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Can zoning reform change urban development patterns? Evidence from Auckland

Ryan Greenaway-McGrevy and James Allan Jones

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Abstract

In 2016, the city of Auckland implemented large-scale zoning reforms, precipitating a boom in residential housing construction. This paper describes the zoning reforms, quantifies the changes in land use across the metropolitan area, and documents changes in residential housing development over the five years subsequent to the zoning reform. We show that approximately three-quarters of residential land was upzoned, predominantly in areas close to transportation links and between five and twenty-five kilometres of the CBD. Five years on from the reform, housing construction in the metropolitan region: (i) has increased; (ii) is located closer to the CBD, employment locations, and transportation network access points; and (iii) is more reliant on infill development and attached housing. These patterns are driven by changes in housing construction in upzoned areas, consistent with zoning reforms causing changes in observed development patterns, and suggesting that the policy successfully stimulated housing supply in the areas targeted for increased capacity.

Keywords: Upzoning, Land Use Regulations, Redevelopment, Housing Construction.

JEL Classification Codes: R14, R31, R52

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†University of Auckland. Corresponding author. Postal address: The University of Auckland, Private Bag 92019 Auckland 1142, New Zealand. Email: r.mcgrevy@auckland.ac.nz.

1 Introduction

Zoning reform is increasingly being advocated to achieve a variety of urban policy goals, such as increasing housing supply and reducing housing costs (Glaeser and Gyourko, 2003; Freeman and Schuetz, 2017), reducing spatial inequities (Manville *et al.*, 2020), and enabling a more compact and environmentally sustainable form of urban development (Wegmann, 2020). There remains, however, little empirical evidence on the impacts of zoning reforms on housing supply and costs (Schill, 2005; Freeman and Schuetz, 2017), let alone changes on urban development patterns or spatial inequality. While a handful of studies have examined localised upzonings, this research typically finds that the housing supply response is muted or non-existent (Freemark, 2020; Murray and Limb, 2022; Peng, 2023), suggesting that zoning reform may struggle to achieve intended policy objectives (Rodríguez-Pose and Storper, 2020).

Reforms of a scale sufficient to have a substantial impact on metropolitan development patterns are scarce (Freeman and Schuetz, 2017). However, in 2016 the city of Auckland, New Zealand, upzoned most of its residential land under the Auckland Unitary Plan (AUP), precipitating a residential construction boom in the city (Greenaway-McGrevy and Phillips, 2022). Because there is strong evidence that this upzoning stimulated housing supply, Auckland provides a unique and important case study for the design and implementation of large-scale zoning reforms in other contexts.

In this paper we examine the impact of Auckland's zoning reform on spatial development patterns in the city. To give readers an impression of the scale and scope of the reform, we begin by quantifying the amount of upzoned land, both across the city and in relation to key amenities. Using a geocoded dataset of land parcels matched to planning zones, we show that the maximum floor-to-area ratio (FAR) was relaxed on approximately three-quarters of residential land, with much of this upzoning occurring between 5 and 25km of the CBD, and in close proximity to transportation networks and areas of concentrated employment. We then document how housing development has changed in the five years subsequent to the reform. Using a geocoded dataset of new dwelling consents ('building permits' in the US), we show that housing construction has: (i) increased; (ii) become more geographically compact, with the spatial distribution of consents shifting closer to the CBD, transportation network access points, and employment locations; and (iii) become more reliant on infill development and multi-family units, rather than greenfield and single family dwellings.

Further geographic analysis suggests that the zoning reform is driving these documented changes in housing construction. Most of the increase in construction is occurring on upzoned parcels, and, importantly, there was no difference in trends between upzoned and non-upzoned parcels prior to the policy: It is only *after* the zoning reforms that trends in upzoned parcels increase relative to non-upzoned. This divergence continues to hold after conditioning on variables that plausibly account for a parcel being selected for upzoning, such as distances to transportation networks or land quality, indicating that the divergence is driven by the policy change rather than alternative mechanisms moderated by planners' zoning selection criteria. We also decompose the change in the

spatial distribution of consents, showing that the contraction in the spatial distribution is driven exclusively by changes in development patterns in upzoned areas, consistent with the zoning reforms causing more compact development.

The effects of zoning reforms on housing and urban development remains an important but regrettably understudied topic, with only a handful of studies focussing on what happens after land use 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 localised upzonings in New York. Dong (2021) finds that small-scale upzoning in Portland approximately doubled the long-term probability of parcel development, but the number of new units constructed remains small. In recent work, Stacy *et al.* (2023) show that various reforms in US cities between 2000 and 2019 generated negligible increases in housing supply, on average. In contrast, large-scale zoning reforms are found to have larger effects in a couple of papers. 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 neighbourhoods, while Greenaway-McGrevy and Phillips (2022) show that the AUP precipitated a significant increase in housing construction. Our paper complements the latter by detailing how the spatial distribution of land use and housing construction has changed, thereby demonstrating that the reform successfully encouraged a more spatially compact pattern of growth.

The remainder of the paper is organized as follows. The following section describes the AUP and how it's structure informs our empirical work. It also provides an overview of the policy objectives and institutional processes that culminated in the large-scale zoning reform. Section 3 documents how land use regulations changed, while 4 shows how housing construction changed. Section 5 concludes.

2 Institutional Background and Data

In this section we describe institutional institutional background underpinning the zoning reform. We then describe our dataset, and how it captures key elements of the policy.

2.1 Institutional Background

Auckland is the largest city in New Zealand, with a rapidly growing population that increased from 1.16 million in 2001 to 1.57 million by 2018 (source: census). It is centred on a long isthmus between two harbours, and extends over 4,894 km^2 of land, including a large metropolitan area, several towns, populated islands, and a substantial amount of rural land.

Since 2010, the region has been under the jurisdiction of a single local government, the Auckland Council (AC). Previously the region comprised seven city and district councils, each developing and implementing land use plans. The four city councils (Auckland, North Shore, Manukau, Waitākere) encompassed the developed areas in the suburbs around the CBD, with the former Auckland City Council covering the CBD and central isthmus. Two of the district councils (Rodney and Franklin)

covered predominantly rural areas, while the Papakura district council administered a formerly discontiguous town to the South. The seven councils were amalgamated to form AC by an act of parliament,[1] with subsequent legislation requiring the development of (i) a strategic spatial plan[2] and (ii) a consistent set of planning rules for the region.[3]

AC released the spatial plan in 2012.[4] Motivated by the need for more sustainable development, it included strategic policy directives for the majority of growth to occur within the existing urban area, including a target of 60-70% of new dwellings within the metropolitan urban limit as at 2010.[5] AC then released consistent planning rules under the 'draft' AUP in March 2013, which included widespread relaxation of LURs to achieve the strategic goals set out in the spatial plan. After eleven weeks of public consultations, AC released a revised 'Proposed' AUP (PAUP) in September. However, prior to its release, the central government amended the facilitating legislation to appoint an Independent Hearings Panel (IHP)[6] under the ostensible purpose of accelerating the operationalisation the new plan through a streamlined and one-off hearings process.[7]

An interim agreement between the Auckland Council and the central government allowed developers to build to the rules of the PAUP, as 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.[9] The program ended once the AUP was implemented. Thus, the AUP process began to have a limited effect from September 2013 onwards because SpHA developments fell under the more relaxed LURs of the PAUP.

The IHP took submissions between April 2014 and May 2016, before setting out recommended changes to the plan on 22 July 2016. 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 19 August 2016, the AC released the 'decisions' version, including new zoning maps. Several of the IHP's recommendations were voted down, including the abolishment of minimum floor sizes on apartments. This was followed by a 20-day period for the public to lodge appeals in the Environment Court, while appeals to the High Court were only permitted if based on points of law. The 'final' version of the AUP became operational in part on

[1] *The Local Government (Auckland Council) Act 2009.* https://www.legislation.govt.nz/act/public/2009/0032/latest/DLM2044909.html, accessed 14/03/2023

[2] *Local Government (Auckland Council) Amendment Act 2010.* https://www.legislation.govt.nz/act/public/2010/0036/latest/DLM3016073.html, accessed 22/03/2023

[3] *The Local Government (Auckland Transitional Provisions) Act 2010.* https://www.legislation.govt.nz/act/public/2010/0037/latest/DLM3016607.html, accessed 22/03/2023

[4] https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/Documents/auckland-plan-2012-full-document.pdf, accessed 14/03/2023

[5] paragraph 88, pp.36–37, and p.48; paragraphs 124–129, p.48

[6] *Local Government (Auckland Transitional Provisions) Amendment Act 2013.* https://www.legislation.govt.nz/act/public/2013/0064/latest/DLM5464006.html, accessed 14/03/2023

[7] See Hansard debate https://www.parliament.nz/en/pb/hansard-debates/rhr/document/50HansD_20130827_00000032/resource-management-amendment-bill-local-government-auckland, accessed 14/03/2023

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

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

15 November 2016.[10]

Each version of the AUP ('draft', 'proposed', 'decisions' and 'final') could be viewed online by the public and contained new LURs that would potentially change restrictions on the extent of site development, depending on zoning. The AUP introduced four residential zones to urban areas. Listed in decreasing order of permissible site development, these were: Terrace Housing and Apartments (THA); Mixed Housing Urban (MHU); Mixed Housing Suburban (MHS) and Single House (SH). Table 4 in the Appendix summarizes various LURs for each zone, including site coverage ratios, height restrictions, setbacks and recession planes. For example, five to seven storeys and a maximum site coverage ratio of 50% is permitted in THA, whereas two storeys and a coverage ratio of 35% is permitted in SH. As we demonstrate below, in the vast majority of residential areas, the new LURs were more permissive than those of the pre-AUP plans. The AUP also included two additional zones for semi-rural areas: 'Large Lot' and 'Rural and Coastal Settlement' that generally applied peri-urban areas or to small settlements distant to the CBD. LURs in these zones restricted development to very low intensity, as shown in Table 4. We refer to these zones as 'semi-rural'.[11]

2.2 Data

Our dataset comprises: (i) individual parcel GIS data from Land Information New Zealand; (ii) new building consents issued by Auckland Council and its predecessors; and (iii) GIS information on residential zones (the AUP and the seven pre-AUP council plans). The parcel data are as of November 2016, when the AUP became operational, and contain title information and the geocoordinates of each parcel's vertices, enabling calculation of land area and matching to other spatial information. Contiguous parcels with identical title(s) are amalgamated into single polygons. Each parcel is matched to its AUP and pre-AUP planning zones using the geocoordinates of the polygon, which enables identification of LURs before and after the AUP. Consents are matched to individual parcels using an algorithm that combines the geocoordinates of the consent and its address string. The data include the number of new dwellings and their total floor area.

3 Changes in Residential Land Use

In this section we document how LURs changed once the AUP was operationalised, paying particular attention to the amount of residential land that was subject to a relaxation in regulations. This requires a measure of the allowable capital intensity of housing development. While it is relatively straightforward to derive a such measure for the AUP zones, there were approximately 115 residential zones across the seven pre-AUP council plans, each with site coverage ratios, height restrictions, minimum lot sizes (MLS) per dwelling, setbacks and recession planes.

[10] 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.

[11] These zones are technically classified as 'residential' under the AUP. We include the 'Waitākere Ranges' zone in the semi-rural set, as it has similar LURs to 'Large Lot' (e.g. 15% site coverage), despite being classified as 'rural' in the AUP. It applies to a specific geographic area in the west.

We use the maximum floor-to-area ratio (FAR) as the measure of LUR stringency. FARs are frequently used for this purpose (Brueckner *et al.*, 2017; Brueckner and Singh, 2020; Tan *et al.*, 2020) Because site coverage ratios and height limits were near universal in all pre-AUP zones, each zone's FAR can straightforwardly be obtained as the product of the site coverage ratio and the number of storeys implied by the height limit[12, 13] The majority of the pre-AUP zones also had MLS restrictions, which do not apply to extant parcels under the AUP.

We group the pre-AUP residential zones into categories based on their respective FARs (henceforth 'zoning categories'). Because we will compare how LURs changed, these categories accord with the maximum FAR permitted in the four residential zones introduced under the AUP. THA has a FAR of 2.5 under its five storey limit. We therefore define 'Residential-High' as zones with a FAR no less than 2.5.[14] MHU has a FAR of 1.35, and thus 'Residential-Medium' comprises zones with a FAR greater than or equal to 1.35 and less than 2.5. MHS has a FAR of 0.8, and thus 'Residential-Medium-Low' comprises zones with a FAR greater than or equal to 0.8 and less than 1.35. SH has a FAR of 0.7, and thus 'Residential-Low' comprises zones with a FAR greater than or equal to 0.7 and less than 0.8. We include zones intended to preserve built or natural heritage as 'Residential-Low', unless applied to semi-rural areas. Although most of these areas allowed two storeys, some had site coverage ratios less than 35%. Finally, we define 'Semi-Rural' as having a FAR less than 0.7 but greater than or equal to 0.15.

We allocate each parcel to (i) an AUP zone and (ii) either one of the pre-AUP residential zone categories, a 'business' category, a 'rural and open space' category, or a 'mixed' category (for a few pre-AUP 'special area' zones that allowed various housing forms within one contiguous area). The aggregate amount of land in each AUP residential zone can then be decomposed into the various pre-AUP zone categories, enabling us to observe changes in land use and the amount of land that was upzoned.

Table 1 presents the amount of land allocated to the various pre-AUP categories and AUP zones. The AUP enabled a significant increase in the amount of land allocated to medium or high intensity residential development. Prior to 2016, the total residential area with a FAR of 2.5 (equivalent to THA) or above (i.e., Residential-High) was less than half a square kilometre. The AUP introduced 25 square kilometres of THA that allows a FAR of 2.5. Similarly, prior to 2016, there was 4.04 (= 3.66 + 0.38) km^2 of residential land that allowed a FAR of 1.35 (equivalent to MHU) or above. This increased to approximately 100 km^2 (= 75.49 + 24.52) under the AUP.

The final three rows of Table 1 display the total amount of residential land upzoned. Upzoned land is comprised of: (i) all residential land that previously had a FAR below that of the AUP zone; (ii) all residential land that was previously zoned rural or open space; and (iii) business land that was previously zoned residential or rural. The first row also includes land that was previously classified as mixed, and represents and upper bound on the estimated area of upzoned land. The

[12] FARs are not directly regulated under the AUP or the pre-AUP plans. See the Appendix for a plausible mapping from height to storeys. A few pre-AUP zones imposed storey limits.

[13] The 'Integrated Intensive Housing' zone in Manukau city had design codes instead of restrictions on heights and site coverage. We assign it a FAR of 1.5 based on the design code. It covered only 0.0773 km^2 of land.

[14] Descriptors such as 'high' reflect relative differences in FARs, rather than absolute levels.

second row excludes mixed.

Between 260 and 256 of the 335 square kilometres (76.4 to 77.6%) of residential land was upzoned, depending on whether residential land previously zoned business or mixed is classified as upzoned. Looking at the four main residential AUP zones, between 22.7 and 23.5 of the 24.5km^2 of THA was upzoned, with the majority of it – 17.2 km^2 – being rezoned from Residential-Low. Meanwhile, between 73.4 and 74.6 of the 75.5km^2 of MHU was upzoned, again with the vast majority – 59.5 km^2 – from Residential-Low. Similarly, 146.0 to 146.8 of the 150.7 km^2 of MHS was upzoned, 129.5 km^2 of which came from Residential-Low. In contrast, most SH land was not upzoned, as it was previously classified as Residential-Low. Nonetheless, approximately 13.7 km^2 of SH was previously classified as Rural or Semi-Rural, and thus was upzoned to SH.

Very little land was downzoned, in the sense that the parcel was in a more intensive residential category prior to 2016. For example, 0.26 km^2 of MHU was classified as Residential-High or Business, while 0.90 km^2 of MHS was classified as either -High, -Medium or Business.

Table 1: Changes in Land Use

City and District Plans (before 2016)	Unitary Plan (from 2016)									
Zoning Category	Business	Residential Zones					Total Residential Area		Rural & Open Space	Total Area
		THA	MHU	MHS	SH	Semi-Rural	Excl. Semi-Rural	Incl. Semi-Rural		
Business	68.57	0.85	0.25	0.44	0.15	0.05	1.68	1.73	3.61	73.92
Residential-High	0.23	0.14	0.01	0.00	0.00	0.00	0.14	0.14	0.00	0.38
Residential-Medium	0.04	1.76	0.64	1.17	0.01	0.04	3.58	3.62	0.00	3.66
Residential-Medium-Low	0.69	2.18	3.02	2.31	1.59	0.01	9.10	9.11	0.84	10.64
Residential-Low	2.93	17.19	59.54	129.46	67.48	8.12	273.66	281.79	6.54	291.26
Semi-Rural	0.18	0.19	0.77	3.51	5.74	72.54	10.21	82.75	26.45	109.37
Rural and Open Space	18.39	1.42	10.06	13.01	7.96	7.95	32.45	40.40	3,514.35	3,573.14
Mixed	2.30	0.80	1.20	0.81	0.91	1.71	3.73	5.44	7.54	15.28
Total	93.34	24.52	75.49	150.72	83.83	90.41	334.56	424.97	3,559.34	4,077.65
Upzoned	24.77	23.54	74.59	146.80	14.61	9.66	259.53	269.19		
Upzoned excl. Mixed	22.46	22.73	73.39	145.99	13.70	7.95	255.81	263.75		

Notes: Tabulated figures are square kilometres and calculated based on land parcels. Roading and transportation infrastructure are excluded, including ferry terminals, ports, and strategic transportation corridors. Special purpose areas (including hospitals, airports and airfields, education, recreation and Māori use among others) are included under 'business' before and after the AUP. 'Future urban' zone under AUP is included in Rural. Semi-rural zones under the AUP include 'large lot', 'residential - rural and coastal settlement', and 'Waitākere Ranges'. Residential areas under the seven pre-AUP city and district plans are grouped according to the maximum floor to land area ratio (FAR) allowed in the zone. These groups accord with the maximum FAR permitted in the four residential zones under the AUP. Residential-High is comprised of all zones with FAR $\geq$ 2.5; Medium, 1.35$\leq$ FAR <2.5; Medium-Low, 0.8$\leq$ FAR <1.35; Low, 0.7$\leq$FAR <0.8; and semi-rural, 0.15$\leq$FAR <0.7. Prior to the AUP, all heritage, natural and special character zones are included in Residential-Low or Semi-Rural. Mixed areas under city and distract plans include 'special areas' in the Rodney and Waitākere Council plans that had a mix of residential building intensities allowed within the designated area. Upzoned areas are the sum of pre-AUP residential areas that had a FAR less than that permitted under the AUP, rural and open space.

Figure 1 depicts the geographic distribution of upzoned residential areas, decomposed into upzoned to THA, MHU and MHS. For clarity we zoom in on the central urban area of Auckland, and omit parcels upzoned to business or semi-rural, focussing exclusively on residential areas. Non-upzoned residential areas comprise SH, MHS, MHU and THA zoned-parcels that, prior to 2016, had a FAR greater or equal to that permitted under the AUP. The majority of this area consists of SH parcels that were not upzoned from semi-rural or rural.

In the analysis to follow, we classify residential land under that was previously zoned as mixed as upzoned. As the Table 1 suggests, this classification makes little difference given the small amount of area.

3.1 Spatial Distribution of Upzoning

In this section we quantify the amount of upzoned land relative to geographically-fixed points that influence household locational choice. Specifically, we measure the amount and proportion of upzoned land at different distances to: the CBD; the nearest job centre; the nearest highway on-ramp; and the nearest rapid transit (RT) station. We use Manhattan distances (based on extant road networks) from the centroid of the meshblock in which the parcel is located.[15] Job centres are defined as areas with a disproportionately high number of employees.[16]

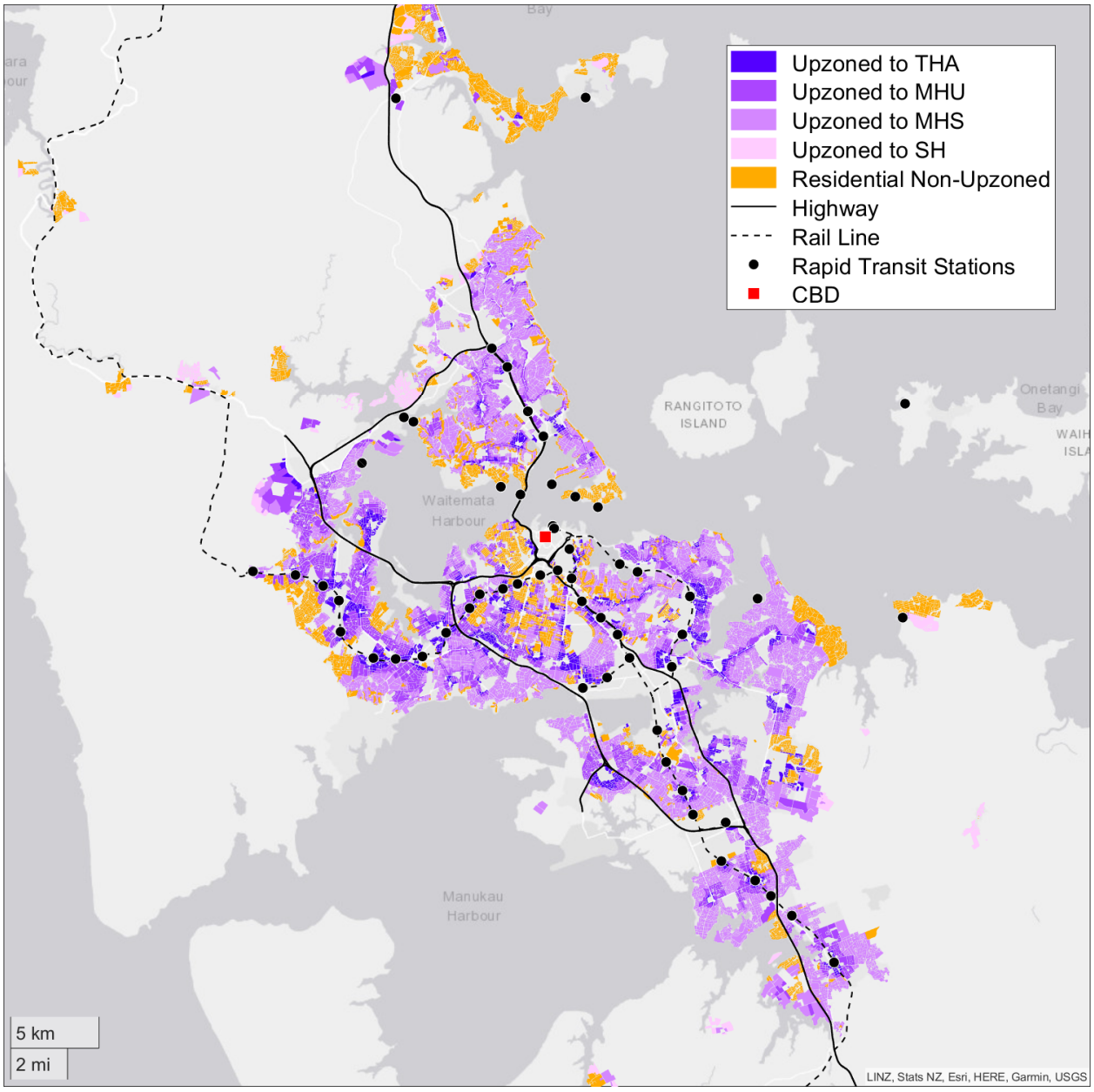
For each location, we calculate the amount of non-upzoned and upzoned residential land at different distances to the location. Figure 2 depicts the results, alongside the proportion of upzoned land. The supplementary material contains a figure that decomposes the upzoned areas by residential zone.

The bulk of residential land is between 5 and 25km of the CBD. The proportion of upzoned land is highest between 5 and 35km, consistently exceeding 60%. This reflects the fact that Single House areas are predominantly located either close to the CBD, due to character neighbourhood protections, or far from the CBD. For example, within 2km of the CBD, approximately 30% of land is upzoned, while between 2 and 4km, less than 40% is upzoned. For job centres, the bulk of residential land is between 2 and 10km of a job centre. The proportion of upzoned land is fairly constant, at approximately 80% or above, out to 18km. For access to transportation networks, the bulk of residential land is within 1 to 6km of a highway on-ramp or an RT station. The proportion of upzoned land is fairly uniform with respect to distance to on-ramps, whereas its decreases beyond 6km of RT stations.

[15] Meshblocks are the most granular geographic unit used by Statistics New Zealand and are similar to census tracts in the US. We use 2018 vintages.

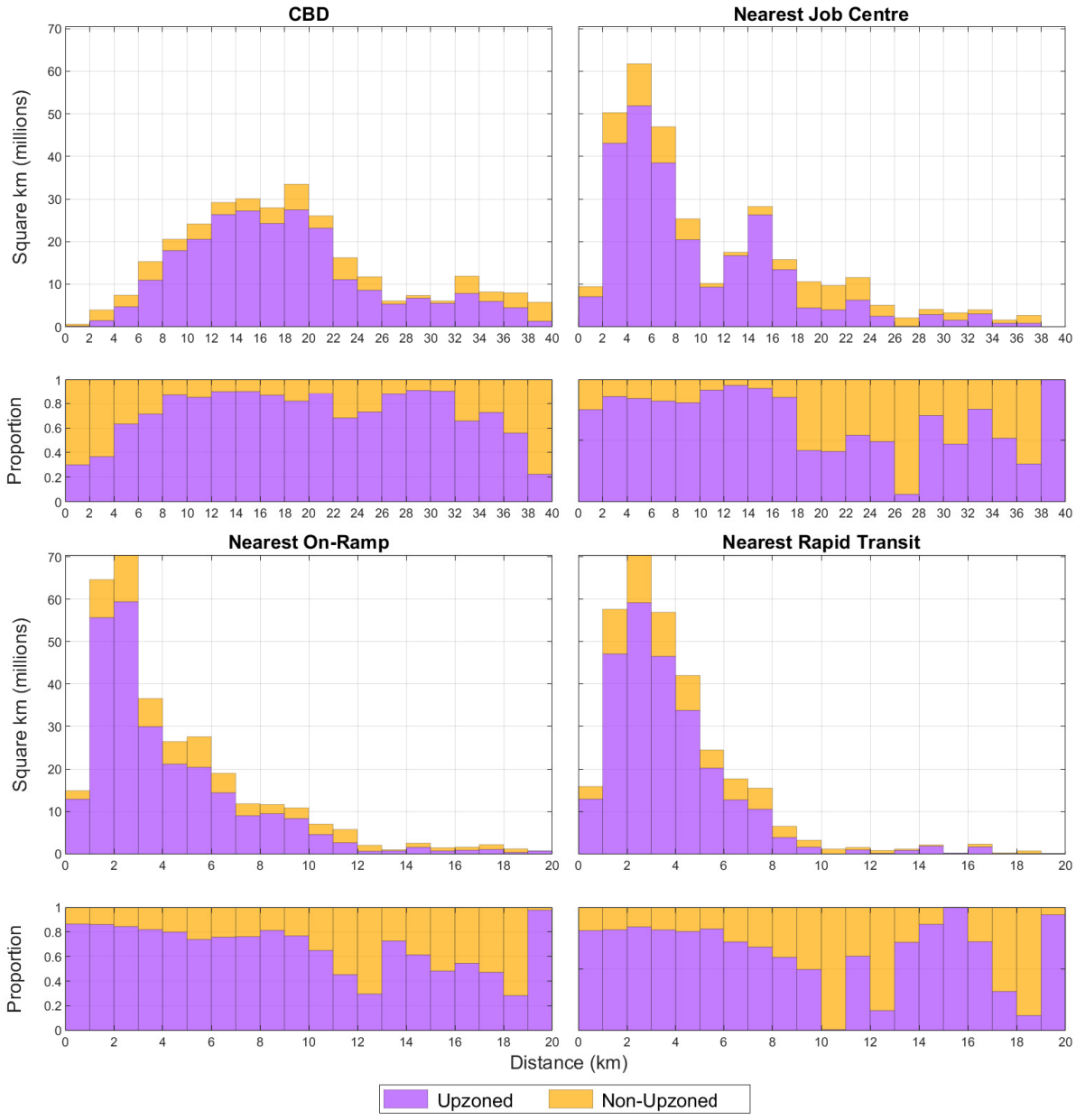
[16] Specifically, job centres comprise the smallest set of Statistical Areas that contain at least a third of all employees in Auckland under the 2018 census. Fifteen of 553 SAs are classified as job centres. We use 2018 SA2s.

Figure 1: Upzoned and Non-upzoned Residential Areas of Auckland



Notes: Rapid Transit stations include heavy rail stations, dedicated busway stations, and ferry terminals. The CBD marker is centred on the iconic 'Sky Tower' skyscraper in the CBD. Water in grey.

Figure 2: Distance between Upzoned Land and Locations of Interest



Notes: Total areas (in sq km) and proportions of upzoned and non-upzoned residential land. Residential comprises SH, MHS, MHU and THA, and excludes semi-rural zones.

4 Changes in Housing Development

We use individual dwelling consents (hereafter 'consents') as our measure of housing construction.[17] This section documents changes in consents after the operationalisation of the AUP.

4.1 Number of Consented Dwellings

Table 2 displays the number of consents issued in the five years before and after the AUP. The number of consents doubles, increasing from approximately 38,000 over the 2012 to 2016 period, to 76,000 in the 2017 to 2021 period. There is also a substantial increase in the number of attached (or multi-family) dwellings, which increase from approximately 11,000 to 41,000. This increase pushes the share of attached dwellings up from 29.6 to 53.9%. Decomposing consents into zoning categories, there is substantially more construction occurring in the Residential-High (THA), Medium (MHU), and Medium-Low (MHS) areas post-AUP. To confirm that this increase is driven, in part, by the compositional shift in the amount of land in higher zoning categories (see Table 1), we also decompose consents into upzoned and non-upzoned areas. Consents in upzoned areas increased by approximately 37,000, while non-upzoned areas increased by 2,000, confirming that almost all of the overall increase in consents is occurring on upzoned parcels.

Figure 3 presents annual consents between 2000 and 2022 decomposed into different areas according to zoning changes. Total consents increase from approximately 9,200 in 2015, the year prior to the AUP becoming operational in November 2016, to 21,000 by 2022. The 2022 peak far exceeds the previous peak of 12,500 consents in 2002, which was driven by a construction boom in business areas (particularly the CBD).[18]

Figure 3 reaffirms that most of the increase in consents since 2016 is due to increased consents located in areas upzoned to MHS, MHU or THA. The proportion of dwelling consents issued in areas upzoned to Business, Single House or Semi-Rural are very small. The middle panel of figure 3 decomposes consents into attached and detached dwellings, and shows that most of the increase since 2016 is attached dwellings in upzoned areas.

In the analysis to follow, we focus solely on residential areas (SH, MHS, MHU and THA), as the spatial plan underpinning the AUP was focussed primarily on increasing density in residential areas, and most of the increase in dwelling consents are in upzoned residential areas.

[17] Consents are a measure of housing starts – not completed dwellings. Unfortunately the institutional features of administrative data collection in Auckland make it difficult to directly measure completions. However, experimental estimates from Statistics New Zealand (SNZ) imply completion rates in New Zealand are well above 90%. Using 'code of compliance certificates' (CCC) as a measure of completion indicates a 91.2% completion rate for New Zealand over the ten years to December 2018. However, dwellings can be inhabited without a CCC. Using the final building inspection as a measure of completion results in a completion rate of 92.9%. See https://www.stats.govt.nz/experimental/experimental-building-indicators-march-2022-quarter/ [accessed 05/09/2023]. 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] SNZ does not provide experimental estimates of completions for Auckland.

[18] Records for the Auckland region begin in 1991. Prior to the AUP, annual consents peaked in 2002. Annual consents for 2018 to 2022 inclusive exceed this previous peak.

Table 2: New Dwelling Consents, 2012–2021

By Zoning Category

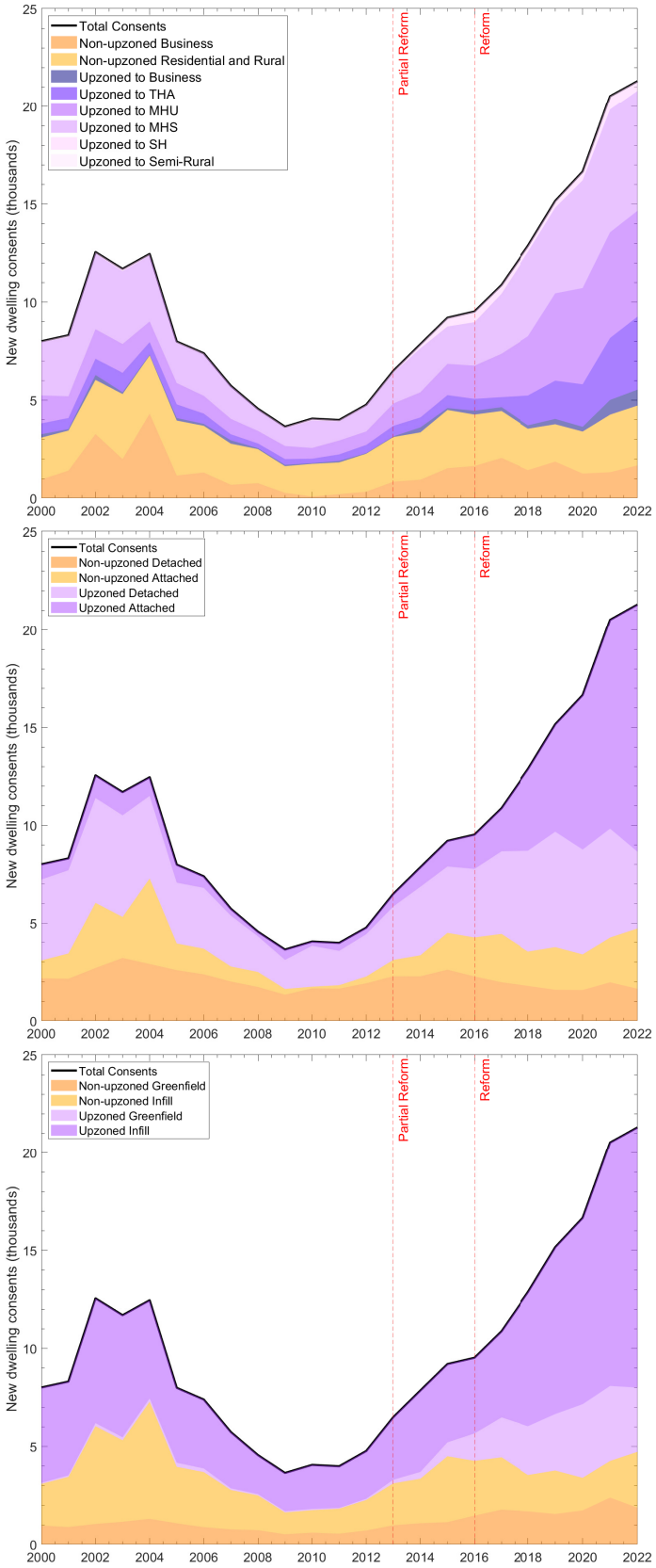
Zoning Category	District and City Plans (operational before 15 Nov 2016) Consented Dwellings, 2012-16			Unitary Plan (operational after 15 Nov 2016) Consented Dwellings, 2017-2021		
	Attached	Detached	Total	Attached	Detached	Total
Business	5,244	738	5,982	8,280	967	9,247
Residential-High or THA	61	211	272	8,580	1,349	9,929
Residential-Medium or MHU	687	1,048	1,735	12,428	7,994	20,422
Residential-Medium-Low or MHS	604	603	1,207	9,027	14,952	23,979
Residential-Low or SH	3,261	17,550	20,811	1,436	5,617	7,053
Semi-Rural	32	1,715	1,747	183	918	1,101
Rural and Open Space	667	3,569	4,236	1,057	3,274	4,331
Mixed	615	1,189	1,804			
Total	11,171	26,623	37,794	40,991	35,071	76,062

By Zoning Change

Zone change (November 2016)	District and City Plans (operational before 15 Nov 2016) Consented Dwellings, 2012-16			Unitary Plan (operational after 15 Nov 2016) Consented Dwellings, 2017-21		
	Attached	Detached	Total	Attached	Detached	Total
Upzoned to Business	381	163	544	1,047	448	1,495
Upzoned to THA	1,283	1,293	2,576	7,681	1,250	8,931
Upzoned to MHU	1,600	3,574	5,174	10,997	7,514	18,511
Upzoned to MHS	1,126	7,754	8,880	8,989	14,403	23,392
Upzoned to SH	30	1,234	1,264	331	1,789	2,120
Upzoned to Semi-Rural	3	74	77	10	67	77
Total Upzoned	4,423	14,092	18,515	29,055	25,471	54,526
Non-upzoned	6,133	11,342	17,475	10,487	8,759	19,246
Indeterminate	615	1,189	1,804	1,449	841	2,290
Total	11,171	26,623	37,794	40,991	35,071	76,062

Notes: See notes to Table 1. Areas classified as 'Mixed' prior to the AUP comprise the 'Indeterminate' zoning change category.

Figure 3: Dwelling Consents by 2016 Zoning Change, 2000 to 2022



Notes: Infill is based on the 2016 urban extent. 'Partial Reform' refers to the SpHA-PAUP program, which begins in September 2013. Full zoning reform occurs in November 2016. See section 2.1.

4.1.1 Difference-in-Differences Event Study

Table 2 and figure 3 shows that consents increased once the AUP became operational, and that the increase was on upzoned parcels. However, these patterns may reflect systematic differences in long-run trends between upzoned and non-upzoned parcels, rather than the policy change itself. For example, planners may have targetted desirable suburbs or parcels for upzoning, such that the increase in consents in upzoned areas reflects a supply response to increasing demand that would have occurred under the counterfactual of no upzoning.

We assess whether there are differences in trends between upzoned and non-upzoned areas prior to the policy change by fitting a multiperiod difference-in-differences (DID) regression:

$$\begin{aligned} y_{i,t} &= \alpha_0 + \alpha_1 \mathbf{1}_{i\in j=1} + \sum_{s=-\underline{T},s\neq 0}^{\overline{T}} \phi_s \mathbf{1}_{s=t} + \sum_{s=-\underline{T},s\neq 0}^{\overline{T}} \beta_s \mathbf{1}_{s=t}\mathbf{1}_{i\in j=1} + \xi_0' Z_i \\ &\quad + \sum_{s=-\underline{T},s\neq 0}^{\overline{T}} \mathbf{1}_{s=t}\xi_s' Z_i + \mathbf{1}_{i\in j=1}\gamma_0' Z_i + \sum_{s=-\underline{T},s\neq 0}^{\overline{T}} \mathbf{1}_{s=t}\mathbf{1}_{i\in j=1}\gamma_s' Z_i + \varepsilon_{i,t}, \end{aligned} \tag{1}$$

where $y_{i,t}$ is the number of consented dwellings for parcel i in year t; $\mathbf{1}_{i\in j=1}$ is an indicator equal to one if parcel i is in area j, where$j = 0$ denotes non-upzoned areas and $j = 1$ denotes upzoned; and $\mathbf{1}_{s=t}$is an indicator equal to one if $s = t$. The period index t ranges from $t = -\underline{T}$ years prior to upzoning to $t = \bar{T}$ years post upzoning, with $t = 0$ signifying the year when upzoning occurred. We set this to 2016, when the AUP was operationalised.

The sequence of fitted coefficients $\{\beta_s\}_{s=-\underline{T}}^{-1}$ reveals whether trends in consents in upzoned areas differed from trends in non-upzoned areas prior to 2016. If these coefficients are not trending up prior to operationalisation, then there was no difference in trends between upzoned and non-upzoned areas prior to the policy. Meanwhile$\{\beta_s\}_{s=1}^{\overline{T}}$ capture the relative increase in consents in upzoned areas for each year post-operationalisation. These coefficients should be positive if trends in consents in upzoned areas increase relative to non-upzoned areas.

The model also includes parcel-level covariates in the vector Z_i to account for potential confounders and parcel selection for upzoning in the planning decision. Because areas close to transportation and the CBD (excluding character areas) were targetting for upzoning, we include Manhattan distance to the nearest transportation network access point (either on-ramp or RT station) and the Haversine distance to the CBD. To account for land quality, we include the proportions of parcel area: above a 15% slope[19]; under a flood plain, flood sensitive or flood prone area; and subject to coastal inundation. Finally, we include Haversine distance to the nearest coastline as a natural amenity.

These covariates account for alternative mechanisms moderated by the factors that were used by planners to select parcels for upzoning. For example, suppose that a significant increase in traffic congestion at the same time of the reform increased demand for housing close to transportation network access points, generating an increase in consents on upzoned parcels because such parcels are more likely to be close to on-ramps or RT stations.

[19] Saiz (2010) uses designates under 15% slope as buildable land

Following the suggestion of Meyer (1995), the covariates have differential impacts in upzoned and non-upzoned areas, which allows for heterogeneous treatment effects in the covariates (Sant'Anna and Zhao, 2020). We provide evidence of this heterogeneity in the supplementary material to the paper. Because the covariates are time-invariant, estimation of the treatment effects is straightforward, obviating the need for more complicated methods proposed by Sant'Anna and Zhao (2020). We estimate models both with and without these covariates.

The top panel of Figure 4 exhibits the estimates of $\{\beta_s\}_{s=-\underline{T},s\neq 0}^{\overline{T}}$ alongside 95% confidence intervals. Estimates are statistically indistinguishable from zero, and exhibit no trend, until operationalisation in 2016. The lack of a clear trend prior to 2016 indicates that there was no difference in the trends in consents in upzoned areas and non-upzoned areas prior to the policy. Thereafter the coefficients trend upwards, reaching 0.045 by 2021. This indicates that each upzoned parcel had 0.045 more consents issued (on average) than non-upzoned parcels in 2021.

The supplementary material contains results for when parcels that were of indeterminate FAR classification prior to the AUP are excluded and when downzoned parcels are excluded. Patterns remain unchanged.

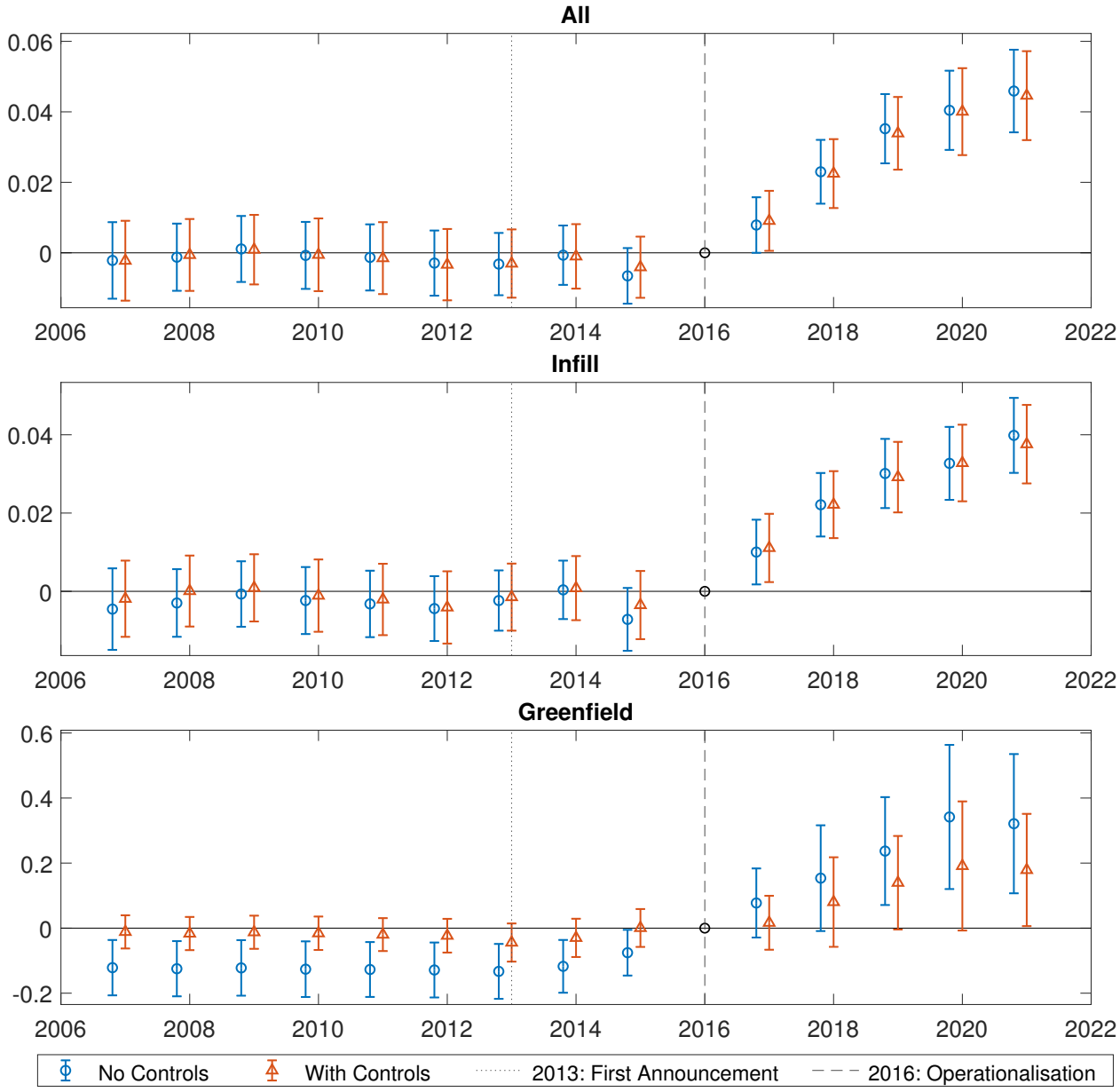
4.2 Greenfield and Infill Development

As discussed above, a key strategic goal underpinning the zoning reform was to promote housing in existing urban areas. To examine the extent to which this is occurring, we bifurcate our sample into greenfield and infill development. Greenfield land refers to parkland or farmland on the urban periphery Biddle *et al.* (2006) that necessitates substantially higher infrastructure costs to develop compared to infill housing, including electricity, water, sewerage, transport, and telecommunications (Hamilton and Kellett, 2017). Following Biddle *et al.* (2006), we use 'infill' development to refer to redevelopment or intensification of existing residential land, as well as residential construction on commercial zoned land.

We use the "urban extent" of Auckland to delineate greenfield and infill housing development. The urban extent is a geographical measure of developed urban areas that excludes rural, peri-urban (i.e., semi-rural) and open space areas. It is constructed by AC using satellite imagery of cadastral land parcels. See Fredrickson (2014) for further description of the concept and classification methodology, and the supplementary material for a graphical depiction. For descriptive analysis, we decompose our sample into parcels inside and outside the urban extent for urban extent measures in 2010 and 2016.

The bottom panel of figure 3 presents consents decomposed into infill and greenfield areas, showing that most of the increase in upzoned areas is infill development. However, there has also been a sizeable increase in greenfield development in upzoned areas.

Figure 4: Difference-in-Differences Event Study



Notes: Point estimates of treatment effects and 95% confidence intervals. Standard errors are clustered by parcel and include a Conley Bartlett kernel in the cross sectional dimension (with a bandwidth of 1km) to account for spatial dependence. See the Appendix. Infill (greenfield) denote parcels inside (outside) the 2016 urban extent.

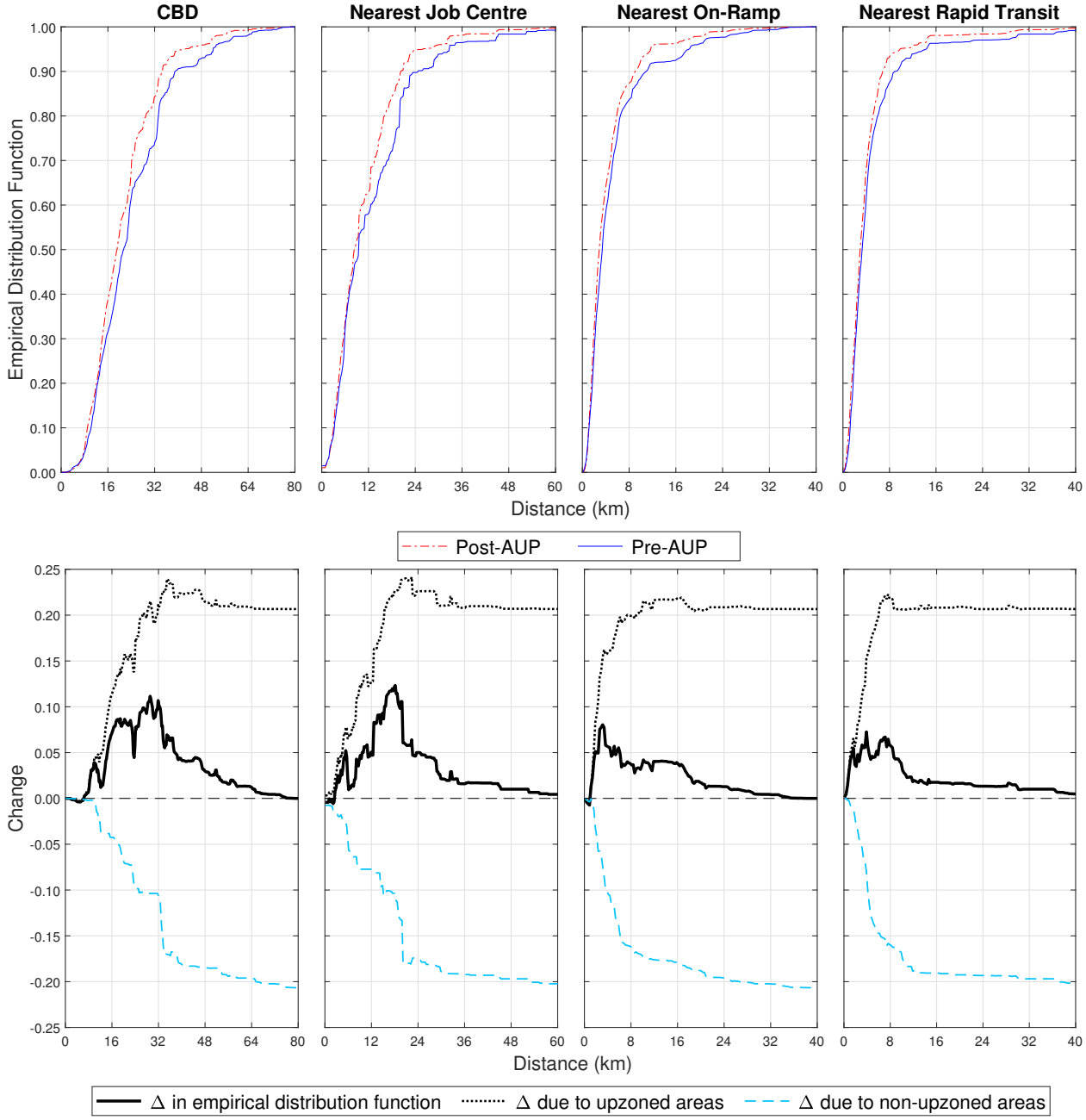
Table 3: Greenfield and Infill Consents by Zoning Change, 2012–2021

Zone Change (November 2016)	Greenfield					
	District and City Plans (prior to Nov 2016)			Unitary Plan (from Nov 2016)		
	Consented Dwellings, 2012-16			Consented Dwellings, 2017-21		
	Attached	Detached	Total	Attached	Detached	Total
Upzoned to Business	107	64	171	129	360	489
Upzoned to THA	138	237	375	385	175	560
Upzoned to MHU	402	548	950	1,824	2,549	4,373
Upzoned to MHS	65	2,410	2,475	1,447	5,544	6,991
Upzoned to SH	18	1,141	1,159	281	1,623	1,904
Upzoned to Semi-Rural	3	74	77	10	67	77
Total Upzoned	733	4,474	5,207	4,076	10,318	14,394
Non-upzoned	761	8,167	8,928	2,325	6,642	8,967
Indeterminate	510	919	1,429	396	330	726
Total	2,004	13,560	15,564	6,797	17,290	24,087

Zone Change (November 2016)	Infill					
	District and City Plans (prior to Nov 2016)			Unitary Plan (from Nov 2016)		
	Consented Dwellings, 2012-16			Consented Dwellings, 2017-21		
	Attached	Detached	Total	Attached	Detached	Total
Upzoned to Business	274	99	373	918	88	1,006
Upzoned to THA	1,145	1,056	2,201	7,296	1,075	8,371
Upzoned to MHU	1,198	3,026	4,224	9,173	4,965	14,138
Upzoned to MHS	1,061	5,344	6,405	7,542	8,859	16,401
Upzoned to SH	12	93	105	50	166	216
Upzoned to Semi-Rural	0	0	0	0	0	0
Total Upzoned	3,690	9,618	13,308	24,979	15,153	40,132
Non-upzoned	5,372	3,175	8,547	8,162	2,117	10,279
Indeterminate	105	270	375	1,053	511	1,564
Total	9,167	13,063	22,230	34,194	17,781	51,975

Notes: Infill (greenfield) development occurs within (outside) the urban extent (UE). 2010 UE is used for consents issued 2012–2016; 2016 UE for 2017–2021.

Figure 5: Spatial Distribution of Consents before and after Upzoning



Notes: Top row: Empirical cumulative distribution functions (EDFs) of the distances between consents and various locations. Bottom row: Difference in EDFs between 2012–2016 and 2017–2021, and decomposition into upzoned and non-upzoned areas.

4.3 Spatial Distribution of Housing Development

Next we illustrate changes in the spatial distribution of consents relative to geographically-fixed points. To do so, we calculate the Manhattan distance between the centroid of each consent's meshblock and: (i) the CBD; (ii) the nearest job centre; (iii) the nearest highway on-ramp; and (iv) the nearest RT station.

The top row of Figure 5 depicts the empirical (cumulative) distribution function (EDF) of the distance between consents and the various locations. The x-axis plots distance to the location. The EDF is then the proportion of consents that are within a given distance as measured on the the x-axis. Let $y_{i,s}$ denote the number of consents during period s on parcel i, and let x_i denote the distance from parcel i to a fixed point of interest (e.g. CBD). The EDF for period s is

$$F_s(x) = \frac{\sum_{i=1}^{n} y_{i,s} \mathbf{1}_{x_i \leq x}}{\sum_{i=1}^{n} y_{i,s}} \tag{2}$$

where $\mathbf{1}_{x_i \leq x} = 1$ for $x_i \leq x$ and zero otherwise. As distance increases, the EDF approaches one, as all consents are within an arbitrarily large distance of the location.

The EDF for CBD has increased, showing that residential construction is moving closer to the CBD. For example, prior to the AUP, approximately 50% of consents were within 20km of the CBD. After the AUP, 60% of consents were within this distance. Much of the contraction is occurring in the outer suburbs. The 25th percentile barely changes, from 13.2km prior to the AUP, to 12.6km after. Meanwhile the 50th and 75th percentiles shift from 19.9 to 17.9km, and from 32.1 to 25.1km, respectively. We see a similar pattern for nearest on-ramp, RT station, and job centre: The spatial distribution of consents has contracted towards these locations.

The second row of Figure 5 depicts the difference in EDFs, namely $F_1(x) - F_{-1}(x)$, where $s = 1$ denotes post-AUP, and $s = -1$ denotes pre-AUP. Positive values indicate the distribution of consents has contracted towards the location. To examine whether the shift in the spatial distribution is driven by upzoning, we decompose the difference in EDFs into changes in upzoned and non-upzoned areas. Let S_U denote the subset of n_U parcels that are upzoned, and let S_N denote the subset of n_N parcels that were not upzoned, such that $n = n_U + n_N$. The difference in EDFs can be decomposed as

$$F_1(x) - F_{-1}(x) = F_{U,1}(x) - F_{U,-1}(x) + F_{N,1}(x) - F_{N,-1}(x) \tag{3}$$

where $F_{k,s}(x) = \left(\sum_{i=1}^{n} y_{i,s}\right)^{-1} \sum_{i \in k} y_{i,s} \mathbf{1}_{x_i \leq x}$ and $k \in \{U, N\}$.

For each location, the contraction in the spatial distribution is being driven by changes in upzoned areas: $F_{U,1}(x) - F_{U,-1}(x)$ is generally positive in x,while $F_{N,1}(x) - F_{N,-1}(x)$ is negative, but of smaller magnitude.

5 Conclusion

Beginning in 2010, Auckland's policymakers embarked on an ambitious plan to encourage more compact urban development for the growing city, culminating in the 2016 Auckland Unitary Plan (AUP). We show that the AUP upzoned approximately three-quarters of residential land, predominantly in areas close to transportation links and between five and twenty-five kilometres of the CBD. Subsequent patterns in housing construction indicate that the AUP achieved many of its goals. Housing construction has increased; is located closer to the CBD, employment locations, and transportation network access points; and is more reliant on infill development and attached housing. These patterns are driven by changes in housing construction in upzoned areas, consistent with zoning reforms causing changes in observed development patterns, and suggesting that the policy successfully stimulated housing supply in the areas targeted for increased capacity.

6 Appendix

6.1 LURs under the AUP

Table 4: Summary of Land Use Regulations by Residential Zone under the Unitary Plan

Regulation	Terraced Housing Apartments	Mixed Housing Urban	Mixed Housing Suburban	Single House	Large Lot	Rural and Coastal Settlement
Max. height	16m (5 to 7 storeys)	11 to 12m (three storeys)	8 to 9m (two storeys)	8 to 9m (two storeys)	8 to 9m (two storeys)	8 to 9m (two 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	does not apply	2.5m up + 45° recession plane
Setback (side and rear)	0m	1m	1m	1m	6m	1m
Setback (front)	1.5m	2.5m	3m	3m	10m	5m
Max. site coverage (%)	50%	45%	40%	35%	lesser of 20% or 400m^2	lesser of 20% or 400m^2
Max. impervious area (%)	70%	60%	60%	60%	lesser of 35% or 1400m^2	lesser of 35% or 1400m^2
Min. dwelling size (1 bedroom)	45m^2	45m^2	45m^2	n/a	n/a	n/a
Max. dwellings per site	does not apply	3	3	1	1	1
Min. Lot Size (subdivision)	1200m^2	300m^2	400m^2	600m^2	2500m^2	4000m^2

Notes: Restrictions are 'as of right' and can be exceeded through resource consent notification. 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. Number of storeys (in parentheses) are obtained from the stated purpose of the height restriction in the regulations. Planners have discretion in setting height in relation to boundary and setbacks in the large lot zone, with regulations requiring "development to be of a height and bulk and have sufficient setbacks and open space to maintain and be in keeping with the spacious landscape character of the area". 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.

6.2 Conley Clustered Standard Errors

Let x_i denote a $T \times m$ matrix of regressors and let $\hat{e}_i$ denote a $T \times 1$ vector of regression errors. Then the covariance matrix is $\left(\sum_{i=1}^{n} x_i x_i'\right)^{-1} \hat{\Omega} \left(\sum_{i=1}^{n} x_i x_i'\right)^{-1}$

$$\hat{\Omega} \quad = \quad \sum_{j=1}^{n} \sum_{i=1}^{n} k_{i,j} x_i' \hat{e}_i \hat{e}_j' x_j$$

for Bartlett kernel $k_{i,j} = max\left(1 - \frac{d_{i,j}}{b}, 0\right)$, where $d_{i,j}$ is the Haversine distance between i and j,and b is the bandwidth.

6.3 Geomatching Consents to Parcels

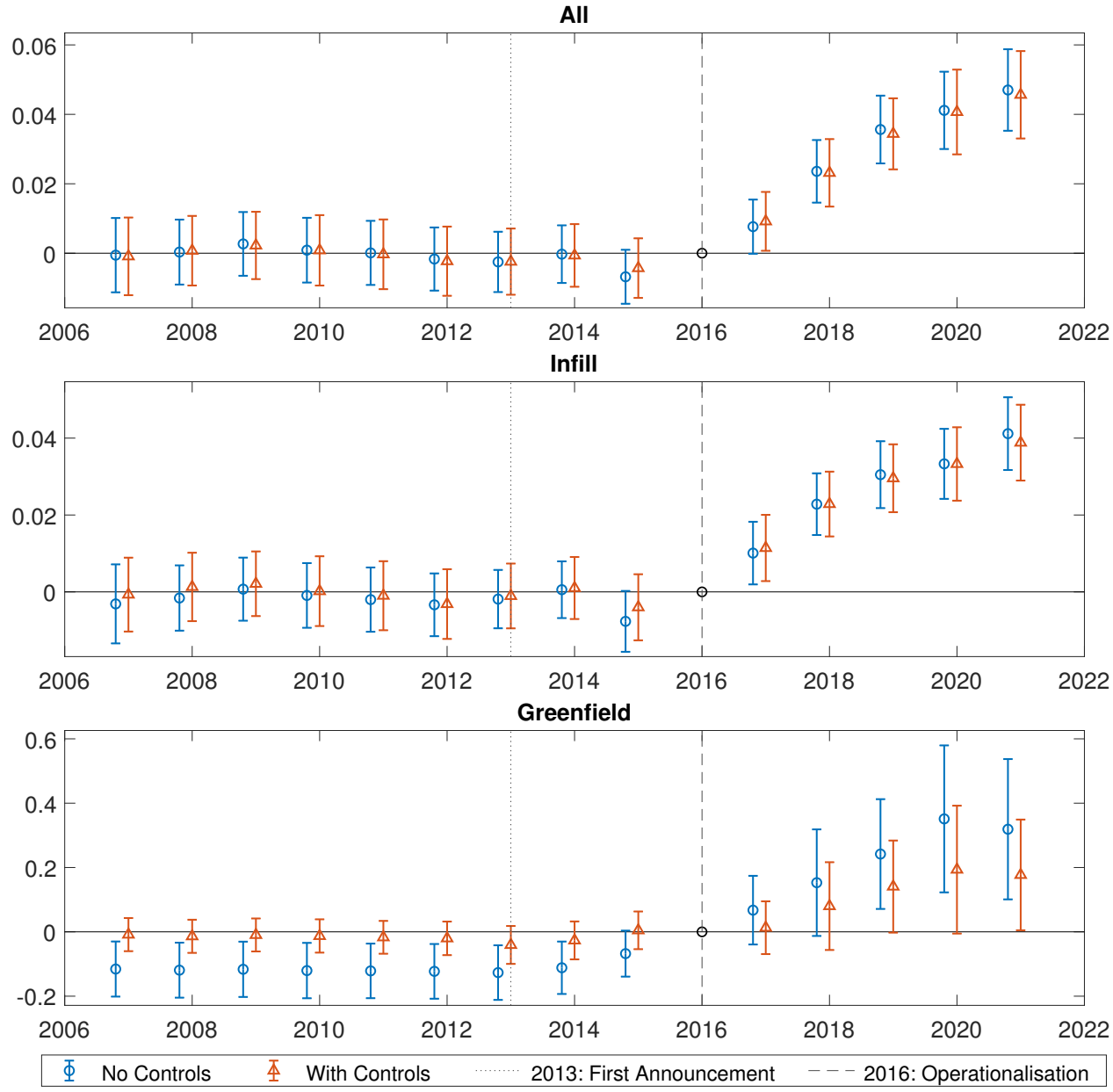
Consents are matched to parcels through the following algorithm: 1. Find the LINZ parcel of the geocoordinate of the consent and check whether the road number and first word of the road match. If these do not match: 2. Find all the LINZ parcels within 1250m of the geo-coordinate of the consent and search 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 and check whether the road number and first word of the road match the address of the parcel at the geocoordinate of the consent. If there is no match: 4. Find all the LINZ parcels within 1250m of the geo-coordinate of the consent 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 LINZ parcel of the geo-coordinate of the consent. Check whether the name of the road in the address of the LINZ parcel matches the road name of the address given in the consent. If there is no match: 6. Identify the nearest LINZ parcel of the geo-coordinate of the consent 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 set of parcels.

6.4 Supplementary Material

6.4.1 Additional Difference-in-Differences Results

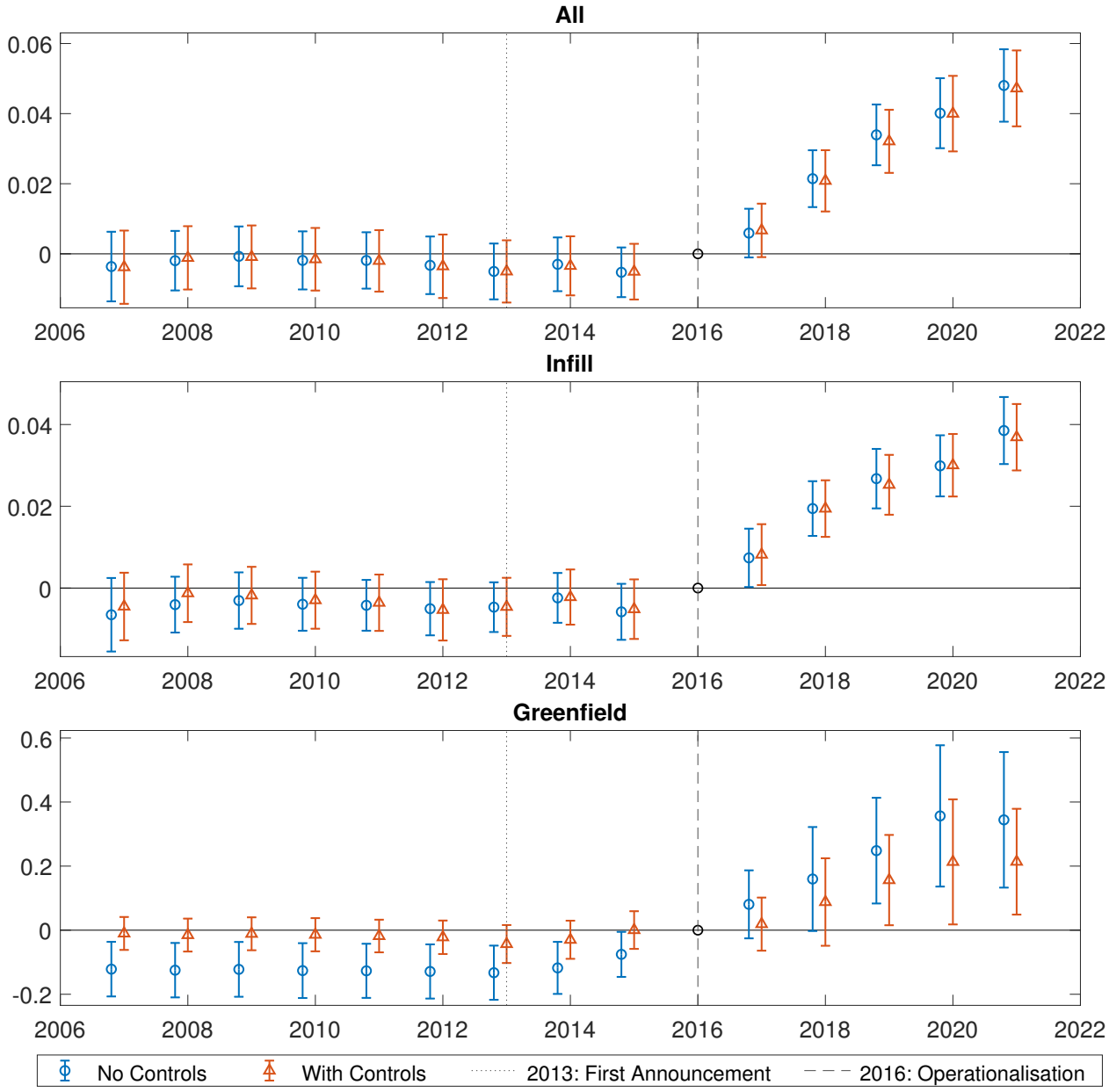
This section contains multiperiod difference-in-differences (DID) results with different samples.

Figure 6: DID Event Study with Indeterminate Zones Excluded



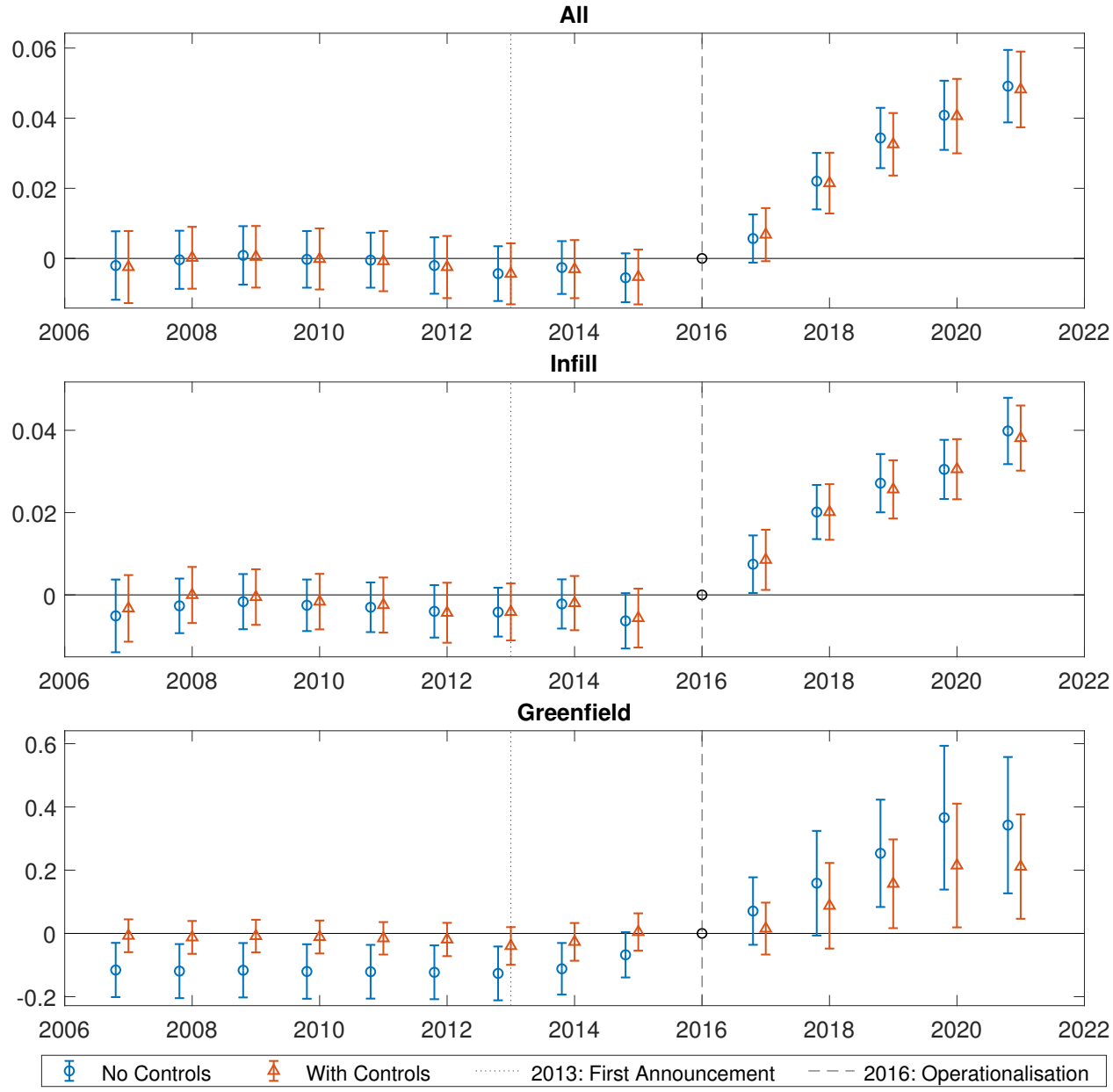
Notes: Sample excludes parcels that were indeterminate FAR classification prior to the AUP. Model with covariates allows for heterogeneous treatment effects. Standard errors are clustered at the parcel level to account for time series heteroskedasticity and dependence, and include a Conley Bartlett kernel in the cross sectional dimension (with a bandwidth of 1km) to account for spatial dependence. Vertical dotted and dashed lines denote the first announcement of the AUP in 2013 and its operationalisation in 2016.

Figure 7: DID Event Study with Downzoned Areas Excluded



Notes: Sample excludes parcels that were indeterminate FAR classification prior to the AUP and downzoned parcels. Model with covariates allows for heterogeneous treatment effects. Standard errors are clustered at the parcel level to account for time series heteroskedasticity and dependence, and include a Conley Bartlett kernel in the cross sectional dimension (with a bandwidth of 1km) to account for spatial dependence. Vertical dotted and dashed lines denote the first announcement of the AUP in 2013 and its operationalisation in 2016.

Figure 8: DID Event Study with Indeterminate Zones and Downzoned Areas Excluded



Notes: Sample excludes downzoned parcels. Model with covariates allows for heterogeneous treatment effects. Standard errors are clustered at the parcel level to account for time series heteroskedasticity and dependence, and include a Conley Bartlett kernel in the cross sectional dimension (with a bandwidth of 1km) to account for spatial dependence. Vertical dotted and dashed lines denote the first announcement of the AUP in 2013 and its operationalisation in 2016.

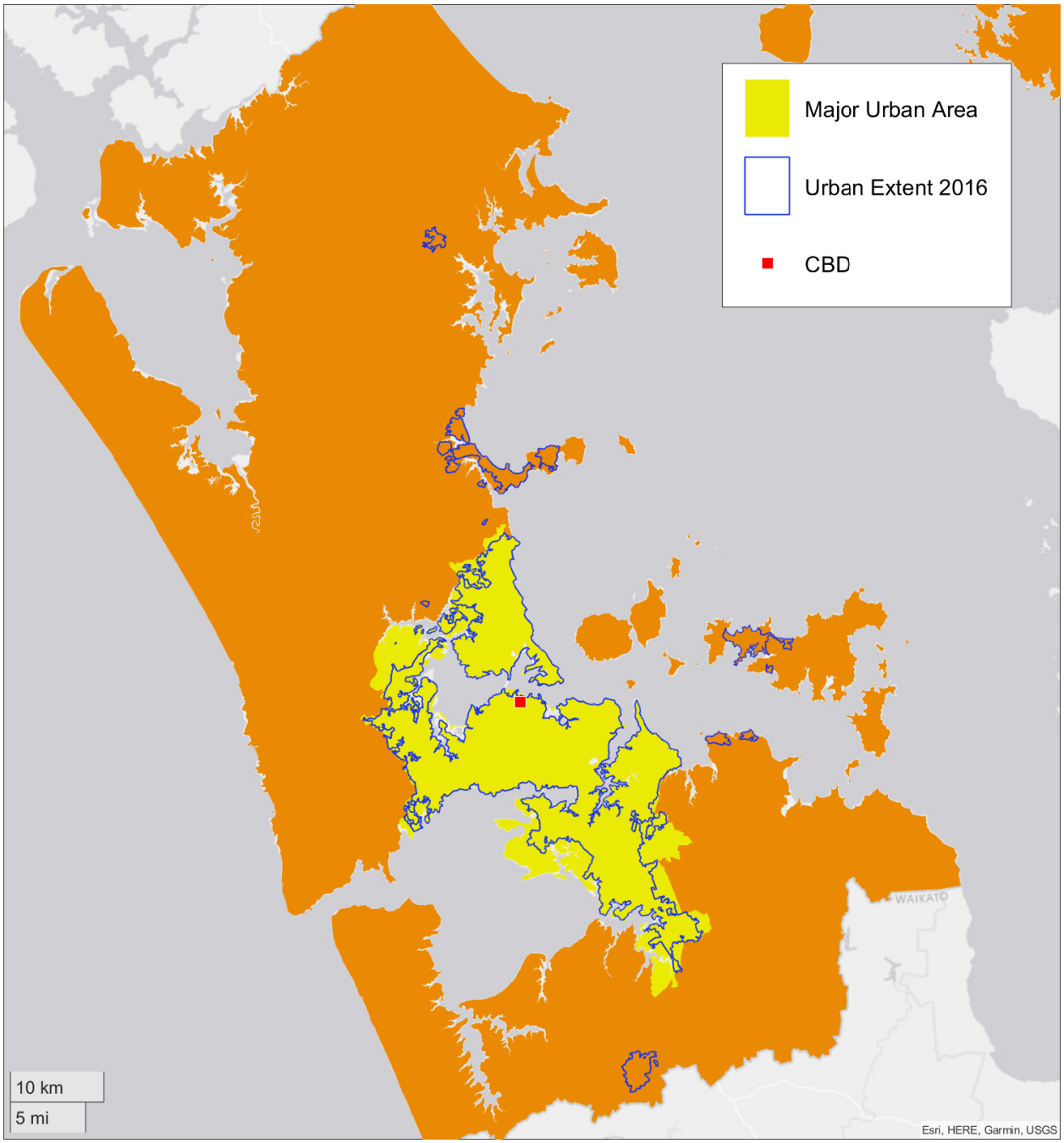
6.4.2 Additional Tables and Figures

Table 5: Statistical Areas ordered by total employment

			Proportion of Total Employment	
Code	Name	Total Employment	Proportion	Cumulative Proportion
145900	Penrose	25,737	0.0348	0.0348
118600	North Harbour	24,459	0.0331	0.0680
152300	East Tamaki	24,165	0.0327	0.1007
147900	Auckland Airport	23,658	0.0320	0.1327
133300	Quay Street-Customs Street	16,884	0.0229	0.1556
138500	Newmarket	15,462	0.0209	0.1765
133200	Queen Street	15,306	0.0207	0.1972
131300	Wynyard-Viaduct	15,234	0.0206	0.2178
155500	Manukau Central	15,000	0.0203	0.2382
147700	Mount Wellington Industrial	13,257	0.0179	0.2561
157600	Wiri West	12,654	0.0171	0.2732
132700	Hobson Ridge North	11,583	0.0157	0.2889
126600	Takapuna West	10,632	0.0144	0.3033
136400	Parnell West	10,416	0.0141	0.3174
123500	Wairau Valley	10,008	0.0135	0.3310
136000	Eden Terrace	9,804	0.0133	0.3442
133700	Shortland Street	9,609	0.0130	0.3572
132400	Victoria Park	9,390	0.0127	0.3700
144200	Ellerslie West	9,153	0.0124	0.3823
136100	Grafton	8,190	0.0111	0.3934
145500	Onehunga-Te Papapa Industrial	7,941	0.0108	0.4042
128700	Rosebank Peninsula	7,707	0.0104	0.4146
127500	Henderson Central	7,653	0.0104	0.4250
126800	Takapuna Central	7,500	0.0102	0.4351
117300	Albany Central	7,182	0.0097	0.4449
125100	Henderson Lincoln East	6,474	0.0088	0.4536
133500	Grey Lynn East	6,174	0.0084	0.4620
156000	Botany Junction	6,126	0.0083	0.4703
134800	Auckland-University	5,139	0.0070	0.4772
133900	New Lynn Central	5,079	0.0069	0.4841
150100	Otahuhu Central	5,079	0.0069	0.4910
166000	Pukekohe Central	5,070	0.0069	0.4979
152700	Middlemore	4,989	0.0068	0.5046

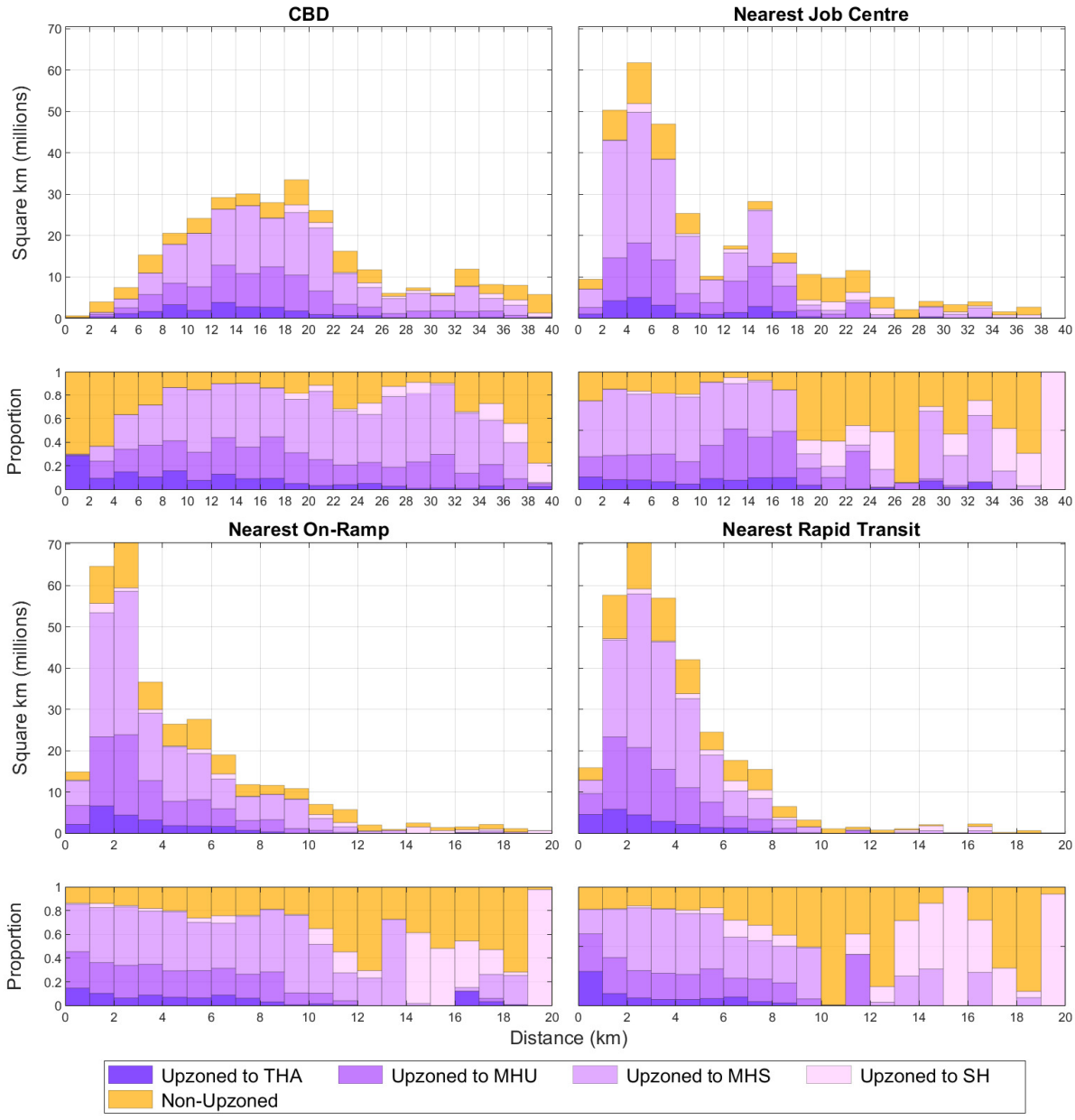
Source: 2018 census based on 2018 Statistical Area 2 (SA2) units. Total employment includes self employed individuals. For brevity, the top 32 out of 553 Statistical Areas are tabulated.

Figure 9: Auckland Region



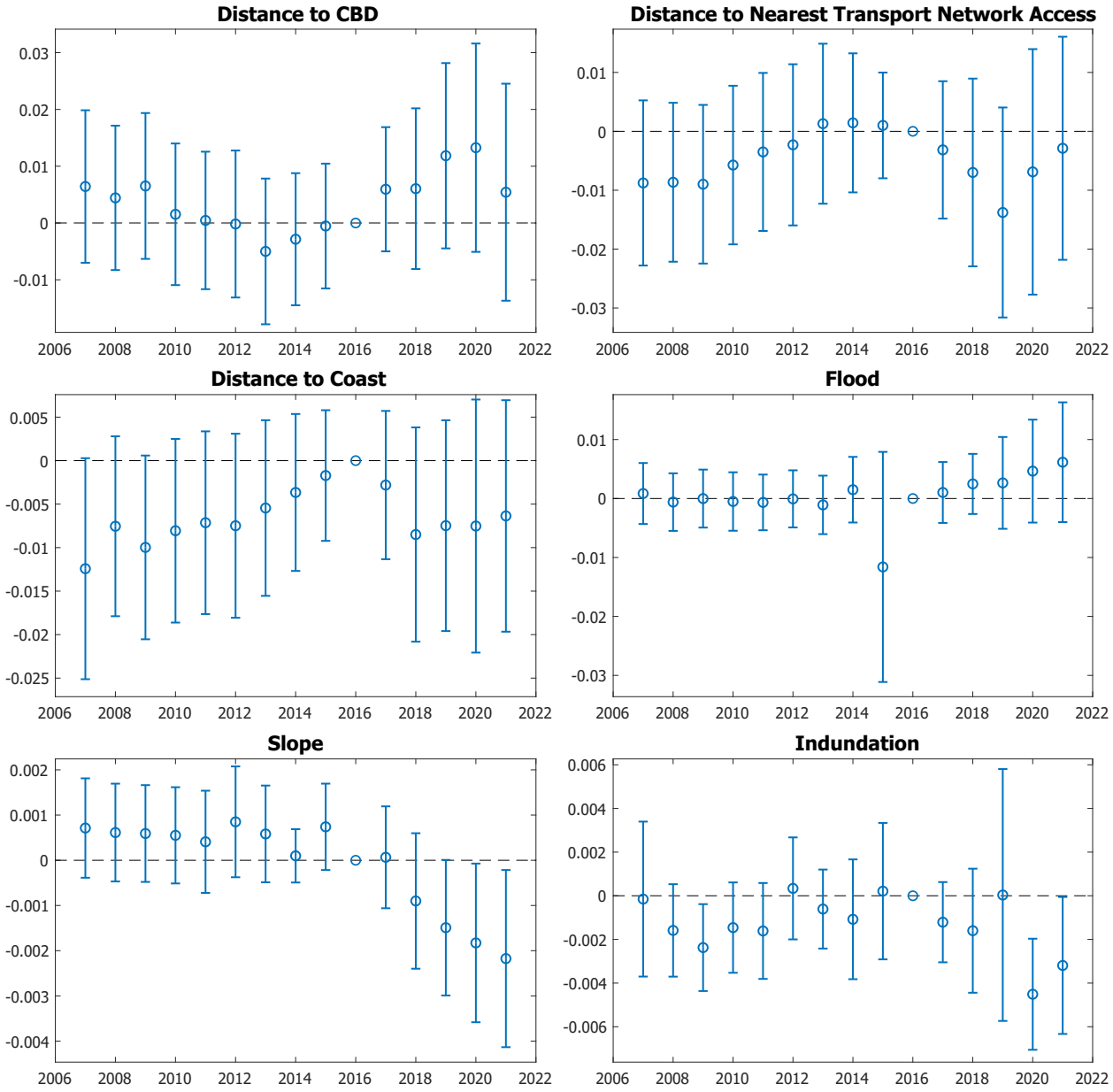
Notes: Auckland region with 2016 Urban Extent and Major Urban Area.

Figure 10: Distance between Upzoned Land and Locations of Interest



Notes: Total areas (in sq km) and proportions of upzoned and non-upzoned residential land. Residential comprises SH, MHS, MHU and THA, and excludes semi-rural zones.

Figure 11: Heterogeneous Treatment Effects



Notes: Estimated coefficients (circles) and 95% confidence intervals (error bars) on covariates interacted with upzoning and year indicators. Statistically significant coefficients indicate heterogeneous treatment effects.

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