density housing. Figure A1 depicts the share of consents by territorial authority, showing that Lower Hutt accounts for a plurality of consents soon after the reforms begin.

3 Data and methodology

3.1 Synthetic control method

The synthetic control (SC) method has been used to evaluate a variety of policies (Abadie, 2021) and is used by the Minneapolis Federal Reserve Bank to evaluate the ongoing impact of zoning changes in Minneapolis.[17] We use synthetic controls instead of difference-in-differences because the substantial heterogeneity in the housing outcomes of interest between different regions render the requisite parallel trends assumption tenuous.

This subsection provides an overview of synthetic controls.[18] Readers familiar with the method may wish to proceed to the next subsection.

We have time series data on an outcome of interest for $N+1$ units indexed by $i = 1, ..., N+1$, where $i = 1$ corresponds to the unit receiving the policy intervention, and $i = 2, ..., N+1$ indexes the "donor pool", a collection of untreated units that is unaffected by the intervention. Observations on the outcome of interest span $t = 1, ..., T$, where the observations prior to intervention span $t = 1, ..., T_0$, $T_0 \leq T - 1$.

$y_{i,t}$ denotes the observed outcome of interest for unit i in period t. Let $y^N_{i,t}$ be the outcome without intervention for each i, while $y^I_{1,t}$ is the outcome under the intervention for the affected unit in period $t > T_0$. A synthetic control is defined as a weighted average of the units in the donor pool. Given a set of weights $w = (w_2, ..., w_{N+1})$, the synthetic control estimator of $y^N_{1,t}$ is $\hat{y}^N_{1,t} = \sum_{i=2}^{N+1} w_i y_{i,t}$. The effect of the intervention is then $y^I_{1,t} - \hat{y}^N_{1,t}$.

triggering a requirement for ministerial approval of the proposed zoning changes. Approval was granted in May 2024.

[16] See https://www.upperhuttcity.com/Your-Council/Plans-policies-bylaws-and-reports/District-Plan/Intensification-Planning-Instrument-IPI and https://poriruacity.govt.nz/your-council/city-planning-and-reporting/district-plan/proposed-district-plan/ [accessed 1 October 2024].

[17] See https://minneapolisfed.shinyapps.io/Minneapolis-Indicators/ [accessed 1 October 2024].

[18] The section parallels Greenaway-McGrevy (2023), which also applies the synthetic control method to housing starts, with minor modifications.

Abadie and Gardeazabal (2003) and Abadie, Diamond, and Hainmueller (2010) choose $\boldsymbol{w}$ so that the resulting synthetic control resembles a set of pre-intervention "predictors" for the treated unit (below we refer to these as "matching variables"). For each i, there is a set of k observed predictors contained in the vector $X_i = (x_{1,i}, ..., x_{k,i})$, which can include pre-intervention values of $y_{i,t}$. The $k \times N$ matrix $\boldsymbol{X}_0 = [X_2 \cdots X_{N+1}]$ collects the values of the predictors for the N untreated units. Abadie and Gardeazabal (2003) and Abadie, Diamond, and Hainmueller (2010) select weights $w^* = (w_2^*, ..., w_{N+1}^*)$ that minimize

$$\|X_1 - \boldsymbol{X}_0 \boldsymbol{w}\|_{\boldsymbol{v}} = \left(\sum_{h=1}^{k} v_h \left(x_{h,1} - w_2 x_{h,2} - ... - w_{N+1} x_{h,N+1} \right)^2 \right)^{1/2} \tag{1}$$

subject to the restrictions $w_i \in [0, 1]$ and $\sum_{i=2}^{N+1} w_i = 1$, and where $\boldsymbol{v} = (v_1, ..., v_k)$ is a set of non-negative constants. Weights $\boldsymbol{w}$ that minimize (1) can found using standard quadratic programming solvers. Following Abadie, Diamond, and Hainmueller (2010), we choose $\boldsymbol{v}$ to assign weights to linear combinations of the variables in $\boldsymbol{X}_0$ and X_1 that minimize the mean squared prediction error (MSPE) between the synthetic control $\hat{y}_{1,t}^N$ and the outcomes of the treated unit $y_{1,t}$ over the pre-treatment period. This helps ensure that the synthetic control time series tracks the outcome variable prior to the intervention. Then, the estimated treatment effect for the treated unit at time $t = T_0 + 1, \ldots, T$ is $\hat{y}_{1,t}^N = \sum_{i=2}^{N+1} w_i^* y_{i,t}$.

3.2 Data

We use residential building data released by Statistics New Zealand (Stats NZ), the nation's official statistical agency. Our outcome variable of interest is annual consents for new dwellings per thousand residents, which we sometimes refer to as the "consenting rate" for brevity.[19] We normalize dwelling consents by resident population to ensure comparability of construction rates between different regions.[20] We consider specifications where the outcome variable is not normalized by resident population as a robustness check (see section 5).

We subtract the pre-treatment average from the time series of outcomes prior to treatment (Ferman and Pinto, 2021). Abadie (2021) emphasizes that the validity of the synthetic control approach hinges on its ability to replicate the treated unit's outcome prior to intervention. De-meaning the outcome variable can allow the comparison group to reproduce

[19] Consents are not completions. We estimate that between 90 and 96% of all consents result in a completed dwelling. See Appendix B for further details, as well as estimates of the number of houses demolished for redevelopment in Lower Hutt.

[20] A drawback of this approach is that sub-national population data are only available from 1996 onwards. This reduces pre-treatment years available for matching.

the changes in the outcomes for the treated unit even if the level of the outcome variable cannot be reproduced. In our application, de-meaning normalization results in substantial reductions in pre-treatment Mean Squared Prediction Error (MSPE), suggesting that it is useful. De-meaning is also relevant to our method for identifying displacement effects, which is based on whether the intervention in Lower Hutt has a clear and persistent impact on nearby locations. This requires the synthetic control method to satisfactorily fit pre-treatment outcomes across a variety of units, not just the treated unit.

Our data is at the territorial authority (TA) level. TAs are the second tier of local government in New Zealand, below regional councils, and are responsible for drafting and implementing spatial plans, zoning and land use regulations. There are 67 TAs in New Zealand. These form the basis for the donor pool.

We curate the donor pool to ensure that the synthetic control can provide a valid counterfactual for the Lower Hutt reforms. First, we remove the other TAs comprising the Wellington metropolitan area (Wellington City, Upper Hutt, Porirua City, and Kāpiti Coast) from the donor pool, as these jurisdictions are potentially affected by spillovers from the Hutt City zoning changes, given that these TAs either comprise the Wellington commuting zone together with Lower Hutt (Wellington City, Upper Hutt, Porirua City), or else represent a distinct but contiguous commuting zone (Kāpiti Coast) (see section 2.3 for additional details). We remove Auckland because it underwent a widespread upzoning in 2016, making it subject to a very similar policy intervention. We also remove Christchurch City due to the idiosyncratic effects of the 2011 earthquakes on its housing market.[21] Finally, we remove Chatham Islands due to its small size and location far offshore from the mainland. This means that there are 59 TAs for Lower Hutt to be matched with in curated the donor pool.

3.3 Matching variables

As demonstrated above, the synthetic control method selects comparable controls by matching outcomes prior to the policy intervention. Our matching variables consist of housing market, economic, and demographic characteristics for each TA:

- Intercensal population growth: The logged difference in population between censuses, observed in 2001, 2006, 2013, and 2018.

[21] As noted by Abadie (2021), donor units with large idiosyncratic shocks to the outcome variable during the study period should be omitted. The earthquakes damaged 100,000 homes (approximately half the housing stock) and rendered approximately 7,000 dwellings uninhabitable (Paton and McClure, 2013). Land use reforms in 2013 under the "Land Use Recovery Plan 2013" enabled replacement through construction in geographic locations more resilient to earthquake risk. Regardless, neither Christchurch nor Auckland are selected when both are included in the donor pool.

- Intercensal personal income growth: The logged difference in average personal income between censuses.
- People per dwelling: The ratio of the resident population to the number of occupied private dwellings in census years.
- The proportion of households that are renters in census years.

We also match on the outcome variable (consents per thousand residents) in census years (2001, 2006, 2013) as well as the final pre-treatment intervention year (2017).

We consider an alternative set of matching variables as a robustness check, where matching variables consist of only dwelling consents per thousand residents (the outcome of interest) for each pre-intervention time period (1996 through 2017). Using the maximum range of pre-intervention time series data has the advantage of reducing the bias in the synthetic unit (Abadie, Diamond, and Hainmueller, 2010; Abadie, 2021), but can result in overfitting.

3.4 Intervention timing

Selection of an intervention date is complicated because Lower Hutt gradually implemented a sequence of zoning reforms from the late 2010s through to the early 2020s (see section 2 above). We select 2018 as the beginning of the treatment period, which is the first full year after Plan Change 43 is notified in November 2017. We do this for three reasons:

- Plan Change 43 is the first widespread medium density upzoning in the sequence of zoning changes. It is only preceded by a reduction in parking minimums (from generally two to one space) under Plan Change 39 (see section 2.2.1) that was unlikely to enable significant increases in medium density housing without the subsequent relaxations in in floorspace restrictions or minimum lot sizes. However, Plan Change 39 was notified in late 2016 and partially operative in 2018, meaning that the combined effects of the new medium density regulations and parking reductions are captured in the policy evaluation exercise.[22]
- Abadie, Diamond, and Hainmueller (2010) recommend that the beginning of the treatment period be set to the first period in which the outcome may possibly react to the intervention. Plan Change 43 influenced consent application decisions after

[22] Alternatively, if the reduction in parking minimums independently caused the increase in attached housing from 2018 onwards, then the 2018 date coincides with operationalization of Plan Change 39. However, in this case setting the post-intervention period to begin in 2017 would be appropriate as this is the first full year after notification.

notification, and the observed increase in consents for attached housing from 2018 onwards is consistent with this.

- It is also possible that notification caused developers to abandon planned low density construction and develop plans for medium density housing projects. If this occurred, setting a later treatment date would result in an overstated policy effect, as it would misidentify consents that were simply delayed until after the plan was operative as policy impacts.

Before proceeding, we note that the goal of the policy evaluation exercise is to measure the impact of the sequence of reforms, and not Plan Change 43 independently of the other zoning changes. We cannot disentangle the combined effect of Plan Change 39 and 43, the subsequent abolition of parking minimums, and the further medium- and high- density reforms under Plan Change 56. These will all be captured in estimated policy impacts. Instead, notification of Plan Change 43 serves to determine our treatment date because it was the first widespread medium density upzoning in the sequence.

As discussed in section 2.2.4, there was another policy to stimulate construction during the 2010s, the *Development Stimulus Package*, which waived resource consent and building consent fees from 2013 through to 2018. The cessation of the policy coincides with notification of medium density zoning reform in 2018, meaning that any negative impacts from ending the policy will be misattributed to the zoning reforms, causing estimated policy effects to be biased downwards. If these concessions stimulated construction during the pre-treatment period, TAs with persistently higher housing construction are more likely to be selected as donors, again causing policy impacts to be underestimated in the post-treatment period. Similarly, any reduction in housing starts due to the increase in developer contributions from 2021 onwards (see section 2.2.4) will also bias estimated policy impacts downward.

Note that some of the matching variables are taken from the 2018 census, which coincides with the first year of intervention. However, the census is taken early in the year, in March, and thus the matching variables are unlikely to be affected by the intervention, which occurred in November 2017.

4 Results

Table 1 compares Lower Hutt's matching variables to those of the synthetic unit. We also include the average of the donor pool for comparison. Household size and personal income growth are well-matched, while population growth and the proportion of renters are well-matched immediately prior to intervention.

Table A2 in the Appendix exhibits the weights for the selected donors. The synthetic unit relies heavily on the South Waikato District (with a weight of 0.487), Dunedin City

Table 1: Matched variables

Variable	Lower Hutt	Synthetic Lower Hutt	Average of Donors
People per dwelling, 2001	2.754	2.777	2.641
People per dwelling, 2006	2.735	2.705	2.587
People per dwelling, 2013	2.635	2.613	2.508
People per dwelling, 2018	2.913	2.931	2.842
Income growth, 2001-2006	0.216	0.223	0.282
Income growth, 2001-2013	0.359	0.378	0.463
Income growth, 2001-2018	0.456	0.451	0.544
Population growth, 2001-2006	0.023	0.009	0.036
Population growth, 2001-2013	0.028	0.011	0.069
Population growth, 2001-2018	0.129	0.130	0.200
Proportion renters, 2001	0.321	0.284	0.227
Proportion renters, 2006	0.311	0.283	0.291
Proportion renters, 2013	0.318	0.321	0.310
Proportion renters, 2018	0.340	0.331	0.317

Notes: Matching variables also include consents per thousand residents in pre-intervention census years (1996, 2001, 2006, 2013) and 2017. These are not tabulated for the sake of brevity.

(0.224), and the Tasman District (0.14). South Waikato is located in the North Island of New Zealand, and has exhibited population growth comparable to Lower Hutt. Its main urban center is Tokoroa, which is home to half of the district's population and is classified as a "medium" urban area by Statistics New Zealand. Meanwhile, Dunedin is a classified as a "metropolitan" urban area in the south of the South Island, and has a population of approximately 130,000. Finally, the Tasman District is located on the northern tip of the South Island and has a population of around 50,000. Much of its eastern portion is part of the Nelson commuting zone, which is classified as a "large" urban area. Richmond is the largest town in the region, accounting for about a third of the population, and is located 13km south of the city of Nelson. The "small" urban area of Motueka accounts for another 13% of the district's population.

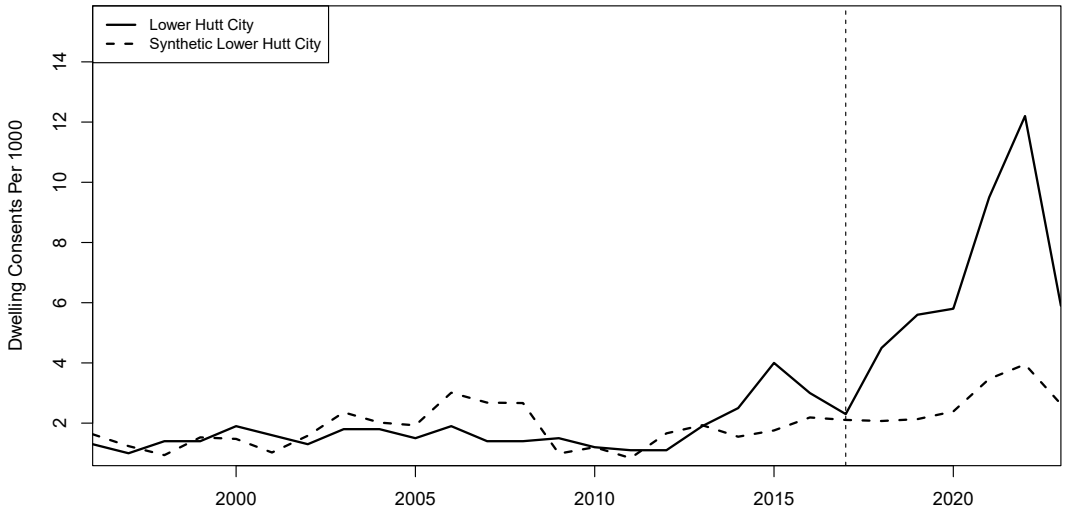
Figure 4 exhibits the actual and synthetic consents per thousand residents in Lower Hutt. There is a steady and notable divergence from 2018 onwards, with the actual consenting rate growing rapidly, while its synthetic counterpart remains at approximately the same level until 2020, after which there is a moderate increase. Synthetic consents per thousand residents are 2.07 in 2018, 2.13 in 2019, 2.38 in 2020, 3.46 in 2021, 3.95 in 2022, and 2.63 in 2023. Meanwhile, actual consents per thousand residents was 4.5, 5.6, 5.8, 9.5, 12.2 and 5.9 in these years.[23] The impact of the reforms peaked in 2022, generating a more than three-fold increase in the consenting rate ($12.2/3.95 = 3.08$).

There is a substantial fall in the actual consenting rate between 2022 and 2023, coin-

[23]Lower Hutt's consents per thousand residents reached the same level as that of Auckland in 2022, which had upzoned in 2016.

ciding with a decline in housing starts across New Zealand that is likely due to an unprecedented rise in interest rates and a macroeconomic contraction. Nonetheless, Lower Hutt's actual consenting rate remains over two-and-a-half times its synthetic counterpart in 2023 ($2.5 > 5.9/2.33$), indicating that housing starts remain higher than under the counterfactual of no upzonings despite the unfavorable economic conditions.

Figure 4: Synthetic and actual consents per thousand residents



Notes: Vertical dashed line denotes the intervention date.

We can also calculate the number of new consents generated by the zoning changes by taking the difference between actual and synthetic consents, where synthetic consents are obtained by multiplying synthetic dwellings per thousand residents by Lower Hutt's population (in 000s). Approximately 3006 additional units were consented between 2018 and 2023, which is 61.8% of the 4867 consents issued over this period. Upzoning therefore almost tripled the number of housing starts over the six years since notification of Plan Change 43.

To assess whether the increase relative to the counterfactual is statistically significant, we run placebo interventions on the other donor units and implement the Abadie, Diamond, and Hainmueller (2010) rank permutation test. Define the Mean Squared Prediction Error (MSPE) between the synthetic and actual outcomes as:

$$R_i(t_1, t_2) = \frac{1}{t_2 - t_1} \sum_{t=t_1}^{t_2} (Y_{i,t} - \hat{Y}_{i,t}^N)^2 \tag{2}$$

The above is the MSPE between time periods t_1 and t_2. We then take the ratio of the MSPE of the intervention period relative to the pre-intervention period as a measure of the post-treatment fit of the synthetic control:

$$r_i = \frac{R_i(T_0+1, T)}{R_i(1, T_0)} \tag{3}$$

For brevity, we refer to this as the "MSPE ratio". A drawback of the MSPE ratio is that it does not distinguish between positive and negative deviations from the synthetic unit, whereas many hypotheses posit a directional change from an intervention. In this case, the relevant alternative hypothesis is that intensification reforms increased consents. Increases in power can be obtained by testing for increases relative to the synthetic control, rather than differences (Abadie, 2021). We therefore define

$$R_i^+(t_1, t_2) = \frac{1}{t_2 - t_1} \sum_{t=t_1}^{t_2} \left(\lfloor Y_{i,t} - Y_{i,t}^N \rfloor \right)^2 \tag{4}$$

where $\lfloor x \rfloor = 0$ if $x < 0$ and $\lfloor x \rfloor = x$ otherwise. The "Positive Error MSPE Ratio" (PE-MSPE-R) is then:

$$r_i^+ = \frac{R_i^+(T_0+1, T)}{R_i(1, T_0)} \tag{5}$$

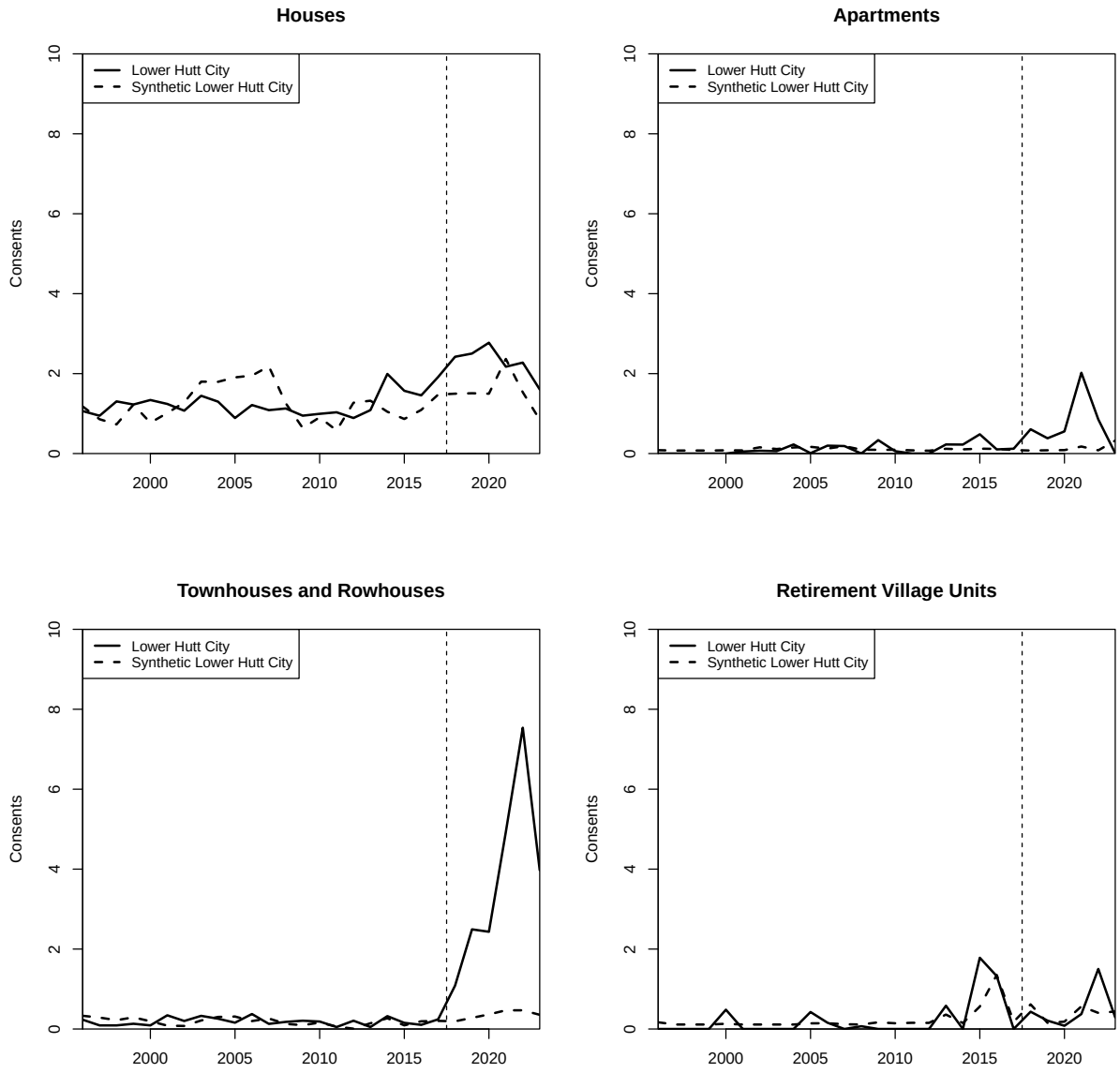
Figure A2 in the Appendix plots the prediction errors and the PE-MSPE-R for Lower Hutt and each donor unit. Lower Hutt has a PE-MSPE-R of 39.92, which is the largest among the donor pool. If we were to assign the intervention at random to a donor unit in the pool, the probability of obtaining a ratio as large as that of Lower Hutt is 0.017 (= 1/60). This is very strong statistical evidence that upzoning increased the consenting rate.

4.1 Results by housing type

In this subsection we investigate how upzoning may have affected construction of different types of housing forms. Statistics New Zealand distinguishes between consents for houses, apartments, townhouses and rowhouses, and retirement village units. We repeat the synthetic control exercise for each of the four housing types using the specification defined in section 3.3. Donor weights are omitted for brevity but are available upon request.

Figure 5 depicts actual and synthetic consenting rates. It is immediately apparent that the policy had the largest absolute effect on townhouses and rowhouses. Dwelling consents for townhouses and rowhouses per capita are almost eight times higher than their counterfactual in 2022. Consents for apartments also increase relative to the synthetic control, having barely featured in Lower Hutt's housing market prior to the reforms. Consents for detached houses slightly exceed their synthetic counterfactual in all years except 2021. Overall, these findings are consistent with upzoning encouraging medium- and high- density housing forms.

Figure 5: Synthetic and actual consents per thousand residents by housing type



Notes: Vertical dashed lines denote the 2017 intervention date.

4.2 Spillovers

In this subsection we investigate whether the reforms in Lower Hutt have affected construction in the other constituent cities of the Wellington metropolitan area. On the one hand, reforms may have displaced housing in other cities through a reallocation of housing construction to Lower Hutt. On the other, they may have increased housing consents in nearby cities by spurring investment in the construction sector or through the export of

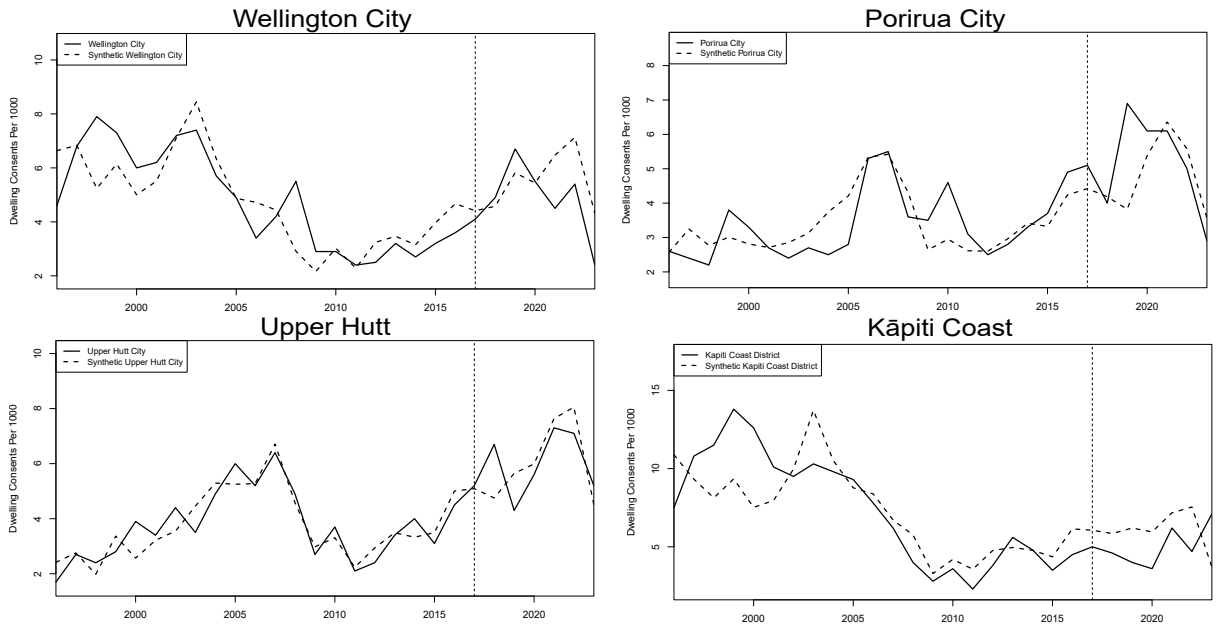
single-family houses from redeveloped parcels.[24] With an estimate of the spillover effect at hand, we can then produce an estimate of policy effects of the Lower Hutt reforms on the wider Wellington metropolitan region.

To estimate the magnitude of these potential spillover effects, we generate a synthetic control for each of the four other largest TAs in the wider Wellington metropolitan area (Wellington City, Porirua City, Upper Hutt, and the Kāpiti Coast District), taking the Lower Hutt reforms as the policy intervention. We exclude Lower Hutt and the three other TAs from the donor pool when conducting this exercise. This ensures that the synthetic controls are constructed from units that are less likely to be affected by intra-regional spillovers.

Table A2 in the Appendix reports the donor weights for the four TAs. Notably, there is substantial heterogeneity in the donor units selected. For example, Waikato features for both Upper Hutt and Porirua, while Tasman features for both Wellington City and Kāpiti Coast. The Rotorua District features for Wellington City. Rotorua is classified as a "large" urban area with approximately 70,000 residents in the middle of the North Island of New Zealand. Wellington City also features Hamilton City and Tauranga City, which are urban territorial authorities located within "metropolitan" urban areas. Meanwhile, the synthetic control for Porirua attributes the largest weight (0.543) to the Kawerau district. Kawerau has about 8,000 residents and is close to Rotorua. Upper Hutt loads heavily onto the Stratford district, which is a mostly rural area of about 10,000 people in inland Taranaki on the North Island. Finally, Thames-Coromandel features heavily for Kāpiti Coast. Like the Kāpiti Coast, the region is a popular holiday and retirement destination for residents of nearby cities.

[24] In New Zealand it is common for detached houses on piles to be moved to new locations on trucks.

Figure 6: Synthetic and actual consents per thousand residents for other territorial authorities in the Wellington metropolitan area



Notes: Vertical dashed lines denote the 2017 intervention date.

Figure 6 displays the synthetic and actual consenting rates for the four TAs. There are no substantial deviations between the actual and synthetic consenting rates in any of the four cities. To test whether the deviations are statistically significant, we conduct a two-tailed MSPE ratio test against other donors. P-values from the rank-permutation test are above conventional significance levels. Wellington City ranks 41st out of 60 (p-value = 0.68), Upper Hutt ranks 17th (p-value = 0.28), Porirua ranks 21st (p-value = 0.35) and Kāpiti Coast ranks 48th (p-value = 0.8). There is no statistical evidence to support spillovers.

Over the six post-intervention years, a total of 16,501 consents were issued in the five TAs of Wellington City, Lower Hutt, Upper Hutt, Porirua and Kāpiti Coast. If there are no spillovers, upzoning in Lower Hutt increased housing starts across the Wellington metropolitan area by 18.2% ($= 3006/16,501$).

It is nonetheless prudent to allow for spillovers when estimating policy effects of the Lower Hutt reforms on the wider metropolitan region. This ensures that region-wide estimates are conservative. To this end, we can use the deviations between actual and synthetic consents in the four TAs to estimate the size of spillovers. Actual consents in Porirua and Upper Hutt follow their synthetic controls closely, Porirua exceeding by a cumulative total of 126 and Upper Hutt trailing by 18 dwellings between 2018 through 2023. Wellington City exceeds its synthetic control until 2019, after which it falls below its counterfactual.

This could be due to displacement, but it is also plausible that this decline is driven in part by out-migration from the city during the COVID-19 pandemic, since Wellington City's population declined by 1.5% between 2020 and 2022.[25] Wellington City lags its counterfactual by a cumulative total of 920 units over 2018 through 2023. Finally, Kāpiti Coast trails its synthetic control throughout most of the post-treatment period, with a cumulative deficit of 407 units.

The cumulative differences across the four TAs therefore aggregates to a deficit of 1157 units. If we attribute this deficit to displacement from the Lower Hutt reforms, it implies that roughly two out of every five consented dwellings in Lower Hutt displaced a consented dwelling elsewhere in the region (38% = 1157/3006), and that housing starts across the Wellington metropolitan region increased by 1848 units (= 3006-1157). The net increase of 1848 consents across the Wellington metropolitan area therefore corresponds to a 12.6% $(= 1848/(16,501 - 1848))$ increase in housing starts.

We also explore whether there is stronger statistical evidence for spillovers by amalgamating the four other TAs in the wider Wellington metropolitan region (Wellington City, Porirua, Upper Hutt and Kāpiti Coast) and repeating the synthetic control exercise. Figure A3 presents actual and synthetic consenting rates. Note, however, that there is substantial heterogeneity in the selected donor units when the synthetic control is fitted to the individual TAs, which is indicative of significant differences in measured outcomes. Selected donor units are consequently pulled towards the largest TA in the group, Wellington City (see table A2, which provides the weights). This exercise also results in a statistically insignificant spillover effect under the rank permutation test applied to the MSPE ratio (p-value = 0.6). Point estimates imply that roughly two out of every five consented dwellings in Lower Hutt displaced a consented dwelling elsewhere in the region, or that upzoning increased region-wide supply by 9.5%.

To conclude, there is no strong statistical evidence that upzoning in Lower Hutt displaced construction from nearby regions over the post-reform period. If displacement occurred, point estimates of the magnitude of the effect are moderate, and imply that new dwelling consents increased across the metropolitan region by a substantial margin, of between 9.5 to 12.6%.

[25]For comparison, only Dunedin City experienced a larger decrease of 1.8%. Auckland's population fell by 1.1% over this period, while that of the four other TAs in the Wellington metropolitan area increased by between 0.62 and 2%. Unlike Auckland and Dunedin, Wellington City had not recovered its population loss by the March 2023 census, and registered a population decrease between the 2018 and 2023 censuses. We consider the impact of COVID-19 in section 5.5.

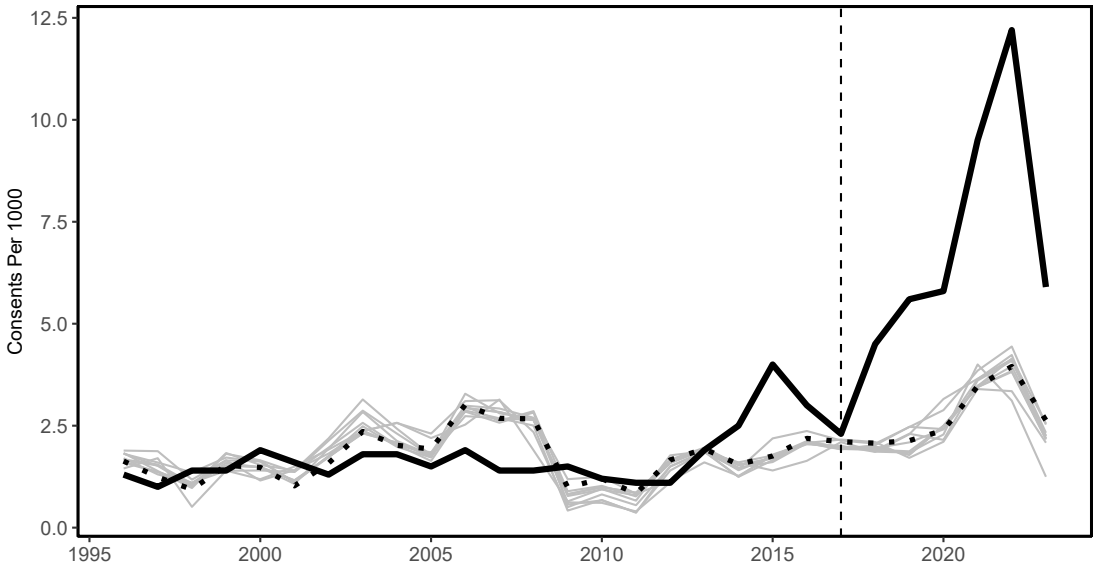
5 Robustness checks

5.1 Leave-one-out

Under the conventional leave-one-out robustness check, units from the donor pool are iteratively removed and the synthetic control re-constructed to examine whether the original synthetic control depends on any single donor unit (Abadie, Diamond, and Hainmueller, 2010).

Figure 7 displays the leave-one-out replications for Lower Hutt. The synthetic units follow a common trend over both the pre- and post- sample period, indicating that the results are generally not dependent on any single TA being included in the donor set. There is one replication in which the synthetic unit diverges from the others over the post-treatment period, corresponding to when South Waikato is omitted. Synthetic permits per thousand residents are much less under this specification, dropping to 3.11 in 2022 and 1.24 in 2023, thereby implying a near four-fold increase in the consenting rate in 2022 and a five-fold increase in 2023. If we were to remove this donor unit due to concerns that the synthetic unit is too dependent on it, the estimated policy effects would be larger.

Figure 7: Leave-one-out tests



Notes: Leave-one-out replications in grey. The synthetic control for the full sample is the dotted black line. Vertical dashed line denotes the 2017 intervention date.

5.1.1 Spillovers and region-wide effects

Figure A4 exhibits leave-one-out (LOO) results for each of our four other TAs in the Wellington metropolitan region. Both Upper Hutt and Porirua have similar synthetic counterfactuals under all LOO samples. Removing the Thames-Coromandel District from the donor pool results in a larger synthetic consenting rate for the Kāpiti Coast District in the post-intervention period, implying large spillovers. Wellington City's synthetic consenting rates are somewhat dissimilar across the LOO replications. Removing either Rotorua or the Tasman District results in the synthetic consenting rate better matching the actual consenting rate over the post-intervention period. This pushes spillovers towards zero. Thus, if we were to remove donor units that have a significant impact on the the synthetic unit, estimated displacements effects would be smaller, and estimated region-wide policy effects would be larger.

5.2 Matching on the outcome variable

In this subsection, we specify the set of matching variables consists only of the outcome of interest (normalized consents per thousand residents) for each pre-intervention time period (i.e. 1996 through 2017). It does not include any area characteristics. Using the maximum range of pre-intervention time series data reduces the bias in the synthetic unit (Abadie, Diamond, and Hainmueller, 2010; Abadie, 2021) and results in a smaller pre-intervention MSPE.[26]

For Lower Hutt, several donors are drawn upon, with the largest weight allocated to the Timaru District (0.583), which is located on the east coast of the South Island with a population of around 50,000. The largest urban area in the district is Timaru, which is home to approximately one half of the district's population and is classified as a "medium" urban area by Statistics New Zealand. Full donor weights can be found in table A3.

Figure A5 displays the synthetic and actual consenting rates. The synthetic rate peaks at 3.15 dwellings per thousand residents in 2022, implying that the zoning changes generated a near four-fold increase (3.9 = 12.2/3.15). Lower Hutt has the largest PE-MSPE-R in the donor pool of 87.6, meaning that if we were to assign the intervention at random, the probability of obtaining a ratio as large is 0.017 (= 1/60). The synthetic control implies that approximately 3260 additional dwellings were consented between 2018 through 2023, which is equivalent to 66% of the 4867 consents issued over this period.

[26] Matching on the outcome variable results in a pre-treatment MSPE of 0.32, which is smaller than the 0.60 MSPE from the main specification that matches on characteristics.

5.2.1 Spillovers and region-wide effects

To see whether there is evidence of spillovers under the specification, we fit synthetic control to the other TAs in the Wellington metropolitan area and conduct the two-tailed MSPE ratio rank permutation test. None rank highly, indicating no statistical evidence for spillovers. Wellington City ranks 36th out of 60 (p-value = 0.61), Porirua ranks 27th (p-value = 0.46), Upper Hutt ranks 20th (p-value = 0.34), and Kāpiti Coast ranks 47th (p-value = 0.80). Donor weights and charts of synthetic and actual units can be found in Appendix A.

The cumulative differences in synthetic and actual consents across the four TAs aggregates to a deficit of 921 units, driven largely by Wellington City and Kāpiti Coast. If we attribute this deficit to displacement from the Lower Hutt reforms, it implies that roughly one-in-four consents in Lower Hutt displaced a consent elsewhere in the region (28% = 921/3260) and that housing starts across the Wellington metropolitan region increased by 2339 units (= 3260-921). The net increase of 2339 consents across the Wellington metropolitan area corresponds to a 16.5% (=2339/(16,501-2339)) increase in housing starts over the six years subsequent to the intervention.

5.3 Backdated intervention

In this subsection we set the final pre-treatment year to 2012, five years before the final pre-intervention date in our baseline specification. This exercise examines whether the synthetic outcomes are heavily dependent on time-specific values of the matching variables immediately prior to the intervention (Abadie, 2021).

Major donors are similar to the baseline specification, including the South Waikato District (with a weight of 0.529), the Tasman Distrct (0.168), and the Rotorua District (0.090). Other donors include the Tararua District (0.089), the Waimakariri District (0.076), and the Gore District (0.032). The remaining donors each have a weight of less than 0.02.

Figure A6 displays synthetic and actual consenting rates. The synthetic rate is remarkably similar to that of the baseline specification exhibited in figure 4. This gives us confidence that the synthetic unit in our baseline specification is not dependent on the time-specific values of the matching variables immediately prior to intervention. As in the baseline specification, the synthetic rate is less than the actual consenting rate between 2013 and 2017. It is plausible that this may be due to the *Development Stimulus Package* operating over this period (see section 2.2.4). But, it may also be due to several large retirement village developments over this period. There were 384 retirement village units over this period – 185 in 2015, 140 in 2016, and 49 in 2013. The largest deviation occurs in 2015, coinciding with the large, one-off retirement village project that year (as noted in

section 2).

Actual consents per thousand residents still peaks at approximately three times its counterfactual in 2022, while actual consents exceed synthetic consents by 3662 units, which is approximately 60% of supply over this longer, eleven-year period (2013 to 2023). Lower Hutt's PE-MSPE-R ranks first in the donor pool (p-value = 0.017).

5.4 Consents as the outcome variable

In this subsection we use various transformations of consents as the outcome variable, including dwelling consents in levels, dwelling consents normalized by their pre-treatment mean, and log-normalized dwelling consents. For ease of comparison between variable choices, we depict consents in levels in figure A7. Weights are available upon request.

Estimated policy effects on consents are similar to our baseline specification based on the consenting rate as the outcome variable. The intervention is estimated to generate 2978 additional units when raw dwelling consents is the outcome variable, 3296 additional units when normalized consents is the outcome variable, and 2864 additional units when log-normalized consents is the outcome variable. These numbers correspond to two-thirds of the 4867 consents issued between 2018 and 2023. Under all specifications, Lower Hutt's PE-MSPE-R ranks first in the rank permutation test.

5.4.1 Spillovers and region-wide effects

We also examine whether there is evidence of spillover effects under these alternative specifications. For each of the three outcome variables, none of the TAs rank highly in the two-tailed MSPE ratio rank permutation test, ranging from 15th to 58th, and indicating little statistical evidence for spillovers. Estimated region-wide impacts are larger than under the baseline specification, ranging from 2641 to 4034 units. This corresponds to a 19% to 32.3% increase in region-wide consents over the six years since the reform.

5.5 COVID-19 impacts and in-migration

The later zoning changes in Lower Hutt coincide with the onset of the COVID-19 pandemic in 2020. COVID-19, and the policy responses to it, had a variety of health, economic, and social impacts, many of which are still not well understood. The synthetic control relies on matching areas in their housing construction up until 2017, before the pandemic started. If the pandemic somehow had a disproportionately positive effect on construction in Lower Hutt, or a disproportionately negative effect on construction in the selected donor units, the comparison of actual outcomes to the synthetic counterfactual could bias estimated policy impacts upwards.

There is little evidence to suggest that COVID-19 induced a structural shift that rendered in-sample behavior unrepresentative of out-of-sample behavior in the selected donors. Placebo interventions remain clustered around an MSPE ratio of one, suggesting that consenting rates in the donor pool are well predicted by their synthetic counterparts after the onset of the pandemic. In addition, the leave-one-out robustness check would identify if estimated policy effects were driven by abnormal out-of-sample behavior from a single donor unit that was idiosyncratically affected by the COVID-19 pandemic.

However, it would be plausible for Lower Hutt to have experienced an idiosyncratic shock to housing demand during the pandemic through a shift in migration patterns. It has been documented across much of the developed world that housing demand shifted away from the inner urban areas to suburban, exurban and rural areas, as households required more space and working from home became a feasible option in many service industries. If many households decided to move away from the central and more urban Wellington City into Lower Hutt, this could have increased construction activity even in the absence of zoning reform.

Such migration patterns would be evident in population estimates, and we would expect an abnormally large population shock to Lower Hutt during the pandemic. However, there is no such supporting evidence. The city's population grew by just 0.6% between 2020 and 2022, which is only slightly below the national rate of 0.66%. The other TAs in the Wellington metropolitan area (Upper Hutt, Porirua, and Kāpiti Coast) experienced population growth in both absolute and percentage terms well within the range of other TAs over this period. Thus, while Wellington City itself saw a declining population during the pandemic, it does not appear that out-migrants were moving to the suburbs or exurbs of the Wellington metropolitan area in large numbers.

To confirm this finding, we generate a synthetic control for Lower Hutt based on trends in population growth prior to COVID-19. We set the intervention date to 2020, and the outcome variable is the annualized rate of population growth.[27] Figure A8 exhibits actual and synthetic population growth.

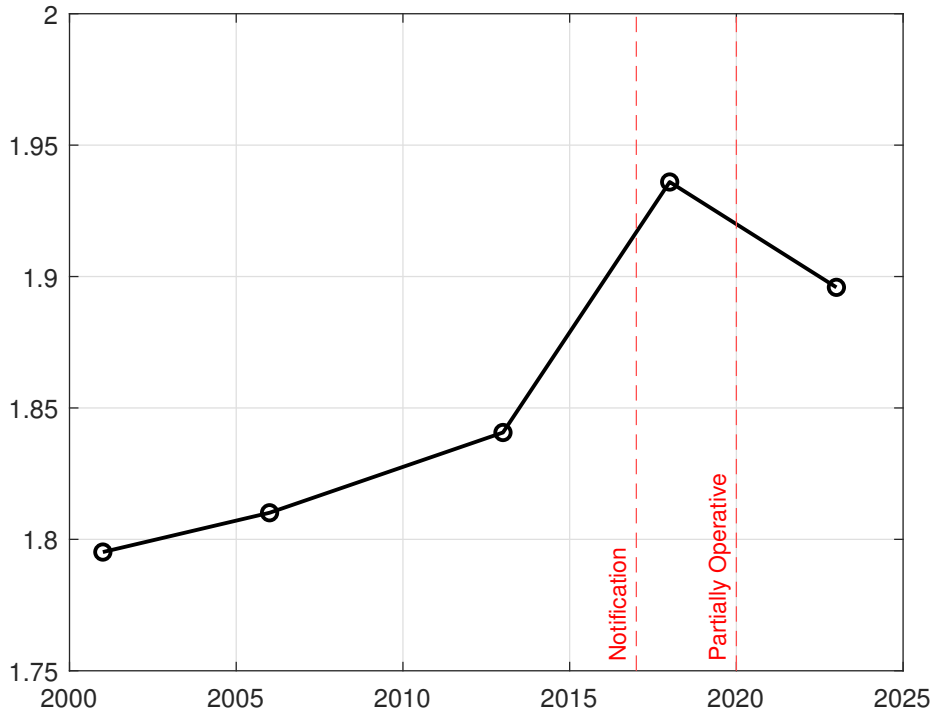
Population growth slightly under-performs its synthetic counterpart, and the rate of growth decreases after the onset of the pandemic. Using the MSPE ratio rank permutation test, we find no statistical evidence that population growth meaningfully diverges from its synthetic control after the pandemic (p-value = 0.57).

This has two implications. First, it is evidence that the increase in construction in Lower Hutt is not due to an idiosyncratic population shock. If anything, insofar as population growth drives housing construction, it may suggest that the donors cause the synthetic

[27]The main donors include the Rangitīkei District (with a weight of 0.328), Ōpōtiki District (0.228), Tasman District (0.187), and Waikato District (0.107).

counterfactual to overstate construction. Second, it is evidence that the increase in housing construction in Lower Hutt has not (yet) generated a substantial increase in in-migration. The increased construction has instead absorbed the existing population, and likely increased household formation rates. As illustrated in figure 8, the ratio the adult-aged population (persons aged 20 years or above) to the number of dwellings decreased between 2018 and 2023 (the dates of the last two censuses), after nearly two decades of sustained increases.

Figure 8: Ratio of adult-aged population to dwellings in Lower Hutt



Source: Statistics New Zealand census data. The ratio is the number of persons aged 20 or above divided by the total number of dwellings in Lower Hutt, including public dwellings, private dwellings, and dwellings under construction. Vertical dashed lines refer to notification and partial operationalized of *Plan Change 43*.

6 Rents

We now consider the effect of upzoning on housing costs by assessing changes in rents. We use rents, rather than house prices, because they are not directly affected by enhanced redevelopment rights from zoning reform, whereas the effects on house prices is mediated by the land endowment of affected properties. Land in desirable locations is priced higher when regulations are more relaxed, reflecting increased capacity of the land to hold additional floorspace (Bertaud and Brueckner, 2005). Properties that are relatively land intensive,

such as detached single family dwellings on large lots, are likely to appreciate in value when upzoned to allow greater density. Greenaway-McGrevy, Pacheco, and Sorensen (2021) present evidence consistent with this reasoning after the reforms in Auckland. Rents, on the other hand, are not affected by the enhanced development rights, which accrue to the landowner.

To do so, we use the hedonic rental price indexes constructed by Greenaway-McGrevy and So (2024) for TAs. These indexes are based on individual data on new tenancies collected by the Ministry of Housing and Urban Development (MHUD). Data are available from 2000 through 2023. In addition to the rental price, the tenancy dataset contains information on the rental property, including the number of bedrooms; the housing type; whether it is publicly or privately owned; and its meshblock, which are geographic units equivalent to census tracts in the U.S.. Hedonic imputation price indexes are constructed using the number of bedrooms, housing type indicators, and neighborhood indicators. The index is based on the "double" imputation method, whereby hedonic regressions are used to estimate prices in both the period of transaction and the period prior to the transaction (Eurostat, 2013). We set the base value of the index to 1 in 2017, the final pre-treatment year, for all TAs. Refer to Appendix C for a detailed description of the method.

Using a hedonic index, rather than an average of rental prices, is particularly important when considering zoning changes, as the location and types of housing constructed in Lower Hutt changed substantially after upzoning. As noted in section 2, the composition of housing construction in Lower Hutt shifted towards attached dwellings in the central upzoned areas. These compositional shifts are accounted for in hedonic methods, resulting in more accurate measures of inflation that often diverge from changes in averages. For example, the arithmetic mean of the rental bond series for Lower Hutt increased by around 53% since 2017, while the hedonic index increased by only 47%.

As is common practice in the synthetic control literature, when assessing a different outcome variable we re-run the matching algorithm and select a new set of donors instead of using common donor weights across all outcome variables (see, for example, Grier and Maynard, 2016, and Jones and Marinescu, 2022). We repeat the same specification outlined in section 3, matching on census characteristics and the outcome variable in census years.[28] Again, to avoid local spillovers, we remove the other TAs from the Wellington metropolitan area. Table 2 compares Lower Hutt's matching variables to those of the synthetic unit, while table A4 displays the selected donors. Palmerston North is the largest donor (with a weight of 0.390). The synonymous urban area is classified as a "large" city, with a population of 90,000, and is located approximately 130 kms northeast of Lower Hutt. South Waikato

[28]Because all TAs have the same index value in the final pre-treatment year by construction, we do not match on the final pre-treatment year outcome..

(0.270) and Tararua (0.106) make up the remaining significant donor units. Tararua is a predominantly rural TA located within the larger Manawatū-Whanganui region that lies to the north of the greater Wellington region.

Table 2: Matched variables, rental price index synthetic control

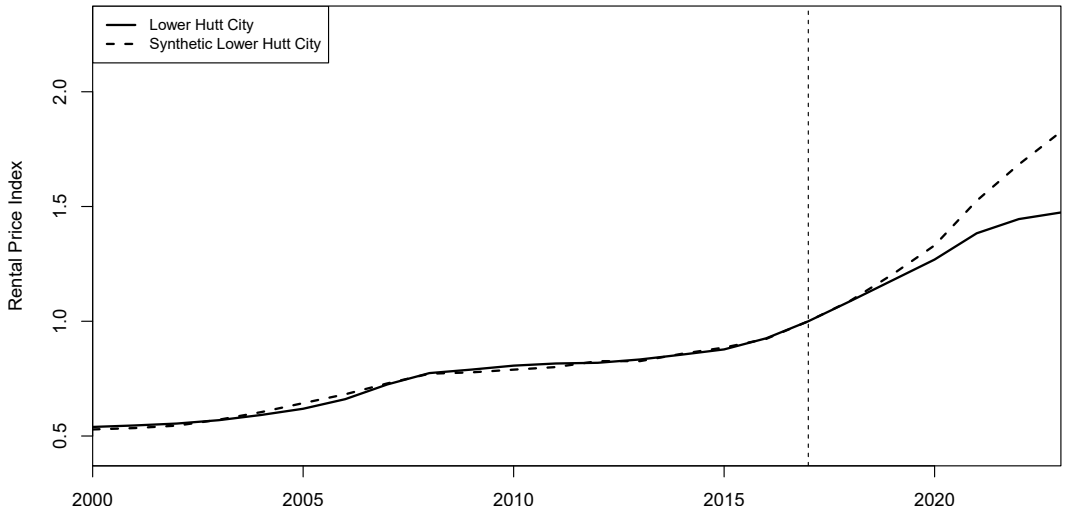
Variable	Lower Hutt	Synthetic Lower Hutt	Average of Donors
People per dwelling, 2001	2.754	2.735	2.641
People per dwelling, 2006	2.735	2.637	2.587
People per dwelling, 2013	2.635	2.624	2.508
People per dwelling, 2018	2.913	2.911	2.842
Income growth, 2001-2006	0.216	0.246	0.282
Income growth, 2001-2013	0.359	0.391	0.463
Income growth, 2001-2018	0.456	0.464	0.544
Population growth, 2001-2006	0.023	0.012	0.036
Population growth, 2001-2013	0.028	0.027	0.069
Population growth, 2001-2018	0.129	0.130	0.200
Proportion renters, 2001	0.321	0.309	0.277
Proportion renters, 2006	0.311	0.316	0.291
Proportion renters, 2013	0.318	0.333	0.310
Proportion renters, 2018	0.340	0.341	0.317

Notes: Matching variables also include the rental hedonic index in pre-intervention census years (1996, 2001, 2006, 2013). These are not tabulated for the sake of brevity.

Figure 9 displays the values of the synthetic and actual hedonic rental price index in Lower Hutt after upzoning. Actual rents begin to diverge from synthetic rents in 2019, but diverge more substantially from 2020 onward. By 2023, the rental index for synthetic Lower Hutt is 1.79, while the actual index is 1.47. This suggests that rents are 17.5% less than the synthetic control, or equivalently, rents would have been 21.2% higher in the absence of the policy.

This is a short- to medium-run assessment of the effect of upzoning on rents. As noted in section 2, Plan Change 43 only became fully operational in 2021, which coincides with consents beginning to sharply increase. Given that consents may take several years to be completed, much of the increased supply may not have yet manifested in rents by 2023.

Figure 9: Synthetic and actual rental price index in Lower Hutt



Notes: Vertical dashed line denotes the 2017 intervention date.

We test for statistical significance of the rent decreases using placebo runs on all donors units. We only consider negative deviations from their respective synthetic unit ("Negative Error MSPE Ratio", or NE-MSPE-R). Lower Hutt ranks second in the donor pool ($p = 0.03$), and is therefore statistically significant under conventional significance levels.

We also consider whether the Lower Hutt reforms generated spillover effects on the other TAs in the Wellington metropolitan area, as these areas are likely substitutes and part of a common rental market. Upzoning may have caused households to locate in Lower Hutt rather than one of the other constituent TAs, leading to lower rents across the region. Actual rents exceed synthetic rents for Upper Hutt, Porirua, and the Kāpiti Coast by between 12 to 14%, but the difference is only statistically significant for Kāpiti Coast. Wellington City exhibits a reduction in rents that is larger than that of Lower Hutt (22%), which likely reflects a largely idiosyncratic population decline in Wellington City over the treatment period: Wellington City was the only TA in New Zealand to experience a decline in population between the 2018 and 2023 censuses. It is challenging to disentangle what proportion of its rent decrease is due to this negative population shock that is not captured by its synthetic counterpart, and what proportion is due to spillovers from increased region-wide housing supply. See Appendix A.3 for additional details.

7 Concluding remarks

Beginning in the late 2010s, Lower Hutt began a sequence of widespread zoning changes to encourage housing supply that culminated in approximately 80% of residential land being

upzoned to support high or medium density housing.

We use the synthetic control method to measure the impact of the zoning changes, finding that they generated a three-fold increase in new dwelling consents per capita and almost tripled the number of consents issued over the six years subsequent to notification of the first medium density reform. Our findings also imply that the zoning changes in Lower Hutt increased consents across the wider Wellington metropolitan area by between 10 to 19%, depending on how displacement from nearby municipalities is accounted for. We also provide evidence that upzoning insulated Lower Hutt from a period of high rental price growth across New Zealand, resulting in rents being 21% lower than a counterfactual outcome six years after reform.

Our findings add to the growing body of evidence that zoning regulations can significantly restrict housing supply, and that easing those restrictions to allow for medium- and high- density housing can have a substantial positive impact on housing construction, and ultimately affordability. Policymakers now have several case studies to learn from as they attempt to redress housing shortages and affordability challenges throughout the developed world. Widespread zoning reform can be a powerful policy tool to stimulate housing supply.

Disclaimer: The rental price indexes used in this study are not official statistics. They have been created for research purposes from the Integrated Data Infrastructure (IDI) which is carefully managed by Stats NZ. For more information about the IDI please visit https://www.stats.govt.nz/integrated-data/.

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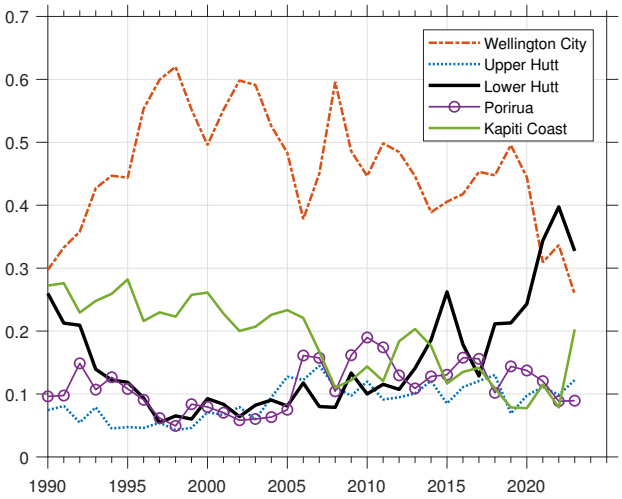
A Additional tables and figures

Table A1: Residential zones under different versions of the Hutt City district plan

District Plan Version	Regulation	Zone			
		Hill Residential	General Residential	Medium Density Residential	High Density Residential
Before Plan Change 43	Max. Height (storeys)	2	2		
	Max. Site Coverage (%)	35	35-40	n/a	n/a
	Min. Lot Size (m^2)	1000	300-400		
	Density classification	*very low*	*low*		
Plan Change 43	Max. Height (storeys)	2	2	3	
	Max. Site Coverage (%)	35	40-60	60	n/a
	Min. Lot Size (m^2)	1000	none	none	
	Density classification	*very low*	*medium-low*	*medium*	
Plan Change 56	Max. Height (storeys)	2		3	6
	Max. Site Coverage (%)	35	n/a	50	50
	Min. Lot Size (m^2)	1000		none	none
	Density classification	*very low*		*medium*	*high*

Notes: *Density classification* is our classification used for figure 2 and is based on the maximum height, site coverage, and minimum lot size restrictions. The 60% maximum site coverage in the *General Residential* zone under Plan Change 43 applied to parcels over $1400m^2$. There were also two zones called *Historic Residential* and *Special Residential* that existed prior to Plan Change 56. These are omitted from the table due to their small total area and are included under *Low Density* in figure 2. *Special Residential* had a minimum lot size of 700 square meters and a maximum site coverage of 30%, while *Historic Residential* had a minimum lots size of 300 to 370 square meters and a maximum site coverage of 35%. "n/a" indicates the zone is not in the given version of the district plan.

Figure A1: Proportion of consented dwellings by Territorial Authority in the Wellington metropolitan area



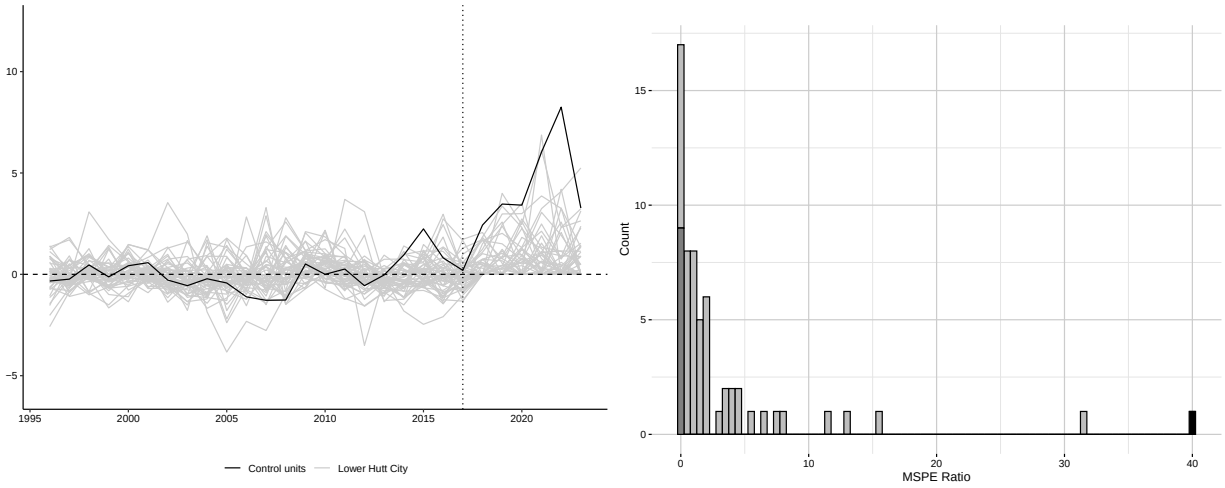
A.1 Main specification

Table A2: Donor unit weights for the main specification

Donor	Lower Hutt	Upper Hutt	Porirua	Wellington City	Kāpiti Coast	W.R. Excl Lower Hutt
Hamilton City	-	-	-	0.116	-	0.252
Dunedin City	0.224	-	-	-	-	-
Gore District	0.002	-	-	-	-	-
Hamilton City	0.006	-	-	-	-	-
Kawerau District	0.073	-	0.543	-	-	-
Manawatū District	-	0.005	-	-	-	-
Otorohanga District	-	-	0.127	-	-	-
Palmerston North City	-	0.097	-	-	-	-
Queenstown-Lakes District	-	0.039	-	0.024	-	0.019
Rotorua District	-	-	-	0.283	-	0.339
South Waikato District	0.487	0.034	0.118	-	-	-
Southland District	-	0.069	-	-	-	-
Stratford District	-	0.452	-	-	-	-
Tasman District	0.140	0.014	-	0.472	0.471	0.233
Tauranga City	-	-	-	0.056	-	0.048
Thames-Coromandel District	-	-	-	-	0.42	-
Waikato District	-	0.261	0.185	-	-	-
Waimakariri District	0.050	0.018	-	0.048	0.109	0.026
Waitomo District	-	-	-	-	-	0.083
Western Bay of Plenty District	0.003	-	-	-	-	-
Whanganui District	0.014	0.007	0.026	-	-	-

Notes: Donors given a weight of less than 0.002 are omitted for visual clarity. The column labeled "WR. excl. Lower Hutt" tabulates weights for the Wellington metropolitan area excluding Lower Hutt.

Figure A2: Prediction errors and positive error MSPE ratios



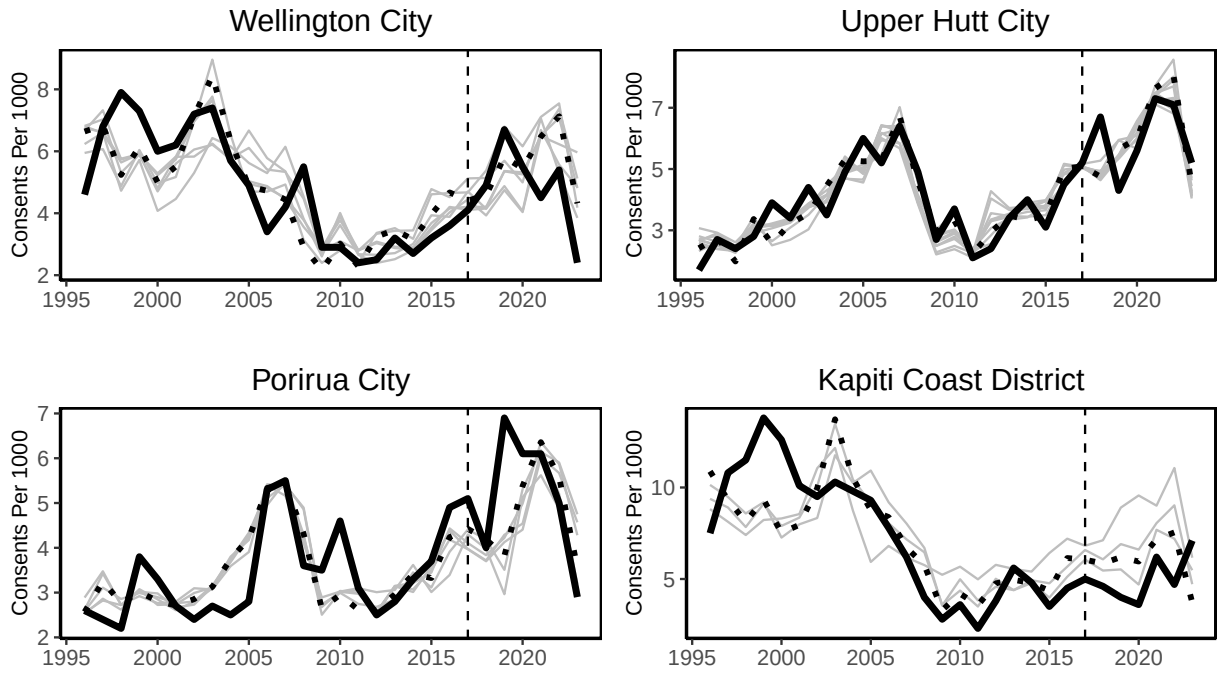
Notes: Prediction errors depicted on left, positive error MSPE ratios on right. Lower Hutt highlighted in black.

Figure A3: Synthetic and actual consents per thousand residents for Wellington metropolitan area excluding Lower Hutt

Notes: Vertical dashed line denotes the 2017 intervention date. The Wellington metropolitan area excluding Lower Hutt consists of the Wellington City, Upper Hutt, Porirua and Kāpiti Coast territorial authorities.

A.2 Robustness checks

Figure A4: Leave-one-out tests for other Territorial Authorities in Wellington metropolitan area



Notes: Leave-one-out replications in grey. The synthetic control for the full sample is the dotted black line. The vertical dashed line denotes the 2017 intervention date.

Table A3: Donor unit weights for matching on outcome variable

Territorial Authority	Lower Hutt	Upper Hutt	Porirua	Wellington City	Kāpiti Coast	WR. excl. Lower Hutt
Central Hawke's Bay	-	0.164	-	-	-	-
Clutha District	-	0.280	-	-	-	-
Horowhenua District	-	0.080	0.208	-	-	-
Hurunui District	-	0.074	-	0.106	0.177	0.124
Kawerau District	-	-	0.105	-	-	-
Masterton District	-	0.077	-	-	-	-
New Plymouth District	-	0.025	0.191	-	-	-
Ōpōtiki District	0.088	-	-	0.505	-	0.402
Rotorua District	-	-	-	-	0.272	0.149
South Waikato District	0.024	0.021	0.233	-	-	-
Selwyn District	0.003	-	-	-	-	-
Tasman District	0.070	-	-	0.311	0.109	0.218
Tauranga City	-	-	-	0.047	0.184	0.031
Thames-Coromandel District	-	-	-	0.031	0.259	-
Timaru District	0.583	-	-	-	-	-
Waipa District	0.075	-	0.032	-	-	-
Wairoa District	0.158	0.048	0.231	-	-	-
Queenstown-Lakes District	-	-	-	-	-	0.017
South Wairarapa District	-	-	-	-	-	0.066
Taupo Distrct	-	-	-	-	-	0.009

Notes: Donors given a weight of less than 0.002 are omitted for visual clarity. The column labeled "WR. excl. Lower Hutt" tabulates weights for the Wellington metropolitan area excluding Lower Hutt when matching on the outcome variable.

Figure A5: Synthetic and actual consents per thousand residents for matching on the outcome variable

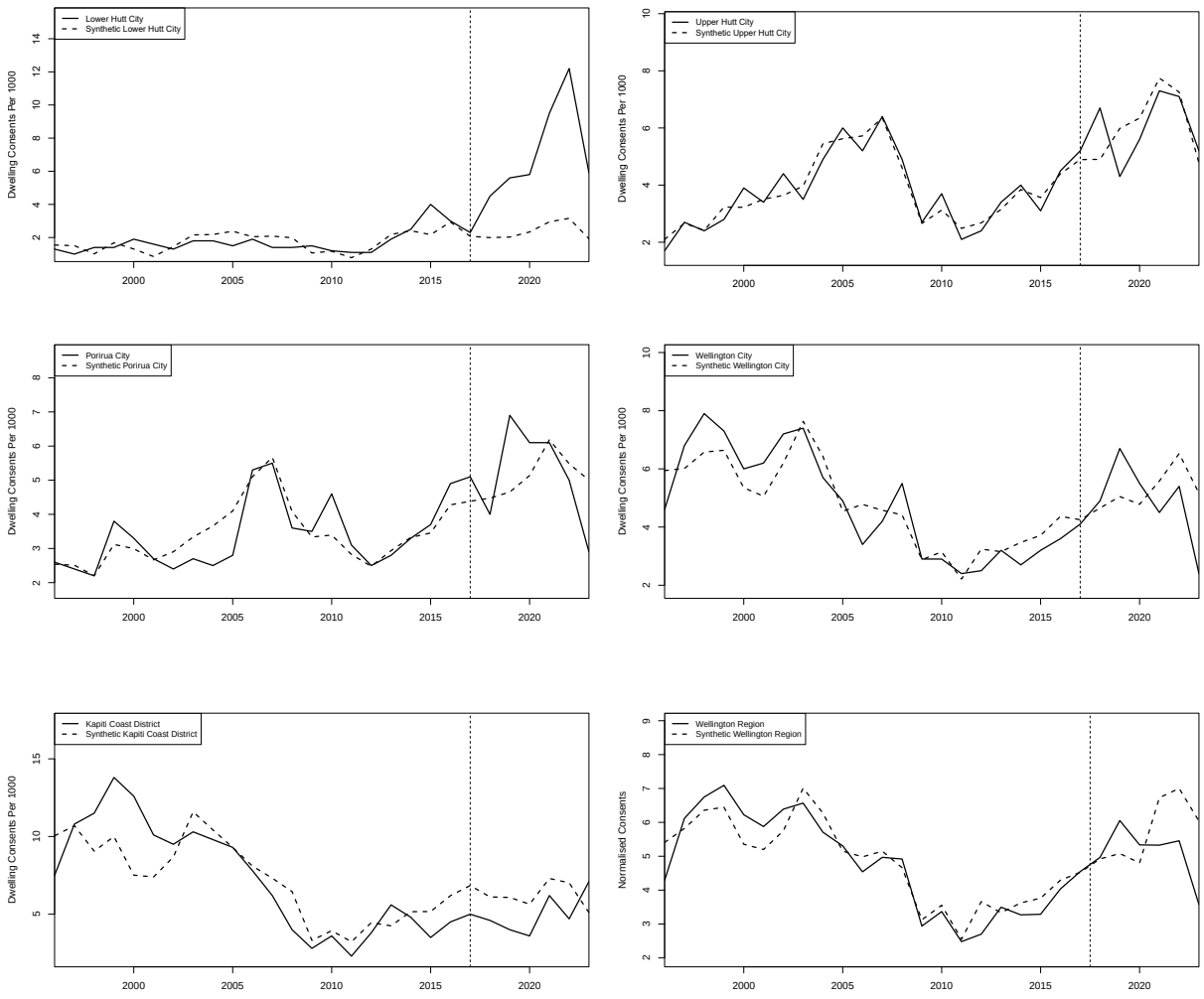
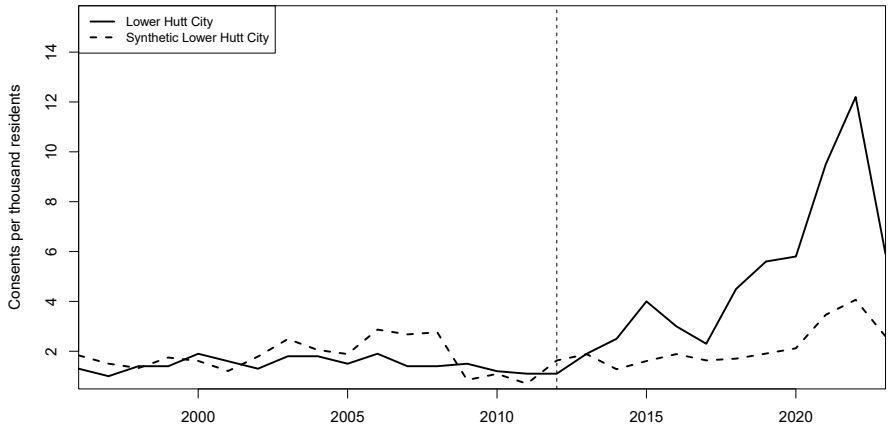
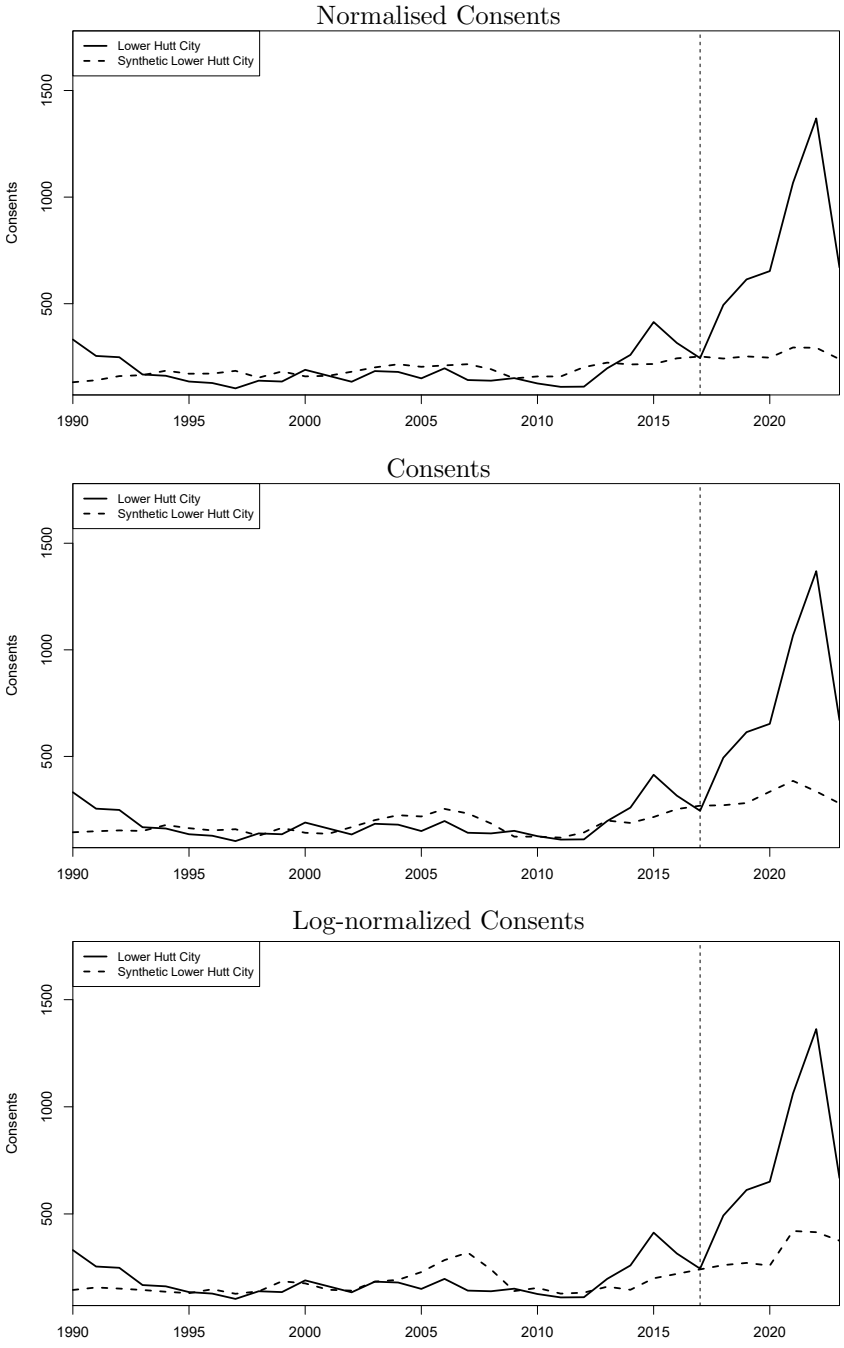


Figure A6: Synthetic and actual consents per thousand residents with earlier intervention date



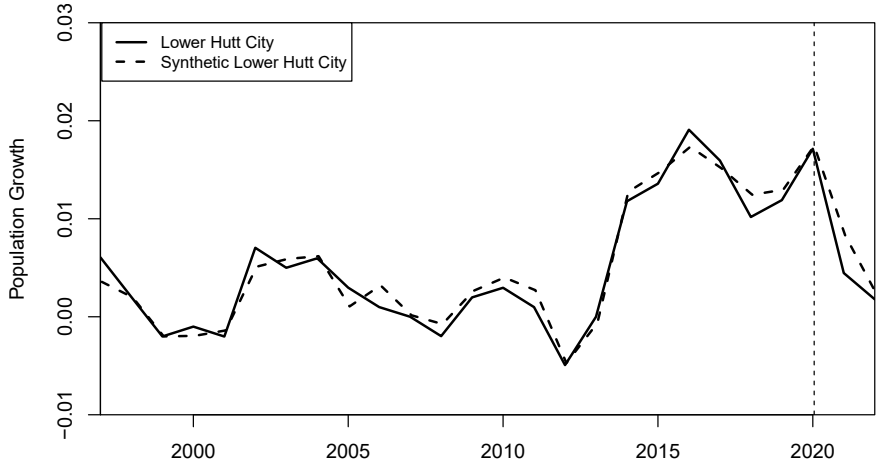
Notes: Intervention date set to 2012. Vertical dashed line denotes the intervention date.

Figure A7: Synthetic and actual consents with consents as outcome variable



Notes: Vertical dashed lines denote the 2017 intervention date.

Figure A8: Synthetic and actual population growth in Lower Hutt



Notes: Vertical dashed line denotes the 2020 intervention date.

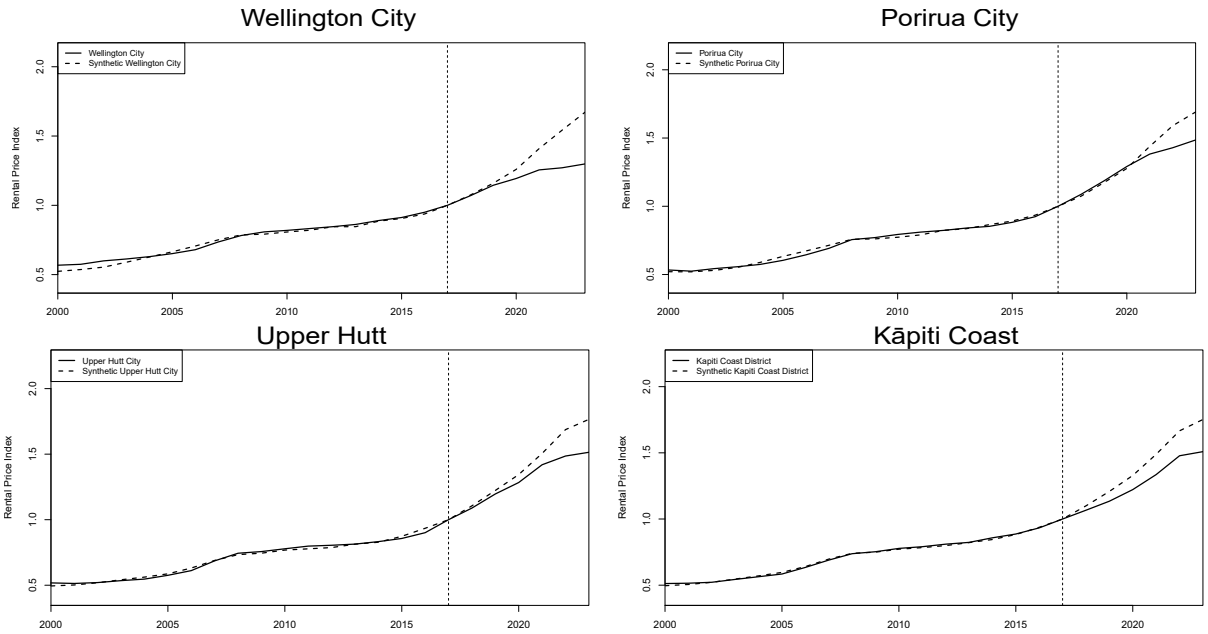
A.3 Rent

Table A4: Donor weights for rental price index synthetic control

Donors	Lower Hutt	Upper Hutt	Porirua	Wellington City	Kāpiti Coast
Buller District	0.035		0.008		
Carterton Distrct	0.084	0.446			0.366
Central Hawke's Bay District	0.092			0.020	
Hamilton City				0.348	
Horowhenua District		0.375			0.378
Kawerau District			0.003		
Manawatū District	0.002	0.062	0.328		
Ōpōtiki District			0.005		
Otorohanga District			0.123		
Palmerston North City	0.390		0.084		
Selwyn District			0.126	0.124	0.078
South Waikato District		0.089	0.248		0.083
Tararua District				0.509	0.094
Ruapehu Distrct	0.002				
South Waikato District	0.270				
Tararua District	0.106				
Whanganui District	0.016	0.028	0.057		

Notes: Donors with a weight less than 0.2% omitted for visual clarity.

Figure A9: Synthetic and actual rental prices for other Territorial Authorities in the Wellington metropolitan area



Notes: Vertical dashed lines denote the 2017 intervention date.

B Individual consents

Administrative records of individual consents for 2010 to 2023 were obtained from Hutt City Council. Each consent was assigned a geocoordinate based on its formatted street address using a locally hosted *Open Street Maps Nominatim* server. The .pbf file version employed was dated 01/06/2024. Output validation revealed a small number that required manual intervention due to poor input formatting or incorrect geolocation outputs. All consents were then spatially joined to the Plan Change 43 geospatial layer data.

The "EHU" field in the dataset records an estimate of the net number of dwellings consented. Each consent was manually checked to ensure that the EHU field accords with the "description_of_work" data field, resulting in a proportionately small number of corrections. An estimate of the gross number of dwellings was generated by manually checking the "description_of_work" and "type_of_work" data fields to identify any demolitions or removals of existing buildings. Comparing gross to net consents enables an estimate of demolitions and removals associated with redevelopment.

The resulting aggregate number of consented dwellings is fewer than reported by Statistics New Zealand for Lower Hutt, averaging 3.6% fewer dwellings per year than official Statistics New Zealand records between 2011 and 2023, and omitting 2016, when there is a large shortfall of 153 dwellings, primarily retirement village units that are located in the Statistical Area 1 unit containing the "Bob Scott" retirement village.

B.1 Completions

Statistics New Zealand publish experimental estimates of completions based on building inspections and 'code of compliance certification' (CCC) issued by a large subset of the country's territorial authorities (TAs). As of 2023, about two-thirds of all consents issued in New Zealand are covered in the experimental estimates. For the TAs included, the proportion of consents that received a CCC over the ten years to December 2018 was 91.2%, on average (Stats NZ, 2022). However, using CCC issuance understates completions to a habitable standard since dwellings can be inhabited without a CCC. Using the final building inspection as a measure of completion results in a 92.9% completion rate over the ten years to December 2018. Unfortunately the experimental estimates are unavailable at the individual TA level.

However, the individual consent data can also be used to calculate completion rates because the they contain information on whether the consent was canceled, lapsed, or subsequently had a CCC issued. Consents with a "decision" field equal to "CCC Issued", "cccIssued", "CCCcptiss" or "CKOfinal" (which indicates the CCC was issued by the state developer, Kāinga Ora) were classified as having a CCC issued. Consents with a "deci-

sion" field equal to "#WITHDRAWN", "#Cancelled", "Lapsed" or "#Withdrawn" were classified as lapsed or canceled consents. Dwellings often take several years to complete. In estimating completion rates, we therefore allow for at least three years to have passed between when the dataset was last updated and when the consent was issued. Between 2010 (when the data begin) and 2020 inclusive, 90.0% of consented dwellings subsequently had a CCC issued, while 95.9% were not classified as canceled or lapsed, as of December 2023. Unfortunately the data do not record whether the consented dwelling has had a final inspection, so we cannot ascertain the proportion of completions based on this milestone. We therefore estimate that between 90 and 96% of consents result in a completed dwelling.

B.2 Demolitions

Completed consents do not reflect increases in the dwelling stock because existing houses may be demolished or removed prior to redevelopment. The individual consent data allow us to produce an estimate of the number of dwellings demolished or removed from the site, as it contains the net number of housing units associated with the consent and a data field that indicates whether the construction involves demolition of existing building(s). Based on this information we estimate that 186 dwellings were demolished over the treatment period (2018 to 2023), compared to 4867 consented dwellings. However, the ratio of demolitions or removals to consented dwellings increases from effectively zero between 2010 and 2020, to 0.028 in 2021, 0.066 in 2022, and 0.099 in 2023.

C Hedonic imputation index

This section follows the exposition given in Greenaway-McGrevy and So (2024) with minor modifications. Hedonic indexes are constructed using data on individual rental bonds lodged with the Ministry of Business, Innovation and Employment at the beginning of rental contract. Data were accessed through a Statistics New Zealand datalab. The sample of tenancies consists of apartments, houses and flats. Bonds with no record of the dwelling type are omitted. The sample is restricted to private dwellings, as many public rentals are subsidized, and this is the convention followed by Statistics New Zealand when constructing rental price indexes. Let $p_{i(t),t}$ denote the logged weekly rent of house $i\,(t)$ sold in period t, and let $X_{i(t),t}$ be a vector of characteristics, where $t = 1, ..., T$ indexes time periods (years), and $i(t) = 1(t), ..., n(t)$ indexes the cross sections observed in period t. The hedonic regression is

$$p_{i(t),t} = X'_{i(t),t}\beta_t + \varepsilon_{i(t),t} \tag{6}$$

The following are included in $X_{i(t),t}$: number of bedrooms, a dummy for apartment, a dummy for flat, neighborhood dummies (specifically, Statistical Area 2 dummies), and a constant. For each territorial authority, (6) is fitted to the cross section of rents for each $t = 1, ..., T$ to obtain $\left\{\hat{\beta}_t\right\}_{t=1}^{T}$. For each observation $i(t)$ in period t, the estimated hedonic function is used to impute rents in period t as $\hat{p}_{i(t),t} = X'_{i(t),t}\hat{\beta}_t$, and period $t-1$ as $\hat{p}_{i(t),t-1} = X'_{i(t),t}\hat{\beta}_{t-1}$. The hedonic index is then obtained from the following regression:

$$\hat{p}_{i(t),t} - \hat{p}_{i(t),t-1} = \delta_t + u_{i(t),t}, t = 2, ..., T$$

The sequence $\left\{e^{\hat{\delta}_t}\right\}_{t=1}^{T}$ yields the hedonic imputation price index, where $\hat{\delta}_1 = 0$.