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Can zoning reform increase housing construction? Evidence from Auckland

Ryan Greenaway-McGrevy

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Abstract

In 2016, Auckland, New Zealand upzoned approximately three-quarters of its residential land, allowing medium and high density housing to be built in areas previously zoned for low density. Permits for the construction of new dwellings subsequently reached record highs. We use a synthetic control method to evaluate the impact of this widespread zoning reform on housing starts. The synthetic control provides an estimate of outcomes under the counterfactual of no zoning reform and implies that the upzoning approximately doubled new dwelling permits per capita within five years of the reform becoming operational. Seven years on from the reform, cumulative permits issued exceed those of the synthetic control by approximately 52,200, forty-six percent of the 112,300 permits issued over this period. These findings suggest that zoning reform can be used to redress housing shortages in other jurisdictions.

Keywords: Upzoning, Land Use Regulations, Redevelopment, Housing Starts, Synthetic Controls.

JEL Classification Codes: R14, R31, R52.

*University of Auckland. Corresponding author. Postal address: The University of Auckland, Private Bag 92019 Auckland 1142, New Zealand. Email: r.mcgrevy@auckland.ac.nz. This research was funded by the Royal Society of New Zealand under Marsden Fund Grant UOA2013. I thank Peter Nunns, Matthew Maltman and Kade Sorensen for helpful conversations and suggestions. A previous version of the paper is available here.

1 Introduction

Zoning reform is increasingly advocated to help address housing shortages and unaffordable housing (Glaeser and Gyourko, 2003; Freeman and Schuetz, 2017; Manville et al., 2020). Proponents argue that overly restrictive land use regulations (LURs) in many cities around the world have restrained housing supply, increasing housing costs in areas of growing demand. Relaxing those regulations would consequently enable housing supply through the redevelopment of existing residential parcels into more intensive housing, including plexes, rowhouses and apartments. Many municipal and gubernatorial governments are now implementing zoning reforms to redress housing shortages. Between 2019 and 2023, the states of California, Oregon, Washington and Maine, and the cities of Minneapolis, Charlotte and Arlington implemented zoning changes to abolish single-family zoning.

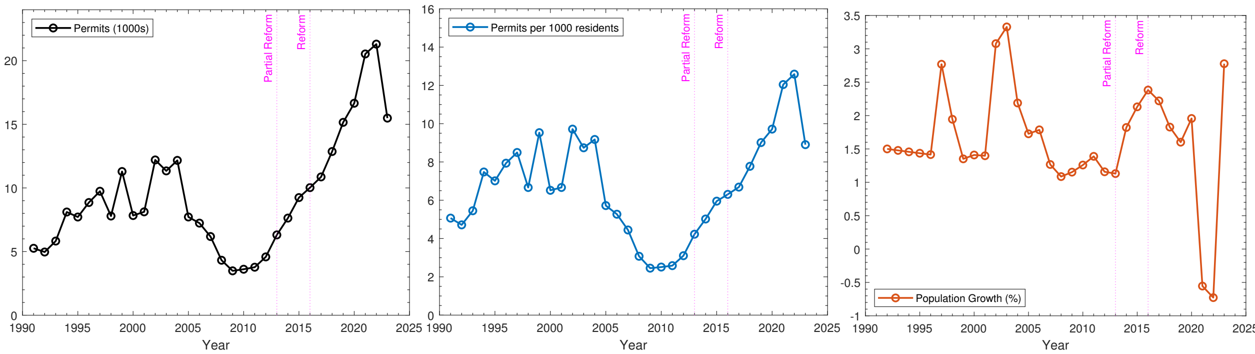
However, there remains skepticism of the ability of zoning reform to meet stated goals (Rodríguez-Pose and Storper, 2020; Wetzstein, 2021). Studies on localized upzonings often find muted or no housing supply response (Freemark, 2020; Dong, 2021; Peng, 2023; Stacy et al., 2023), contravening outcomes anticipated by the supply-side argument for reforms (Rodríguez-Pose and Storper, 2020). Widespread zoning reforms fundamentally differ from localized upzonings due to the scope, scale and speed of zoning changes. There are compelling grounds to posit that widespread reforms could have different impacts due to substantially more development opportunities, less uplift in upzoned land prices (Kulish et al., 2012), increased capacity in the building sector (D'Amico et al., 2024), and faster permitting processes (Manville et al., 2023). However, our understanding of the effects of large-scale zoning reforms is presently limited by a lack of empirical research on the subject (Schill, 2005; Freeman and Schuetz, 2017; Freemark, 2019), which is due, in part, to the fact that, until very recently, no city has systematically upzoned large shares of land as a mechanism to promote affordability (Freeman and Schuetz, 2017, p. 229).

However, in 2016, Auckland, New Zealand, upzoned approximately three-quarters of its residential land under the Auckland Unitary Plan (AUP) (Greenaway-McGrevy and Jones, 2025). Building permits for new dwellings subsequently reached record highs, in both absolute and per capita terms. As illustrated in figure 1, permits increased from approximately 9,200 in 2015, the year prior to the AUP becoming operational, to reach a record high of 21,000 by 2022. Over the same period, permits per thousand residents more than doubled, increasing from 5.95 to 12.57. Permits then fell between 2022 and 2023 after an unprecedented rise in interest rates and a national recession, but still remained above the previous peak in 2002. In total, approximately 112,300 new dwelling permits were issued in the region over the seven years (2017 to 2023) subsequent to the reform. To contextualize the magnitude of this figure, Statistics New Zealand (the nation's statistical agency) estimates that there were 530,000 dwellings in Auckland in 2016, when the reform was implemented.[1] The number of new building permits issued over this subsequent seven year period was therefore equivalent to 21% of the pre-reform housing stock.

While new housing starts have reached record highs, it remains unknown how various outcomes

[1] See Table 8 of the experimental dwelling estimates, available at `https://www.stats.govt.nz/experimental/experimental-dwelling-estimates/` [accessed 2 September 2023].

Figure 1: New dwelling permits and population in the Auckland region, 1991 to 2023



Source: Author's calculations based on Statistics New Zealand data. Population is estimated resident population, 1996 to 2022. Population figures for 1991 to 1995 imputed using a linear spline on census 1991 and 1996 Auckland region population, obtained from `https://teara.govt.nz/files/g-23512-data.txt` [accessed 7 April 2025]. Notes: Zoning reform was implemented in Auckland in November 2016, with a partial reform operating between September 2013 and November 2016. Refer to section 2 for additional details.

of interest would have changed under the counterfactual of no policy intervention. In this paper, we assess the impact of the reform by adopting the synthetic control method to specify the counterfactual scenario. The synthetic control is constructed from a donor pool comprised of other commuting zones in New Zealand, and suggests that the reform doubled the rate at which new dwelling permits are issued within five years of the policy change. Permits per thousand residents in Auckland reached 12.2 in 2021, while permits per thousand residents in the synthetic control were 5.9 – approximately the same level in Auckland immediately prior to the reform. Differences between actual and synthetic permits per capita imply that the reform increased the number of permits by 52,200 over the seven years subsequent to the reform. This means that about forty-seven percent of the 112,300 permits issued in the Auckland commuting zone since 2016 are attributable to the reform, or equivalently that the reform increased permits by 87% over this period.

To assess the statistical significance of these increases, we apply the conventional rank permutation test to the ratios of post- to pre- intervention root mean square errors (RMSEs, Abadie et al. 2010). Auckland has the largest ratio among all 50 placebos. Thus, if one were to assign the intervention at random, the probability of obtaining a ratio as large as Auckland's is 0.02 (= 1/51).

The finding that widespread zoning reform can enable housing supply is important. While researchers have advocated for widespread or large-scale zoning reform as a means to redress housing shortages, studies that focus on localized (or "spot") upzonings typically show muted effects on housing supply (Dong, 2021; Peng, 2023), or no effect at all (Freemark, 2020), casting doubt on the ability of zoning reform to meet intended objectives (Rodríguez-Pose and Storper, 2020). Recently, Stacy et al. (2023) examine over fifty upzonings in various cities in the U.S., finding small effects on housing construction and costs. Meanwhile, early research indicates that some of the recent widespread reforms in the United States have not (yet) enabled significant housing supply (Garcia and Alameldin, 2023).[2] Results from the present synthetic control approach indicate that the widespread zoning reform undertaken as part of the Auckland Unitary Plan did enable a substantial increase in housing construction, suggesting that such reforms can succeed, and thereby play a role in redressing housing shortages and unresponsive housing supply.

Our measure of construction is based on new dwelling permits issued, and it is important to note that this is not a measure of completed dwellings. However, completion rates for new dwelling permits are high in Auckland and New Zealand more generally, typically exceeding 90% (see section 3 below for additional discussion). This means that new dwelling permits are not only a good measure of housing starts, but are a leading indicator of gross additions to the housing stock.

The synthetic control method has been applied to evaluate policies in a variety of contexts (see Abadie (2021) for a comprehensive review). In the housing literature, the Minneapolis Federal Reserve Bank uses the method to assess the effects of the Minneapolis 2040 Plan, which relaxed land use regulations to allow up to three dwellings per parcel, on a variety of housing outcomes.[3] We take several steps to ensure that our research design and implementation is robust to common pathologies. First, we use the longest possible times series on outcomes prior to intervention in order to minimize bias in the synthetic unit (Abadie et al., 2010). Our time series on new dwelling permits spans 1991, when the available permit data begin, to 2023, with the intervention occurring in 2016. Second, we consider whether inter-regional displacement from the synthetic control to Auckland as result of the reform is biasing estimated policy impacts upwards. To so, we estimate a set of auxiliary synthetic controls for the selected donors that constitute Auckland's synthetic control. This allows us to see whether there is any evidence that the zoning reform in Auckland caused a sustained reduction in the permitting rate of the selected donors. We find no statistical support for displacement, but nonetheless present specification sensitivity checks as evidence that any displacement effects, if present, have a negligible impact on our findings. Third, the directional impacts of our findings are robust to various permutations of our modeling choices, including the incorporation of Australian regions in the donor set. Fourth, our findings are largely unaffected by the conventional leave-one-out robustness check (Abadie et al., 2010), whereby units from the donor pool are iteratively removed from the sample while the procedure is repeated.

A substantial body of literature establishes that restrictive land use regulations restrain housing supply and increase housing costs (see Gyourko and Molloy, 2015 for a review).[4] Fewer studies examine changes in zoning, let alone widespread upzonings implemented under zoning reform. The effects of zoning reform on housing and urban development therefore remains an important but regrettably understudied topic. Only a handful of studies focus on what happens after land use

[2] Also see the "Minneapolis Housing Indicators Dashboard" at https://minneapolisfed.shinyapps.io/Minneapolis-Indicators/ [accessed 27 November 2024]. To evaluate the 2019 Minneapolis zoning reform, the Federal Reserve Bank of Minneapolis compares multifamily housing permits to a synthetic control, finding no statistically significant increase as of 2022.

[3] See https://minneapolisfed.shinyapps.io/Minneapolis-Indicators/ [accessed 27 November 2024]

[4] Much of this literature focuses on the United States. Exceptions include Zhang et al. (2013), Hilber and Vermeulen (2016), Kendall and Tulip (2018) and Nunns (2021), who measure and examine the effects of LURs in China, England, Australia and New Zealand, respectively.

regulations (LURs) are relaxed. Freemark (2020) shows that transit-oriented upzoning in Chicago failed to stimulate construction, while Peng (2023) shows that housing supply responded slowly to a sequence of localized upzonings in New York. Dong (2021) finds that localized upzonings in Portland approximately doubled the long-term probability of parcel development, but the number of new units constructed remains small. Buechler and Lutz (2024) examine a sequence of upzonings in Zurich, and find that a 10% increase in zoned capacity leads to a 1.2% increase in housing supply after five years. In recent work, Stacy et al. (2023) show that various reforms in US cities between 2000 and 2019 generated small increases in housing supply, on average. Studies on widespread or large-scale zoning reforms are more rare. Gray and Millsap (2020) show that the city-wide reduction in minimum lot sizes in Houston preceded an increased concentration of development activity in middle-income, less dense, under-built neighborhoods. Houston now issues building permits at a much higher per capita rate than other US cities (Gray, 2022). Anagol et al. (2021) examine a large-scale increase in built-area-ratios in São Paulo, and find that the reform led to a 2.2 percent increase in the housing stock. Finally, Greenaway-McGrevy and Phillips (2023) show that the AUP generated a statistically significant increase in housing starts by modifying the conventional difference-in-differences approach to allow for displacement from control (non-upzoned) to treatment (upzoned) areas via a set of counterfactual scenarios. Treatment effects are set-identified in their framework, meaning that point estimates of the policy impacts are lacking.[5] In contrast, the synthetic control method produces a single counterfactual scenario, enabling point-identification of policy impacts and, consequently, a more accurate quantification of the effects of the zoning reform on housing construction.

The remainder of the paper is organized as follows. The following section provides the institutional details of Auckland's zoning reform, and parallels those made by (Greenaway-McGrevy et al., 2021), Greenaway-McGrevy and Phillips (2023) and Greenaway-McGrevy and Jones (2025) on the same topic, with modifications. Section three describes the data. In section four presents the method and results. Section five concludes.

2 Institutional background

Auckland is the largest city in New Zealand, with a population of 1.57 million as of 2018 (source: New Zealand census). A single municipal government, Auckland Council, governs the entire metropolitan area, as well as outlying rural land and offshore islands.

Prior to 2010, the region comprised seven different city and district councils, each with their own planning regulations. The councils were amalgamated through an Act of Parliament,[6] and the newly formed Auckland Council required to create strategic spatial plan and a consistent set of planning rules for the region.[7] The strategic plan was released in May 2012 and called for a

[5] Point estimates can be obtained when counterfactual sets are restricted to a point. Such an approach is highly restrictive (Greenaway-McGrevy and Phillips, 2023, pp.13–14).

[6] *The Local Government (Auckland Council) Act 2009.* https://www.legislation.govt.nz/act/public/2009/0032/latest/DLM2044909.html [accessed 14 March 2023]

[7] *The Local Government (Auckland Transitional Provisions) Act 2010.* https://www.legislation.govt.nz/act/

more compact form of urban growth, setting a target for 60 to 70% of all future housing to be within existing urban areas. Then, in March 2013, Auckland Council announced the first version of the "Auckland Unitary Plan" (AUP), which introduced a standardized set of planning zones for the jurisdiction. After several rounds of reviews and consultation, the plan was functionally operationalized in November 2016. Approximately three-quarters of residential land was upzoned under the final version of the plan, in the sense that the FAR restrictions implied by height and site coverage limits were relaxed (Greenaway-McGrevy and Jones, 2025). A detailed timeline of key events leading up to the reform can be found in the Appendix. For additional details on the implementation of the plan and information on the spatial distribution of upzoning, see (Greenaway-McGrevy and Jones, 2025).

Although the AUP was implemented in 2016, an interim agreement between the Auckland Council and the central government allowed developers to build to the rules of the "Proposed Auckland Unitary Plan" (PAUP), notified in September 2013.[8] This agreement modified a national inclusionary zoning program called "Special Housing Areas" (SpHAs, also launched in September 2013) that offered developers an accelerated permitting process in exchange for a ten percent affordable housing provision in the development.[9] The modified PAUP-SpHA program was in effect a "density bonus" scheme to incentivize affordable housing provision. The program was scheduled to end once the AUP was implemented. Thus, while the AUP was formally operationalized in 2016, it began to have a limited effect from September 2013 onwards because SpHA developments fell under the more relaxed LURs of the PAUP. Outside of Auckland, the SpHA program operated until November 2019, and was not implemented in conjunction with zoning reform.

Housing supply lagged demand prior to the reform. Between the 2001 and 2018 censuses, the usually resident adult (aged 20+) population of the Auckland region increased by 42.4 percent, while dwellings increased by only 28.8 percent – a shortfall of 13.6 percentage points.[10] The ratio of adults to dwellings consequently increased from 1.9 to 2.11 over this eighteen year period. The shortfall in supply coincided with a significant deterioration in housing affordability. Nominal house prices increased by approximately 350% between 2001 and 2018,[11] compared to a 43% increase in the general price level.[12] Nominal rents approximately doubled.[13] By 2018, the ratio of median house price to household income reached nine.[14] Deteriorating affordability in Auckland mirrored trends in the other metropolitan cities of New Zealand in the two decades preceding the reform

public/2010/0037/latest/DLM3016607.html [accessed 22 March 2023]

[8]The Auckland Housing Accord (AHA). See https://www.beehive.govt.nz/sites/default/files/Auckland_Housing_Accord.pdf [accessed 31 March 2025]

[9]The "Housing Accords and Special Housing Areas Act 2013" (HASHAA). See https://www.legislation.govt.nz/act/public/2013/0072/latest/DLM5369001.html [accessed 31 March 2025]

[10]Source: Author's calculations based on data from https://www.stats.govt.nz/assets/Uploads/2018-Census-population-and-dwelling-counts/Download-data/2018-census-population-and-dwelling-counts-amended-5-3-2020.xlsx [accessed 16 December2023].

[11]Source: Author's calculations based on repeat sales indexes used in Greenaway-McGrevy and Phillips (2021).

[12]Source: https://www.rbnz.govt.nz/monetary-policy/about-monetary-policy/inflation-calculator [accessed 26 February 2025].

[13]Source: Author's calculations based on rental price indexes used in Greenway-McGrevy and So (2024). Statistics New Zealand rental price indexes only begin in 2006.

[14]Source: https://demographia.com/dhi2019.pdf [accessed 26 February 2025].

(Greenaway-McGrevy and Phillips, 2021).

2.1 Zoning changes and increases in capacity

The AUP introduced four new residential zones to the city. Listed in declining levels of permissible site development, these were: Terrace Housing and Apartment Buildings (THA); Mixed Housing Urban (MHU); Mixed Housing Suburban (MHS); and Single House (SH).[15] Table 3 in the Appendix summarizes the various land use regulations (LURs) that apply in each zone, including site coverage ratios, height restrictions, setbacks, and building envelopes, among others. For example, five to seven storeys and a maximum site coverage of 50% is allowed in THA, whereas only two storeys and 35% site coverage is allowed in SH. MHS and MHU allow up to three dwellings per parcel, and THA is unrestricted, whereas SH allows one dwelling.[16]

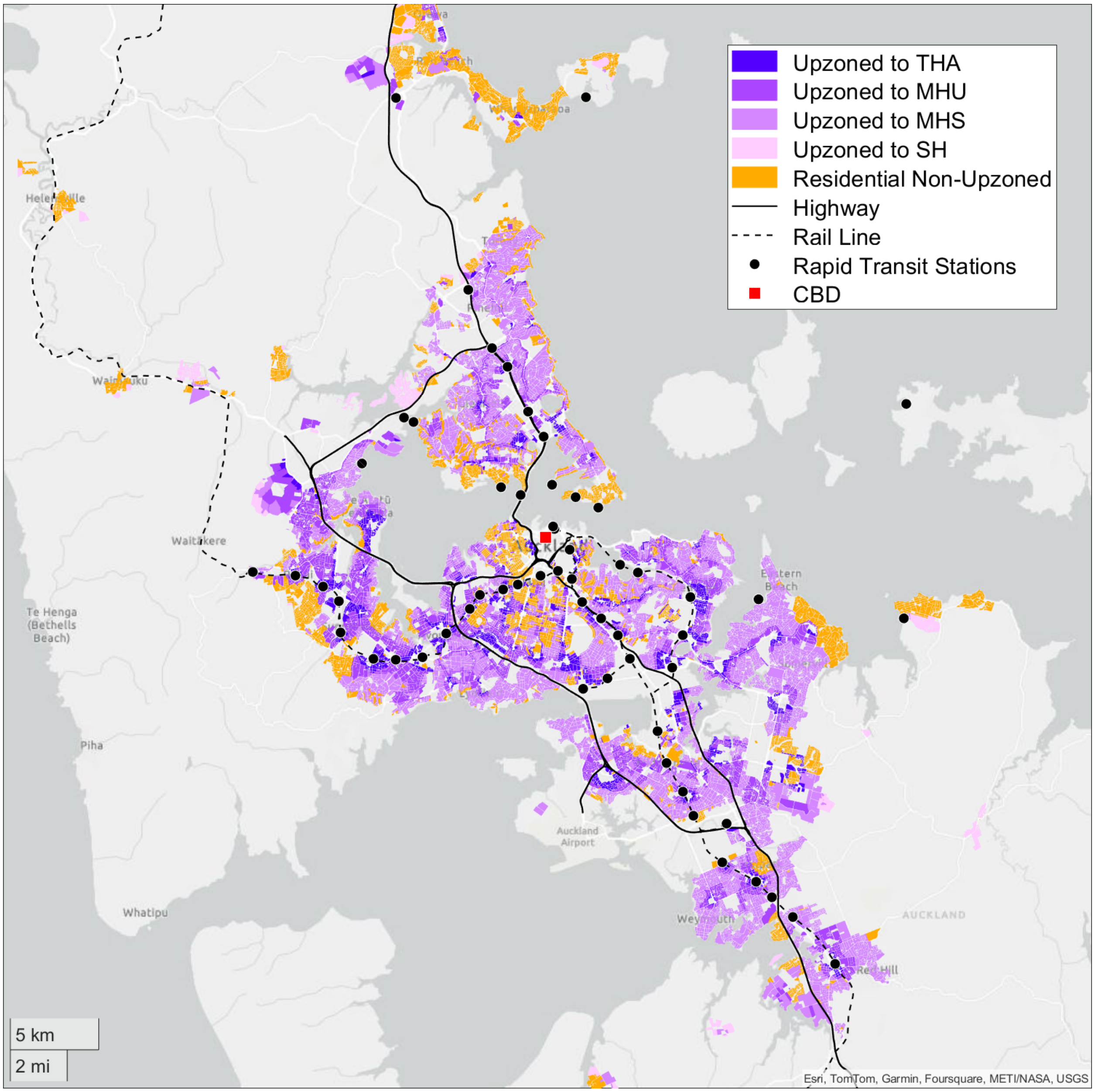
Prior to the AUP, the planning rules for the region were governed by the seven different city and district councils that were amalgamated in 2010. Although most of the seven different plans allocated some residential land to medium density housing, the aggregate area covered was severely limited. Over 95% of residential land in the Auckland region was zoned for site development that was similar to what the SH zone allows (Greenaway-McGrevy and Jones, 2025). Under the AUP, the SH zone only covers about twenty five percent of residential land, mainly at the periphery and the inner suburbs (with the latter often under "character neighborhood" protection that prohibits various forms of redevelopment). Figure 2 illustrates the spatial distribution of upzoned and non-upzoned residential areas of the city, with the upzoned residential areas decomposed into zones that differ in permissible site development. Capacity estimates produced by Auckland Council before and after the AUP indicate that the reform approximately tripled the number of dwellings that could be built in the region (Greenaway-McGrevy et al., 2021). This capacity increase accords with widespread nature of the reform, and the increases in dwellings per parcel and floorspace enabled under the new medium- and high- density zones. For example, the floorspace limit implied by site coverage and height restrictions is 92.8% higher in MHU compared to SH, and 257.1% higher in THA. Meanwhile, both MHS and MHU allow three times as many dwellings per parcel as SH.

Auckland had urban growth boundaries (UGBs) in place both before and after the AUP, further restricting housing supply. Prior to the AUP, development outside of the the "Metropolitan Urban Limit" (MUL) was heavily restricted. Under the AUP, the MUL was replaced with the "Rural-Urban Boundary" (RUB), which expanded the UGB in specific locations, and earmarked greenfield land within the RUB for future development, which was zoned as "future urban" (FU). However, the majority of FU areas were not immediately live-zoned for development. The process, sequencing and anticipated timing of development of FU areas over a thirty-year horizon was initially outlined under the "Future Urban Land Supply Strategy" (FULSS), released by Auckland Council in July

[15] There are two additional zones in the AUP that are classified as "Residential": "Large Lot" and "Rural and Coastal Settlement". These areas are an intermediate, semi-rural zone between outright rural and urban housing areas, and they frequently lack fresh water and sewerage infrastructure. Residential land on inhabited islands have their own unique zoning.

[16] SH allows one accessory dwelling unit of no more that 60m^2 in floorspace.

Figure 2: Upzoned and non-upzoned residential areas in Auckland



Source: Author's calculations based on the method of Greenaway-McGrevy and Jones (2025). Notes: Rapid Transit stations include heavy rail stations, dedicated busway stations, and ferry terminals. The CBD marker is centered on Auckland's iconic 'Sky Tower' skyscraper. Water in grey. Business and rural areas not depicted, including business areas rezoned from residential or rural. Areas upzoned to Single House (SH) were previously zoned as rural or semi-rural.

2017.[17] Figure 24 in the Appendix exhibits the MUL, RUB and FU areas. In summary, prior to the AUP, there were constraints on the city building "out" via urban expansion, and "up" via intensification in residential areas. The AUP relaxed both constraints, but imposed restrictions on the pace of the urban expansion, that have subsequently been further restrained (see footnote 17). Between 2017 and 2022, approximately 2% of new dwelling permits were issued in FU zones (source: Author's calculations based on data depicted in Figure 3). The proportion of developed area within the wider Auckland jurisdiction only increased slightly immediately after the AUP. Prior to the AUP, approximately 12.3% of land within the Auckland area was zoned as either residential or business, with the remainder being rural, open space, or special purpose.[18] This increased to 12.7% after the AUP.[19]

2.2 Changes in housing supply

Data on new dwelling permits suggests that housing supply quickly responded to the reform. Figure 3 exhibits annual permits issued per year, decomposed into permits issued in upzoned and non-upzoned areas. Dwelling permits issued in business and rural areas are included, so that annual totals match new dwelling permit totals provided by Statistics New Zealand,[20] which is the dataset used in our empirical analysis to follow in section 4.

Permits for new dwellings significantly increased year-on-year from 2016 onwards, the year the zoning reform is (fully) operationalized, with all of the new construction occurring in upzoned areas. Figure 2 of Greenaway-McGrevy and Jones (2025) decomposes permits in upzoned areas into the different residential zones, showing that most of the increase occurs in areas upzoned to MHS or MHU. This is because much more land is converted to MHS and MHU than THA, as evidenced in Figure 3 (also see Table 1 of Greenaway-McGrevy and Jones, 2025).

Figure 3 decomposes permits by housing type, revealing that there has been a surge in permits for multifamily, attached dwellings, which are typically associated with medium- and high- density zoning reforms. The previous peak in attached dwellings occurred in 2004, with approximately 5,300 permits issued. This peak was driven by a boom in CBD apartment construction (see figure 27 in the Appendix, which splits out permits issued in business areas). By 2022, approximately 15,700 permits for attached dwellings were issued, far exceeding the approximately 5,750 detached

[17]See https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/topic-based-plans-strategies/housing-plans/Documents/future-urban-land-supply-strategy.pdf [accessed 31 March 2025]. Subsequent policy changes have since reduced and further constrained development of future urban (FU) areas. In 2023, the FULSS was superseded by the "Future Development Strategy", which pushed back the timeline for the development on many FU areas, and either rescinded FU designation from land prone to natural hazards, or required risk mitigation planning to be incorporated into the development processes for such land. See https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/Documents/future-development-strategy.pdf [accessed 31 March 2025].

[18]Special purpose includes airports and airfields and hospitals. Open space and special purpose do not generally support dwellings.

[19]Source: Author's calculations based on information in Table 1 of Greenaway-McGrevy and Jones (2025).

[20]Note that the new dwelling permits depicted are only residential buildings (dwellings). They are do not include permits for non-residential buildings.

permits issued. Greenaway-McGrevy and Jones (2025) provide further information on how the composition of housing starts has changed since the reform. In the six years prior to the 2016 reform, 9.1 percent of dwelling permits were issued in medium or high density housing areas. In the six years after, this proportion increased to 72.2 percent. See Table 4 of Greenaway-McGrevy and Jones (2025)

For the purposes of the synthetic control exercise, we use 2016 as the date of the policy intervention. Although developers could access the upzoned land use regulations through the special housing area program from September 2013, figure 3 suggests that the zoning reform began to have a significant impact after 2016, as evidenced by the dramatic divergence in permitting activity in upzoned and non-upzoned areas from this point in time. However, 2012 or 2013 could also feasibly be used as the intervention date. There is some evidence of policy "leakage" as developers took advantage of the relaxed regulations under the PAUP-SpHA from 2013 onwards. Figure 26 in the Appendix exhibits permits issued in SpHA areas that were upzoned and not upzoned, and shows that SpHA permits were disproportionately located in upzoned areas. We therefore use 2013 in a set of robustness checks. Specifications with an earlier intervention date generally result in larger estimated policy impacts, although there is a greater variance across different model specifications. These results are discussed in section 4.4.3.

3 Data

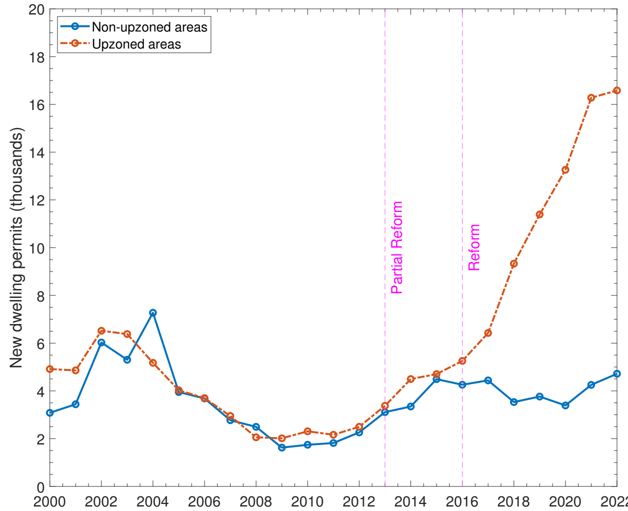
Our outcome of interest is new dwelling permits per thousand residents, which we refer to as the "permitting rate". Normalizing the flow variable (permits) by a measure of stock (population) facilitates comparability between different urban areas.[21]

We use Functional Urban Areas (FUAs) as the geographic units of analysis. These areas are delineated by Statistics New Zealand on the basis of commuting patterns, and are analogous to commuting zones as defined by the OECD.[22] There are 53 FUAs in New Zealand, including Auckland. We omit Christchurch from the donor set due to the effects of the 2011 Christchurch earthquake, which generated a substantial idiosyncratic shock to the housing market as a substantial proportion of the housing stock was demolished and subsequently rebuilt. As noted by Abadie (2021), donor units subjected to large idiosyncratic shocks to the outcome variable during the study period should be omitted (p. 409). We also omit Warkworth, which is FUA within the Auckland region that was consequently subject to the same upzoning under the AUP. This is because Warkworth sits within the jurisdiction of Auckland Council but constitutes its own commuting zone. Although there is commuting between Auckland and Warkworth, it is insufficient for the latter to be considered part of the Auckland commuting zone according to Statistics New Zealand's classification methods. This

[21] Permits per existing dwelling could also be used as a measure of the permitting rate. Unfortunately Statistics New Zealand does not produce estimates of dwellings between census years. Censuses usually occur every five years. The 2011 census was delayed until 2013 due to severe earthquakes in Canterbury in 2011.

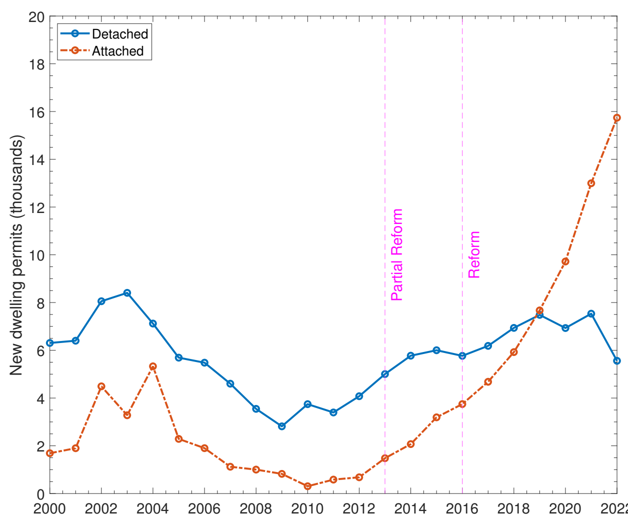
[22] See https://www.stats.govt.nz/assets/Methods/Functional-urban-areas-methodology-and-classification.pdf [accessed 5 September 2023]

Figure 3: New dwelling permits in Auckland region by upzoned and non-upzoned areas



Notes: New dwelling permits in areas that were upzoned and were not upzoned in 2016 under the AUP. Residential, business and rural areas included. The first, "draft", version of the AUP was announced in March 2013, while the "Proposed" AUP (PAUP) was notified in September 2013. Partial zoning reform were implemented in September 2013 under the Auckland Housing Accords. Between September 2013 and November 2016, Special Housing Area (SpHA) developments could build to the regulations of the PAUP in exchange for affordable housing provisions. Full reform occurred in November 2016 when the final version of the AUP became operative. Source: Author's calculations based on individual permits matched to planning zones. See the Appendix for a description of the geomatching algorithm. Upzoning classification is based on comparing floor-to-area (FAR) ratios implied by height and site coverage restrictions before and after the policy change. See Greenaway-McGrevy and Jones (2025) for additional details.

Figure 4: New dwelling permits in Auckland region by housing type



Notes: Attached (or "multi-family") and detached (or "single family") new dwelling permits. See notes to figure 3.

leaves 51 FUAs.[23] For clarity, we henceforth drop the "functional" descriptor and refer to "urban areas" (UAs).

New residential dwelling permits and estimated population by UA were obtained from Statistics New Zealand. Population estimates are as of June of the reference year. Permit data begin in 1991 and end in 2023. Estimated population data begin in 1996. We backcast and linearly interpolate estimated population data using the growth rate in the resident population of the UAs between the 1991 and 1996 censuses.

Dwelling permits include permits issued to both private and government-controlled developers. After the reform, approximately one out of every ten dwelling permits was issued to a government-controlled developer (Greenaway-McGrevy, 2025c). These dwellings were built for a variety of purposes, including tenanted social housing, affordable housing for first-time and low-income home buyers, and market housing. Unfortunately recording conventions do not distinguish between the various purposes, so we cannot , for example, identify the number of social housing units constructed.

Permits are not a measure of completed dwellings. However, unless there is a substantial systematic difference in completions between Auckland and its weighted average of donor units, relative (as opposed to absolute) estimates of policy impacts will reflect changes in completed dwellings. For example, suppose that 7,500 dwelling permits are issued in Auckland, while 5,000 are issued in the synthetic control. If completion rates are the same in Auckland and its donor units, then there has been a 50% increase in both permits and completed dwellings (relative to the counterfactual of no reform).

Completion rates are, however, important for measuring policy impacts in absolute terms. Unfortunately the institutional features of data collection in New Zealand make it difficult to measure completions. Aggregate data on completions at the regional level, including Auckland, are unavailable. Statistics New Zealand (SNZ) does publish "experimental" estimates of completions for the country as a whole, however many administrative areas of the country are not included in the aggregate estimate. Currently SNZ uses the issuance of a "code of compliance certificate" (CCC) as an indicator of completion. CCCs indicate that the building works have been satisfactorily inspected by the local council to certify that the work has been completed to the required local and national building codes and regulations. For the subset of areas covered, SNZ experimental estimates show that the proportion of permits that received a CCC over the ten years to December 2018 was

[23] Hutt City, which is a city council within the Wellington urban area, implemented medium density zoning changes under "District Plan Change 43", which became operative in part on 9 April 2020, and fully operative from 23 February 2021. See https://www.huttcity.govt.nz/council/district-plan/district-plan-changes/completed-district-plan-changes/residential-and-suburban-mixed-use [accessed 5 September 2023]. We keep Wellington in the donor pool since Hutt City constitutes a limited proportion of the greater Wellington region, and the inclusion of donor units subject to a similar policy intervention would bias estimated policy effects downwards, leading to a more conservative assessment of policy effects. Hutt City subsequently implemented further medium and high density reforms in 2022 under "Plan Change 56". Meanwhile, Wellington City implemented a widespread medium and high density upzoning in May 2024. In future updates of this work it may become important to remove Wellington from the donor pool.

91.2%, on average.[24] [25] Greenaway-McGrevy and Jones (2025) use individual permit and CCC data to estimate CCC-based completions in Auckland from 2018 onwards, when administrative data collection processes were changed to include a unique identifier that enables matching of CCCs to their original permits, and show that completion rates exceed 90% in Auckland. Thus, the available evidence indicates that completion rates in Auckland do not differ markedly from estimates for the nation as a whole, and that completions exceed 90% when based on CCC issuance.[26] [27]

Permits applications are typically processed quickly in New Zealand. Since 2004, local councils have been required to process applications within 20 working days, and the available data indicate that the vast majority of applications are processed within the required time frame.[28] Processing deadlines might incentivize rejections (Hilber and Vermeulen, 2016), particularly during construction booms if approval employees or hours do not commensurately increase. If so, processing deadlines would *mediate* the effect of upzoning on permits, and consequently should not be controlled for in the quasi-experimental framework, particularly as a uniform deadline applies across all local councils in our application.

3.1 Comparing Auckland's permitting rate to other urban areas

Figure 5 exhibits the permitting rate in the Auckland urban area between 1991 and 2022. For comparative purposes, in the top panel of the figure we include the average and range of the permitting rates for all other "metropolitan" and "large" urban areas of the country.[29] As described

[24] See https://www.stats.govt.nz/experimental/experimental-building-indicators-march-2022-quarter/ [accessed 05/09/2023].

[25] Legacy surveys typically imply higher completion rates. Until 2017, SNZ surveyed developers to measure completions, resulting in a completion rate above 95% in recent years. See https://www.stats.govt.nz/experimental/experimental-dwelling-estimates/ [accessed 5 September 2023].

[26] CCC issuance provides a conservative estimate of completions, as dwellings can be inhabited without a CCC. The final building inspection provides another milestone for completion, as this occurs after plumbing fixtures and interior wall linings are in place. SNZ experimental estimates show that the proportion of permitted dwellings that received a final inspection over the ten years to December 2018 was 92.9%, on average. Greenaway-McGrevy and Jones (2025) estimate similar rates for Auckland.

[27] New dwellings are also not a measure of the change in the housing stock, as parcel redevelopment often requires an existing dwelling to be demolished or relocated. Unfortunately, assessing the impact of the reform directly on the dwelling stock is difficult, because New Zealand lacks accurate measures of the number of dwellings demolished or removed from redeveloped sites. There is no administrative record of demolitions, as dwellings less than three storeys do not require a permit in Auckland. Relocations require a new dwelling permit at the new site, but not from the local council where the dwelling originated. Jones et al. (2025) compare estimates of the dwelling stock based on Auckland Council administrative records to lagged dwelling permits and estimate that approximately one building is demolished (or exported from Auckland) for every nine constructed.

[28] Data only began to be collected in 2024. The results for the 2025 quarter show that the median processing time was 12.6 working days, and 92.7% were processed within the statutory 20-day time frame. Importantly, Auckland's median processing time, at 15.9 days, is not far above the national median, and 83.7% of applications were processed within the 20-day time frame. See:https://www.mbie.govt.nz/building-and-energy/building/building-system-insights-programme/building-consent-system-performance-monitoring

[29] See figure 25 in the Appendix for the location of these "metropolitan" and "large" urban areas. Statistics NZ classifies FUAs as either "metropolitan", "large", "medium" or "small" according the population of the "urban core". FUAs that have more than 100,000 residents living in their urban core are known as metropolitan areas, while smaller FUAs are divided into large (core population 30,000–99,999), medium (core population 10,000–29,999), and small regional centers (core population 5,000–9,999). See https://www.stats.govt.nz/methods/functional-urban-areas-methodology-and-classification#appendix-3[accessed 5 September 2023].

below in section 4.1, this group of urban areas comprises the set of donors used to construct the synthetic control for Auckland. As such, we refer to it as the "donor pool".

Auckland's permitting rate varies between six and ten permits per thousand residents from the mid-nineties through to the early-2000s. It's high permitting rate in the early 2000s is driven, in part, by a construction boom in business areas and the central business district (see figure 27 in the Appendix). Auckland's permitting rate was above average but in the middle of the range of donor pool over this period. Its permitting rate then declines dramatically from 2004 onwards, falling below the average in 2005, and attaining a low of approximately two-and-a-half between 2009 and 2011.[30] Over this period, Auckland's permitting rate sits near the bottom of the donor pool. From 2011 onwards there is a sustained increase each year. From 2020 to 2022, Auckland's permitting rate altogether exceeds the range of the donor pool. By 2022, its permitting rate of 12.7 is approximately 30% more than the highest permitting rate of 9.7 in the donor pool, held by Whangārei, a city 131 km north of Auckland (as the crow flies) with a population of 87,000 in the urban area.

The bottom panel of figure 5 exhibits Auckland alongside the other metropolitan urban areas of the North Island of New Zealand, namely Hamilton, Tauranga and Wellington. These cities are selected purely for expositional purposes: In the analysis to follow we use the synthetic control method to select donors. By 2020, Auckland's permitting rate had increased to the point where is exceeded that of Tauranga, which had been the fastest growing metropolitan area over the previous three decades. Permits per thousand residents in Wellington trends upwards from 2013 onwards, although the growth rate is not as fast as in Auckland. Beginning in 2017, Hutt City, one of the constituent cities of the Wellington metropolitan area that is home to about one-quarter of residents, notified and implemented a sequence of zoning relaxations and reforms, including a reduction in residential parking minimums, widespread medium density upzoning, the abolition of parking minimums, and a widespread high density upzoning.[31]

4 Synthetic control method and results

This section outlines the synthetic control method, including details on the selection of comparable donors for Auckland. It then presents results.

4.1 Synthetic control method

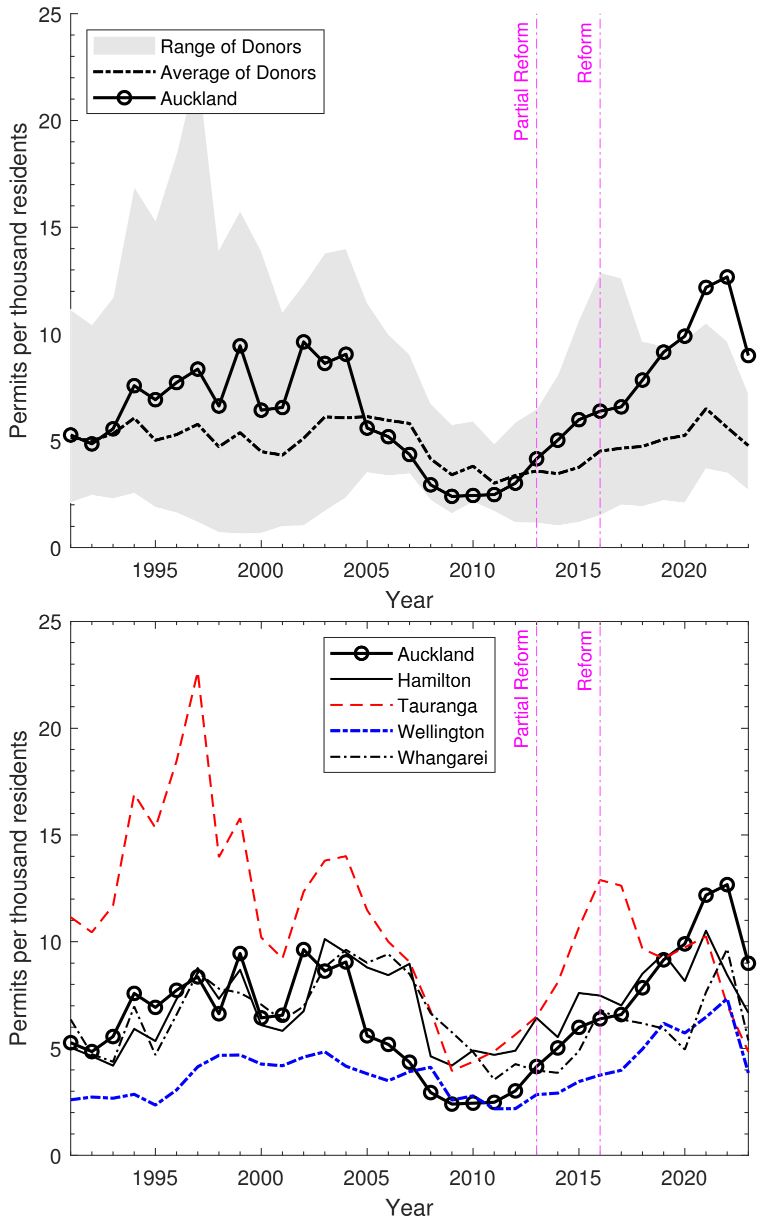
This section is based on the exposition of the synthetic control method presented in Abadie (2021).

We have time series data on an outcome of interest for $N + 1$ different units indexed by $i = 1, ..., N+1$, where $i = 1$ corresponds to the unit receiving the policy intervention, and $i = 2, ..., N+1$

[30] Figure 27 in the Appendix shows that a large proportion of the permits issued in the early 2000s were in business areas, reaching a high of 36% in 2004.

[31] See Plan Changes 39, 43, 56, and the "Removal of minimum car parking rate requirements" on 29 September 2020 here: https://www.huttcity.govt.nz/council/district-plan/district-plan-changes/completed-district-plan-changes/transport [accessed 19 December 2023]

Figure 5: New dwelling permits per thousand residents in Auckland and other urban areas, 1991–2023



Source: Author's calculations based on Statistics New Zealand (SNZ) data. Notes: Urban areas are commuting zones as defined by Statistics New Zealand. Average of donors taken across all urban areas in the donor pool as described in section 4.1. Shaded region denotes the range between the minimum and maximum permits per thousand residents among the donor pool. "Partial Reform" refers to the Proposed Auckland Unitary Plan (PAUP), notified in September 2013. Developments that qualified as "Special Housing Areas" could build to the regulations under the PAUP in exchange for ten percent of the development to qualify as affordable housing. "Reform" refers to the Auckland Unitary Plan, which became operational in November 2016. Hutt City, a constituent city within the Wellington metropolitan area, notified and implemented a sequence of zoning reforms from 2016 onwards.

indexes the "donor pool", a collection of untreated units that are unaffected by the intervention. For reach unit i, the observations on the outcome of interest span time periods $t = 1, ..., T$, where the observations prior to intervention span $t = 1, ..., T_0$, and $T_0 \leq T - 1$. Throughout, $y_{i,t}$ denotes the observed outcome of interest for unit i in period t.

Let $y_{1,t}^N$ be the (unobserved) outcome for the treated unit without intervention, and let $y_{1,t}^I$ be the outcome for the treated unit when it is subject to the intervention in periods $t > T_0$. As per convention, it is assumed that $y_{1,t}^N = y_{1,t}^I$ prior to intervention. The synthetic control method estimates $y_{1,t}^N$ using a weighted average of the units in the donor pool. Given a set of weights $\boldsymbol{w} = (w_2, ..., w_{N+1})$, the synthetic control estimator of $y_{1,t}^N$ is then $\hat{y}_{1,t}^N = \sum_{i=2}^{N+1} w_i y_{i,t}$. These weights are fixed, and therefore do not vary over time, and constrained to preclude over-fitting. The estimated effect of the intervention is then $y_{1,t}^I - \hat{y}_{1,t}^N$ for each period $t > T_0$.

The weights $\boldsymbol{w}$ are chosen using a set of matching variables.[32] For each i, there is a set of k pre-intervention characteristics contained in the vector $X_i = (x_{1,i}, ..., x_{h,i} ..., x_{k,i})'$. Note that by convention in the synthetic control literature (e.g. Abadie, 2021), the first subscript on x indexes the set of matching variables, while the second subscript indexes units. This differs to the subscripts on y, where the first indexes units, and the second indexes time.

The general framework allows substantial flexibility in specifying the set of matching variables. The set can contain covariates or predictors of the outcome of interest. For example, Abadie and Gardeazabal (2003) and Abadie et al. (2010) include pre-intervention time series averages of k different variables that are thought to be predictors of the outcome of interest in their applications. Matching variables can also include repeated observations of a given variable over time, thereby introducing a time series dimension to the elements of X_i. This includes using pre-intervention realizations of the outcomes $y_{i,t}$ as matching variables. For example, Abadie and Gardeazabal (2003) and Abadie et al. (2010) include pre-treatment outcomes. Meanwhile, Doudchenko and Imbens (2016) primarily focus on the case where only the time series of pre-intervention outcomes constitute the set of matching variables, such that $X_i = (y_{i,1}, \dots, y_{i,T_0})'$ (or equivalently, $x_{h,i} = y_{i,t}$ for $h = 1, \dots, k$, where $k = T_0$).

The $k \times N$ matrix $\boldsymbol{X}_0 = [X_2 \cdots X_{N+1}]$ collects the matching variables for the N untreated units. Weights $\boldsymbol{w}$ are then selected to minimize a measure of distance between the matching variables of the treated unit, X_1, and the weighted average of the matching variables of the donors, $\boldsymbol{X}_0\boldsymbol{w}$. Specifically, weights $w^* = (w_2^*, ..., w_{N+1}^*)$ are chosen to 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. Following Abadie and Gardeazabal (2003), Abadie et al. (2010) and Abadie et al. (2015), among others, $\boldsymbol{v}$ is selected to minimize the root mean square error (RMSE) between

[32] The term "matching variables" is introduced by Abadie et al. (2015). The variables are also called "predictors" or "covariates" in the extant literature.

the synthetic and realized outcomes of the treated unit over the pre-treatment period. This helps ensure that the time series of synthetic outcomes tracks realized outcomes of the treated unit prior to intervention. Then, the estimated counterfactual outcomes for the treated unit for periods $t = T_0 + 1, ..., T$ are $\hat{y}^N_{1,t} = \sum_{i=2}^{N+1} w^*_i y_{i,t}$.

Weights $\boldsymbol{w}$ that minimize (1) can found using standard quadratic programming solvers. To select $\boldsymbol{v}$ in the nested RMSE-minimization problem, we use Evolution Strategy with Covariance Matrix Adaptation (CMA-ES), which is a stochastic optimization algorithm for solving difficult optimization problems (Hansen, 2016). It exhibits strong invariance properties (Hansen et al., 2011), is robust to highly non-linear, non-quadratic, non-convex, non-smooth and/or noisy objective problems (Hansen, 2006), and can tackle ill-conditioned optimization problems (Jones, 2021).[33] It is considered a state of the art evolutionary optimizer (Li et al., 2020).[34] $\boldsymbol{v}$ is a fixed $k \times 1$ vector that does not vary over time.

In our application, outcomes and matching variables are logged prior to analysis. We employ a "hierarchical" restriction of the donor pool for each urban area based on Statistics New Zealand categories of the size of the commuting zone. Statistics New Zealand categorizes urban areas as either "metropolitan", "large", "medium" or "small", depending on size (see footnote 29). "Metropolitan" consists of six urban areas, "large" consists of eleven, and "medium" a further fourteen. The remainder are "small". Under hierarchical selection, major areas have their donor pool restricted to other metropolitan and large urban areas. This means that Auckland's donor pool incorporates the four other metropolitan areas (Hamilton, Tauranga, Wellington and Dunedin, since Christchurch is excluded), as well as nearby large urban areas such as Whangārei and Rotorua. For placebo tests (see section 4.3), large urban areas have their donor pool restricted to metropolitan, large and medium urban areas. Medium and small urban areas do not have their donor sets restricted. Figure 25 in the Appendix presents the location of the metropolitan and large urban areas, while Table 4 presents their key statistics. One of the robustness checks considers a donor pool that is not restricted by these size classifications.

There is an ongoing debate in the synthetic control literature regarding the appropriate choice of matching variables. Doudchenko and Imbens (2016) emphasize pre-treatment fit in outcomes as the relevant measure of the synthetic unit's performance, and thus downplay the role of covariates, describing them as playing a relatively minor role (see section 5.5). Abadie (2021) also emphasizes the importance of pre-treatment fit in outcomes, stating that "the ability of a synthetic control to reproduce the trajectory of the outcome variable for the treated unit over an extended period of time [...] provides an indication of low bias". Under this view, the set of matching variables should include the full time series of pre-intervention outcomes in order to minimize both pre-treatment loss

[33] Ill-conditioning refers to when there is a large change in the objective function in response to a small change in arguments. This is possible in the current application because the weights are selected via a quadratic programming problem that sets weights to zero on the majority of donor units.

[34] We adapt the Matlab version of the Synth package provided by Jens Hainmueller (available from `https://web.stanford.edu/~jhain/synthpage.html`) to incorporate CMA-ES minimization of nested RMSE objective function, using the cmaes.m matlab code provided by Nikolaus Hansen (available from `http://cma.gforge.inria.fr/cmaes.m`) CMA-ES generated reductions in the nested RMSE objective function. It also improved the RMSE of Hainmueller's synth STATA package, though the obtained weights for our baseline models were similar under both approaches.

and bias in the synthetic control estimator (Abadie et al., 2010). In accordance with this paradigm, theoretical research such as Doudchenko and Imbens (2016) and Ben-Michael et al. (2021) focus primarily on the case where the matching variables consist of pre-treatment outcomes. Our baseline empirical specification includes pre-treatment outcomes in the set of matching variables in order to maximize pre-treatment fit in outcomes.

However, when the full time series of pre-intervention outcomes is included in the set of matching variables, any additional covariates become irrelevant, because $\boldsymbol{v}$ is chosen to minimize the quadratic loss between synthetic and observed outcomes over the pre-intervention time period (Kaul et al., 2022). In other words, the optimal weights are invariant to the inclusion of covariates. Because any additional covariates would be redundant, our main empirical specification only includes time series of pre-intervention outcomes in the set of matching variables. This ensures that readers do not mistakenly think that covariates informed the selection of weights in our baseline model.

While matching on outcomes optimizes pre-treatment fit, and therefore mitigates bias in the synthetic control estimator in the view of Abadie (2021), a corresponding limitation is that the synthetic unit might not resemble the treated unit in terms of other variables related to the outcome of interest. In addition, Kaul et al. (2022) argue that the exclusion of covariates that have predictive power for the outcome of interest can bias the synthetic control estimator, which is another potential limitation of our baseline specification. They therefore advocate for the inclusion of covariates in the matching variables. This approach has the benefit of tilting the covariates of the synthetic unit towards those of the treated unit, so that the selected characteristics of the synthetic unit resemble those of the treated unit. However, the corresponding limitation is that pre-treatment fit in outcomes can be impaired, which can also be indicative of bias. To bridge this philosophical divide, we examine the extent to which our conclusions depend on the specification of the predictors by implementing both approaches. We consider this covariates approach as a robustness check in section 4.4.3, and include an array of variables associated with housing outcomes in the set of matching variables.

We also subtract the pre-treatment average from the time series of outcomes prior to implementation (Ferman and Pinto, 2021). This adjustment is equivalent to the (cross-sectional) fixed effects synthetic control specification discussed in Ben-Michael et al. (2021). We do this for two reasons. First, Abadie (2021) emphasizes that the validity of the synthetic control hinges on its ability to replicate the treated unit's outcome prior to the intervention. De-meaning the outcome variable can allow the comparison group to reproduce the changes in outcomes for the treated unit even if the level of the outcome variable cannot be reproduced (Abadie, 2021, pp. 411–412). As we show in the Appendix, this de-meaning normalization results in substantial reductions in pre-treatment RMSE, suggesting that it is useful in our application. This is due, in part, to Auckland exhibiting the near-lowest permitting rate among donors between 2009 and 2011: In 2009, its permitting rate of 2.40 permits per thousand residents is only larger than that of Dunedin; while in 2010, its permitting rate of 2.44 is only larger than that of Whanganui. Second, our method for identifying displacement effects is based on whether the intervention in Auckland has a clear and persistent impact on its selected donor units (see section 4.4.1). This requires the synthetic control method to satisfactorily fit pre-treatment outcomes in Auckland's donor units as well. One the selected donors for Auckland – Tauranga – has the highest permitting rate among donors over the 1991 to 2020 period (see figure 5 above), making it difficult for the synthetic control to match Tauranga's outcomes without de-meaning. Pre-treatment model fit for this and other donors is substantially improved when the de-meaning normalization is employed.[35] We add back the pre-treatment average to the synthetic and actual outcomes when presenting outcomes.[36]

4.2 Results and policy impacts

Table 1 exhibits the selected weights for the donor units. Our preferred empirical specification places a weight of 0.573 on Tauranga, 0.213 on Kāpiti Coast, 0.111 on Wellington, and 0.102 on Hamilton. Tauranga is a major urban area 150 km south east of Auckland (as the crow flies) with an estimated population of 156,666 within the urban area as of the 2018 census. Wellington is a major urban area located 800 km south of Auckland with a population of 422,427 in the urban area. It also contains the capital of the nation, Wellington City. Hamilton is another major urban area 140 km south of Auckland with an estimated population of 209,970. Finally, Kāpiti Coast is a large urban area 750 km south of Auckland with an estimated population of 46,839 in 2018. It is contiguous to the Wellington urban area, but constitutes its own commuting zone as approximately 70% of employed residents work within the urban area.

Figure 6 exhibits the actual and synthetic permitting rate (i.e., permits per thousand residents) for Auckland over the 1991 to 2023 period. The model fits well prior to intervention, apart from a period in the early 2000s, when the permitting rate exceeds its synthetic counterpart for four consecutive years. This period is characterized by unusually high levels of dwellings constructed in business areas and the central business district (see figure 27 in the Appendix), and may prove difficult for donors to match this construction boom. Regardless, prior to treatment, the maxi-

[35] Section 6.5.1 in the Appendix presents results for Auckland when the de-meaning normalization is not employed for the various empirical specifications considered, and shows that results are similar. .

[36] For dataset and replication files see Greenaway-McGrevy (2025a).

Table 1: Selected weights

Urban Area	Weight	Urban Area	Weight
Hamilton	0.102	Napier	0
Tauranga	0.573	Hastings	0
Wellington	0.111	Whanganui	0
Dunedin	0	Palmerston North	0
Whangārei	0	Kāpiti Coast	0.213
Rotorua	0	Nelson	0
Gisborne	0	Invercargill	0
New Plymouth	0		

mum absolute deviation between synthetic and actual is 2.8 in 2002, whereas the maximum post-treatment absolute deviation is 8.2 in 2022.[37] Also, the synthetic permitting rate permanently falls below the actual rate from 2014 onwards, prior to intervention, perhaps reflecting "policy leakage" of the SpHA-PAUP program (see section 2).

There is a notable divergence from 2016 onwards, when the reform is implemented, with permits per thousand residents growing very quickly, while its synthetic counterpart remains at pre-intervention levels. Within five years of the zoning reform, the permitting rate is more than double what they would have been in the absence of the policy. Permits per thousand residents reach 12.2 in 2021, while synthetic permits per thousand residents is 5.9. There is also a noticeable decrease in the synthetic permitting rate between 2021 and 2023, from 5.9 to 3.6. Over this period, the nation's central bank swiftly increased interest rates from record lows to combat emergent inflation, and the economy entered a technical recession in the first two quarters of 2023. However, there is still a mild increase in Auckland's permitting rate between 2021 and 2022, which increases from 12.2 permits per thousand residents to 12.7. The actual permitting rate only falls between 2022 and 2023. Nonetheless, the actual permitting rate for 2023 remains more than double the synthetic rate, suggesting that the zoning reform had a positive impact even in the impropitious macroeconomic environment.

Next we consider the impact of the policy on new building permits (as opposed to permits per thousand residents). To calculate the counterfactual change in permits, we multiply the synthetic permits per capita by population implied by synthetic population growth after the policy intervention. That is, synthetic permits are

$$\hat{c}_{1,t}^{N} = \hat{y}_{1,t}^{N} + \hat{\mu}_1 - \hat{p}_{1,t}^{*N} \tag{2}$$

where c denotes (log) permits, p denotes (log) population, $\hat{\mu}_1$ is the pre-treatment mean of outcomes (permits per thousand residents) for the treated unit, and

$$\hat{p}_{1,t}^{*N} = \hat{p}_{1,t}^{N} - \hat{p}_{1,T_0}^{N} + p_{1,T_0}^{N}$$

where $\hat{p}_{1,t}^{N} = \sum_{i=2}^{N} w_i p_{i,t}$.[38]

Figure 7 exhibits actual and synthetic permits. A total of 112,277 new dwelling permits were issued in the Auckland urban area between 2017 and 2023 (inclusive), while 60,105 new dwelling permits were issued in the synthetic Auckland.

The difference of 52,172 new dwelling permits is attributable to the policy intervention. Thus, 46.5% percent of all permits issued in the seven years subsequent to the zoning reform are due to the upzoning. Equivalently, the zoning reform increased new dwelling permits by 86.8% (= 0.465/(1–0.465)) over the seven years subsequent to the reform.

[37] Volatility in the time series over this period is substantial relative to other periods. Smoothing volatility from the time series results in better model fit prior to treatment. See section 4.4.5 below.

[38] We obtain very similar time series of synthetic permits when actual population $p_{1,t}$ is used in place of $\hat{p}_{1,t}^{*N}$ in (2) or when weights are applied directly to de-meaned permits, i.e. $\hat{c}_{1,t}^{N} = \sum_{i=2}^{N} w_i c_{i,t} + \hat{\mu}_{c,1}$, where $\hat{\mu}_{c,1}$ is the pre-treatment mean of permits for the treated unit.

Figure 6: Synthetic and actual permits per thousand residents

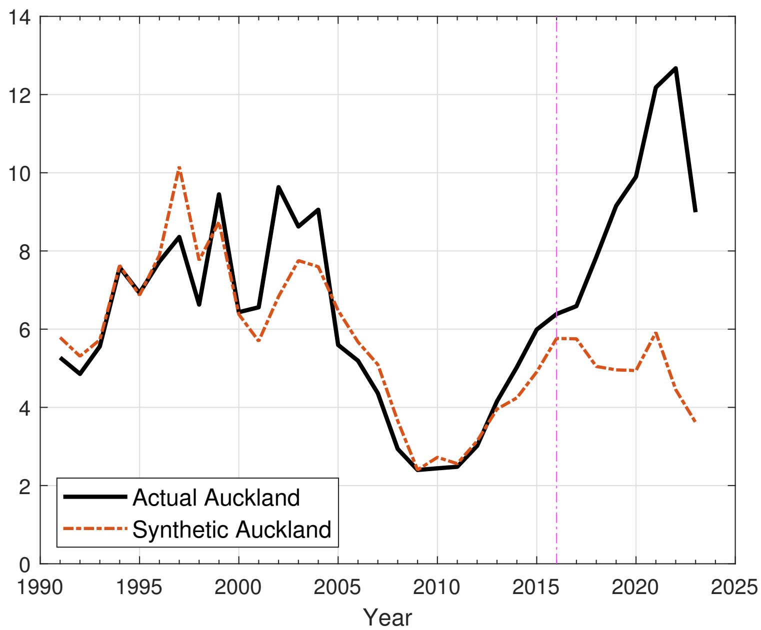
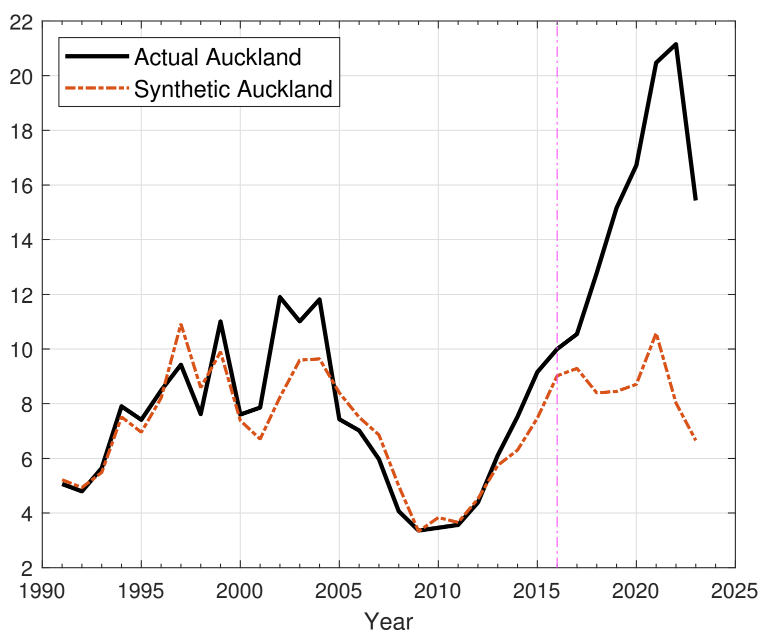


Figure 7: Synthetic and actual permits (thousands)



4.3 Inference

We run placebo interventions on the other urban areas to assess whether the decrease relative to the counterfactual is large. Figure 8 plots the difference between the actual outcomes of each donor and its synthetic control. Evidently there is a large increase in Auckland's prediction error over the post-intervention period, indicating that the zoning reform had a substantive positive impact.

However, many of the placebo runs exhibit a larger positive error than Auckland. To assess whether this is simply due to poor model fit, we construct RMSE ratios. Let

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

such that the RMSE in the post-intervention period is $R_i\left(T_0 + 1, T\right)$, and the RMSE in the pre-intervention period is $R_i\left(1, T_0\right)$. Following Abadie et al. (2010), we use the ratio of pre- to post-intervention RMSE as a basis for inference,

$$r_i = \frac{R_i\left(T_0 + 1, T\right)}{R_i\left(1, T_0\right)}$$

One drawback of the 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. For example, the relevant alternative hypothesis in our case is that zoning reform increased permits. Substantial increases in power can be obtained by testing for increases relative to the synthetic control, rather than differences (Abadie, 2021). To conduct a one-tailed test, we compute

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

where

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

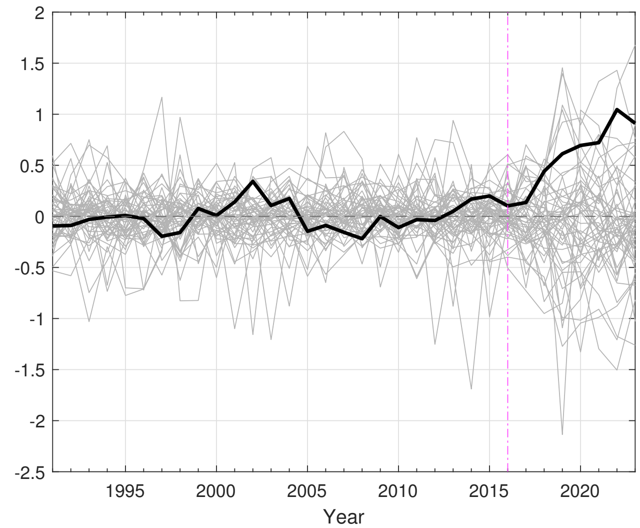
where $\lfloor x \rfloor = 0$ iff $x > 0$ and $\lfloor x \rfloor = x$ otherwise. We refer to this as the "Positive Error RMSE ratio", or PE-RMSE-R.

Figure 9 depicts the histogram of the ratios. Auckland has the largest PE-RMSE-R, meaning that if one were to assign the intervention at random, the probability of obtaining a ratio as large as Auckland's is 0.02 ($= 1/51$). We conclude that the increase in the permitting rate in Auckland is statistically significant at the five percent level.

4.4 Robustness checks

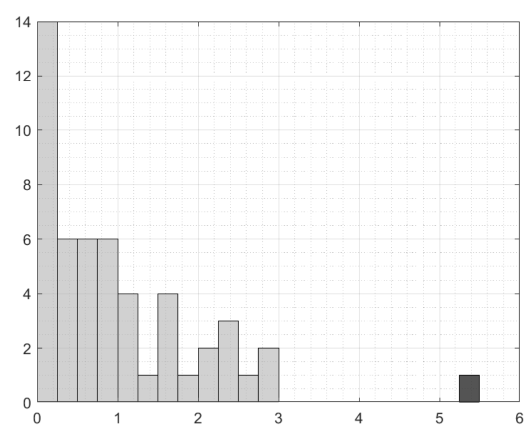
This subsection explores how sensitive our results are to changes in the our preferred empirical model.

Figure 8: Prediction errors



Notes: Difference between synthetic and actual outcomes for Auckland (black line) and placebos (grey line).

Figure 9: Positive-error RMSE ratios



Notes: Histogram of positive-error RMSE ratios for Auckland and placebo policy interventions. Auckland appears in black.

4.4.1 Spillover effects

In this subsection we investigate whether zoning reform in Auckland affected new dwelling permits in its selected donors. For example, the housing construction sector may shift capital and labor to Auckland from the selected donors, such that some of the new dwelling permits in Auckland displaced new dwelling permits in the donors (Tauranga, Kāpiti Coast, Wellington, or Hamilton). These "displacement effects" would manifest as a reduction in dwelling permits in the donors, causing the estimated treatment effect to be biased upwards because the difference between actual and synthetic outcomes in Auckland overstates the policy impact. It is also possible for the reform in Auckland to increase new dwelling permits in the selected donors if houses in Auckland that are removed for redevelopment are exported to the selected donors, as it is common for houses on elevated foundations to be relocated when a parcel is redeveloped. This positive spillover effect would bias estimated treatment effects downwards.

In this subsection we investigate whether there is evidence of displacement effects or positive spillovers from the donor units to Auckland. We are particularly concerned with displacement from Hamilton and Tauranga. Research by the New Zealand Treasury shows that the Far North, Whangārei, Waikato and Bay of Plenty regions received net migrants from Auckland in the time period immediately preceding the reform,[39] indicating that these locations comparatively proximate to Auckland are potentially locational substitutes. Tauranga and Hamilton are located in the Bay of Plenty and Waikato region, respectively.

Our strategy follows Maltman and Greenaway-McGrevy (2025). Displacement effects would manifest as the policy intervention in the treated unit having an opposite, negative impact on outcomes in the selected donor units. Meanwhile, positive spillovers would manifest as the intervention having a positive impact on the donor. We therefore construct synthetic controls for each donor using the Auckland reform as the intervention, and consider whether the synthetic control implies that the permitting rate would have been persistently higher or lower in the donor unit under the counterfactual of no reform. When constructing the counterfactual synthetic control for each urban area, we omit Auckland from the donor set since a weighting to Auckland will manifest as a large decrease by construction. We can then test whether the given donor was affected by the Auckland reforms using the rank permutation methods described above.

Figure 10 exhibits the actual and synthetic units. Neither Tauranga nor Hamilton exhibit a persistent negative or positive deviation from zero after the intervention, as would be expected if these areas were affected by displacement or positive spillovers, respectively. This means that their respective synthetic controls fit reasonably well during the post intervention period, and, in particular, there is no persistent reduction in the permitting rate relative to the synthetic control after the reform in Auckland. Figure 11 exhibits the donors' RMSE-ratios, showing that the RMSE ratios of both Tauranga and Hamilton are far from the right tail of the distribution, indicating lack of statistical significance. Based on this, we conclude that there is little evidence of displacement from either Hamilton or Tauranga to Auckland.

[39] See https://www.treasury.govt.nz/publications/ap/ap-18-02 [accessed 5 September 2023]

Interestingly, there is a persistent increase in Wellington's prediction error after the intervention in Auckland, meaning that the synthetic permitting rate is less than actual over the post-intervention period. Hutt City (a council within the Wellington urban area) notified and implemented a sequence of zoning reforms from 2017 onwards (see section 3.1 and footnote 23 for details), and thus the sustained deviation in the prediction error from 2018 until the end of the sample may be due to this policy, rather than a positive spillover from Auckland. We note that the inclusion of Wellington in the donor pool would cause the treatment effect estimate to be too conservative. However, Wellington's RMSE ratio is far from the left hand tail of the distribution, indicating no statistical significance under the rank permutation approach.

Kāpiti Coast exhibits persistent negative prediction error over the post-treatment period, although it emerges two years prior to the intervention. Unlike Tauranga and Hamilton, Kāpiti Coast is comparatively distant to Auckland, and there is little other evidence to suggest that it is a locational substitute. Kāpiti Coast is however adjacent to Wellington, and thus more likely to be a locational substitute for the city. Displacement to Wellington, in part brought about by the Hutt City upzoning, might account for the sustained decrease in Kāpiti Coast. In any event, its RMSE ratio is far from the right tail of the distribution, indicating no statistical significance.

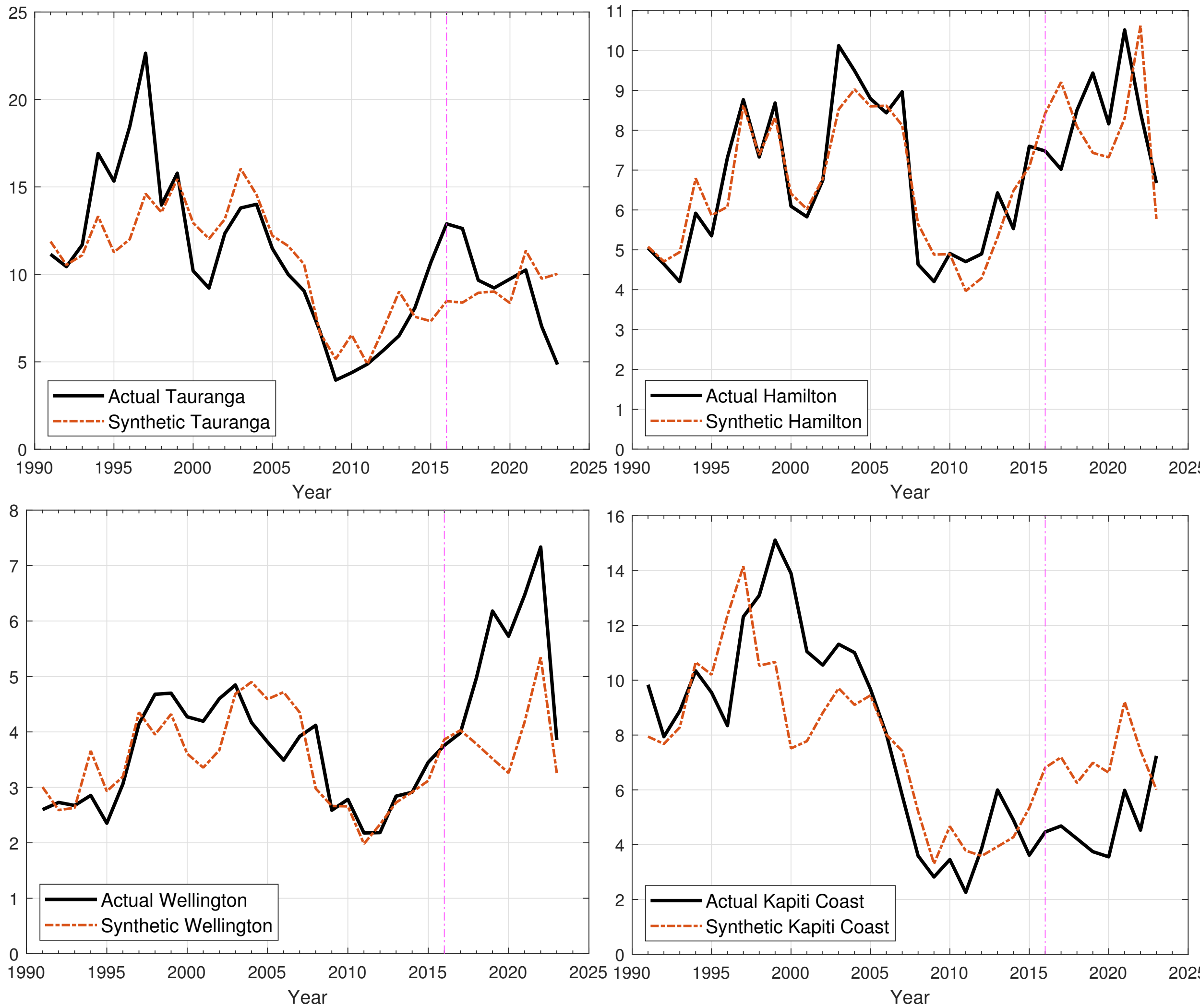
In summary, we find no statistical support for spillovers – positive or negative. Testing only for displacement effects (i.e. negative spillovers) using a "negative error" RMSE ratio analogous to (3) yields the same conclusion. Despite the lack of evidence of spillovers, we consider what happens to Auckland's synthetic unit when the donors are removed from the donor set, in case they are having a large effect on the findings. Given our aforementioned concerns about locational substitutability, we first consider Hamilton and Tauranga, before moving on to Wellington and Kāpiti Coast.

Omitting Tauranga and Hamilton. The left panel of figures 12 and 13 present Auckland's synthetic permitting rates and number of permits when Tauranga and Hamilton are omitted from Auckland's donor set. Kāpiti Coast, Wellington, Nelson and Dunedin receive weights of 0.527, 0.334, 0.109 and 0.029 in the re-estimated synthetic control.

Estimated policy impacts are larger because synthetic permits per thousand residents are lower than when Hamilton and Tauranga are included in the donor set. The synthetic permitting rate is substantially lower than in the baseline specification until 2021, when it reaches 6.3 permits per thousand residents – a little more than half the actual permitting rate of 12.2. The left panel of figure 14 exhibits the PE-RMSE-Rs. Auckland's PE-RMSE-R ranks second, indicating the difference between the actual and synthetic permitting rates are statistically significant at the five percent level . Of the 112,277 permits issued in Auckland since 2016, 52,352 (or 46.6%) are attributed to the reform.

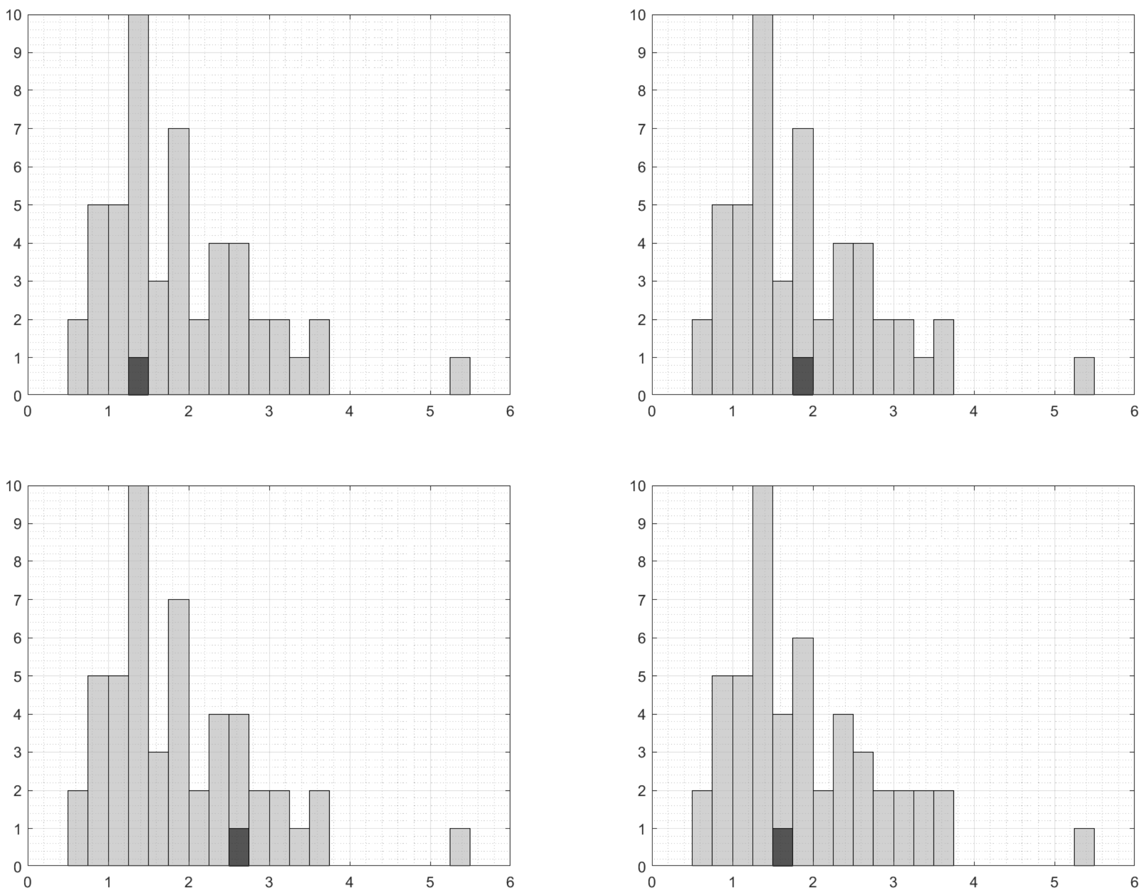
Omitting Wellington and Kāpiti Coast. To guard against the possibility that Wellington and Kāpiti Coast are unsuitable donors, we also present results when these urban areas are omitted from Auckland's donor pool. Given their locational proximity to each other, we remove both donors from the pool since the Hutt City reforms may have displaced construction in Kāpiti Coast,

Figure 10: Spillover effects: Synthetic controls for donors



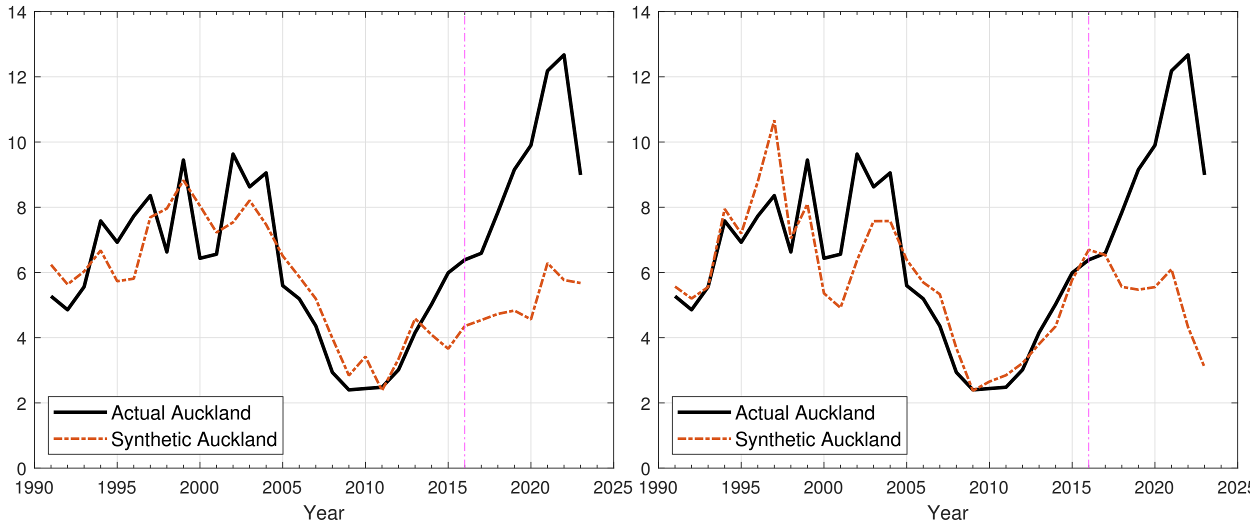
Notes: Synthetic and actual permits per thousand residents for Tauranga (top left), Hamilton (top right), Wellington (bottom left) and Kāpiti Coast (bottom right). Auckland omitted from donor set.

Figure 11: Spillover effects: RMSE ratios for donors



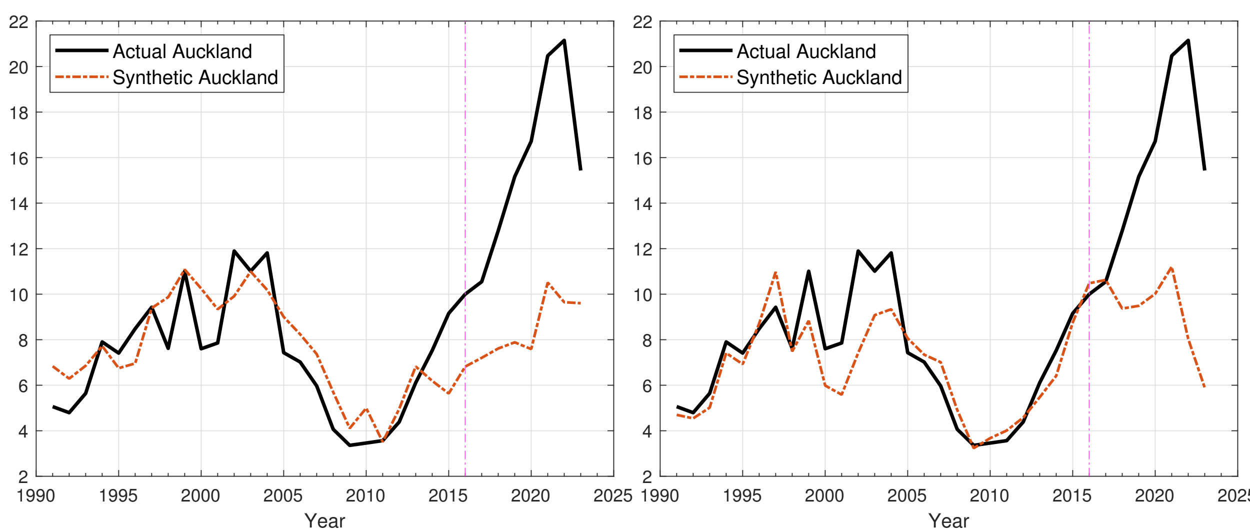
Notes: RMSE ratios for Tauranga (top left), Hamilton (top right), Wellington (bottom left) and Kāpiti Coast (bottom right). Auckland omitted from donor set. Each city is in black.

Figure 12: Synthetic and actual permits per thousand residents, spillover robustness check



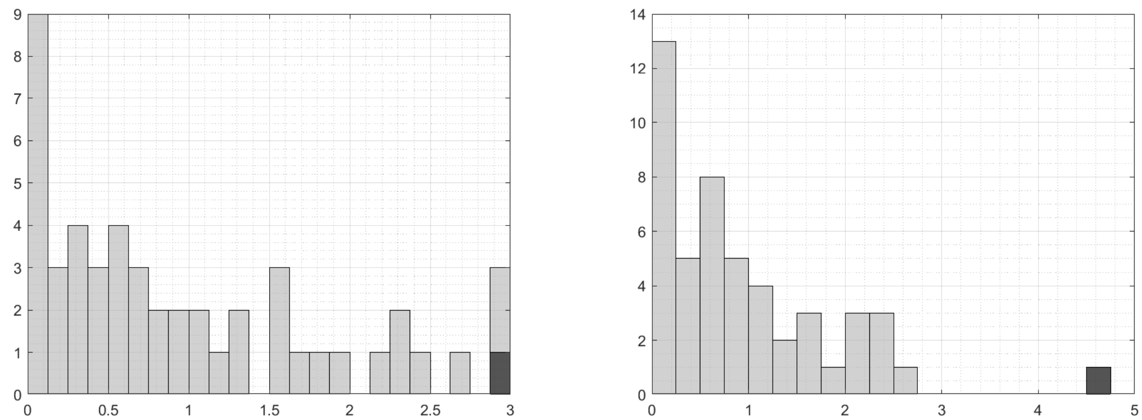
Notes: Left: Hamilton and Tauranga excluded from the donor pool. Right: Wellington and Kāpiti Coast excluded.

Figure 13: Synthetic and actual permits (thousands), spillover robustness check



Notes: Left: Hamilton and Tauranga excluded from the donor pool. Right: Wellington and Kāpiti Coast excluded.

Figure 14: Positive error RMSE ratios, spillover robustness check



Notes: Left: Hamilton and Tauranga excluded from the donor pool. Right: Wellington and Kāpiti Coast excluded.

causing its permitting rate to also have been affected by a zoning reform similar to Auckland's. Tauranga, Hamilton and Palmerston North receive weights of 0.776, 0.205 and 0.018.Auckland's synthetic permitting rate is 6.1 in 2021, falling to 3.1 by 2023. The right panels of figures 12 and 13 present results when Wellington and Kāpiti Coast are omitted. Auckland's PE-RMSE-R ranks first, indicating the difference between the actual and synthetic permitting rates is statistically significant. Of the 112,277 permits issued since 2016, 47,543 (42.3%) are attributed to the policy.

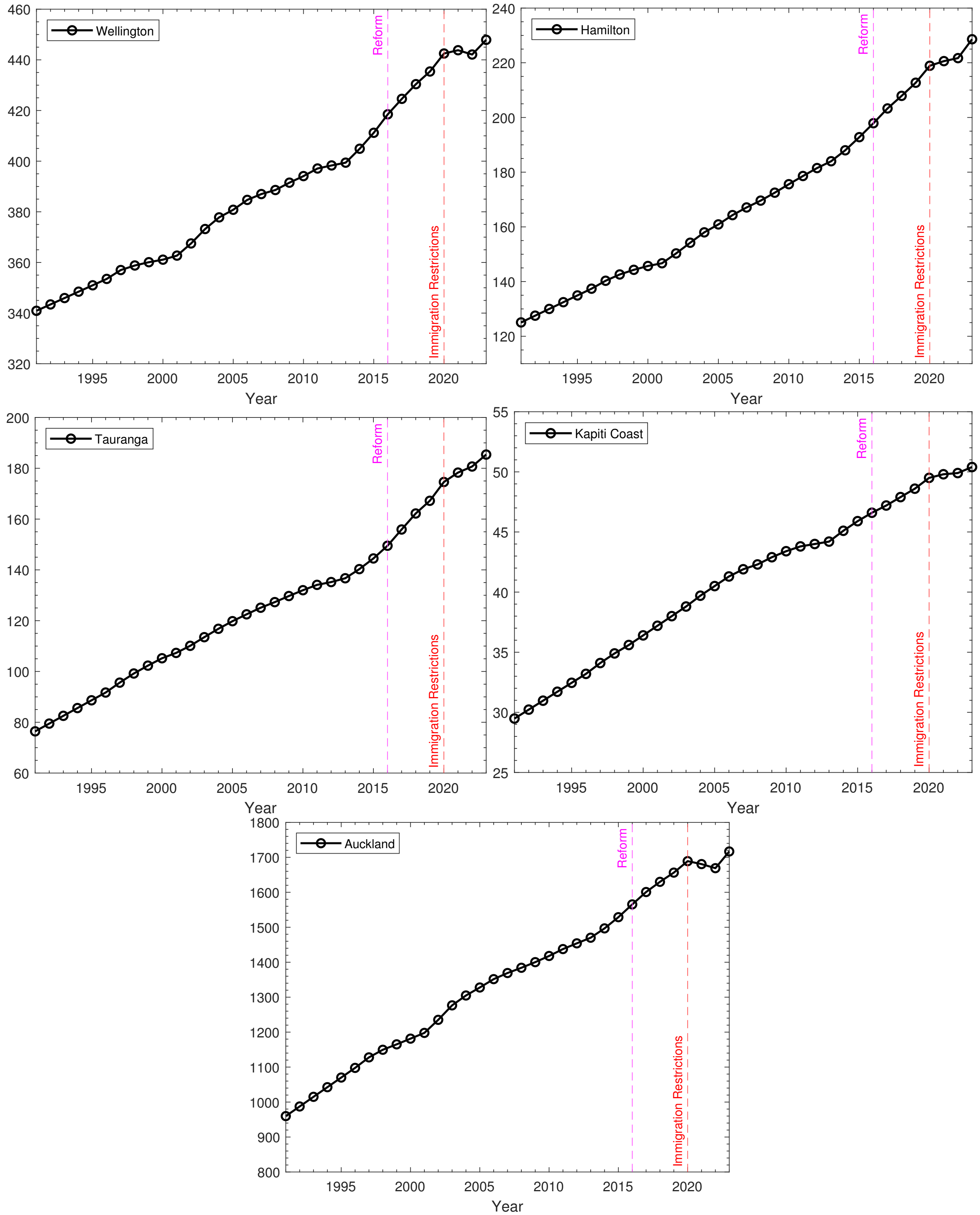
Based on these results, our view is that displacement effects, if present, are negligible. At most, the removal of Wellington and Kāpiti Coast due to potential concerns about their suitability as donors reduces the proportion on permits attributable to the reforms to 42.3%, and there still remains a near doubling of the permitting rate within five years.

Our view is further reinforced by observed trends in population growth in each urban area's population after the reforms. Displacement effects would also manifest as a reduction in population in the donor units, as households that chose to locate in Auckland after the reform would have otherwise chosen to locate in one of the selected donor units under the counterfactual of no zoning reform. Because population growth is typically highly persistent, a clear reduction in the trend rate of growth in donor units after the reform would be consistent with displacement of population.

We plot Statistics New Zealand estimates of the resident populations of the selected donor cities in figure 15. We include Auckland for comparison. In all four donors, there is a discrete increase in the trend rate of population growth in 2013, reflecting higher national immigration rates from 2013 onwards.[40] The higher rate of population growth is maintained until 2020, when the COVID-19 pandemic begins, and the New Zealand government imposes immigration restrictions. There is

[40]Between the 2013 and 2018 censuses, net migration increased by 339% relative to the five years prior to 2013. See https://www.stats.govt.nz/information-releases/2018-census-population-and-dwelling-counts#:~:text=2018%20Census%20data%20will%20be,the%202013%20Census%20(4%2C242%2C048). [accessed 5 September 2023].

Figure 15: Population of Auckland and donors, 1991 to 2023



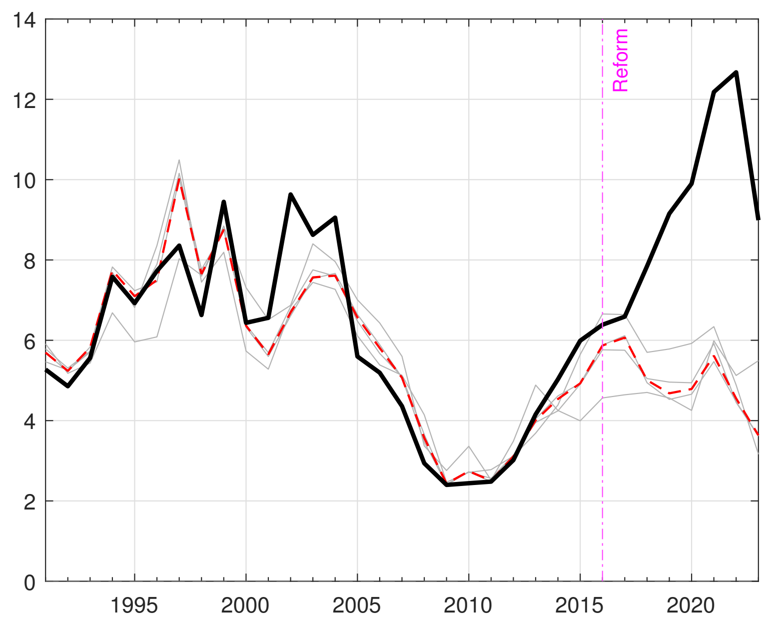
Source: Statistics New Zealand. Estimated usually resident population in thousands.

little, if any, discernible change in the trends in the years immediately after the zoning reform. In particular, there is no discernible reduction in the trend rate of population growth in the donor units until 2020 – when Auckland experiences an even larger reduction in trend population growth. We conclude there is no reduction in population growth in the selected donor units that is consistent with a displacement effect.

4.4.2 Leave-one-out

Under the leave-one-out robustness check, the selected donors are iteratively removed from the sample while the procedure is repeated. The procedure provides an assessment of the extent to which the synthetic control may be dependent on any single given donor unit (Abadie et al., 2010).

Figure 16: Synthetic and actual permits per thousand residents, leave-one-out robustness check



Notes: Leave-one-out replications in grey. The synthetic control for the full sample is the red dashed line.

Figure 16 exhibits the full-sample synthetic control (red dashed line) alongside the four other leave-one-out synthetic controls (grey lines). The synthetic controls follow a common trend over both the pre- and post- sample period, indicating that the results are not that dependent on any single urban area being included in the donor set. Auckland's PE-RMSE-R ranks first in all four of the LOO replications.

4.4.3 Alternative empirical specifications

We consider other variations to our baseline model as robustness checks, including a covariate set of matching variables, an earlier treatment date, and non-hierarchical selection of donor units (so that all urban areas in NZ are potential donors). The various permutations of these different specification choices results in a total of eight different models (including our baseline specification presented in section 4.2). We describe the different permutations of the empirical design before summarizing estimated policy impacts.

Covariate matching variables. Kaul et al. (2022) argue that the exclusion of covariates potentially biases the SC estimator, particularly if the covariates have predictive power for the outcomes of interest. They recommend the inclusion of some pre-treatment outcomes along with covariates, as well as robustness checks to examine how sensitive the findings are to changes in empirical specifications.

We therefore introduce covariates related to housing outcomes to the set of matching variables. We include population growth, household income growth, and dwellings growth. Population growth is the log difference of the urban area's population in census years. Censuses occur in 1991, 1996, 2001, 2006, and 2013 in the pre-reform period of the sample. Dwellings growth is the log difference in the number of occupied dwellings in the urban area between censuses . Household income growth is the log difference in median household income (from all sources) between censuses. We have data for the 2001, 2006 and 2013 censuses, as household income data by urban area for earlier census years is unavailable. We also limit the number of outcome variable observations, permits per thousand residents, to observations in census years (i.e. 1991, 1996, 2001, 2006, 2013). Limiting the number of pre-treatment outcomes ensures the other covariates can affect the selected weights (Kaul et al., 2022).

Table 2 exhibits Auckland's matching variables and those of synthetic Auckland when the treatment date is 2016 and hierarchical donor selection is employed. We include the average of the donor pool for comparison. Population growth is matched well, meaning that the synthetic unit resembles Auckland in terms of population growth between censuses. This is reassuring, because population growth is a key driver of housing demand, and Auckland has exhibited far greater population growth than the average urban area. Household income growth is matched reasonably well, although there is less variation between urban areas. Meanwhile, dwellings growth is consistently lower in Auckland than its synthetic counterpart. Because the inner loop of the synthetic control method minimizes RMSE prior to the intervention, these findings suggest that population growth has strong predictive power for Auckland's permitting rates prior to the reform, while dwellings growth does not.

Nonetheless, overstatement of dwelling growth by the synthetic unit is a limitation that may bias the estimated treatment effects.[41] This may reflect regional differences in preferences over family sizes that is not easily captured by the synthetic unit. Auckland is more ethnically diverse than the rest of the country, and has a large and growing share of people with Polynesian and Asian heritage. Polynesian people typically have more children after controlling for other demographic

[41] Matching on dwelling growth is significantly improved when the Ferman and Pinto (2021) de-meaning procedure is not implemented. Results available upon request. Counterfactual permits per thousand residents are similar to when the de-meaning procedure is implemented. See section 6.5.1 in the Appendix.

factors (Urale et al., 2019), and both Polynesian and Asian adults cohabitate with parents at substantially higher rates than their European counterparts (Jamieson et al., 2018). Under this view, estimated treatment effects are unlikely to be biased, as less dwelling growth in Auckland compared to its synthetic counterpart does not reflect a greater imbalance between supply and demand for housing. On the other hand, if it does reflect a larger imbalance, estimated treatment effects could be biased downwards, because the synthetic unit consists of cities where housing supply persistently kept better pace with demand prior to treatment. If housing supply continued to keep pace with demand in the post-treatment period, the synthetic unit would overstate new dwelling construction.

Earlier treatment date. We set the treatment date to 2013, since the Auckland Housing Accord allowed developers to build to the relaxed LURs of the Proposed AUP between September 2013 and November 2016 (see section 2).

Unrestricted selection of donor units. Finally, we consider non-hierarchical selection of donor units, such that Auckland's synthetic unit is constructed from all urban areas, not just those classified as "metropolitan" and "large". Christchurch continues to be omitted from the donor pool, while Warkworth is also omitted since it is subject to the same upzoning treatment (see Section 3 above).

Results. Section 6.5 in the Appendix presents the results.

Figure 29 exhibits the synthetic and actual permits per thousand residents under the various permutations. Estimated policy impacts are broadly robust to the various permutations. Post-intervention synthetic outcomes are broadly similar when 2016 is the treatment date, regardless of whether hierarchical or non-hierarchical selection and outcomes or covariate matching is employed. However, when 2013 is the treatment date, there generally is much less of an increase in the synthetic permitting rate compared to the 2016 treatment date, resulting in larger estimated policy impacts. Ideally, counterfactual outcomes should be invariant to an earlier treatment date. However, as discussed in section 2 above, the AUP might have had an impact from October 2013 onwards, due to the Auckland Housing Accord density bonus program. Thus to the extent that the differential results under the 2013 intervention date are a cause for concern, our baseline estimates based on the 2016 date are likely to be too conservative. As illustrated 4.4.4, backdating the intervention to be even earlier than 2013 yields similar results to when 2013 is the treatment date.

Table 5 shows that weights are broadly similar across the different permutations, with Tauranga and Kāpiti Coast featuring prominently in all specifications. Together, these two urban areas account for between approximately 75 to 83% of the weights across all specifications. When 2013 is the treatment date, Kāpiti Coast receives a larger weight, and Tauranga a smaller weight. This shift in relative weights away from Tauranga results in the lower synthetic permitting rate over the post-treatment period, as Tauranga has exhibited a persistently higher permitting rate than most other urban areas. The remaining 25 to 17% of weights vary between specifications. Hamilton

Table 2: Matched covariates

Variable	Auckland	Synthetic Auckland	Average of donors
Population growth, 2006 to 2013	0.091	0.093	0.052
Population growth, 2001 to 2006	0.123	0.120	0.064
Population growth, 1996 to 2001	0.076	0.110	0.013
Population growth, 1991 to 1996	0.134	0.142	0.066
Dwellings growth, 2006 to 2013	0.073	0.091	0.061
Dwellings growth, 2001 to 2006	0.108	0.123	0.068
Dwellings growth, 1996 to 2001	0.101	0.143	0.056
Dwellings growth, 1991 to 1996	0.103	0.146	0.075
Household income growth, 2006 to 2013	0.188	0.211	0.208
Household income growth, 2001 to 2006	0.255	0.272	0.267

Notes: Matching variables include permits per thousand residents in census years. Growth rates are log differences. Average of all units in the donor set presented for comparison.

features under hierarchical selection, but is replaced by medium and small urban areas under non-hierarchical selection. Under non-hierarchical selection and covariates matching, Wellington is likewise replaced by medium and small urban areas.

Figure 30 exhibits the synthetic and actual permits. When 2016 is used as the intervention date, estimates of the permits attributable to the reform range between 51,324 to 54,297, or 45.7 to 48.4% of all permits issued. When 2013 is the intervention date, between 66,031 and 70,273 permits are estimated to be attributable to the reforms, corresponding to between 47.5 and 50.5% of the 138,959 permits issued between 2014 and 2023, inclusive.

Because estimated policy impacts are broadly similar across specifications, the moderate differences in weights between alternative specifications further corroborate that policy effects are robust, since impacts are similar despite changes to the donor set and matching variables. As noted by Abadie (2021) (p. 415), the main conclusions of an empirical study should display some level of robustness with respect to changes in the study design, including the choice of units in the donor pool and the choice of matching variables. These alternative specifications show that our findings are indeed robust to such changes in study design.

4.4.4 Backdated intervention

It is feasible that the zoning reform affected developer behavior prior to the zoning change becoming operative in 2016. For example, developers may have delayed projects until after the new rules applied. In section 4.4.3, we use 2013 as the treatment date to account for the potential for developers to build to the relaxed regulations of the PAUP, finding that estimated policy impacts are generally larger than when 2016 is used as the treatment date. In this subsection, we backdate the intervention further, to 2010, which is when the various municipalities in the region were amalgamated to form Auckland Council, but two years before the strategic spatial plan called for more compact development (see Section 2).

Figure 17 exhibits synthetic and actual permits per thousand residents with the 2010 treatment date. Kāpiti Coast, Tauranga,Hastings and Wellington receive weights of 0.480, 0.398, 0.104 and 0.018, respectively. The synthetic unit captures the mid-2010 downturn well, but does not capture much of the subsequent recovery.

This robustness check demonstrates two things. First, the post-reform construction boom cannot be explained by frequently observed empirical regularities such as regression to the mean or cyclicality. Second, synthetic Auckland exhibits a much smaller construction boom than actual Auckland between 2010 and 2021. Synthetic permits per capita are closer to that obtained when 2013 is used as the intervention date.

4.4.5 Smoothed time series

Auckland's permits per thousand residents time series is noticeably more volatile from the mid 90s to mid 2000s (see Figure 1). This period is characterized by a construction boom in apartments in the CBD (see figure 27 in the Appendix). Multi-storey apartment construction typically requires substantially higher cost outlays, and thus can be expected to be more sensitive to macroeconomic and local conditions. This will manifest as volatility in apartment building permits. Individual projects frequently involve more than one hundred units, which means that individual projects have a more substantial impact on aggregate permits than the typical residential project.

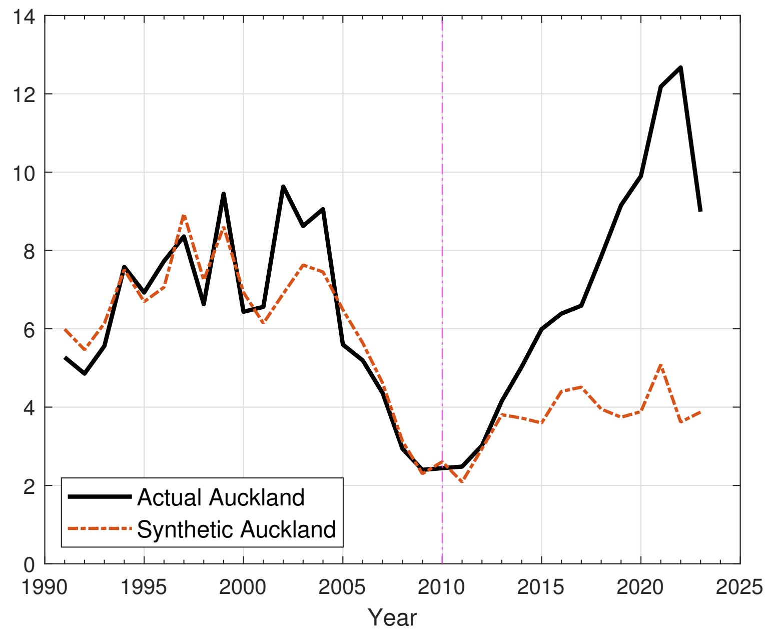
This volatility can be problematic if the synthetic control method places too much weight on sudden jumps in the outcome variable. Abadie (2021) recommends averaging the outcome to smooth out volatility. Thus we repeat the synthetic control exercise, using a centered 3- year moving average on permits per thousand residents. Figure 18 exhibits synthetic and actual outcomes.

Tauranga receives a weight of 0.543, Kāpiti Coast receives 0.234, Wellington receives 0.130, and Hamilton receives 0.092. These weights are very similar to the baseline specification, and suggest that volatility in the outcome times series was not disproportionately affecting the selected weights. In 2021, when smoothed permits per thousand residents peaks at 11.58, the smoothed synthetic rate is 5.16. The synthetic counterfactual implies that 51,538 additional permits are generated because of the policy.

4.4.6 Territorial Authorities

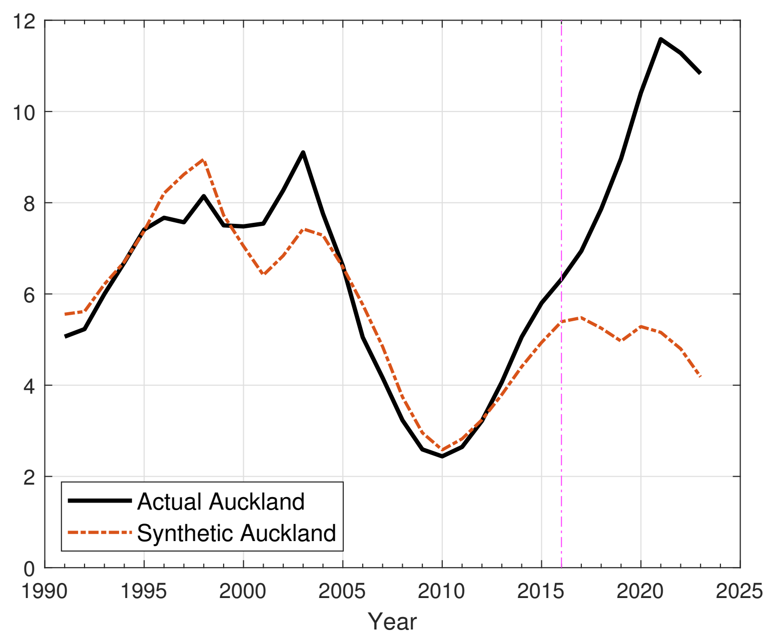
In this section we consider Territorial Authorities (TAs) rather than urban areas (UAs, which are analogous to commuting zones) as the geographic unit of analysis. TAs represent administrative divisions, whereas commuting zones are based on economic activity and are spatial analogues of labour markets. TAs and commuting zones often overlap, and thus constitute different geographic units. The Auckland commuting zone lies almost exclusively within the Auckland TA, with a small proportion of the commuting zone extending into the TA to the south of the Auckland

Figure 17: Synthetic and actual permits per thousand residents, backdated intervention



Notes: vertical dashed line denotes the intervention date.

Figure 18: Synthetic and actual permits per thousand residents, smoothed time series



Notes: 3-year moving averages of permits per thousand residents.

region. However, many other commuting zones intersect several TAs. For example, the Wellington commuting zone spans five TAs: Wellington City, Upper Hutt City, Hutt City, Porirua City and South Wairarapa District. The TA data are annual and span 1996 to 2024, and there are sixty-four TAs in our sample, of which fifteen predominantly urban TAs constitute Auckland's donor pool under hierarchical selection (see section 4.1).[42]

Despite the difference in geographic units, results are very similar to findings based on commuting zones. Tauranga City, Kāpiti Coast District, Hamilton City and Wellington City receive weights 0.647, 0.215, 0.021 and 0.031. Palmerston North City and Dunedin City make up the remaining 0.060 and 0.026, respectively. The actual permitting rate peaks at 12.57 in 2022, while the synthetic rate reaches only 4.02 permits per thousand residents. Auckland's PE-RMSE-R ranks first among the sixty-four TAs in the donor set. Meanwhile, 62,401

of the 126,796 permits (or 49.2%) issued in the Auckland administrative region between 2017 and 2024 are attributed to the reform. Thus, when TAs are used as the geographic units, Auckland's widespread upzoning doubled the number of new dwelling permits issued over the subsequent eight years.

4.4.7 Including Australia in the donor set

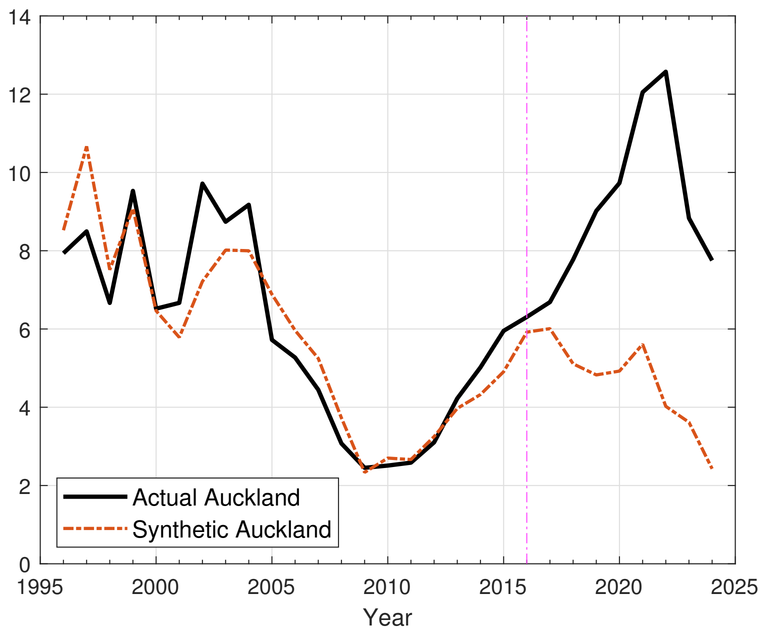
New Zealand is economically and socially integrated with Australia. The two countries share a comprehensive trade agreement (the Australia-New Zealand Closer Economic Relations Trade Agreement) and allow the free movement of workers across their border under the 1973 Trans Tasman Travel Arrangement. Australian regions may therefore provide suitable donor units for Auckland in the synthetic control procedure.

In this subsection we add Australian regions to the donor pool and repeat the analysis. While state data on permits and population for the five largest Australian states are available from the Australian Bureau of Statistics over the time period of our analysis, city-level data are only available from 2002 onwards.[43] However, as illustrated in figure 28 in the Appendix, the patterns of cyclicality and long-term trends in each state closely resemble those in their respective capital cities, suggesting that state time series on permits per thousand residents provide a reasonable approximation to city-level time series that are unavailable over the entire period.

[42] Most TAs are designated as either a "city" or a "district" by Statistics New Zealand. We designate each TA as either (predominantly) urban or rural based on whether the TA has a "city" (urban) or "district" (rural) designation, but including districts that are centered on a "large" FUA as urban when a corresponding "city" designated TA is lacking. This results in Whangārei District, Hamilton City, Tauranga City, Rotorua District, Napier City, New Plymouth District, Whanganui District, Palmerston North City, Kāpiti Coast District, Porirua City, Upper Hutt City, Lower Hutt City, Wellington City, Nelson City, Christchurch City, Dunedin City, and Invercargill City comprising the set of urban TAs. We remove Christchurch City from the donor pool due to the 2011 earthquake (see section 4.1), and Lower Hutt City because it pursued a sequence of upzonings beginning in 2017 (Maltman and Greenaway-McGrevy, 2025). Under hierarchical donor selection, the donor pool for urban TAs (including Auckland) are restricted to other urban TAs, while rural TAs can draw on urban and rural TAs as donors. Estimated policy effects are of a similar magnitude when non-hierarchical selection is employed (for this exercise we exclude the Chatham Islands, an island chain far offshore from mainland New Zealand, from the donor pool).

[43] Australian state capital city data on new residential dwelling approvals are available from July 2001, while annual population data are available from 2001.

Figure 19: Synthetic and actual permits per thousand residents, Territorial Authorities



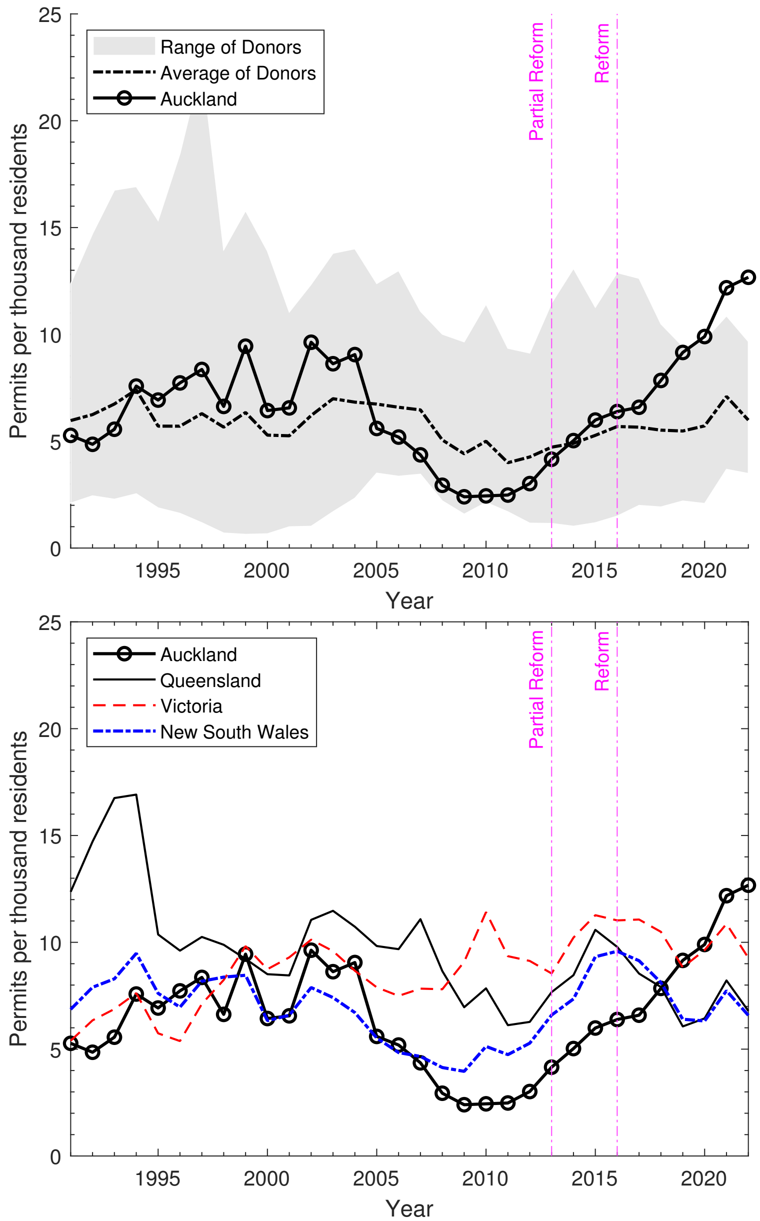
State data. We include the Australian states of New South Wales (NSW), Victoria, Queensland, South Australia, and Western Australia in the donor pool, as data for these five states are publicly available from the Australian Bureau of Statistics over the time period of analysis. Figure 20 exhibits permits per thousand residents in Auckland, the expanded donor pool, and the three largest Australian states.

The inclusion of the five Australian states in the donor pool has a negligible impact on our results. NSW receives a weight of 0.112 and Victoria receives a weight of 0.051, while Hamilton, Tauranga and Kāpiti Coast receive weights of 0.085, 0.506 and 0.247, respectively. Figure 21 exhibits synthetic and actual permits per thousand residents. The synthetic permitting rate is 4.12 in 2022, approximately a third of the actual rate of 12.67. Of the 96,842 permits issued in Auckland between 2016 and 2022, 46,553 (48.1%) are attributed to the reform, and Auckland's PE-RMSE-R ranks first out of sixty placebo runs (not depicted).

Figure 20 illustrates why the Australian states do not receive substantial weights. There are few similarities between Auckland and the Australian states. Auckland exhibits some comparability to NSW and Victoria from the early 1990s through to the early 2000s. Thereafter there is a decrease in NSW and Auckland, while Victoria continues on a mild upward trend. NSW begins its downturn in 2001, and recovers from 2009 onwards. Auckland's downturn begins in 2003 and lasts until 2011, but its downturn is significantly deeper, reaching a low of two-and-one-half permits per thousand residents between 2009 and 2011.[44] Whereas Auckland and NSW exhibited similar levels in the 1990s, from 2008 onwards there is a noticeable level shift, with Auckland consistently lower than

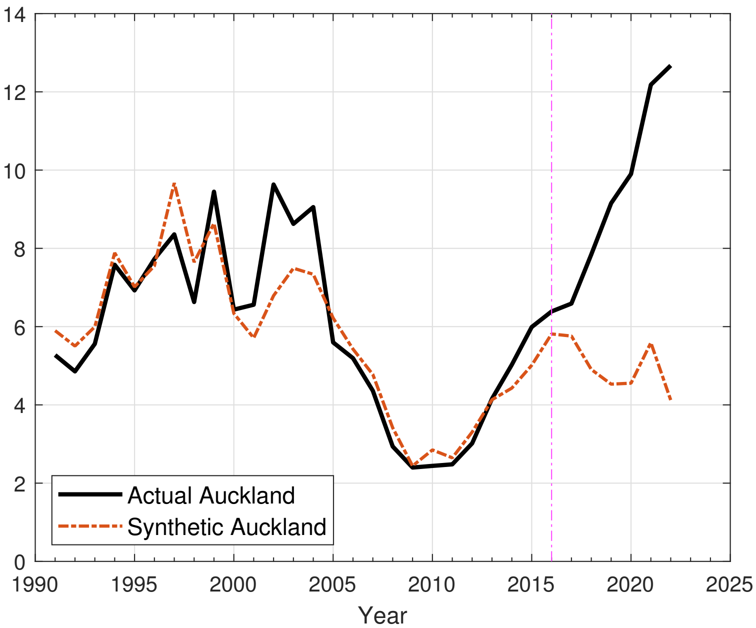
[44]Lagging the Australian states by two years does not result is in any substantive changes to the synthetic unit. NSW is no longer selected, and Wellington is selected. 44,854 permits are attributed to the reform, and synthetic permits per thousand residents is 4.25 in 2022.

Figure 20: Permits per thousand residents, Australian states included in donor pool, 1991 to 2022



Source: Author's calculations based on Statistics New Zealand and Australian Bureau of Statistics data. Notes: Average of donors taken across all urban areas in the donor pool. Shaded region denotes the range between the minimum and maximum permits per thousand residents among the donor pool. Donor pool includes the states of New South Wales, Victoria, Queensland, South Australia and Western Australia.

Figure 21: Synthetic and actual permits per thousand residents, Australian states included in donor pool



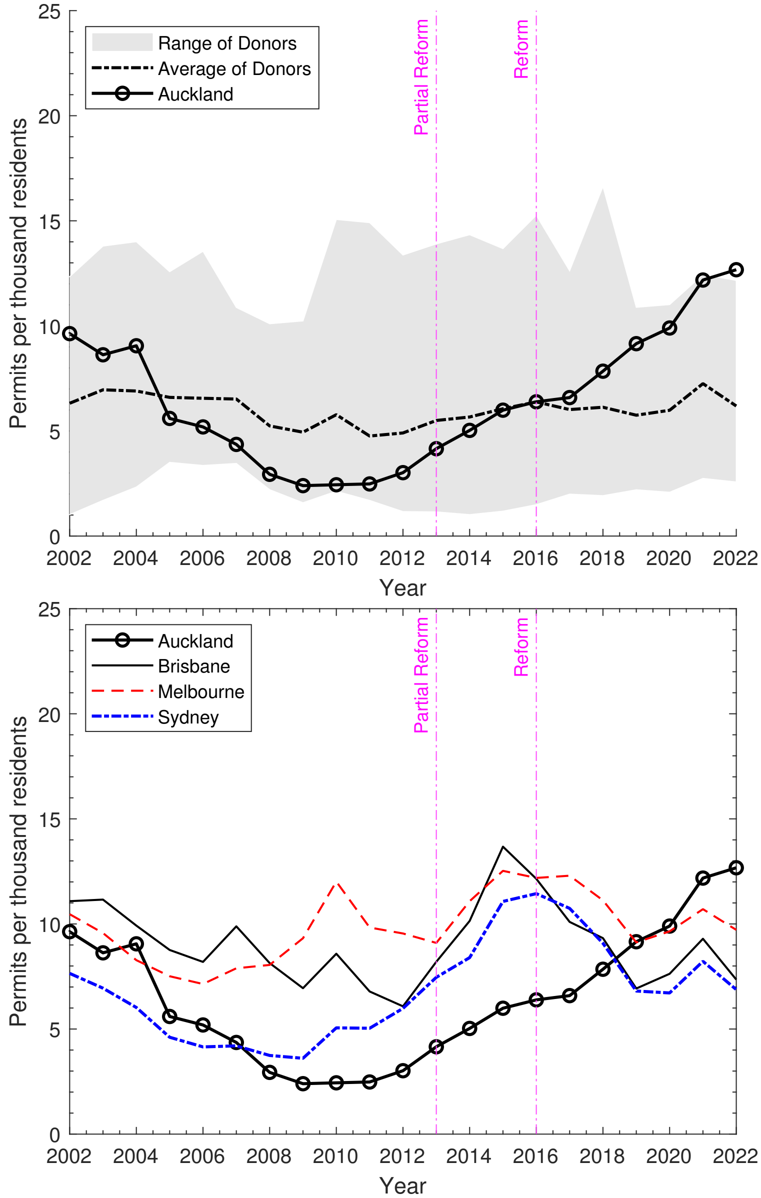
Notes: Donor pool includes New South Wales, Victoria, Queensland, South Australia and Western Australia.

NSW from that point on until 2018, at which point Auckland exceeds NSW. Whereas NSW peaks in 2016, Auckland continuously increases between 2011 and 2022. By 2022, permits per thousand residents in NSW have fallen to 6.6, approximately half of the permitting rate of 12.7 in Auckland.

City data. We also run the analysis with the Australian city data instead of state data. We are able to include a total of eight state capital cities for which permit data are available from the Australian Bureau of Statistics: Sydney, Melbourne, Brisbane, Adelaide, Perth, Hobart, Darwin, and the Australian Capital Territory (ACT). The sample period must be shortened to 2002 to 2022 to accommodate the Australian cities. Figure 22 shows that between 2009 and 2022, Auckland's permitting rate transitions from one of the lowest in the donor pool to the highest.

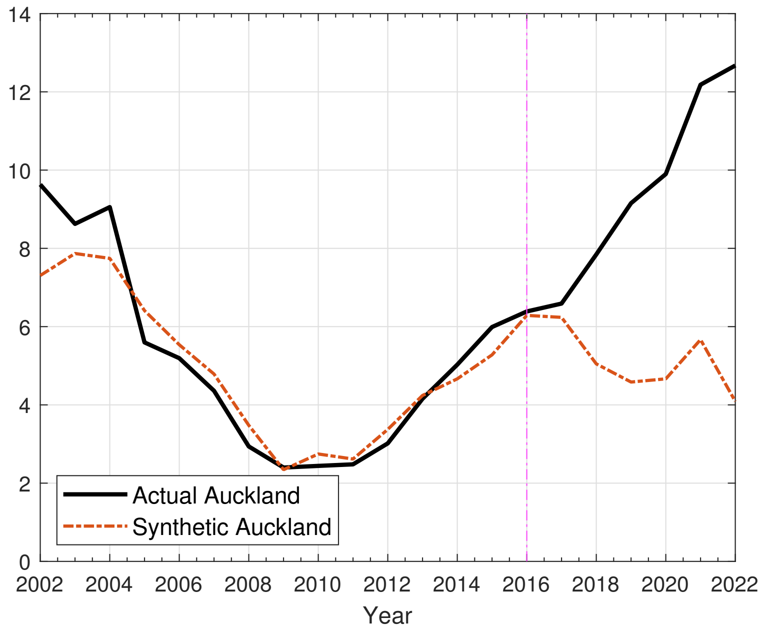
The inclusion of the Australian cities in the donor pool has a negligible impact. Sydney receives a weight of 0.126, while Tauranga and Kāpiti Coast receive weights of 0.609 and 0.264. Figure 23 illustrates actual and synthetic permits per thousand residents over the time period. Synthetic permits per thousand residents is 4.09 in 2022 – about a third of the actual figure of 12.67. 44,875 of the 96,842 permits issued between 2017 and 2022 (or 46.3%) are attributed to the reform, while Auckland's PE-RMSE-R ranks fifth out of sixty placebo runs (not depicted). Thus, if one were to assign the intervention at random to this sample, the probability of obtaining a ratio as large as Auckland's is 0.0847 (= 5/59). However, we note that the in-sample fit of the synthetic control is likely to be affected by the relatively short training period of fifteen years.

Figure 22: Permits per thousand residents, Australian cities included in donor pool



Source: Author's calculations based on Statistics New Zealand and Australian Bureau of Statistics data. Notes: Average of donors taken across all urban areas in the donor pool. Shaded region denotes the range between the minimum and maximum permits per thousand residents among the donor pool. Donor pool includes Sydney, Melbourne, Brisbane, Adelaide, Perth, Hobart, Darwin and the Australian Capital Territory.

Figure 23: Synthetic and actual permits per thousand residents, Australian cities included in donor pool



Notes: Donor pool includes Australian state capital cities of Sydney, Melbourne, Brisbane, Adelaide, Perth, Hobart, Darwin and the Australian Capital Territory. Sample spans 2002 to 2022 to accommodate the Australian cities.

We also perform various changes in empirical specification for the Australian state and cities augmented datasets. This includes employing covariates in the matching variables,[45] and the displacement effects robustness check described in section 4.4.1. Our conclusions remain unchanged. For the state data, when Hamilton and Tauranga are omitted from the donor set, synthetic permits per thousand residents is 4.59 in 2022, and 51,315 permits (equivalent to 53.0% of the 96,842 permits issued between 2017 and 2022) are attributed to the reform. If Wellington and Kāpiti Coast are omitted from the donor set, synthetic permits per thousand residents is 4.23 in 2022, and 39,451 permits (40.7%) are attributed to the reform. For the city data, when Hamilton and Tauranga are omitted from the donor set, synthetic permits per thousand residents is 4.40 in 2022, and 51,682 permits (53.4%) are attributed to the reform. If Wellington and Kāpiti Coast are omitted from the donor set, synthetic permits per thousand residents is 4.00 in 2022, and 38,711 permits (39.9%) are attributed to the reform. For the state dataset with covariates matching, synthetic permits per thousand residents is 4.12 in 2022, and 46,553 (48.1%) are attributed to the reform. For the city

[45]For states and cities, we collect Australian census data on private occupied dwellings and population from the 2001, 2006 and 2011 censuses, and median weekly household income from the 2006 and 2011 censuses. We could not obtain population or occupied dwellings for the 1991 and 1996 Australian censuses, or household incomes for the 1991, 1996 and 2001 censuses. From these, we are able to include dwellings per capita in 2001, 2006 and 2013; intercensal population growth from 2001 to 2006, and 2006 to 2013; and household income growth between 2006 and 2013 in the set of matching variables. We use data from 2011 instead of 2013 for the Australian regions. Matching variable data collected from https://www.abs.gov.au/census/find-census-data/quickstats [accessed 25 August 2023].

dataset with covariates matching, synthetic permits per thousand residents is 4.09 in 2022, and 44,875

permits (46.3%) are attributed to the reform.

5 Discussion and concluding remarks

This papers uses the synthetic control method to assess the impact of a recent widespread zoning reform on housing construction in Auckland, focusing on the rate of new dwelling permit issuance (new dwelling permits per thousand residents) as the outcome of interest. The synthetic control indicates that the zoning reform had a substantial impact. Relative to the counterfactual, the reform doubled the rate at which permits are issued within five years, and implies that almost half of all permits issued over the subsequent seven years are attributable to the reform. These findings are robust to various permutations of the set of matching variables, donor set, treatment timing and geographic unit of analysis. All specifications considered imply that the permitting rate approximately doubled within five years of the reform. Meanwhile, estimates of the percentage of permits issued in Auckland that are attributable to the policy vary between 40 to 51%.

Since enacting the reform, population growth has been outstripped by growth in the dwelling stock, bringing down the ratio of adults to dwellings from the historic high in 2018, and reversing recent trends in population and housing prior to the upzoning (see section 2). 2023 census data show that the adult-aged population grew by 6.5% between 2018 and 2023, while the dwelling stock increased by 11.9%, reducing the ratio of adults to dwellings from 2.11 in 2018 to 2.01.

Auckland's reform has relieved housing pressures by allowing supply to catch up with demand, presumably by increasing household formation rates in the region. But relaxing restrictions on housing supply will likely also induce in-migration over the long-term, thereby increasing population relative to the counterfactual and raising pressures on existing infrastructure networks, including water and electricity distribution, sanitation services, and transportation networks and services. This consequently raises concerns about how infrastructure upgrades and improvements are funded for a growing population.[46] However, it is important to note that – as the history of Auckland demonstrates – population can be inelastic with respect to housing, and thus tying infrastructure funding solely to housing construction could feasibly result in funding shortfalls for maintaining and upgrading existing infrastructure. Broadening the funding base to general taxation is one possible solution, and would align infrastructure funding with other public services like health and education, that must also expand with population.

Several aspects of the reform have not been explored here, some of which have been explored in related work, and some of which deserves attention in future research. Greenway-McGrevy and So (2024) find that the reform reduced rents, while Greenaway-McGrevy and Jones (2025) show that it led to more attached housing and more compact urban development. Greenaway-McGrevy et al. (2021) and Cheung et al. (2023) examine the short-run effects of the upzoning on property

[46]It is primarily people that place demands on existing infrastructure networks, not houses. Stormwater infrastructure is an exception, as it is directly affected by development patterns rather than population growth.

values, finding that land intensive properties appreciated relative to non-upzoned properties, while extant capital intensive properties depreciated.[47] Greenaway-McGrevy (2025c) examines the effect of Auckland's zoning reform on state-developed housing, noting that the sixth Labour government (2017–2023) prioritized housing access and affordability upon coming to power, and presents evidence that Auckland's reform complemented state development in the city. The effects of the reform on socioeconomic demographics have yet to be examined and warrant further research, especially given ongoing concerns that upzoning can promote gentrification, or the potential for it to promote upward mobility, household formation and fertility. We leave these aspects for future research.

The success of Auckland's zoning reform in stimulating housing supply is particularly important given that other recent attempts to encourage housing construction through large-scale zoning reforms have, to date, met with limited success. For example, the California HOME Act of 2021 allows up to four dwellings per parcel, but one year on was found to have had only a small impact on new dwelling permits (Garcia and Alameldin, 2023). The Minneapolis 2040 plan, implemented in January 2020, allows up to three dwellings per parcel, but as yet has not increased dwelling permits for multifamily dwellings (see footnote 2). But these reforms have some noticeable differences with Auckland's reform. First, Auckland's reform relaxed restrictions on floorspace in addition to restrictions on dwellings per parcel. Relaxing restrictions on dwellings per parcel without relaxing restrictions on floorspace mean that any new dwellings constructed on redeveloped sites will be small and less suitable for home buyers that desire space for large households, such as young adults wanting to start a family. Second, Auckland's reform was initiated by the city itself – it was not a top-down imposition like the California reform. Given that council planning departments are often tasked with operationalizing these reforms, it seems likely that buy-in from the institutions that oversee planning departments is important to achieve the goals of the reform. Unwilling local authorities may otherwise find mechanisms to subvert the intention of the regulatory changes, such as permitting delays and parking requirements (von Bergmann et al., 2025). It is notable that another widespread upzoning in Lower Hutt, New Zealand, was also initiated by the local council and resulted in a substantial increase in housing supply (Maltman and Greenaway-McGrevy, 2025). Third, as discussed in section 2, residential zoning in Auckland was almost exclusively designed for low-density detached housing prior to the reform, such that enabling a "missing middle" of medium density housing was both readily implemented on conventional lost sizes, and economically feasible, particularly when compared to enabling high-density housing, which requires large parcels and significant capital outlays. Further research on New Zealand's reform can help us understand the factors that mediate the success or failure of zoning reform, thereby improving the design and implementation of upzoning policies in the future to redress burgeoning inequalities in housing access. We leave this task for future research.

[47] These findings accord with upzoning improving housing affordability via a compositional shift in the dwelling stock, from land intensive housing (detached single family homes) to capital intensive housing (townhouses, rowhouses and apartments). See Greenaway-McGrevy (2025b).

6 Appendix

6.1 Auckland Unitary Plan timeline

This timeline parallels and builds on the timeline provided in Greenaway-McGrevy et al. (2021). Prior to 2010, the greater Auckland metropolitan region comprised seven city and district councils: Auckland City Council, North Shore City Council, Waitākere City Council, Manukau City Council, Rodney District Council, Papakura District Council, and Franklin District Council. On 1 November 2010, Auckland Council (AC) was formed when the eight previous governing bodies in the region were amalgamated. Legislation was also passed by the central government requiring AC to develop a consistent set of planning rules for the whole region under the Local Government Act 2010. This set of planning rules is embodied in the Auckland Unitary Plan (AUP).

Key dates in the development and implementation of the AUP are as follows:

- 15 March 2013: AC releases the draft AUP. Eleven weeks of public consultation followed, during which AC held 249 public meetings and received 21,000 items of written feedback.
- 3 September 2013: In response to a request from AC, the central government passes legislation to enable an Independent Hearings Panel to take public submissions and recommend changes to the Proposed AUP to be released later in the month (the Local Government (Auckland Transitional Provisions) Amendment Act 2013). The additional front-end community engagement would substitute for limited rights of appeal to IHP recommendations, thereby accelerating implementation by avoiding lengthy litigation.
- 13 September 2013: The Housing Accords and Special Housing Areas Act is passed, offering developers accelerated permitting process in exchange for limited affordable housing in the development.
- 30 September 2013: AC releases the Proposed AUP (PAUP) and notified the public that the PAUP was open for submissions. More than 13,000 submissions (from the public, government, and community groups) were made, with over 1.4 million separate points of submission.
- 3 October 2013: Mayor of Auckland and Minister of Housing sign the Auckland Housing Accord, allowing Special Housing Area developments to build under the LURs of the PAUP. The agreement is stipulated to expire once the AUP becomes operational.
- April 2014 to May 2016: An Independent Hearings Panel (IHP) was appointed by the central government, which subsequently held 249 days of hearings across 60 topics and received more than 10,000 items of evidence.
- 22 July 2016: The IHP set out recommended changes to the PAUP. One of the primary recommendations was the abolition of minimum lot sizes for existing parcels. The AC considered and voted on the IHP recommendations over the next 20 working days. On 27 July the public could access and view the IHP's recommendations.
- 19 August 2016: AC releases the "decisions version" of the AUP. Several of the IHP's recommendations are voted down by AC, including a IHP recommendation to abolish minimum floor sizes on apartments. However, the abolition of minimum lot sizes for existing parcels was maintained. This was followed by a 20-day period for the public to lodge appeals on the decisions

version in the Environment Court. Appeals to the High Court were only permitted if based on points of law.

- 8 November 2016: A public notice was placed in the media notifying that the AUP would become operational on 15 November 2016.
- 15 November 2016: AUP becomes operational. There were two elements of the AUP that were not fully operational at this time: (i) any parts that remain subject to the Environment Court and High Court under the Local Government Act 2010; and (ii) the regional coastal plan of the PAUP that required Minister of Conservation approval.

All versions of the AUP ("draft", "proposed", "decisions" and "final") could be viewed online, including zoning maps.

6.2 Land use regulations under the AUP

Table 3: Summary of land use regulations by residential zone under the Auckland Unitary Plan

Regulation	Terraced Housing Apartments	Mixed Housing Urban	Mixed Housing Suburban	Single House
Max. height	16m (5 to 7storeys)	11 to 12m (3 storeys)	8 to 9m (2 storeys)	8 to 9m (2 storeys)
Height in relation to boundary	3m up + 45° recession plane	3m up + 45° recession plane	2.5m up + 45° recession plane	2.5m up + 45° recession plane
Setback (side and rear)	0m	1m	1m	1m
Setback (front)	1.5m	2.5m	3m	3m
Max. site coverage (%)	50%	45%	40%	35%
Max. impervious area (%)	70%	60%	60%	60%
Min. dwelling size (1 bedroom)	$45m^2$	$45m^2$	$45m^2$	n/a
Max. dwellings per site	does not apply	3	3	1
Min. parcel size (new subdivision)	$1200m^2$	$300m^2$	$400m^2$	$600m^2$

Notes: Restrictions are 'as of right' and can be exceeded through resource consent notification. Number of storeys (in parentheses) are obtained from the stated purpose of the height restriction in the regulations. Height in relation to boundary restrictions apply to side and rear boundaries. Less restrictive height in relation to boundary rules than those tabulated apply to side and rear boundaries within 20m of site frontage. Maximum dwellings per site are permitted as of right. Minimum lot sizes do not apply to extant residential parcels. Impervious area is the area under the dwelling and structures such as concrete driveways that prevent rainwater absorption into the soil.

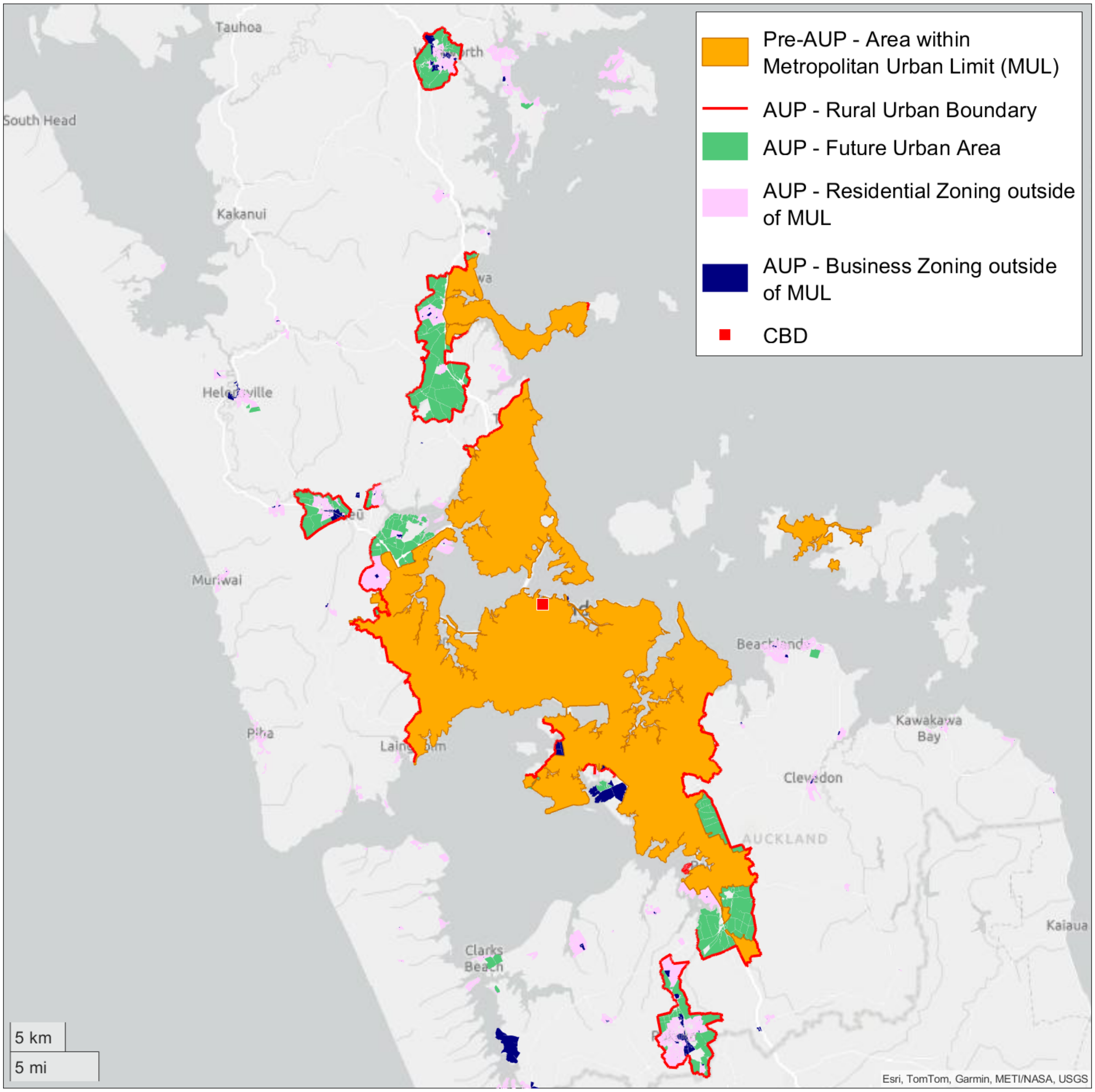
6.3 Geomatching algorithm

This subsection describes the geomatching procedure for the data depicted in figures 3, 26 and 27. Geo-referenced data on individual permits were obtained under license from Auckland Council. Annual totals closely match SNZ data for the Auckland region. Permits are matched to GIS information on individual land parcels as at November 2016 that contains the AUP planning zone and the zone prior to the AUP. This enables the identification of upzoned parcels following the FAR classification used in Greenaway-McGrevy and Jones (2025).

Permits are matched to parcels through the following sequence of steps. 1. Find the parcel of the geo-coordinate of the permit and check whether the road number and first word of the road match. If these do not match: 2. Find all the parcels within 1250m of the geo-coordinate of the permit and search for a match based on the road number and first word of the road address. If no match is found: 3. Check whether the address contains a number or letter to indicate a subdivision or cross lease (such as “10B” or “2/10”). If not, proceed to step 5. If so, the remove the additional number of letter and check whether the road number and first word of the road match the address of the parcel corresponding to the geocoordinate of the permit. If there is no match: 4. Find all the parcels within 1250m of the geo-coordinate of the permit and search for a match based on the road number and first word of the modified road address. If no match is found: 5. Identify the parcel of the geo-coordinate of the permit. Check whether the name of the road in the address of the parcel matches the road name of the address given in the permit. If there is no match: 6. Identify the nearest parcel of the geo-coordinate of the permit and assign this parcel. Parcels coded to “Water”, “Strategic Transport Corridor Zone”, “Road”, “Coastal - General Coastal Marine Zone”, “Coastal - Coastal Transition Zone”, “Green Infrastructure Corridor”, or any of the “Open Space” zones, are removed from the parcel dataset from this matching.

6.4 Additional tables and figures

Figure 24: Urban growth boundaries in Auckland



Source: Author's calculations. Notes: Area within the Metropolitan Urban Limit (MUL) before the AUP are depicted in orange. The AUP replaced the MUL with the Rural-Urban Boundary (RUB) in 2016. Greenfield rural land between the RUB and MUL was designated as Future Urban areas. In 2017, Auckland Council set out a process and anticipated timeline for conversion of these areas to residential zoning over a thirty-year horizon.

Figure 25: Major and large urban areas of New Zealand

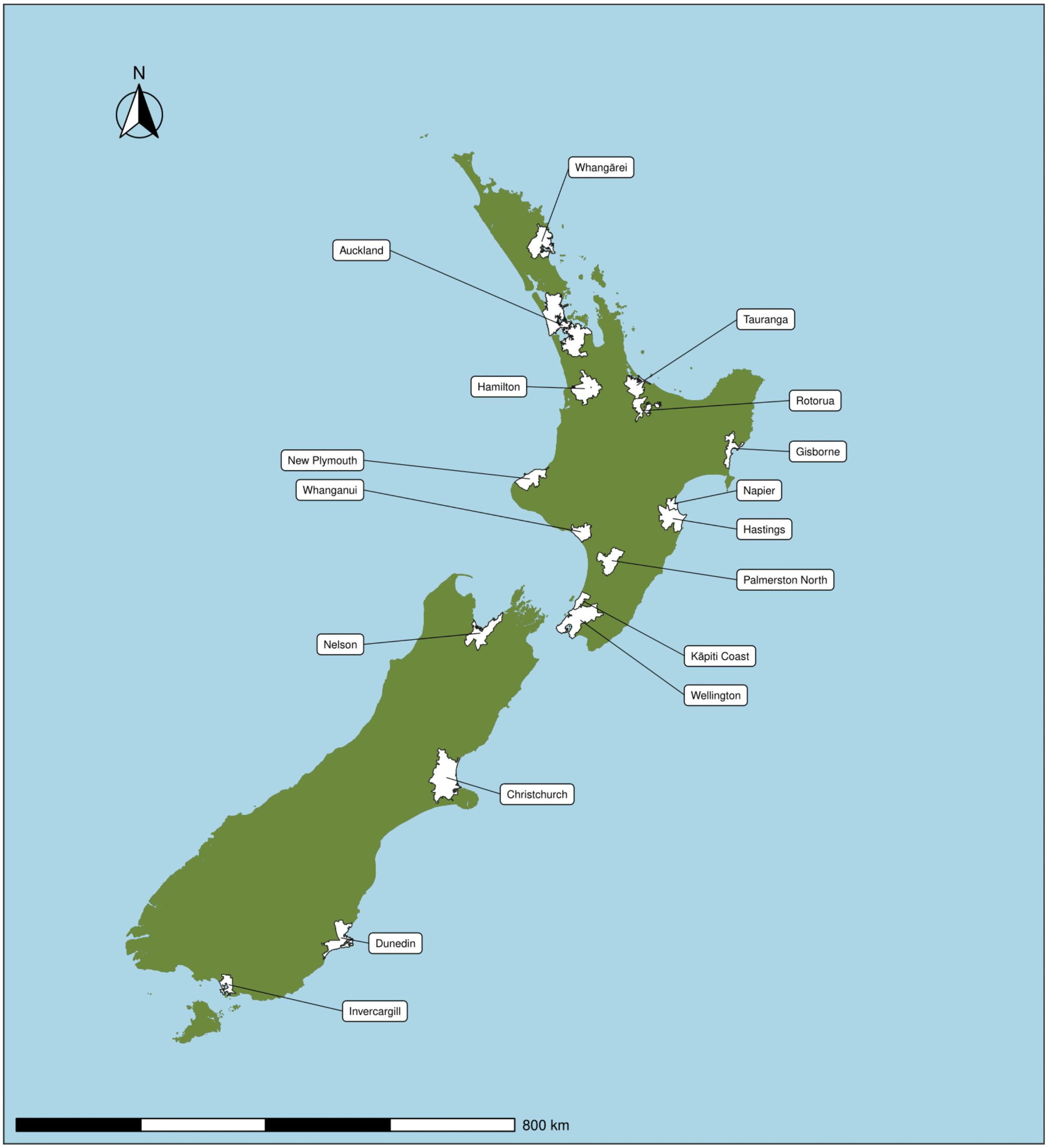
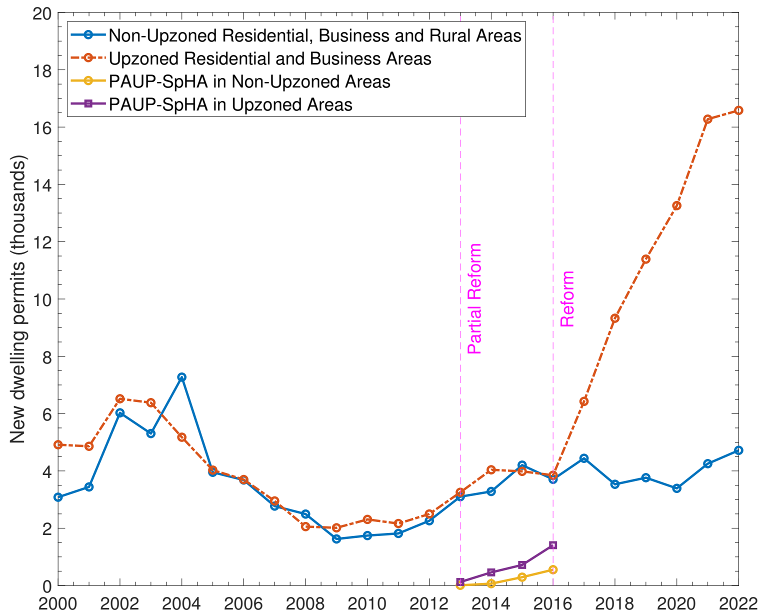


Table 4: Major and large urban areas

Urban Area	Population	Dwellings	Household Income ($)	Area (km^2)	Distance to Auckland (km)
Auckland	1,567,038	490,695	107,000	3356.9	-
Hamilton	209,970	70,596	91,700	1412.7	114
Tauranga	156,666	57,690	87,500	789.9	155
Wellington	422,427	149,820	107,900	1754.2	493
Christchurch	482,088	177,135	91,500	2408.0	764
Dunedin	132,006	49,533	77,400	1033.8	1,064
Whangārei	86,538	31,407	78,100	1433.6	131
Rotorua	74,028	24,795	78,900	649.2	194
Gisborne	43,953	15,360	73,800	612.8	350
Hastings	79,431	26,823	80,200	1160.4	359
Napier	66,459	24,834	77,700	259.8	348
New Plymouth	80,997	31,002	82,500	920.9	253
Whanganui	45,747	18,249	63,900	598.1	344
Palmerston North	96,552	34,737	83,200	978.3	397
Kāpiti Coast	46,839	19,128	86,000	317.4	452
Nelson	84,846	31,833	81,500	1177.2	508
Invercargill	55,386	21,825	75,800	428.5	1,188

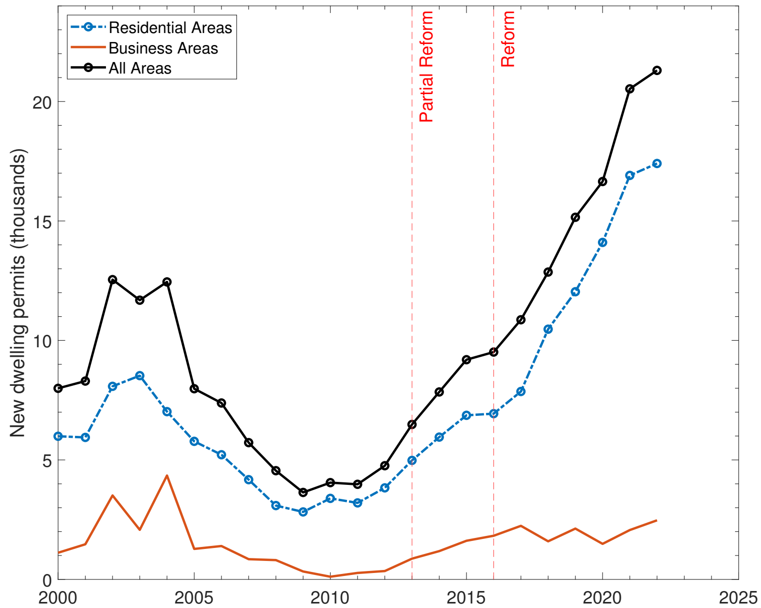
Source: Author's calculations based on 2018 Census. Notes: Dwellings are occupied dwellings. Note that Christchurch is omitted from the donor pool due to the effect of the 2011 earthquakes on the housing stock and subsequent rebuild. Tabulated distance is Haversine. Household income is arithmetic mean.

Figure 26: New dwelling permits in Auckland by location and including Special Housing Areas, 2000 to 2022



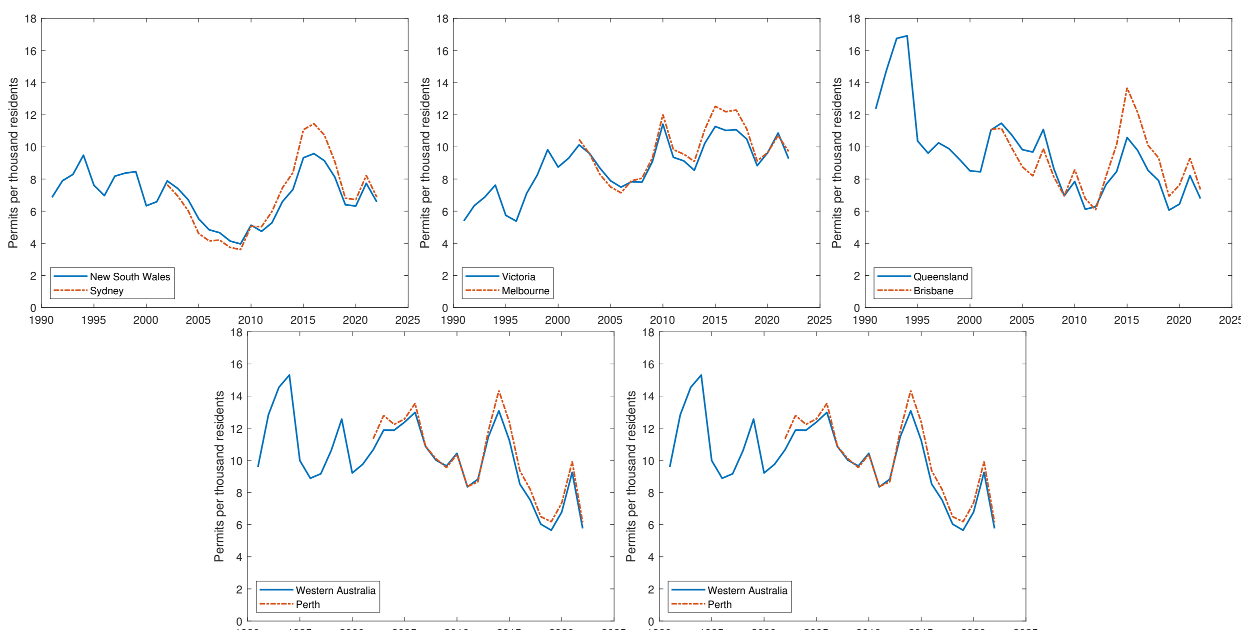
Notes: New dwelling permits in areas that were and were not upzoned in 2016 under the AUP. The first, "draft", version of the AUP was announced in March 2013, while the "Proposed" AUP (PAUP) was notified in September 2013. Partial zoning reform was implemented in September 2013 under the Auckland Housing Accords. Between September 2013 and November 2016, Special Housing Area (SpHA) developments could build to the regulations of the PAUP in exchange for affordable housing provisions. "PAUP-SpHA" denotes permits issued in SpHAs between 2013 and 2016. Full reform occurred in November 2016 when the final version of the AUP became operative. Source: Author's calculations based on permits matched to planning zones. Upzoning classification is based on comparing floor-to-area (FAR) ratios implied by height and site coverage restrictions before and after the policy change. See Greenaway-McGrevy and Jones (2025) for additional details.

Figure 27: New dwelling permits in Auckland by residential and business areas, 2000 to 2022



Source: Author's calculations based on permits matched to AUP planning zones. See Greenaway-McGrevy and Jones (2025) for additional details on the method.

Figure 28: New dwelling permits per thousand residents, Australian cities and states



Source: Author's calculations based on Australian Bureau of Statistics data.

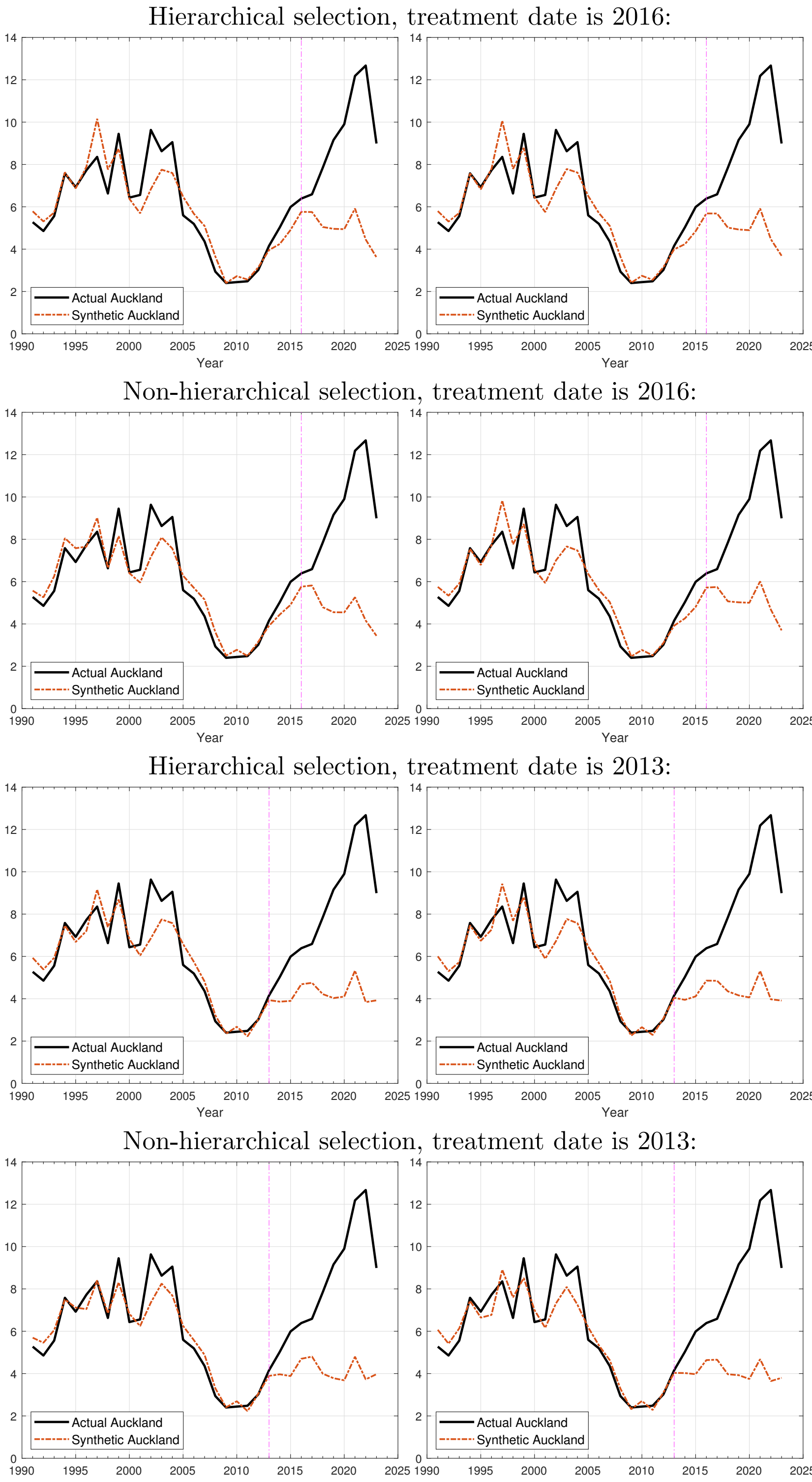
6.5 Robustness checks

Table 5: Donor weights under alternative specifications

	Treatment date: 2016				Treatment date: 2013			
	Hierarchical selection		Non-hierarchical		Hierarchical selection		Non-hierarchical	
Urban Area	Outcomes	Covariates	Outcomes	Covariates	Outcomes	Covariates	Outcomes	Covariates
Hamilton	0.102	0.110			0.076	0.164		
Tauranga	0.573	0.547	0.536	0.552	0.405	0.398	0.320	0.348
Wellington	0.111	0.111		0.189	0.019			0.077
Hastings					0.074			
Kāpiti Coast	0.213	0.232	0.227	0.224	0.426	0.401	0.458	0.454
Nelson						0.036		
Te Awamutu				0.019				
Taupo							0.030	
Motueka			0.033				0.047	0.083
Wānaka			0.130	0.016			0.089	0.038
Cambridge			0.060					
Queenstown			0.014					
Alexandra							0.058	
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

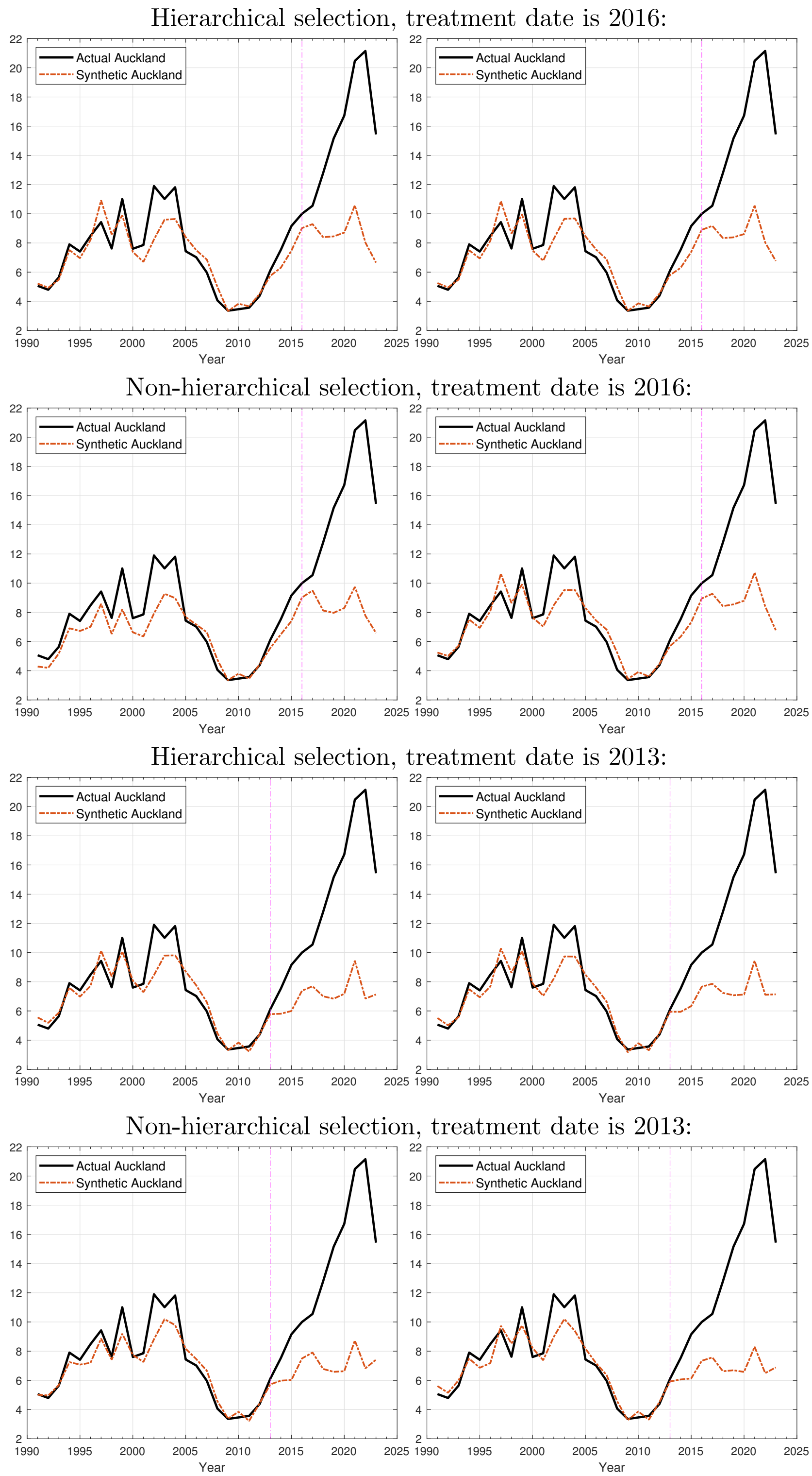
Notes: "Outcomes" denotes synthetic control specifications where the entire time series of pre-treatment outcomes constitute the matching variables (i.e. "outcomes matching"). "Covariates" denotes synthetic control specifications where covariates constitute the matching variables (i.e. "covariates matching"). See section 4.4.3 for a description of the various specifications.

Figure 29: Synthetic and actual permits per thousand residents under alternative specifications



Notes: The left column presents synthetic control designs that match to the entire time series of outcomes (i.e. "outcomes matching"). The right column presents synthetic control designs that match to covariates (i.e. "covariate matching"). See section 4.4.3 for a description of the various specifications. The baseline outcome matching specification presented in the main text is in the top left panel.

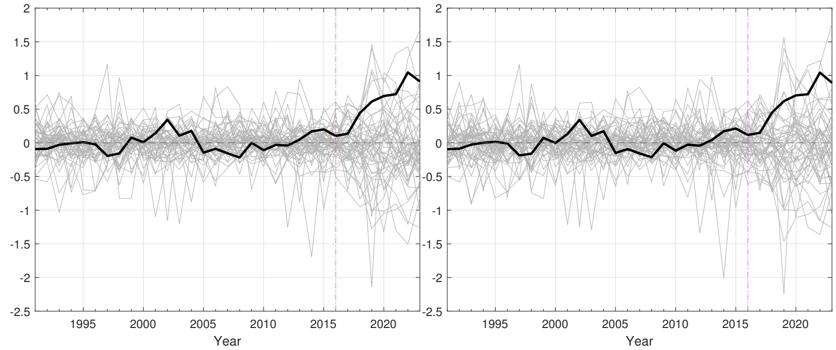
Figure 30: Synthetic and actual permits (thousands) under alternative specifications



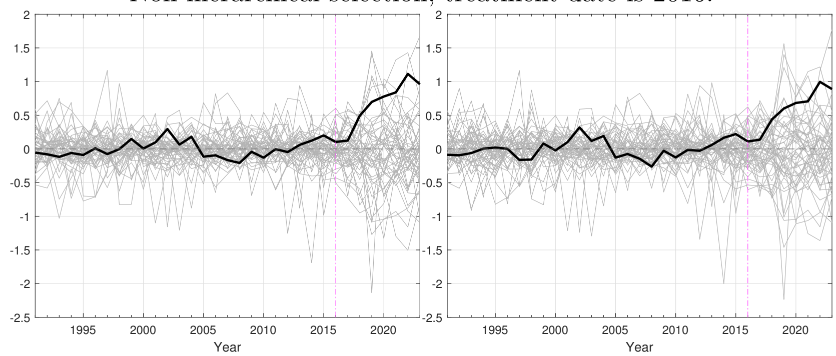
Notes: The left column presents synthetic control designs that match to the entire time series of outcomes (i.e. "outcomes matching"). The right column presents synthetic control designs that match to covariates (i.e. "covariate matching"). See section 4.4.3 for a description of the various specifications. The baseline outcome matching specification presented in the main text is in the top left panel.

Figure 31: Prediction errors under alternative specifications

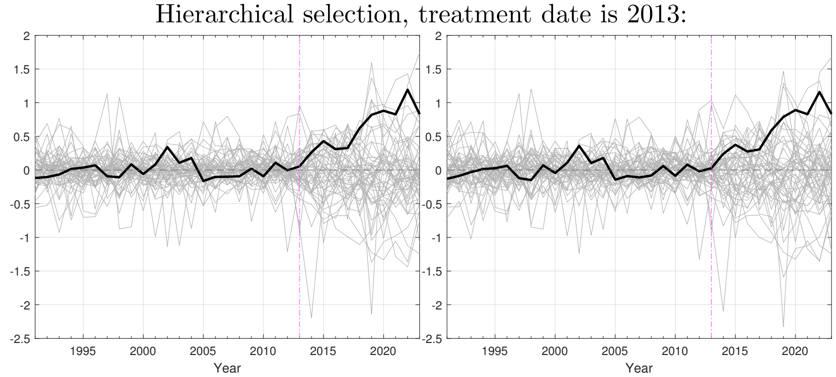
Hierarchical selection, treatment date is 2016:



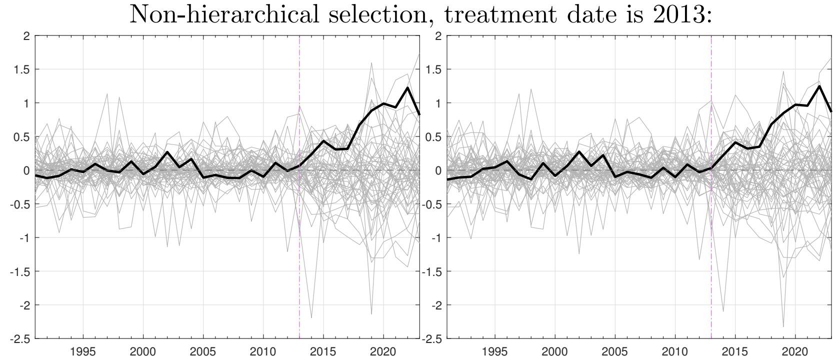
Non-hierarchical selection, treatment date is 2016:



Hierarchical selection, treatment date is 2013:



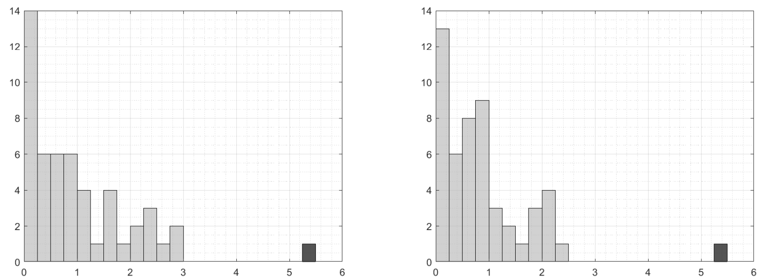
Non-hierarchical selection, treatment date is 2013:



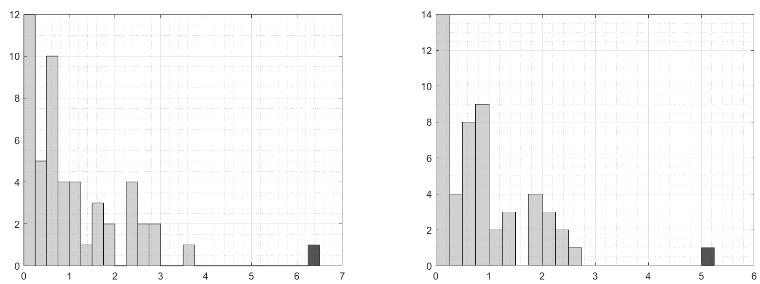
Notes: The left column presents synthetic control designs that match to the entire time series of outcomes (i.e. "outcomes matching"). The right column presents synthetic control designs that match to covariates (i.e. "covariate matching"). See section 4.4.3 for a description of the various specifications. The baseline outcome matching specification presented in the main text is in the top left panel.

Figure 32: Positive-error RMSE ratios under alternative specifications

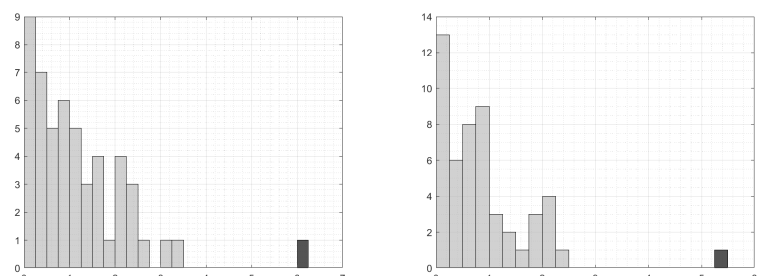
Hierarchical selection, treatment date is 2016:



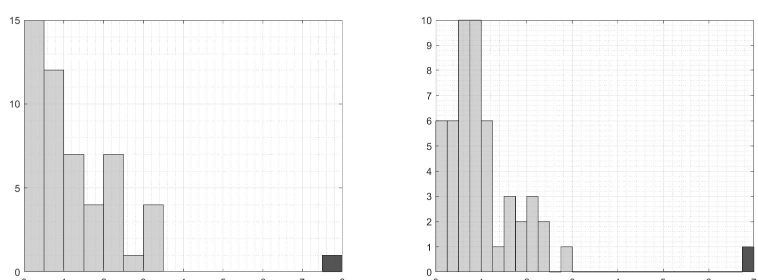
Non-hierarchical selection, treatment date is 2016:



Hierarchical selection, treatment date is 2013:



Non-hierarchical selection, treatment date is 2013:



Notes: The left column presents synthetic control designs that match to the entire time series of outcomes (i.e. "outcomes matching"). The right column presents synthetic control designs that match to covariates (i.e. "covariate matching"). See section 4.4.3 for a description of the various specifications. The baseline outcome matching specification presented in the main text is in the top left panel.

6.5.1 Results without de-meaning normalization

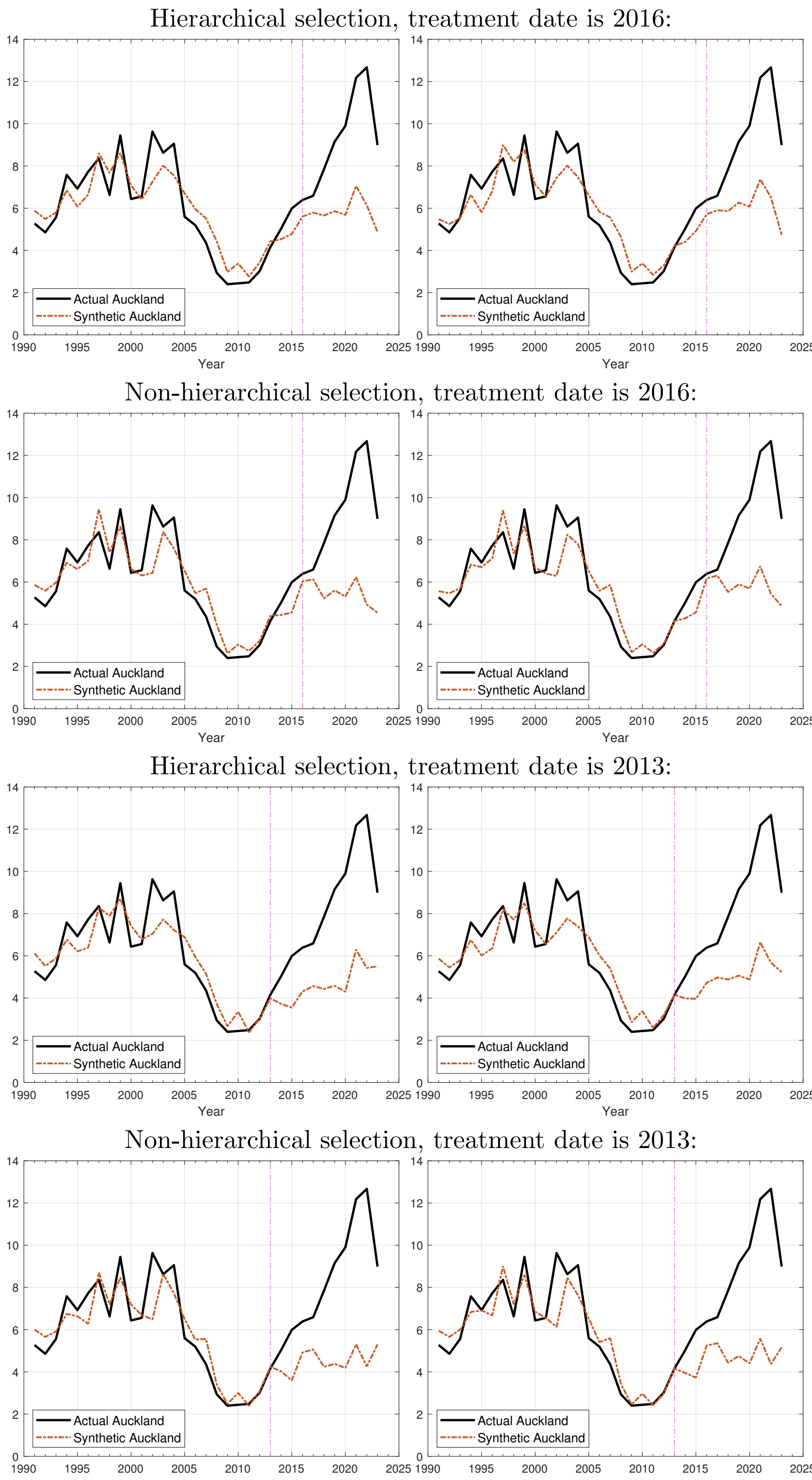
This subsection presents results when the times series of outcome variables for each urban area (log permits per thousand residents) does not have its pre-treatment mean subtracted. Figure 33 exhibits synthetic permits per capita for the various permutations of the empirical design presented in section 6.5. The synthetic units are similar to those presented in figure 29, although they generally do a poorer job of matching the downturn from 2004 to 2010. Table 6 shows that the de-meaning normalization reduces pre-treatment RMSE.

Table 6: Pre-intervention RMSEs

	Hierarchical donor selection			
	Treatment date: 2016		Treatment date: 2013	
Matching variables	No normalization	De-meaning normalization	No normalization	De-meaning normalization
Outcomes	0.173	0.134	0.159	0.116
Covariates	0.177	0.134	0.168	0.119

	Non-hierarchical donor selection			
	Treatment date: 2016		Treatment date: 2013	
Model	No normalization	De-meaning normalization	No normalization	De-meaning normalization
Outcomes	0.158	0.122	0.143	0.100
Covariates	0.160	0.133	0.145	0.111

Figure 33: Synthetic and actual permits per thousand residents without de-meaning normalization



Notes: The left column presents synthetic control designs that match to the entire time series of outcomes (i.e. "outcomes matching"). The right column presents synthetic control designs that match to covariates (i.e. "covariate matching"). See section 4.4.3 for a description of the various specifications. The baseline outcome matching specification presented in the main text is in the top left panel.

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