Cost-Benefit Analysis of proposed Medium Density Residential Standards

Context

In response to housing supply shortages, the Ministry for the Environment required cost-benefit analysis of two amendments to the Resource Management Act that require councils to up-zone:

- Implement a new default Medium Density Residential Standards (MDRS) in their residential areas; and
- Bring forward the timing of implementation for the intensification policies of the National Policy Statement on Urban Development (NPS-UD), to enable denser housing close to jobs, transport options and areas of high demand.

This report provides an estimate of the MDRS effects on the housing market and an assessment of the costs and benefits associated with those effects, as well as commentary and new insights on the likely impacts of the NPS-UD.

Contents

Figures

Tables

pwc
SENSE PARTNERS
DATA LOGIC ACTION

Nicholas Smith
Ministry for the Environment
23 Kate Sheppard Place
Wellington, 6011
18 October 2021

Cost-benefit analysis for the proposed Medium Density Residential Standards

Dear Nicholas,

We are pleased to present to you the **Final report** for our cost-benefit analysis (CBA) of the proposed Medium Density Residential Standards (MDRS) in the five Tier 1 cities.

This report is a final deliverable submitted in accordance with our Consulting Services Order (CSO), dated 28 June 2021, and is subject to the restrictions included at the end of this report.

This document is developed in partnership between PwC and Sense Partners for use to support Government preparation and decisions during the policy making process. This final report supersedes all previous drafts.

Yours sincerely,

Colin Lynch   KR Lees

Colin Lynch

Partner, PwC

Colin.j.lynch@PwC.com

T: 0212417752

Kirdan Lees

Partner, Sense Partners

Kirdan@sense.partners

T: 0212647336

Executive Summary

The Government is proposing a new policy to improve housing affordability

The cost of housing is increasingly unaffordable…

House prices in New Zealand's largest cities have risen faster than median income for over a decade.[1] This makes households who rent and those looking to purchase their first home worse off. An ever-increasing fraction of future earnings must be spent to meet basic needs, reducing disposable income for those New Zealanders who are least financially secure and most likely to spend disposable income within the local economy.

But there are broader costs to soaring house prices. These include labour markets that lock many out of opportunity in cities that are increasingly expensive and lower productivity since firms cannot hire the workers they need. Environmental costs increase when families are pushed further away from city centres, and social connections weaken when households can't afford to live close to supporting familial networks.

…reducing land use restrictions within New Zealand's fastest growing cities could help

Existing evidence shows that land use regulation – the rules that determine what can be built where – is impeding the flexibility of housing supply to respond to high prices. With different land use regulations, high-demand areas could accommodate many more people, reducing the amount of land needed per dwelling and slowing the rise of house prices, improving outcomes for many New Zealanders.

Land use regulation is not the only determinant of house prices. The cost of and access to finance matters. The cost of constructing a new home is not getting cheaper.

But within New Zealand's cities the price of land remains the largest cost to new homes. And land use regulation is one area where local and central government can both take constructive steps to benefit local communities and New Zealand.

Government proposes a new default Medium Density Residential Standard (MDRS) to reduce barriers to housing supply

To address the issue, Government is proposing amendments to the Resource Management Act. The amendments will require councils in Tier 1 urban environments to up-zone in two ways:

1. Bring forward the timing of implementation for existing intensification policies of the National Policy Statement on Urban Development (NPS-UD).
2. Implement a new default Medium Density Residential Standard (MDRS) in residential areas

The costs and benefits of the intensification policies in the NPS-UD are estimated elsewhere,[2] but the timing implications are important.

The proposed MDRS is new and would:

a) allow three-storeys and three-units as of right per site

---

[1] Median house price history from REINZ data, median incomes from Stats NZ.
[2] See PwC 2020.

b) enable:

- more flexible heights in relation to boundary standards to enable three stories on average sized sites
- smaller private outlook spaces (that is, space between windows and other buildings) and private outdoor spaces (for example, balconies)
- development closer to side boundaries
- more planning consents (when needed) to proceed on a non-notified basis without neighbour approvals.

The MDRS would apply to all existing residential zones, unless zones in place are already more enabling than the MDRS, with some exemptions. The MDRS would also be applied to new residential zones, such as when rural land is urbanised, as a minimum enablement. It would not apply to land zoned for recreation, open space, or business.

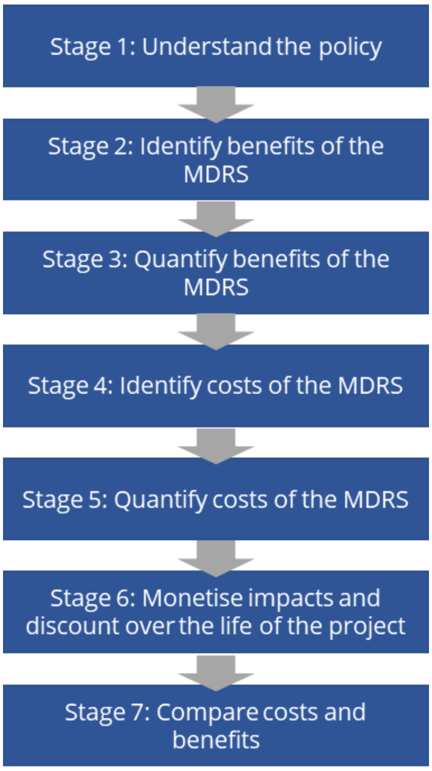
The change implied by the MDRS amounts to a permanent shift in the responsiveness of housing supply to rising prices. This means the impacts of the policy will begin slowly, but continue to build for generations, or as long as it remains in place.

An evidence base is needed to assess the proposed policies

Our cost-benefit analysis takes a staged approach

The purpose of this report is to conduct a cost-benefit analysis of the policies to help form the evidence base for decisions on the proposed changes. At a high level, our cost-benefit analysis to the MDRS takes the approach outlined in Figure 1.

Figure 1: Our staged approach to assessing the MDRS and bringing forward the NPS-UD



Source: Authors.

The MDRS seeks to make housing supply more flexible

The MDRS is not just a one-time increase in the housing stock, but a permanent shift in the flexibility of the supply of housing. By extension, the policy addresses housing affordability on two fronts, both directly by slowing the rise of home prices, and indirectly by slowing the reduction of disposable income and savings capacity of households who do not own their home.

This means that the effects of the policy will continue to build over time as New Zealand's cities grow. While these effects can be most confidently assessed in the medium-term, the true value of the policy is in its long-term realisation of a more compact, efficient, and socially equitable urban form than what would take place without it.

It is crucial to assess the external costs and benefits of the policy

The impacts of the MDRS are wider than just the change in the market for housing. Our cost-benefit analysis requires assessment of the broader costs and benefits of the policy to society. We assess the costs borne by supporting infrastructure networks as urban development intensifies, the costs of lost views and sunshine for existing residents that occur when new structures are built near existing ones, the environmental costs of enabling more populous cities, and the implementation costs of the policy for local governments.

We also incorporate the benefits of:

- more efficient labour markets and knowledge spillovers that accompany dense urban agglomeration
- more efficient use of existing infrastructure where growth is diverted from fringe expansion to intensification
- avoiding unnecessary expansion of the urban footprint and thereby preventing the loss of the natural landscape, the expensive expansion of infrastructure networks, and the compounding congestion from the car-dependent lifestyles that accompany that expansion.

But the first step to estimating any of these costs and benefits is to understand how the housing market will respond to the policy.

We estimate the MDRS would have a significant impact on supply

We assess impacts on the supply of dwellings by understanding the impact of the Auckland Unitary Plan

To assess costs and benefits we first need to estimate the likely increase in dwellings in the medium-term to result from the policy. Our analysis relies on a spatial econometric model to generate forecasts for Auckland and then adapts the model to data from the wider urban areas of Christchurch, Wellington, Hamilton, and Tauranga for application to those cities.

Our modelling is based on a standard theoretical framework, but we need to calibrate the theory to the housing market in each city to arrive at a forecast. The increase in dwelling supply following the Auckland Unitary Plan (AUP), enacted in 2016, provides a useful natural experiment. The proposed changes under the MDRS would create a new city-wide minimum allowable density level similar to the building constraints for one of the AUP zones (Residential Mixed Housing Urban or MHU). We use this recent observed increase in response to a similar policy change to calibrate our forecasts.

However, there are important ways that what happened under the AUP is different from what we expect to happen under the MDRS. The AUP favoured development at the urban fringe over intensification near the city centre and left in place other constraints to development beyond zoning rules, resulting in some measured results that do not align with the demand patterns predicted by theoretical frameworks for urban spatial equilibrium. The MDRS is intended to alter this. To align our forecasts with that intent, we adjust our model to neutralise the AUP bias toward urban fringe development, allowing demand and opportunity cost characteristics to drive the response to up-zoning instead.

We estimate the proposed MDRS will increase dwellings across New Zealand's fastest growing cities

Table 1 shows our estimates of the additional new dwelling consents in residential areas subject to the MDRS policy during the five to eight years following policy enactment. The MDRS would enable nearly 75,000 additional dwellings above what would otherwise take place in New Zealand's fastest growing cities in the medium term.

Table 1: Five-to-eight-year additional dwellings added forecasts with sensitivity range

	Low	***Base estimate***	***High***
Auckland	27,900	39,200	53,700
Hamilton	3,400	8,300	12,200
Tauranga	3,800	5,800	8,500
Wellington	6,500	9,800	14,000
Christchurch	6,500	11,500	17,200
Totals	48,200	74,600	105,500

Source: Authors' analysis.
Note: The low-high range represents the minimum and maximum results by urban area from sensitivity tests.

We find the MDRS would have significant benefits

Projected benefits are large…

The primary economic benefit of the MDRS is the decline in house prices that generates a transfer between existing homeowners and would be homebuyers. We measure the consumer surplus, that is the difference between the prices homebuyers pay and their willingness to pay as a key benefit of the policy.

We estimate these benefits using the standard comparative statics approach. This approach is used in the CBA calculations for both the NPS-UD and its predecessor, the National Policy Statement on Urban Development Capacity (NPS-UDC).

In Table 2 below, we compare the overall costs and benefits of estimated policy impacts on housing supply across our three scenarios (base case, low and high sensitivities). We do this for a medium-term time horizon, as our estimates are most robust for this timeframe. Note that while we comment on the effects of supply chain and construction market constraints later in the report, these are not included in our overall cost and benefit calculations.

Table 2: Summary of medium-term costs and benefits of the MDRS

Variable	*Low*	*Base*	*High*
Policy impacts			
New dwellings added			
Auckland	27,927	39,167	53,683
Hamilton	3,389	8,260	12,191
Tauranga	3,819	5,818	8,462
Wellington	6,516	9,833	14,002
Christchurch	6,535	11,501	17,165
Total additional dwellings	48,186	74,579	105,503
Benefits – all Tier 1 urban areas ($m)			
Added consumer surplus from lower housing prices	$437	$1,015	$1,998
Agglomeration benefits	$2,391	$5,487	$8,983
Total Benefits	$2,828	$6,502	$10,981
Costs of growth – all Tier 1 urban areas ($m)			
Supporting infrastructure	-$33	-$50	-$71
New dwellings	$88	$136	$193
- Fewer greenfield developments	-$121	-$187	-$264
Congestion	$1,261	$1,944	$2,765
Loss of sunshine	$344	$514	$684
Loss of views	$295	$434	$604
Environmental costs	$367	$409	$460
Implementation costs	$2	$2	$2
Total external costs	$2,234	$3,250	$4,442
Summary – all Tier 1 urban areas ($m)			
Total external costs	$2,234	$3,250	$4,442
Total benefits	$2,828	$6,502	$10,981
Net Benefits	$594	$3,252	$4,442
Benefit-Cost Ratio	**1.27**	**2.00**	**2.47**

Source: Authors' analysis.

…and costs scale alongside benefits

Our results are proportionally similar to those for the NPS-UD, with agglomeration economies showing the strongest economic benefits and congestion costs having the largest costs. Since both costs and benefits are driven directly by the number of additional dwellings, apart from the implementation costs of the policy, we expect the benefit-cost-ratio to be above 1 even if policy effects are a lot lower than our estimates.

But the purpose of the policy goes beyond costs and benefits

But even within the housing market, the economic benefits are only part of the story. Rising house prices become a crisis not because they create net economic losses to society, but because they accelerate transfers of wealth from those whose labour is their primary asset to those who own land and capital. If the MDRS succeeds in slowing the rise of house prices, its pure benefits outweigh its costs as shown above, but it also slows down this transfer of wealth from renters and first-time buyers to existing property owners. These distributional impacts matter, especially in the long-term, but are excluded from our calculation of the benefit-cost ratio since they are a transfer of welfare rather than a pure addition to net welfare.

Table 3 summarises long-term projected housing market benefits, both pure economic benefits (net gains to the economy) and the magnitude of desirable transfers of value from existing property owners to renters and first-time buyers.

Table 3: Summary of MDRS cumulative benefits and distributional effects to 2043[3]

	Auckland	***Hamilton***	***Tauranga***	***Wellington***	***Christchurch***	***All urban areas***
Without-policy total dwellings ('000s)	691	160	105	237	269	1,462
Policy impact on dwellings ('000s)	112	24	17	28	33	213
With-policy total dwellings ('000s)	803	183	122	265	302	1,675
Implied housing supply impact vs. without-policy supply	16.2%	14.8%	15.8%	11.9%	12.2%	*14.6%**
Price impact with vs. without policy in 2043 ($000s)	-129	-167	-182	-175	-81	*-133**
Pure economic benefits ($m)	**7,226**	**1,972**	**1,513**	**2,460**	**1,324**	**14,496**
Transfers from existing property owners to renters and first-time buyers ($m)	**89,227**	**26,671**	**19,168**	**41,494**	**21,703**	**198,264**

Source: Authors' analysis.

*Note: Figures are in undiscounted 2019 dollars. Without-policy levels include projected NPS-UD impacts as modelled in the cost-benefit analysis for that policy (PwC 2020), updated using 2021 baseline prices and population forecasts described in Appendix C. *Figures for all urban areas shown in italics are averages weighted by 2043 household numbers in each city.*

The pure economic benefit of long-term MDRS effects on house prices, cumulatively from enactment to 2043, is estimated at $14.5 billion in 2019 dollars, or about $11,800 per 2022 household in added disposable income over 21 years. The total cumulative value of long-term distributional impacts over the same period is about $198 billion. This is the value of prevented transfers of wealth to property owners that would otherwise occur due to rapid growth in housing prices. It represents about $161,000 per household present in the five Tier 1 urban areas at the time of policy enactment in 2022, or $133,000 per 2043 household—enough for a deposit on a modest home.

Our study has led to a clear bottom line

The analysis presented in this report is technical, aimed at an audience of policy analysts and urban development professionals. It is presented at this level of detail so that the strengths and weaknesses of our conclusions can be as transparent as possible given the difficulty of this type of forecast.

However, the lessons from our study are straightforward. Recent history in Auckland under the AUP has shown again that zoning constraints are indeed the barrier to housing supply that economists have argued they are. If we size our forecasts to this recent benchmark, the proposed amendment to the RMA appears likely to lead to more affordable and equitable urban living than

---

[3] We use the period to 2043 as our horizon for long-term assessment to align with the cost-benefit analysis for the NPS-UD, which selected that year based on Stats NZ population projection intervals.

what would happen in its absence. The difference will be small at first, noticeable within a decade, and enormous for the next generation.

1. Assessing the Medium Density Residential Standard

1.1. The policy

In response to the current housing supply shortage, the Government is urgently amending the Resource Management Act 1991 (RMA) to unlock additional development capacity for intensive housing in Tier 1 urban environments, and potentially Tier 2 urban environments.

The RMA amendments will require councils in Tier 1 urban environments to up-zone in two ways:

- Implement a new default Medium Density Residential Standard (MDRS) in their residential areas
- Bring forward the timing of implementation for the intensification policies of the NPS-UD to enable denser housing close to jobs, transport options and areas of high demand.

Although specific timeframes are yet to be confirmed, developers should be able to start building within these more permissive zones by mid-2022 (MDRS) and mid-2023 (NPS-UD intensification policies).

The proposed MDRS:

a) allows three-storeys and three-units as of right per site

b) enables:
    - more flexible heights in relation to boundary standards to allow three stories on average sized sites
    - smaller private outlook spaces (i.e. space between windows and other buildings) and private outdoor spaces (e.g. balconies)
    - development closer to side boundaries
    - more planning consents (when they are needed) to proceed on a non-notified basis without neighbour approvals.

c) The MDRS would apply to all existing residential zones, with some minor exemptions.[4] The MDRS would also be applied to new residential zones, such as when rural land is urbanised, as a minimum enablement. It would not apply to land zoned for recreation, open space, or business.

1.2. How the MDRS relates to the NPS-UD

Both policies have effects across all major residential zones

The NPS-UD made several big changes. One of them was to require areas in walking-distance from urban commercial centres and frequent public transport stops to allow at least six-storey building heights (‘policy 3c’). Another was to have councils think about other places they might relax zoning constraints, wherever there is strong demand or good amenities (‘policy 3d’).

---

[4] For example, large-lot residential zones are excluded.

Policy 3c is easy to interpret—councils will need one definition for walking distance (‘walkable catchments’) and a second for frequent public transport, but once they have that we know where six storeys can be built. Policy 3d is not as easy to implement. There are many ways to interpret what strong demand or good amenities might mean.

The parts of the city affected by these two policies are mutually exclusive—3c for the defined walkable catchments, 3d for everywhere else. By contrast, the MDRS will affect nearly all residential-zoned areas, including those covered by both policy 3c and policy 3d, but because these two policies are already in place, the added change we can attribute to the MDRS is different in each area.

Our analysis focuses on the areas covered by NPS-UD policy 3d

We argue that in policy 3c areas, most of the impact will be from the NPS-UD’s six storey rule, with a small amount more coming from the MDRS. We also argue that the opposite is likely in policy 3d areas—the MDRS will have a more widespread impact and one that is more easily attributed to it.

In policy 3d areas, it will be difficult to know whether any changes in zoning might have happened without either policy or whether we can attribute them to the NPS-UD. By contrast, the MDRS is clearly defined—up to 3 storeys and 3 dwellings as of right, easier consenting, 50 percent building coverage, clear rules on setbacks and boundary angles—so it is not only easier to estimate the potential impact, but the impact is more likely to take place.

For these reasons, our forecasts focus on the expected impact in the 3d areas, outside of the NPS-UD walkable catchments. This helps us avoid double-counting effects in those areas that were estimated as part of the benefits of the NPS-UD in the CBA for that policy.

Our data suggests that the NPS-UD may have a greater impact than previously estimated

Our study of the MDRS, and of the Auckland Unitary Plan (AUP) as a way to benchmark its impact, have provided new insight into the potential impact of the NPS-UD as well as the MDRS. The CBA provided for the NPS-UD was intentionally conservative in its assumptions for policy impacts on housing supply response to rising prices, since the authors of that study did not have a way to forecast actual market response. With the benefit of more data and analysis, we think the benefits of the NPS-UD were underestimated. Our benefit estimates for the MDRS will appear large by comparison, but this is because we need less conservatism given our better data and more robust model for forecasting the policy’s effects.

The proposed policy will accelerate implementation of the NPS-UD intensification policies

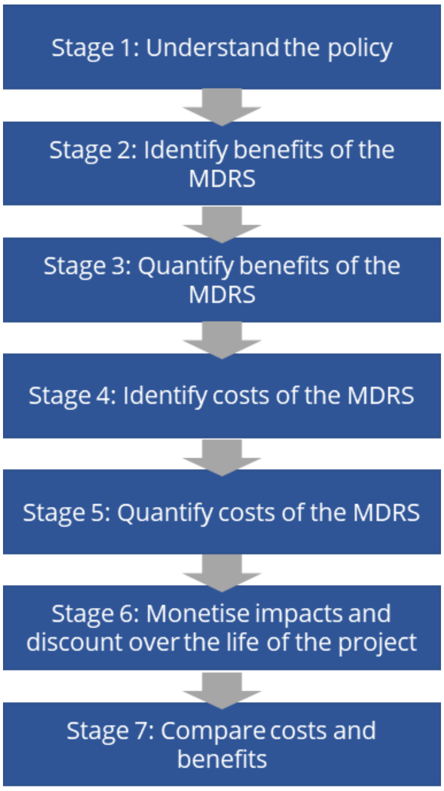
In addition to the MDRS, the proposed amendment to the RMA seeks to bring forward the timing of implementation for the NPS-UD intensification policies (policy 3) by simplifying the plan making process. We do not directly estimate the potential impact of this change in timing but expect it to be net positive. The full impacts of changes to zoning policies take decades to manifest. In the long-term, the effects of this timing difference are likely to be small compared both to the overall effect of the NPS-UD and to the range of uncertainty with which we can estimate those effects. There may be some differences in the medium-term, but these are difficult to assess given that foreknowledge of the policy is already influencing market behaviour.

1.3. The stages of our CBA assessment

Our cost-benefit analysis (CBA) of the MDRS seeks to show costs and benefits of the policy to help inform decision-making. We take a staged approach to the CBA that we set out in Figure 2. To identify and then quantify the benefits of the MDRS, we first undertake a housing supply impact assessment. This sets up likely growth patterns and provides an estimate of the MDRS impact on the number of dwellings consented and built over the medium and long term.

Then, with the housing supply assessment in hand, we first identify likely costs and benefits of the policy before providing estimates of each cost and benefit. Key benefits include returns to consumers of housing and agglomeration benefits that accrue when cities can accommodate additional workers. Key costs of the policy include congestion externalities, loss of views, loss of sunshine, intensified use of open spaces, conversion of peri-urban land, and impacts on water and air quality.

Figure 2: The stage of our CBA analysis



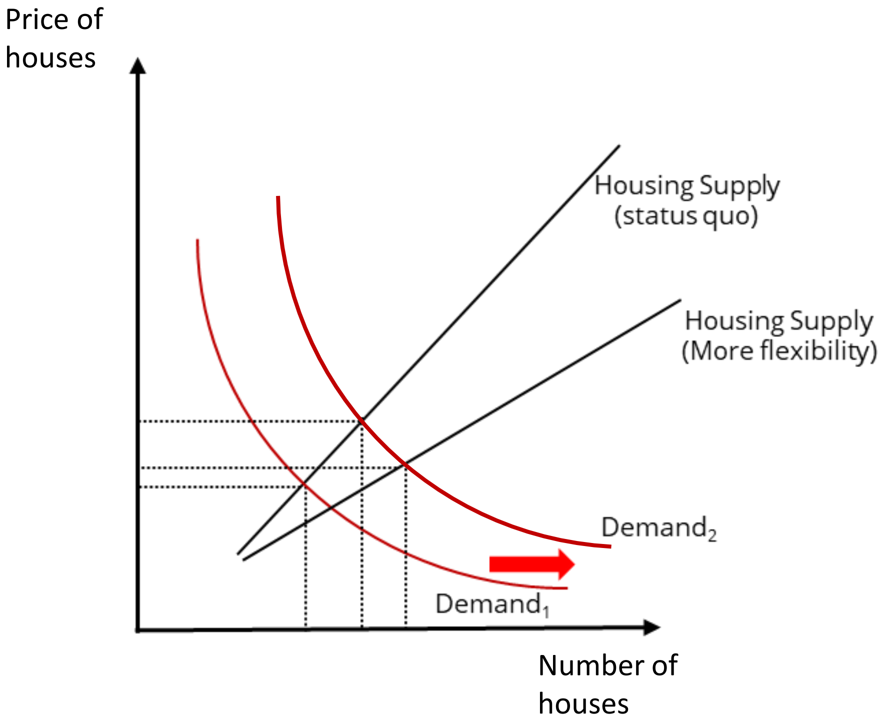
Source: Authors.

At a high level, the policy should be considered not as a one-time increase in the housing stock, but a permanent shift in the flexibility of the supply of housing (see Figure 3). We seek to assess the costs and benefits of how this more flexible housing supply affects New Zealand's cities.[5]

---

[5] See Grimes and Aitken 2010 and Productivity Commission 2015 on the importance of understanding how land price dynamics affect housing supply.

Figure 3: The MDRS increases the flexibility of housing supply

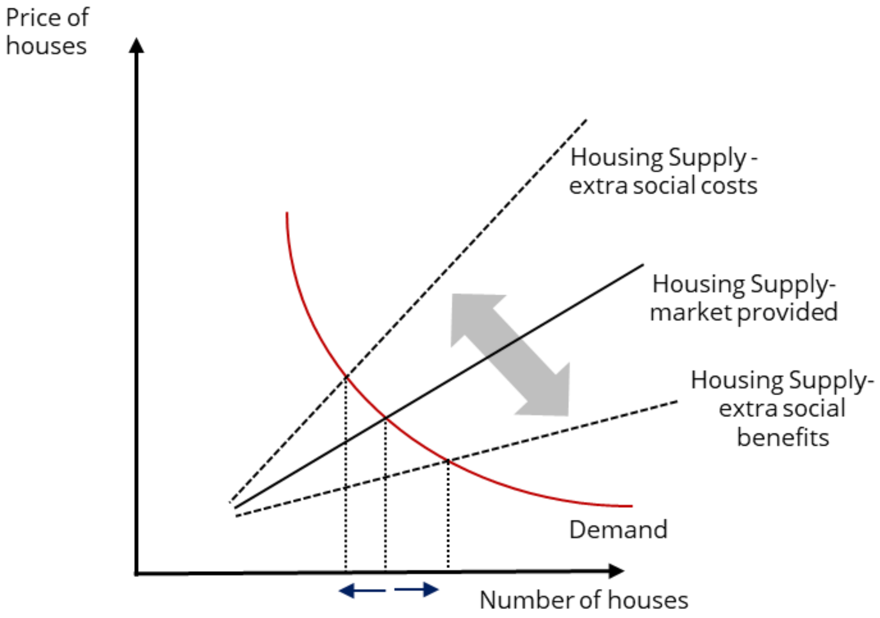


Source: Authors' illustration.

It is crucial to assess all the external costs and benefits of the policy

The impacts of the MDRS are wider than just the change in the market for housing. The policy is expected to produce costs and benefits external to housing market participants. Our cost-benefit analysis of status quo regulations requires assessment of the broader costs and benefits of the policy to society.

Figure 4: We aim to assess the full range of impacts of the MDRS as closely as possible



Source: Authors' illustration.

2. Housing supply impact assessment

2.1. Overview

2.1.1. The MDRS is estimated to have a significant effect on supply

The proposed Medium Density Residential Zone (MDRS) will affect about 33,600 hectares of residential land in Auckland, including all of the four major residential zones established by the Auckland Unitary Plan (AUP). This is comparable in size to the total area zoned for 3 dwellings or more per site under the AUP, but on average allows for significantly more intensification than the AUP did. In the four other Tier 1 urban areas, the policy will affect most of the residential land in each of the Tier 1 urban areas.

We have a fortunate alignment of timing with the AUP and post-AUP data that allows us to form a robust estimate of the supply response to a policy change that was a lot like the MDRS. We have high quality data on what happened and can use it to inform a forecast for what the MDRS is expected to do in Auckland and other Tier 1 cities. This helps us understand how closely Auckland's case aligns to theoretical predictions, despite the many real-world factors that theoretical models ignore. In other New Zealand cities, we can use local data where it is available, and triangulate between theory and observations of Auckland where it is not.

Beyond the AUP, our without-policy forecasts must incorporate another recent and significant departure from past trends—the impact of the National Policy Statement on Urban Development (NPS-UD). The NPS-UD aims to remove some of the barriers to urban intensification and attempts this using several instruments.

One of these is to mandate a minimum enabled development intensity of 6-storeys within a walkable catchment of rapid transit stops and City Centre and Metropolitan Centre Zones. Figure 5 shows these NPS-UD affected zones, as well as the AUP residential zones for Auckland's core urban area.

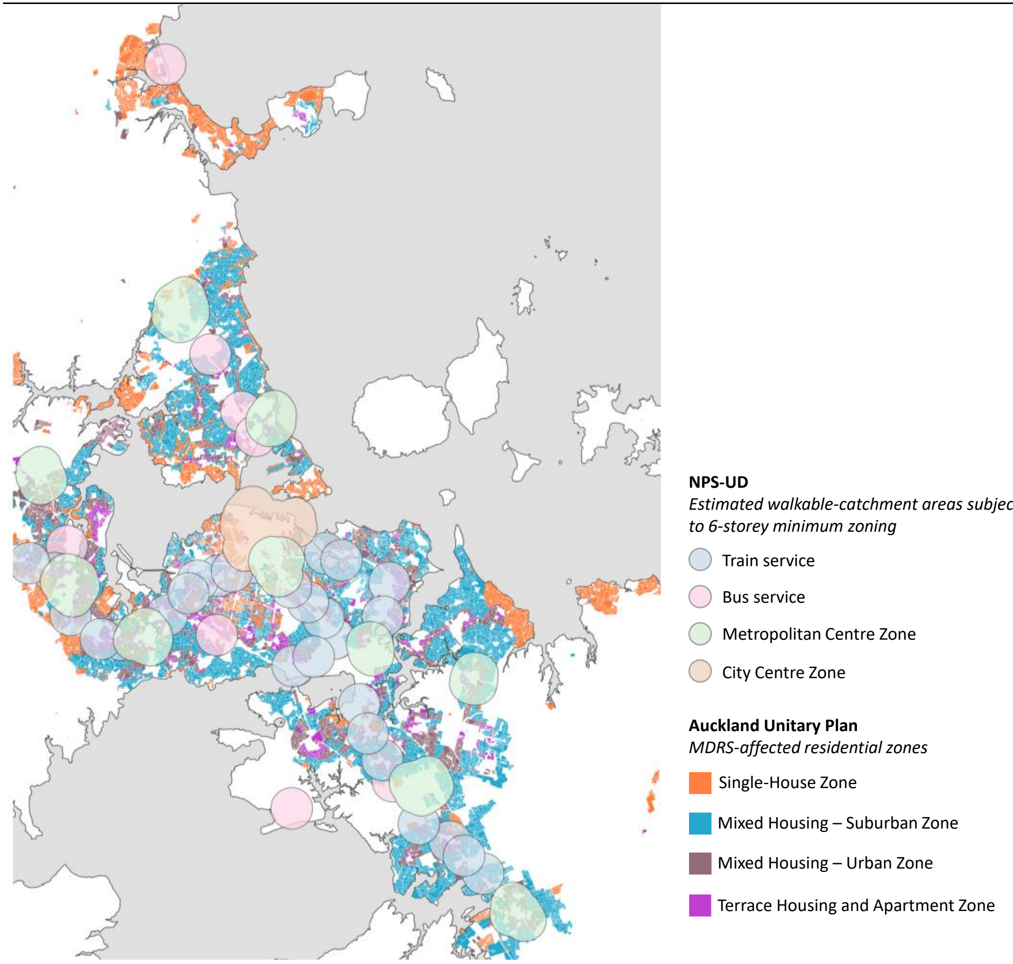
The walkable catchment areas shown in Figure 5 are excluded from our estimates of the MDRS impact on housing supply for the reasons discussed in Section 1.2. However, MDRS rules still apply in these areas. While the MDRS allows for a lower minimum intensity than required by the NPS-UD, it also allows development up to that lower level to proceed 'as of right', without a resource consent (building consents are still required). In this sense, the MDRS may have additional impact inside these NPS-UD catchment areas. These impacts are not included in our modelling.

Of the policy-affected area of 33,600 hectares, we estimate about 12,300 hectares will fall into the walkable catchment areas required to be up-zoned to at least 6-storeys by the NPS-UD. This impact assessment focuses on housing supply effects in the residential land outside of those catchments, where the MDRS represents the greatest departure from the zoning rules that would otherwise prevail.[6] For Auckland, this is an area of 21,300 hectares, or 56 percent of the four major residential zones.

---

[6] The relationship between this policy and the NPS-UD, as well as distinctions of scope between that policy's cost-benefit analysis and this one, are detailed in Section 1.2.

Figure 5: Areas affected by the MDRS policy



Source: HUD data, Auckland Council, authors' analysis.
Note: Walkable catchments are authors' estimates based on Auckland Council Planning Committee proceedings (July 2021).

2.2. Utilising the AUP as a natural experiment

Our model approach and estimates are built on a common theoretical foundation to those used for the cost-benefit analyses (CBAs) of the NPS-UD and NPS-UDC, but differ in important ways:

- The CBA for the NPS-UD assessed the benefits of the policy under the assumption that it achieves its stated intent of increasing the responsiveness of housing supply to price increases. To do this, the authors chose to model the implied costs and benefits of a deliberately conservative supply impact, to avoid optimism bias in their estimates.
- The chosen and assessed impact was small enough that it was within the range of observed historical variation in supply response to price increases in each of the six urban areas assessed. In other words, it was assumed to be much lower than the market-transforming levels to which the policy aspired, as data constraints and the policy's complexity prevented a more robust estimate. As the authors of the CBA for the NPS-UD note:

> "…our assumed policy impacts are well within the scope of historical variation in elasticity for New Zealand cities as a starting point…an impact of this

> magnitude would be unremarkable if it happened by mere chance. Our high and low estimates…do not represent the extremes of possibility, but two unremarkable outcomes within a much larger range. We intend this conservative choice for potential benefits to guard against undue optimism and ultimately to emphasise the mismatch in orders of magnitude between the potential benefits and costs of the policy."[7]

- Now, with the benefit of five years of building consent data since the enactment of the finalised AUP, a more sophisticated population growth model (described in Appendix C), and a more tightly scoped policy to assess, we have what we need for a high-quality forecast of actual supply and price responses to a relaxation of zoning constraints in these cities.

Our method builds on the NPS-UD models for calculation of benefits but replaces the assumption of a modest supply response with this forecast. As we will show below, the evidence suggests that:

- the actual impact of the NPS-UD may be significantly greater than assumed for that policy's CBA
- the AUP shows a responsive market, but also a bias toward development at the urban fringe compared to theoretical expectations.

Our model is based on the theoretical framework provided by the Alonso-Muth-Mills model of urban spatial equilibrium (Alonso 1964, Muth 1969, Mills 1967), with parameters fitted to empirical data taken from the up-zoning under the AUP as a natural experiment.

2.2.1. Theoretical framework

Historical Data – AUP as a natural experiment

The AUP guides Auckland's natural and physical resources, including land development. It determines what can be built, where, and how much of it. The AUP is both simpler and more permissive than the fragmented plans it replaced, and it has allowed thousands more property owners across Auckland to develop their land through zoning changes (up-zoning), increasing the potential number of dwellings. However, not all land parcels were up-zoned, and constraints in some areas were relaxed less than in others. This forms a natural experiment as there are natural control and treatment groups.[8]

We can look at historical data on how land values changed after the enactment of the AUP to determine how the up-zoning affected land values, and on how zone changes predict building consents to estimate the likelihood and quantity of residential development.

However, there are important ways that what happened under the AUP is different from what we expect to happen under the MDRS. The AUP favoured development at the urban fringe over intensification near the city centre and left in place other constraints to development beyond zoning rules, such as around 17,000 residential properties under 'special character overlays'—areas subject to much stricter conditions for redevelopment. The post-AUP period also has yet to reveal

---

[7] PwC 2020, pages 32-33.

[8] Ideally the assignment of parcels into these groups would be random. In areas where very similar properties were allocated to different zones, say on either side of the same street, we can consider the allocation to be 'pseudo-random'. However, we expect a significant portion of the allocation of zones in older areas of the city to have aligned loosely with the levels of development that were already present under the 90-odd zones that existed before the AUP. This would bias our results toward underestimating the policy's effect in terms of the general level of response to upzoning.

the results of the NPS-UD, which introduced large-scale changes to all Tier 1 urban areas. The NPS-UD was enacted in August 2020, and originally planned to take full effect by 2024, so the data to date does not capture the significant changes in underlying trends it will likely create.

Both the MDRS and the NPS-UD are designed with an intention to reverse the bias toward urban-fringe development observed under the AUP. To inform our assumptions about how future development might occur both with and without the MDRS, we need a theoretical framework for how market forces act on urban spatial arrangements in both the presence and absence of policy constraints. For this, we rely on the Alonso-Muth-Mills (AMM) model, introduced in the next section.

Box A: Key insights from the AUP inform our forecasts

Properties up-zoned under the AUP increased in value in subsequent years more than properties that remained at pre-AUP constraint levels. The more permissive the new zone, the more the value increased, all else equal. This observation aligns with the theoretical expectation for high-demand areas—more permissive development implies greater potential revenue from built floor area, which is capitalised into land values. Measurements of these patterns allow us to simulate land value shocks following the MDRS.[9]

The land value and improvement value characteristics of residential properties before the AUP show a strong relationship to how zoning affected the probability of adding at least one dwelling after the AUP. We find:

- for properties in the AUP zone most similar to the MDRS (the MHU zone), there was a 20% probability of houses adding at least one dwelling if they have high relative land value and low opportunity cost of development,
- this probability drops to below 10% for properties with average relative land value and average opportunity cost of development.

Zoning changes strongly predicted the amount of floor area increase for properties that added at least one dwelling. The more permissive the new zone, the more floor area a property added on average (for those that added at least one dwelling), in ratio to land area. This implies that, on average, zoning rules worked as intended, leading to more intense development in the more permissive zones.

Since we have data on land and improvement values at the individual property level, we can analyse development likelihood based on these results with high granularity. However, the AUP released constraints by much more on the outskirts of the city than in the high-demand areas. Following the AUP, adding dwellings was statistically more likely the further away a parcel is from the city centre after controlling for land and improvement values, zone, and special character status.

This does not align with the demand patterns predicted by theoretical frameworks for urban spatial equilibrium. Further analysis reveals that while the zones themselves are distributed widely across distances, areas where the zones increased the permissible development capacity beyond the existing improvements by enough to add at least one dwelling were much less common as we approach the centre. In other words, the AUP effectively dispersed development to the city fringes.

When we adjust the model to neutralise the AUP bias toward urban fringe development, allowing demand and opportunity cost characteristics (linked with low value of existing improvements) to drive the response to up-zoning instead, we find the most intensive development moving much closer to the city centre.

Where the unadjusted AUP-based scenario shows the hubs of development projected in Flat Bush, Howick, Half-Moon Bay, Warkworth, Omaha, Algies Bay, and Whangaparāoa, our base-case scenario shows development closely hugging the NPS-UD walkable catchments around public transport and metropolitan centre areas. This bodes well for the NPS-UD intensification policies, suggesting that previous estimates of their impact may have been understated.

---

[9] See Greenaway-McGrevy et al. 2020 on the impact of the AUP on intensification, land values and house prices.

The Alonso-Muth-Mills Model

The AMM model is a depiction of urban spatial structure that explains the economic substitutions associated with spatial choices that individuals make regarding where to live and work within the urban landscape. It is one of the most widely used spatial models in urban economics.

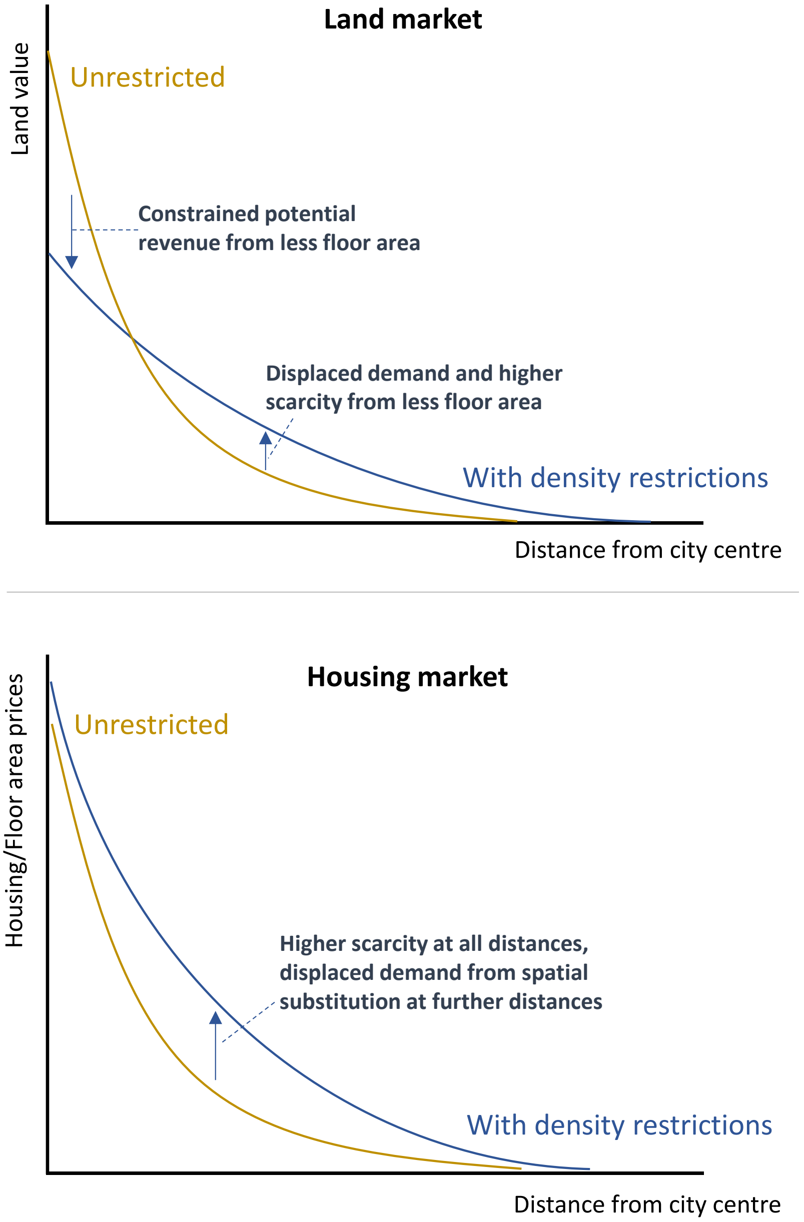
The AMM model is built on two key assumptions:

1. Cities exist to maximise access to opportunity and amenity
2. Access can be attained by either direct proximity, or by transport.

Since commuting is costly in terms of money and time, households prefer to live closer to the centre of the city, all else equal. Land is less scarce further away from the city centre, but the cost of transport to the city centre is higher. Thus, households trade off the cost of housing with the cost of travel. In spatial equilibrium, the sum of all housing and commuting costs can be held constant or near-constant as distance changes, assuming households have similar preferences.

When zoning restrictions prevent development from reaching the density levels that would occur in an unrestricted market, land values react differently at different levels of existing demand, but housing prices rise throughout the city. This concept is illustrated in Figure 6 below.

Figure 6: The Alonso-Muth-Mills model – effects of density restrictions in the urban core



Source: The AMM model is developed in Alonso (1964), Muth (1969), and Mills (1967). This figure is adapted by the authors.

Up-zoning relaxes restrictions on density. Accordingly, we expect the MDRS to allow the urban landscape to move closer to the unconstrained spatial equilibrium that the AMM model would predict, reversing the arrow directions in both diagrams in Figure 6. The top diagram of the figure shows that land values react differently to zoning restrictions depending on the strength of demand at each location and at constrained locations nearby. The bottom diagram of Figure 6 shows that house-price effects of zoning restrictions move in the same direction at all distances from the centre regardless of what happens to land values at each distance. Our model design is informed by this theoretical framework, as we describe further below.

2.2.2. Model Approach

To estimate the effects of MDRS on housing supply, we use a parcel-level[10] spatial econometric model to simulate how a change in zoning rules would affect the number of dwellings added over time based on observations of what happened in Auckland following the enactment of the AUP.

We use the historical data from the AUP as a natural experiment, to fit our model for forecasting the effect of an up-zoning on the number of dwellings added.

There are three steps to the model:

Step 1: Simulate the land-value shock that accompanies a relaxation of zoning constraints

Since the AUP and MDRS policies relax zoning restrictions, this increases the potential revenue of a parcel of land (if demand is sufficient) because more floor area can be added. This in turn increases the land value, which captures the present value of greater potential future cash flows.

We simulate this change in land value for each parcel caused by the change in zone. This phenomenon is described in the literature as the “up-zoning premium” (see Greenaway-McGrevy 2020 for a recent estimate of this premium based on post-AUP property sales).

We can quantify the actual land-value shocks following the AUP using a difference-in-difference estimate for Auckland (see the appendix for a description of this method). This is a robust method for estimating the effects of a treatment, such as upzoning, on a subset of a population, such as residential parcels. The method requires data measured from both a control and a treatment group at different times, which we have for Auckland before and after the AUP.

For other cities, we have no natural experiment in the recent past, so we estimate the land-value shock using a regression discontinuity approach. This method uses the observed differences in land value across zones for otherwise similar properties to estimate the effect of zoning on land value.

We use these simulated land-value shocks as inputs into steps 2 and 3 of our model, informing both the probability of development for an observed parcel and the amount of added floor area for parcels that do develop.

Step 2: Find the probability that a parcel added at least one dwelling, based on each parcel’s post-shock land value, zone status, and existing level of development

The purpose of step two is to simulate a set of locations where added dwellings might be built under each forecast scenario, whether with or without the MDRS. While the model cannot accurately predict where development will occur, it is useful to generate hypothetical scenarios according to the statistical probability of development for each observed parcel given its relevant characteristics. This allows us to examine how differences in model assumptions influence the spatial distribution of development. It also helps in choosing sample developments to assess for the costs of lost views and overshadowing (see sections 6 and 10).

In any medium-term period, only a small fraction of homeowners will consider further developments on their property at all, regardless of the development viability their property may have. Many

---

[10] By ‘parcel-level’, we mean that individual rateable units of property are aggregated to the level of LINZ primary parcels. For cases where multiple parcels are associated with the same set of rateable units, we cluster the parcels and treat the resulting cluster as a single large observation. Single-parcel observations make up most of the sample for all urban areas in the study.

factors contributing to a homeowner's decision to redevelop will not be affected by zoning rules, but others will. The major factors affected by zoning rules are:

- The permissible dimensions of development, which affect the potential revenue or benefits of redevelopment, as described in Step 1.
- The costs in money, time, and effort to obtain legal clearance to develop. Both the AUP and the MDRS involve an element of intended reduction in this cost factor.

Other factors contributing to the homeowner's decision but not influenced by zoning rules include:

- The opportunity costs of any demolition of existing buildings required for redevelopment.
- The level of market demand for dwellings at or near a parcel's location.

There are many other potential factors, but our data is limited, so our model only accounts for those listed above. One consequence of this limitation is that our model cannot be expected to accurately predict development for specific individual parcels. However, it can still provide good estimates of aggregated city-wide development levels.

We use our observations of how land values, opportunity costs, zoning, and distance from the city centre were statistically associated with whether a parcel added at least one dwelling (thus excluding floor area expansions that added to an existing house) during the 2016 to 2021 period to arrive at an implied probability of development for each of the 218,000-plus parcels in our study area, based on updated data for those characteristics. This updated data includes the most recent available (as opposed to pre-AUP) data points for each parcel as well as any adjustments, such as for land-value shocks. We use these estimated probabilities in two ways:

- We sum them to arrive at our estimate for the total number of development events across the study area.
- We rank properties by probability, then choose our hypothetical development locations from the most likely properties.

Step 3: Find the increase in the floor-area ratio if at least one dwelling was added

The amount of floor-area ratio (FAR) increase is determined by the cost-benefit considerations of the developer or homeowner. A homeowner/developer will consider the opportunity costs, the construction and consultation costs, and intangible costs such as the nuisance of construction or the stress of managing the process, as well as the potential revenue increase from adding more floor area. The higher the potential revenue, the more floor area will be added, all else equal. The higher the opportunity costs of development, the less floor area will be added, all else equal.

For each development event simulated in Step 1, we can quantify the statistical relationship between the actual FAR increase observed since the AUP and the pre-AUP levels of demand, zoning restrictions, simulated land-value changes, and opportunity cost of development for each parcel.

We can then use these quantified, or 'fitted' relationships to forecast the likely increase in FAR for each parcel, after updating what we know about changes in demand, opportunity cost, and zone since the pre-AUP date used for fitting. We calculate the number of dwellings added based on this estimate of FAR increase, the land area of each parcel, and the updated regulatory limits of each zone.

To find the number of dwellings added that can be attributed to the MDRS, we forecast and compare the number of dwellings added in both a with-policy (applying less restrictive zone assumptions and simulating a land-value shock), and a without-policy counterfactual case (keeping zones as they are and using actual current land values).

2.2.3. Application to other Tier 1 Urban Areas

The next part of the analysis applies this model to other Tier 1 urban areas: Hamilton, Tauranga, Wellington, and Christchurch. Both demand and constraint conditions differ in each city, and Auckland is an outlier particularly in terms of demand. To apply our fitted model to non-Auckland cities, we need to adjust each of the three model steps:

- For Step 1, the land value shock from up-zoning, we use regression estimates on data from each city to measure the difference by zone in the relationship between land value and distance from the city centre. This is a proxy for the level of constraint in land values from zone restrictions. Using the theoretical framework of the AMM model, these regression results also inform our assumptions below about how the level of constraint influences the estimated increase in FAR from relaxing zone restrictions.
- For Step 2, the estimate of likelihood to add at least one dwelling, we use the AUP-based relationships between development demand, opportunity cost, and zone constraints to predict likelihood to develop based on property-level equivalence across cities for relative land values and relative opportunity costs. We also adjust the assumed base level of likelihood in each city to align the number of forecast development events in the without-policy case to each city's observed level of development over the same historical period covered by the AUP data.
- For Step 3, the estimate of added dwellings given that a property adds at least one, we adjust the expected change from up-zoning (for example, from Wellington's Outer Residential zone to the new MDRS) to the difference in predicted FAR increase between two relevant zones from the Auckland case (the 'zone gap'). We choose the zone gap in Auckland (taken from available combinations of the four measured AUP zones) that showed the most similar degree of relaxation in constraints to what we expect in that city. These expectations are informed by consideration of the differences in allowable development between existing zones and the MDRS in each city, which AUP zones they align most closely to in terms of defined building constraints, and the observed land value discontinuities between zones in each city as described above. Full zone alignment tables are provided in Appendix B.

2.2.4. Data

The available data for our model necessitates the use of proxies for the following driving factors:

- As a combined proxy for the level of demand adjusted for opportunity cost of development at the individual parcel level, we use the Quality of Capacity metric ("quality score") developed for HUD as part of the Wider Costs and Benefits of Urban Growth Methodology (PwC 2020). The quality score is described further in the following subsection.
- The development limits under the MDRS have no exact equivalent in the residential zones of any Tier 1 urban area's operative district plans, and zones in non-Auckland cities do not perfectly correspond to AUP zones. To complete our forecast, we must associate our observed zone effects with the modelled zone changes by matching each zone and simulated zone change with its closest available proxy in the data. Details of these associations are provided in Appendix B.

The quality score

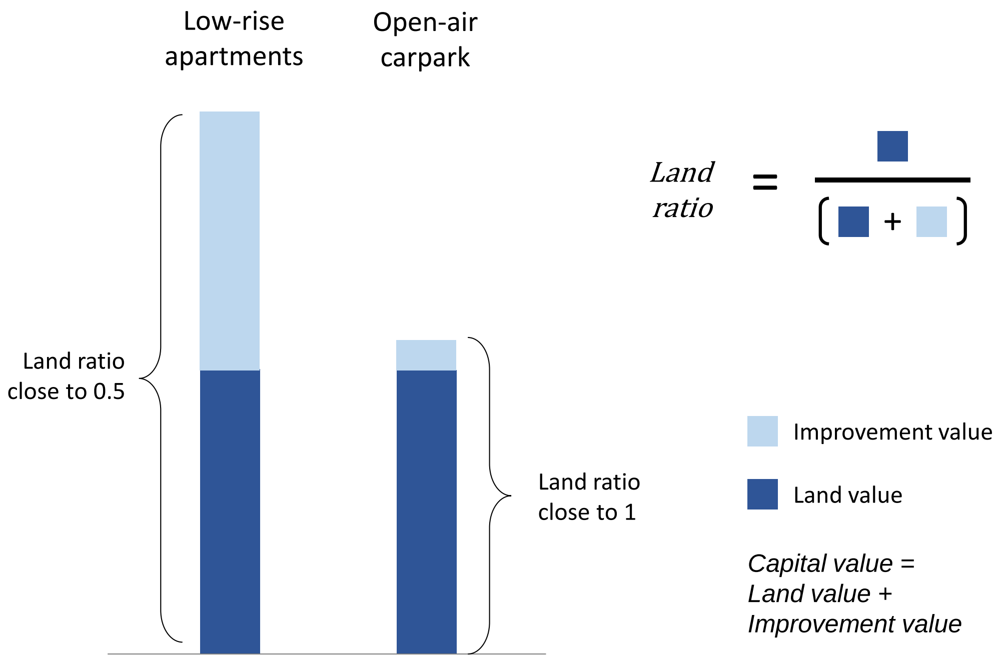
The quality score is a useful metric to efficiently proxy demand-side development potential at the parcel level. It is a combination of two proxies—one for demand relative to other areas of each city, the other for opportunity cost of development. The first component uses land value per square metre (m^2) to proxy the level of demand for built floor area in that location.

The second component captures the opportunity costs of development. When landowners or developers consider whether to build more floor area on a specific property, one of the key factors is the opportunity cost of giving up the value of whatever is already built on the required land. Two properties with the same land value in the same neighbourhood will still have different levels of development appeal if the existing improvements are different.

Figure 7 compares two such hypothetical properties. We expect that adding dwellings is more likely for the open-air carpark than for the low-rise apartments due to the high opportunity cost of tearing down an apartment building and foregoing the revenue it could earn without adding dwellings.

Our data separates land value from improvement value at the parcel level. This allows us to incorporate the opportunity cost of redevelopment into our regression analysis using the land ratio (the land value of a property divided by the total capital value of the property). This is written as *LV/CV* and illustrated in Figure 7. Typically, the higher the land ratio, the greater the potential for development.

Figure 7: The role of the land ratio



Source: Authors' illustration.

A high land ratio represents a lower cost of development as the improvement value is relatively low compared to the land value. Thus, the higher the land ratio, the higher the quality score. The same applies for the land value per m^2 component.

The two components of the quality score are combined as a geometric average, by raising both to a power between 0 and 1 before multiplying them together. This has the effect of favouring balanced combinations of the two components over extreme values in one or the other. Both component values are numbers between 0 and 1, as is the final score. The full equation is as follows:

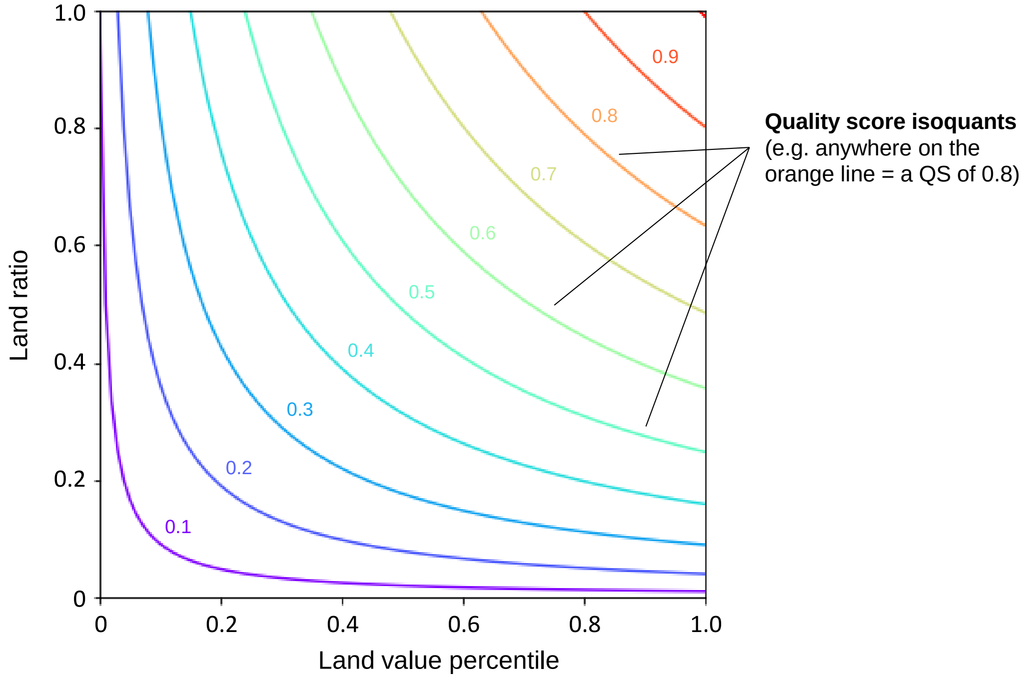
$$Quality\ Score = (LV/CV)^{\alpha} LVrank^{\beta}$$

Where:

- *CV* is the capital value or likely price a parcel or property would sell for at the time of valuation
- *LV* is the likely price a parcel's land would sell for at the time of valuation without any buildings or improvements
- *LVrank* is the percentile rank of a parcel's land value per m^2 among all parcels in the urban area
- α and β are weightings between 0 and 1 (that sum to 1) for the geometric weighted average. These are used to emphasise the effects of one component or the other according to the analytical question at hand. In this analysis, both are set to 0.5, so equal weight is given to each component.

Figure 8: Quality score by component inputs

(balanced weighting at α = 0.5)



Source: PwC 2021.

Advantages of the quality score include:

- It accounts for both site-specific opportunity cost and location potential relative to other sites.
- It does these two things in a way that is easily calculated, applicable in any city, and uses a dataset that is readily available historically and at a granular level to councils and ministries.
- It does not rely on actual sales, but on ratings valuation estimates, so it is available for all rateable units in a city.

- Its components, such as land value, can be modified to reflect expected shocks arising from policy changes based on a well-developed body of empirical analysis. In other words, we can observe today's actual quality scores, but also simulate what they would be if land values changed.
- The land value component is an effective general proxy for a broad range of factors contributing to desirability from a development perspective, including access to opportunity and proximity to amenities.

Disadvantages of the quality score include:

- It does not capture much about the willingness of a landowner to participate in the market for development.
- It relies on a dataset that is difficult for the public to access in bulk (data for individual properties is publicly available), making replication difficult for non-government researchers.

Zones

There are four primary residential zones under the AUP that will also be subject to the MDRS. These are:

- Single House Zone (SHZ): Allows for a single primary dwelling or conversion of existing (2013 or older) dwellings into a maximum of two dwellings. Maximum building site coverage is 35%, maximum height is 8 metres.
- Mixed Housing Suburban Zone (MHS): Allows for up to three dwellings and two storeys. Maximum building coverage is 40%, maximum height is 8 metres.
- Mixed Housing Urban Zone (MHU): Allows for up to three dwellings and three storeys. Maximum building coverage is 45%, maximum height is 11 metres.
- Terrace Housing and Apartment Zone (THAB): Enables apartment buildings of up to 5-7 storeys depending on proximity to centres. No explicit limit on dwellings. Maximum building coverage is 50%, maximum height is 16 metres.

A map of these zones is shown in Figure 5 above.

The SHZ provides a control group for our observations of the effect of up-zoning under the AUP, since these areas did not experience a significant change of zoning rules under that policy. The other three zones provide different levels of 'treatment' with which we can align our future zone change to say, "if the MDRS in City X has a similar effect to Zone Y under the AUP, the impact is likely to be Z given a similar time-frame…". That we have three different levels of constraint release (ie the three up-zoned zones in the AUP) allows us to adjust for differing levels of baseline constraint in different cities.

The zone with rules most like the MDRS in terms of allowable floor area is the MHU. Both the MHU and MDRS allow 3 dwellings and 3 storeys, but the MDRS allows slightly more site coverage, more permissive height in relation to boundary (HIRB), and easier consenting.

As such, while we use the MHU as our proxy for the MDRS in our Auckland forecast, we believe these differences in zoning rules will bias results toward a conservative estimate. Full descriptions of alignment of zones for the other Tier 1 urban areas and their constituent territorial authorities (TAs) are provided in Appendix B.

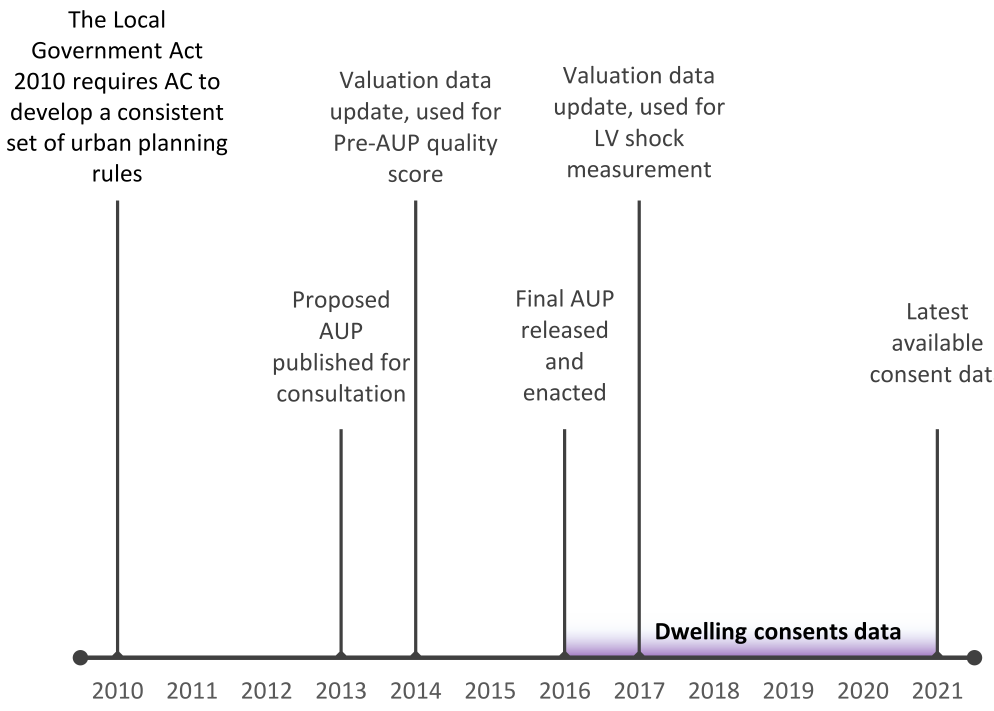
2.2.5. Model specifications

Step 1: Estimate the land value shock from a change in zoning constraints

To simulate the land value shock resulting from the MDRS policy, we first measure the actual shock that took place following the AUP, then apply the observed difference between zones according to the planned zone change under the new policy.

In Auckland, our data allows a robust estimate of the effects of upzoning on land values. We fit Step 1 of our forecast model using a simple regression estimate that tests the relationship between zone interacted with distance from Britomart as predictor variables, and the percentage change in land value observed from 2014 (the most recent valuation update before the release and enactment of the final AUP) and 2017 (the first valuation update following full enactment of the final AUP) as the response variable. The timing of these valuation updates with the AUP policy development and enactment is summarised in Figure 9 below.

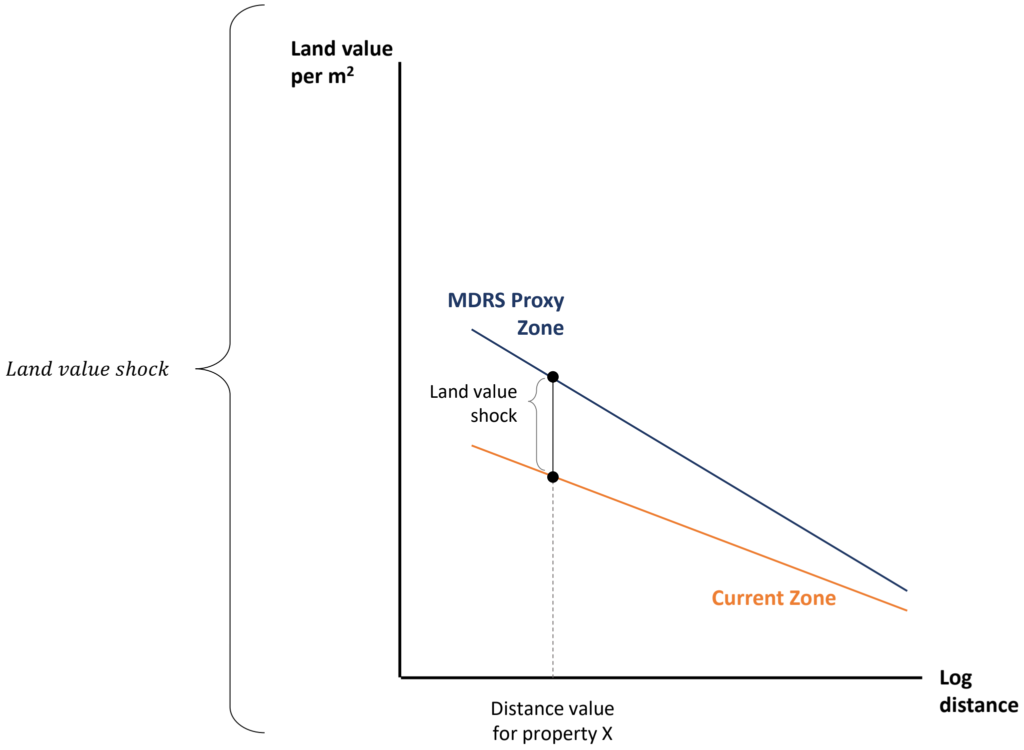
Figure 9: Timeline of the AUP and relevant data sources



Source: Greenaway-McGrevy et al 2020; Auckland Council, HUD data.

In Figure 10 below, the estimated land-value shock for a single property is the difference in the y-axis value (given that particular property's distance from the city centre) between the predicted land value for the property's current zone and the predicted land value for the MDRS proxy zone (eg MHU).

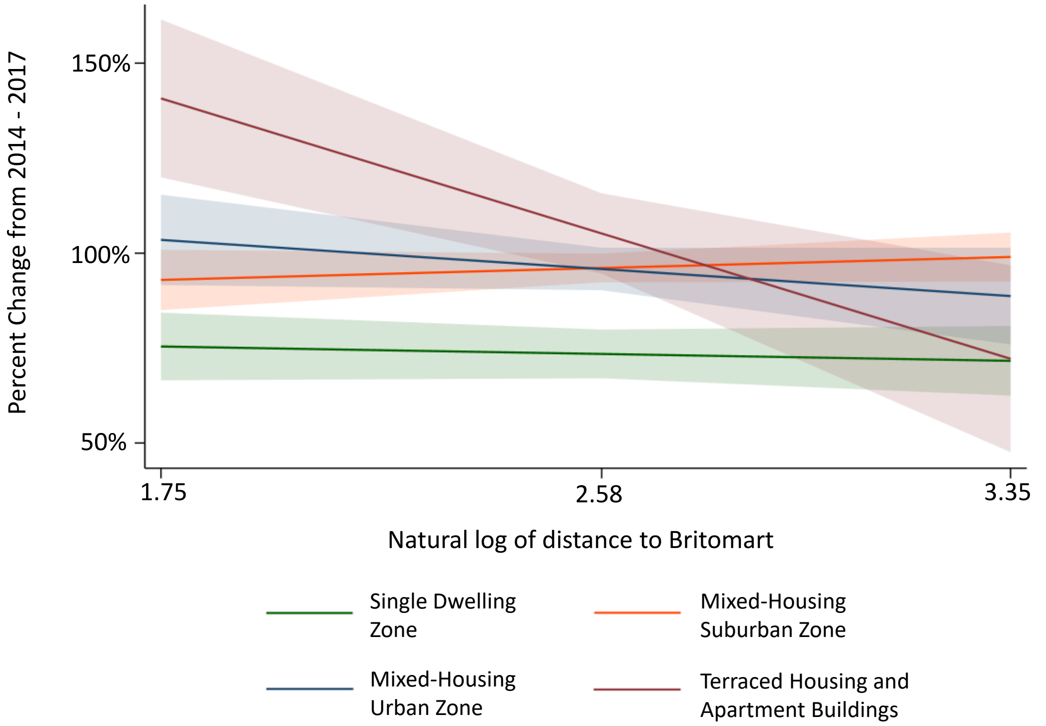
Figure 10: Land value shock simulation for model Step 1



Source: Authors' illustration.

Results for Auckland land-value shocks post-AUP are shown in Figure 11 below. The SHZ shows nearly no variation in relative LV appreciation according to distance from Britomart. In other words, single-house plots across the city increased in nominal value by about 75 percent on average, whether they were in Pukekohe, Herne Bay, or anywhere else.

Figure 11: Change in land value following AUP enactment



Source: HUD data, authors' analysis.
Note: Shaded bands represent 95% confidence intervals. Regression includes control for land ratio. Margins plotted here hold land ratio constant at the mean.

In the MHS, the increase was slightly less the closer a parcel was to Britomart, but not statistically different from a slope of zero (a flat line), like the SHZ. However, the MHS effect independent of interaction with distance (the intercept) was significantly different from both SHZ and zero. This means that parcels in the MHS zone reliably increased in value by more than parcels in the SHZ zone did, but that the difference between the two was not significantly affected by distance from the city centre.

In the MHU, the increase in land value was greater than the SHZ, and the increase was greater the closer a parcel was to Britomart. In the THAB, distance to Britomart had by far the largest effect on the land value increase, moving from about the same as the SHZ on the outskirts to nearly double the increase nearer to the centre.

We use the difference between the way land parcel values reacted to the AUP in different zones at different distances to simulate the way land parcel values will react to the MDRS in the future. To do this for Auckland, we use the marginal change from each parcel's current zone to the level of change expected at the new zone at that parcel's distance from the city centre. Forecast results are presented in Section 2.3.

Step 2: Estimate the likelihood of adding at least one dwelling

Using data up to 2021, we estimate the probability of properties in our control and treatment zones to have at least added one dwelling since the AUP enactment. We use the quality score (interacted with zone status) of each property as our primary predictor, and control for the pre-NPS-UD special character status and distance to Britomart of each property.

We then use these estimates (coefficients) to project the probability of adding at least one dwelling in the medium term. The fitted model is applied to an updated dataset, using quality scores updated to include land value shocks from step 1, zone coefficients using the MHU as a proxy for the MDRS (so up-zoned parcels apply the MHU coefficient), and neutralising the effect of special character status. Model equations are shown below.

Estimation using historical data (post AUP): logit with continuous-categorical interaction

$$AddedDwelling_i = \beta_0 + \beta_1 QS_{pre_i} + \beta_2 Zone_i + \beta_3 QS_{pre_i} * Zone_i + \beta_4 \ln(Distance_i)$$
$$+ \beta_5 SpecialCharacter_i + \varepsilon_i$$

Forecast for post-MDRS

Without MDRS

$$P(AddDwelling) = \hat{\beta}_0 + \hat{\beta}_1 QS_{post_i} + \hat{\beta}_2 Zone_i + \hat{\beta}_3 QS_{post_i} * Zone_i + \hat{\beta}_4 \ln\,(AdjustedDistance_i)$$
$$+ \hat{\beta}_5 NewSpecialCharacter_i$$

With MDRS

$$P(AddDwelling) = \hat{\beta}_0 + \hat{\beta}_1 QS_{shocked_i} + \hat{\beta}_2 NewZone_i + \hat{\beta}_3 QS_{shocked_i} * NewZone_i$$
$$+ \hat{\beta}_4 \ln\,(AdjustedDistance_i) + \hat{\beta}_5 NewSpecialCharacter_i$$

Where:

$AddedDwelling_i$	is a dummy indicating whether a property added at least one dwelling from 2016 to 2021.
$P(AddDwelling)$	is the predicted probability[11] that a property adds at least one dwelling in the medium term.
β_{0-5}	are the coefficients to be estimated using historical post-AUP data.
$\hat{\beta}_{0-5}$	are the fitted coefficients from the estimation using historical data.
QS_{pre_i}	is the pre-AUP quality score calculated using 2014 land values and land ratios for each parcel.
QS_{post_i}	is the latest available quality score for each parcel (ranges from 2017 to 2021, depending on valuation updates).
$QS_{shocked_i}$	is QS_{post_i} adjusted for land value shocks from Step 1.
$Zone_i$	is the AUP zone for each parcel.
$NewZone_i$	is the zone category for the 'treatment' zone, ie the zone chosen as a proxy for the MDRS. The fitted coefficient for the proxy zone replaces the original zone coefficient in this equation.

---

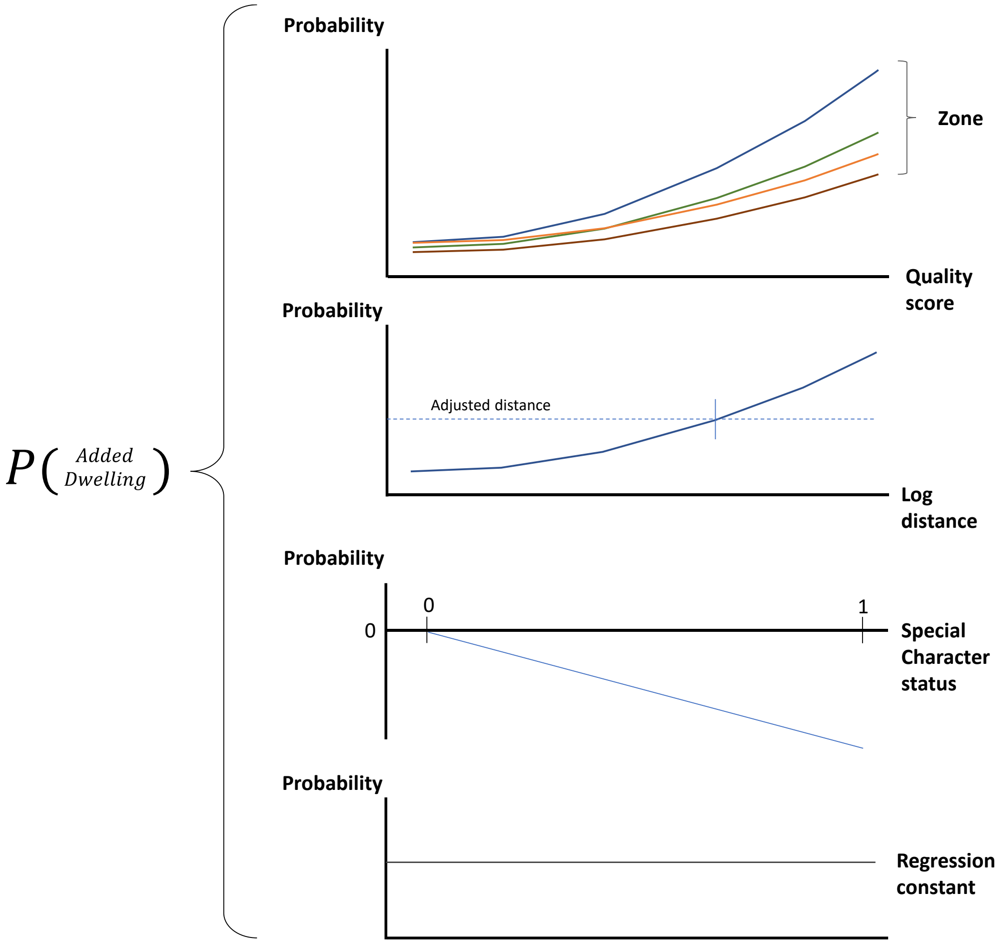
[11] Our forecast equations here use notation for probability for ease of interpretation. Estimated logit coefficients predict odds ratios, not probability, and must be converted to probabilities, resulting in the non-linear relationship between dependent and independent variables observed in Figures 12 and 13.

$\ln(Distance_i)$	is the natural log of distance in kilometres from a selected point in the city centre.
$\ln\ (AdjustedDistance_i)$	is a scalar replacing the distance covariant for all observations. This collapses the distance effect to a constant.
$SpecialCharacter_i$	is a dummy for whether a property is located in a special character overlay area.
$NewSpecialCharacter_i$	is set to zero for base case estimates both with and without the policy, as the special character effect is assumed to have been nullified by the NPS-UD. We test variations to this in our sensitivity analysis.
ε_i	is the error term.

Step 2 visual summary

Figure 12 illustrates how the parts of the forecast equations above are combined to arrive at a final probability estimate for each parcel. The coefficients determine the slope and direction of each line, and the final probability of adding at least one dwelling is the sum of the y-axis value from each set of axes in the figure.

Figure 12: Probability of adding at least one dwelling, by model component

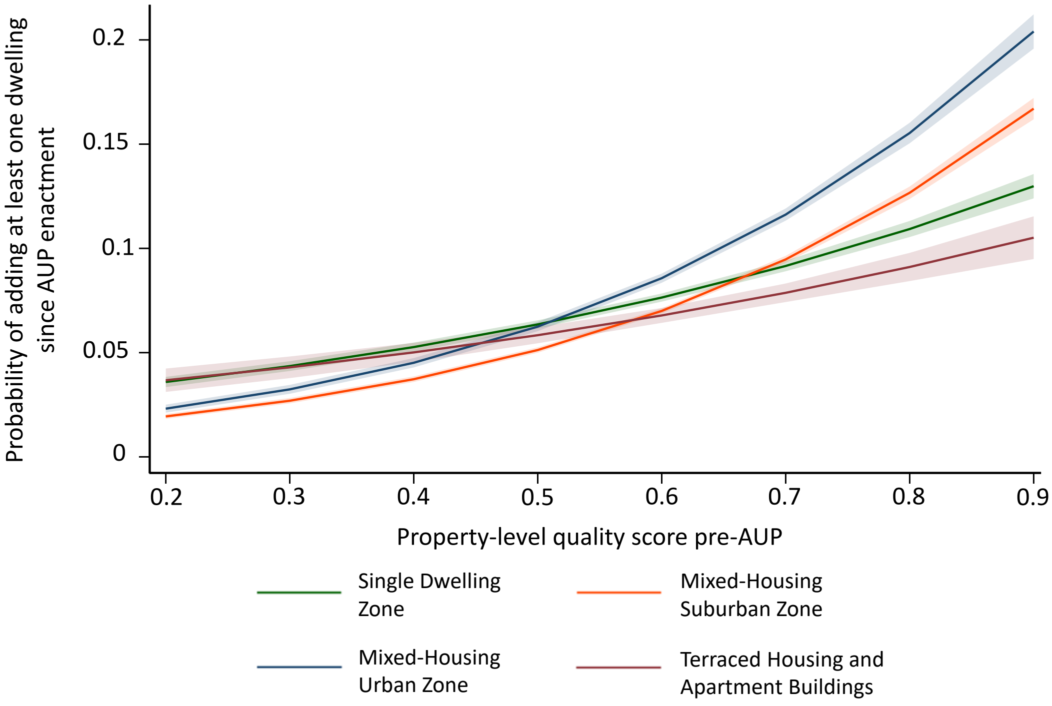


Source: Authors' illustration.

Fitted model results

Figure 13 summarises the coefficient results from the first regression as a logit margin plot. It shows the probability of adding at least one dwelling post-AUP at different pre-AUP quality scores for each zone, with special character status at zero and distance from Britomart at the median. Full regression outputs are provided in Appendix A.

Figure 13: Probability of development as predicted by quality score and zone



Source: Auckland Council and HUD data, authors' analysis.

These results show that as quality score increases, there is an increase in the probability of adding at least one dwelling for every zone as would be expected. For zones that are less constraining for the intensity of development, the relationship between quality score and probability of development is more pronounced at higher quality scores (eg >0.6).

The results for MHS and MHU compared to SHZ are evidence that zoning restrictions continue to constrain Auckland's housing supply and exacerbate affordability issues. This is also evidence that wider up-zoning across Auckland is likely to lead to more residential development than would otherwise take place.

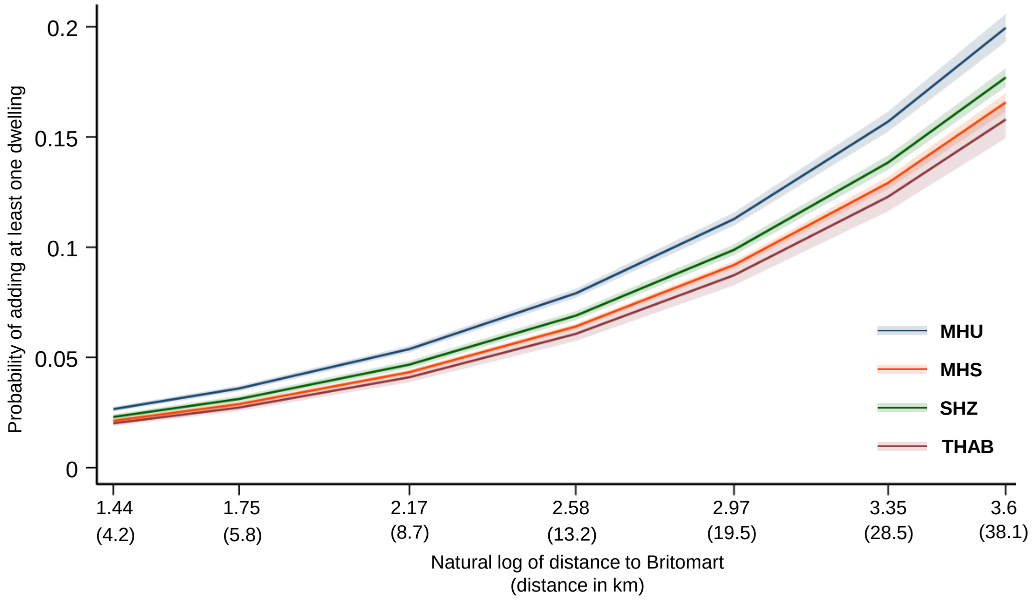
The exception is for the THAB, which shows a weaker likelihood response to higher quality scores than even the SHZ. This may be due to the higher risk and more complex preparation required for mid-rise and larger developments resulting in slower uptake. One THAB development also represents more dwellings on average than developments in the other zones, as our Step 3 analysis shows, so on the level of individual dwellings the development probability for THAB zones will be understated compared to the others.

The conclusion of Step 2 is to take the sum of calculated probabilities across all residential parcels in the policy-affected area. We do this for each tested scenario. This total becomes the estimate for that scenario of the total count of parcels that will add at least one dwelling in the medium term. We then rank all parcels from highest to lowest estimated probability and select the top *n* most likely parcels, where *n* is the sum of probabilities for the scenario.

Breaking the pattern of the AUP – adjustments to the distance effect

Our analysis reveals a counterintuitive insight about the pattern of development that took place following the AUP. Adding dwellings was statistically *more likely* the *further away* a parcel is from the city centre, after controlling for quality score, zone, and special character status. This does not align with the demand patterns predicted by the AMM model. Further analysis reveals that while the zones themselves are distributed widely across distances, areas where the zones increased the permissible development capacity beyond the existing improvements by enough to add at least one dwelling were much less common as we approach the centre. In other words, the zoning changes released constraints by much more on the outskirts of the city than in the high-demand areas. Figure 14 shows the fitted relationship between distance and probability of adding at least one dwelling for each zone at the median quality score.

Figure 14: Development likelihood by distance and zone at the median quality score



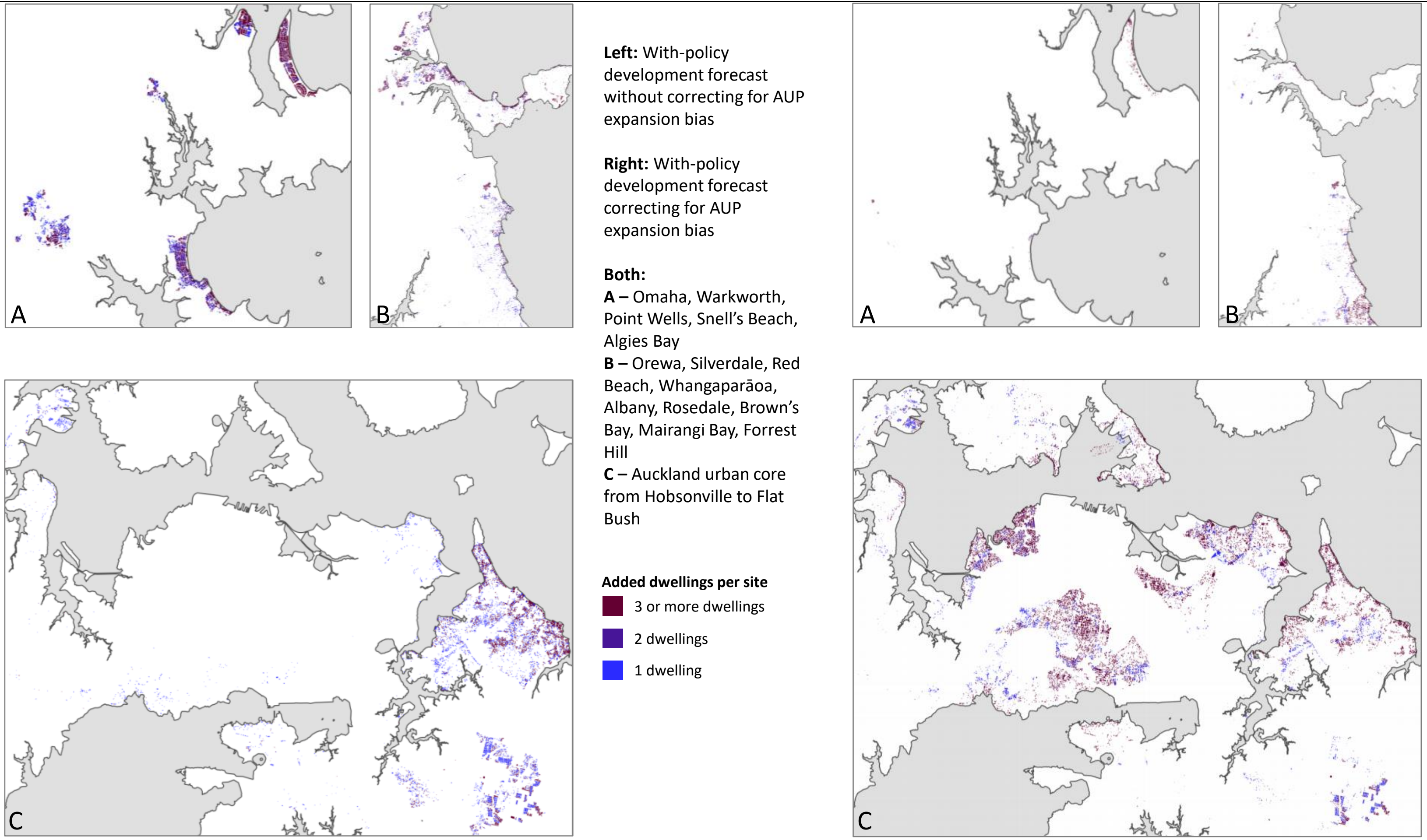
Source: Authors' analysis.

The presence of a recent natural experiment such as the AUP makes our approach one of the most analytically robust methods available for quantifying the actual results of relaxing zoning restrictions. However, the NPS-UD and the MDRS are intended to alter fundamental patterns about where and how much housing development takes place. Fitting any model to historical data will tend to replicate some of those historical patterns in our forecasts in ways that may not hold if the policy succeeds as intended.

The distance parameter in our model provides a way for us to neutralise this effect in our forecasts, to simulate how development might take place if the MDRS and NPS-UD are successful in unlocking development where demand is strongest.

The maps in Figure 15 on the following page show the difference in spatial development patterns generated by our model both with and without a correction for the bias toward city-fringe development observed in the AUP data. Note that the total policy impact in both cases is approximately equal, and that the NPS-UD walkable catchments are not included in the forecast.

Figure 15: Modelled spatial distribution of development with and without correcting for the AUP urban fringe expansion bias



Left: With-policy development forecast without correcting for AUP expansion bias

Right: With-policy development forecast correcting for AUP expansion bias

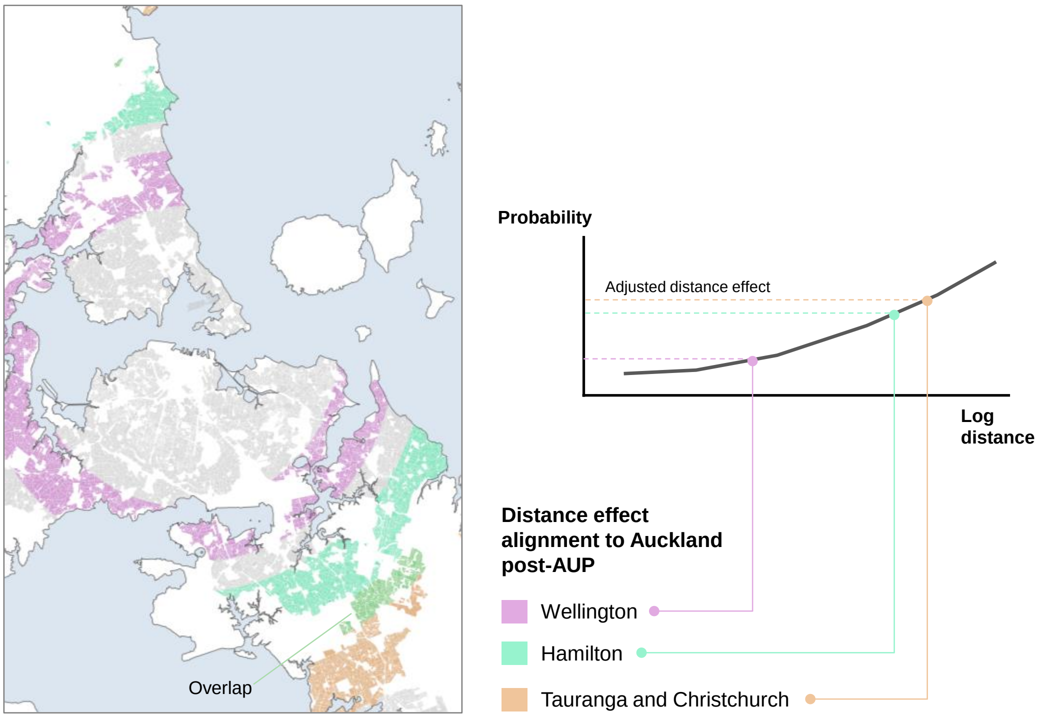
Both:
A – Omaha, Warkworth, Point Wells, Snell's Beach, Algies Bay
B – Orewa, Silverdale, Red Beach, Whangaparāoa, Albany, Rosedale, Brown's Bay, Mairangi Bay, Forrest Hill
C – Auckland urban core from Hobsonville to Flat Bush

Added dwellings per site
🟥 3 or more dwellings
🟪 2 dwellings
🟦 1 dwelling

Source: Authors' analysis.

This adjustment to the distance parameter for modelled parcels is also useful when we come to applying the fitted model to non-Auckland urban areas, where the coefficient for distance from Britomart in Auckland has little relevance. We use the distance parameter instead to adjust the base-level modelled constant to align the without-policy forecast with historical consent trends in each city (Figure 16).

Figure 16: Aligning without-policy forecasts to historical consents for non-Auckland cities



Source: Authors' analysis.

Figure 16 above shows the results of this alignment as well as the range of distance tested in our sensitivity tests for each city. As we discuss further in the sensitivity analysis, Wellington's unusually low levels of consents cause it to align at a much lower distance parameter than the other cities.

Step 3: Estimate the expected increase in FAR conditional on adding at least one dwelling on historical data

For each parcel that passes the probability threshold for adding at least one dwelling, we estimate the expected FAR increase in the five-to-eight years following enactment of the MDRS. We then derive dwelling counts from this expected FAR increase based on the average 2019 dwelling size in each zone and TA, subject to the regulatory limits on building dimensions and total dwellings for each parcel's simulated zone. Model equations for FAR estimates are shown below.

Estimation using historical data (post-AUP)

$$(FAR\ increase|AddedDwelling) = \beta_0 + \beta_1 QS_{pre_i} + \beta_2 Zone_i + \beta_3 QS_{pre_i} * Zone_i + \beta_4 LandArea_i + \varepsilon_i$$

Forecast for post-MDRS

Without MDRS

$$(\text{Est.}\,FAR\ increase|AddDwelling) = \hat{\beta}_0 + \hat{\beta}_1 QS_{post_i} + \hat{\beta}_2 Zone_i + \hat{\beta}_3 QS_{post_i} * Zone_i + \hat{\beta}_4 LandArea_i$$

With MDRS

$$(Est.\,FAR\ increase|AddedDwelling) = \hat{\beta}_0 + \hat{\beta}_1 QS_{post_i} + \hat{\beta}_2 NewZone_i + \hat{\beta}_3 QS_{post_i} * NewZone_i + \hat{\beta}_4 LandArea_i$$

Where:

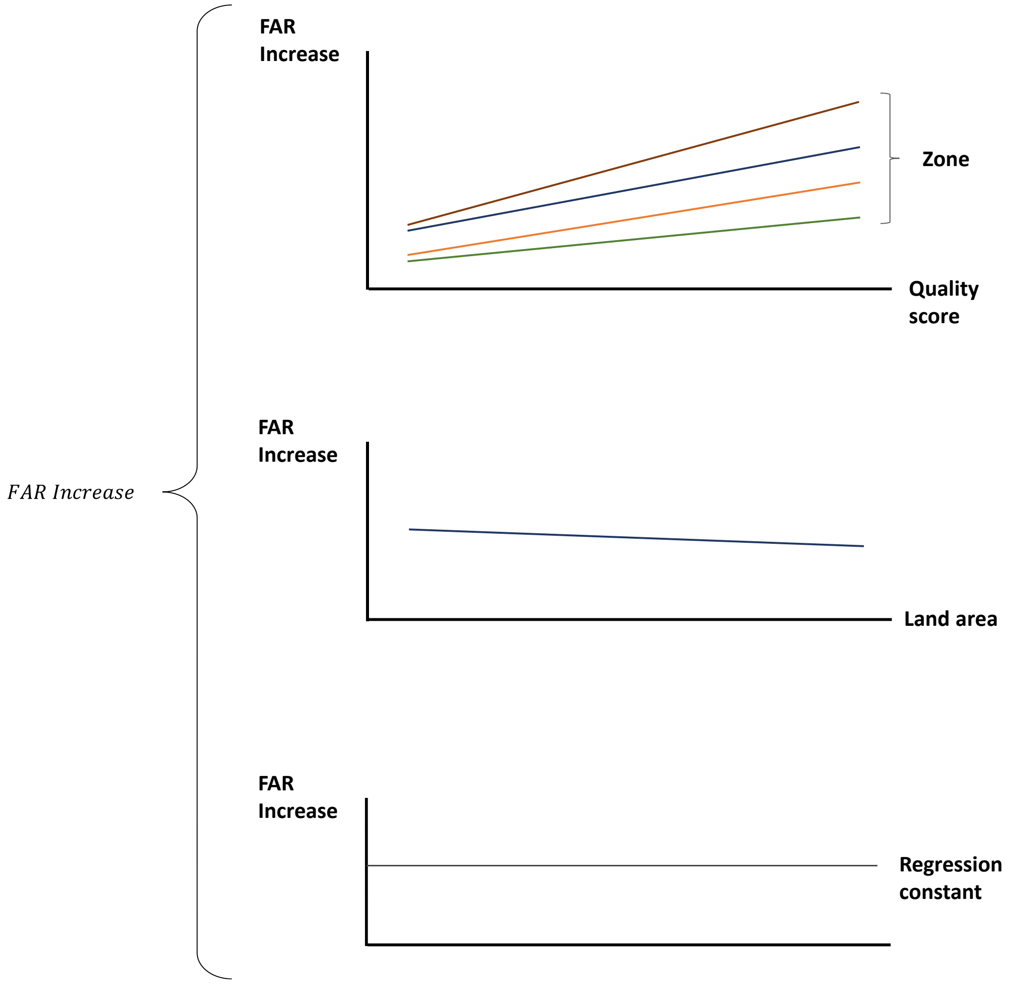
$(FAR\ increase|AddedDwelling)$	is the observed floor area ratio added in the post-AUP data for each parcel, conditional on that parcel having added at least one dwelling.
$(Est.\,FAR\ increase|AddedDwelling)$	is the expected floor area ratio added for each parcel, conditional on that parcel adding at least one dwelling.
$LandArea_i$	is the land area in metres squared for each parcel.

**All other variables are as defined in Step 2 above.*

Step 3 visual summary

Figure 17 illustrates how the parts of the forecast equations above are combined to arrive at a final FAR increase estimate for each parcel. The coefficients determine the slope and direction of each line, and the final estimated increase in FAR is the sum of the y-axis value from each set of axes in the figure.

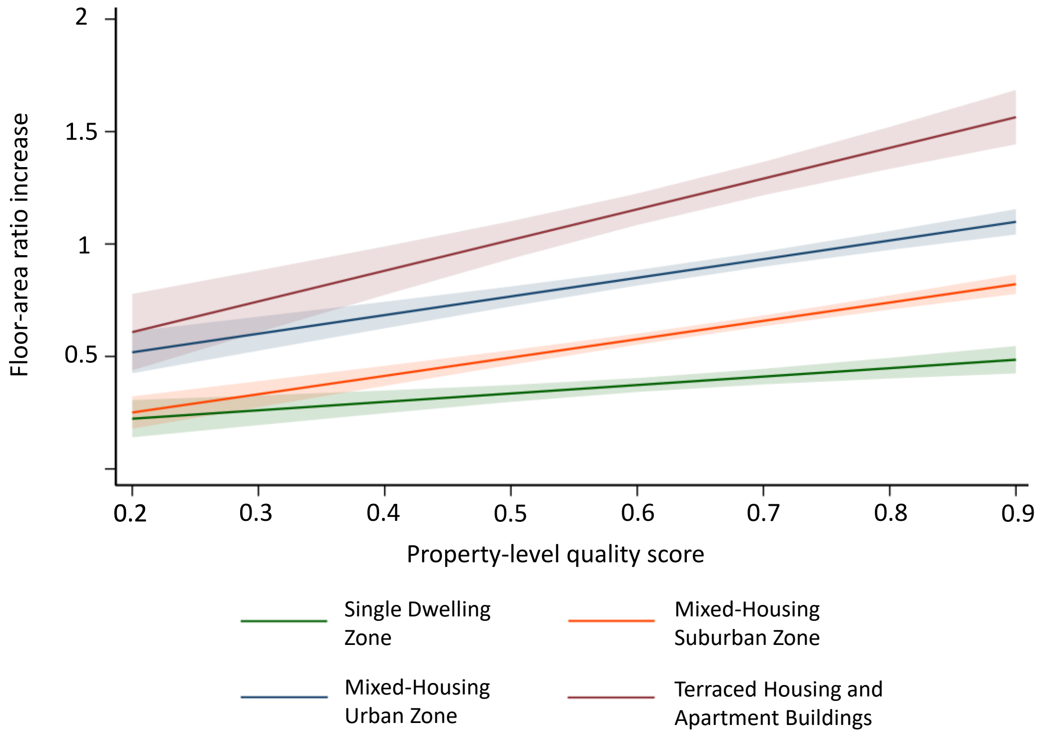
Figure 17: Estimate FAR increase



Source: Authors' illustration.

Figure 18 below summarises results from the first (historical estimation) regression. It shows that the increase in FAR becomes greater as quality score increases, regardless of zone, and that this relationship becomes stronger the more permissive the new zone is. The subset of data used here is those that added at least one dwelling, but we do not have data on whether any floor area was demolished in the process. For our model forecasts, we make the conservative assumption that one average-sized dwelling's worth of floor area is removed for each up-zoned parcel that adds at least one dwelling.

Figure 18: FAR increase per development event



Source: Auckland Council and HUD data. Authors' analysis.

In the figure, a FAR increase of 0.5 on the y-axis for a property with a building coverage of 50% implies an increase of one storey. We use this relationship along with a control for land parcel area to predict the increase in FAR for each parcel that adds at least one dwelling in each simulated scenario.

Applying the model in non-Auckland cities

Different cities have different levels of demand and different constraints. As described above, we make adjustments in each of the three model steps to adjust our forecasts to the local conditions of each city.

For the land-value shock from up-zoning, we can get an estimate of the impact of zoning on a parcel's land value by comparing parcels that are similar in most relevant respects (such as general demand in the area), but different in their zone status. As we only have a natural experiment for up-zoning in Auckland, we use this alternative approach with local data from each non-Auckland city.

The results are not as robust as a difference-in-difference design using a natural experiment because we do not know what other factors contributing to land value may differ by zone in a non-random way. However, the estimates we observe are consistent with our expectations informed by the AMM model in all cities, and the resulting shocks to quality scores are small compared to the distribution of quality scores in each city.

Box B: Key model features, assumptions, and limitations

The unit of analysis for this study is the individual land parcel, allowing the model to take advantage of a rich dataset covering the full set of residential parcels in all five Tier 1 urban areas. The key purpose of the analysis is to understand the effects of zoning rules on development, especially following a change in those rules. Our model incorporates, at the parcel level:

- differences in demand for new dwellings both between cities and within each city, and how these vary by zone
- the opportunity cost of redeveloping existing improvements
- the effect of special character protections
- the maximum permissible building dimensions and floor area for each plot.

Our design prioritises the closest possible simulation of future policy effects rather than a fine-tuned depiction of causal relationships in the post-AUP data.

The interaction between zone and demand characteristics as summarised in a custom metric called the *quality score* is the common thread to a three-step forecast method for additional dwellings. This model incorporates the willingness (in terms of probability) of property owners to enter the market as developers and add a least one dwelling to supply following a relaxation of zoning constraints.

We assume that the average rate of participation in the development market among homeowners, including participation by selling to developers (holding our model variables constant), is similar over time and between cities. In other words, most homeowners will not build more dwellings on their property regardless of the potential revenue, but some will no matter what, and others will only if the economics improve.

The variables that we can model are limited to the data available at the land parcel level, and much of the variation in development is not explained by these variables. This means our modelled scenarios for the distribution of development locations across an urban area will have a wide margin of error.

For our base-case estimates, we assume the MDRS works as intended, unlocking development where demand is highest, and the opportunity cost is lowest. Our model explicitly nullifies the observed statistical effect of special character zones, which historically reduce the likelihood of development. In our forecast, development likelihood is driven instead by the economic quality of the property as a development opportunity given the expected changes to zoning limits. In Auckland’s case, most of the properties under special character protections sit within the NPS-UD walkable catchments, so are excluded from the forecasts of MDRS impact.

Areas required to be zoned for a minimum of 6-storeys under the NPS-UD are not included in the analysis, as the primary impact in those areas over the study period is expected to be driven by that policy. While the MDRS does apply to these areas, it is outside the scope of the present analysis to differentiate the effects of the MDRS in these areas from those of the NPS-UD (which have been estimated elsewhere).

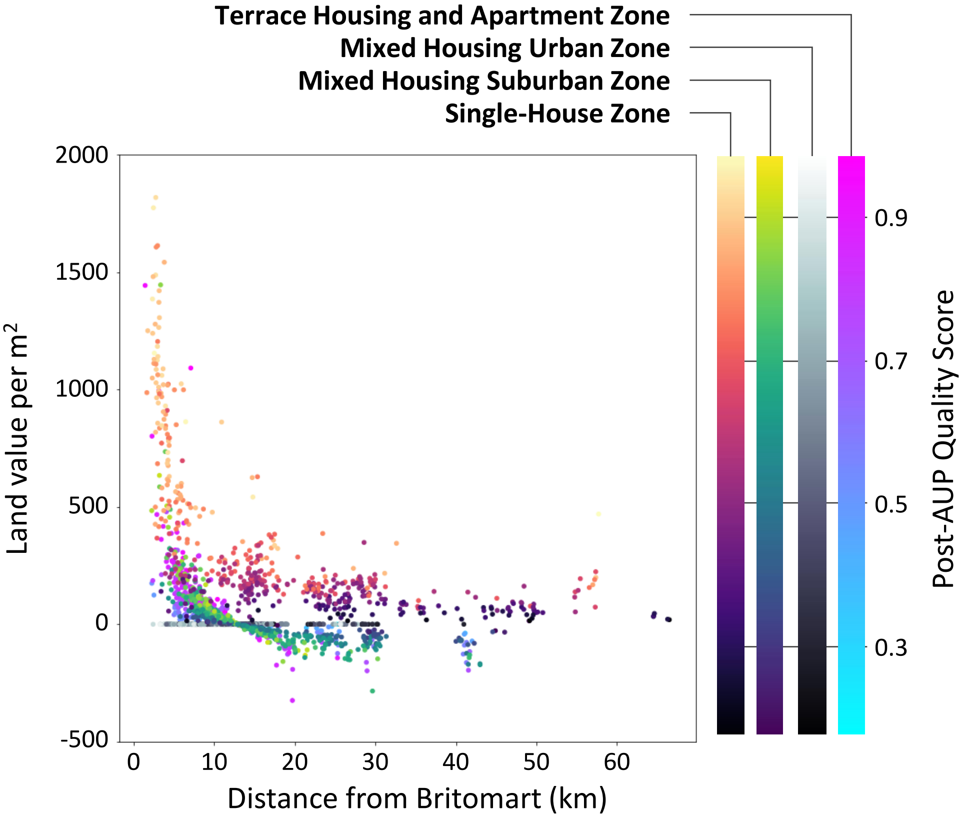
2.3. Results and Discussion

2.3.1. Auckland

Step 1: Estimate the change in land value post-MDRS

Based on the land value shocks by zone following the AUP, and their relationship to distance from Britomart, we forecast a similar shock following the MDRS. The simulated changes in land value per m² post-MDRS in Auckland are shown in Figure 19 below.

Figure 19: Simulated post-MDRS land value shock in Auckland by zone and quality score

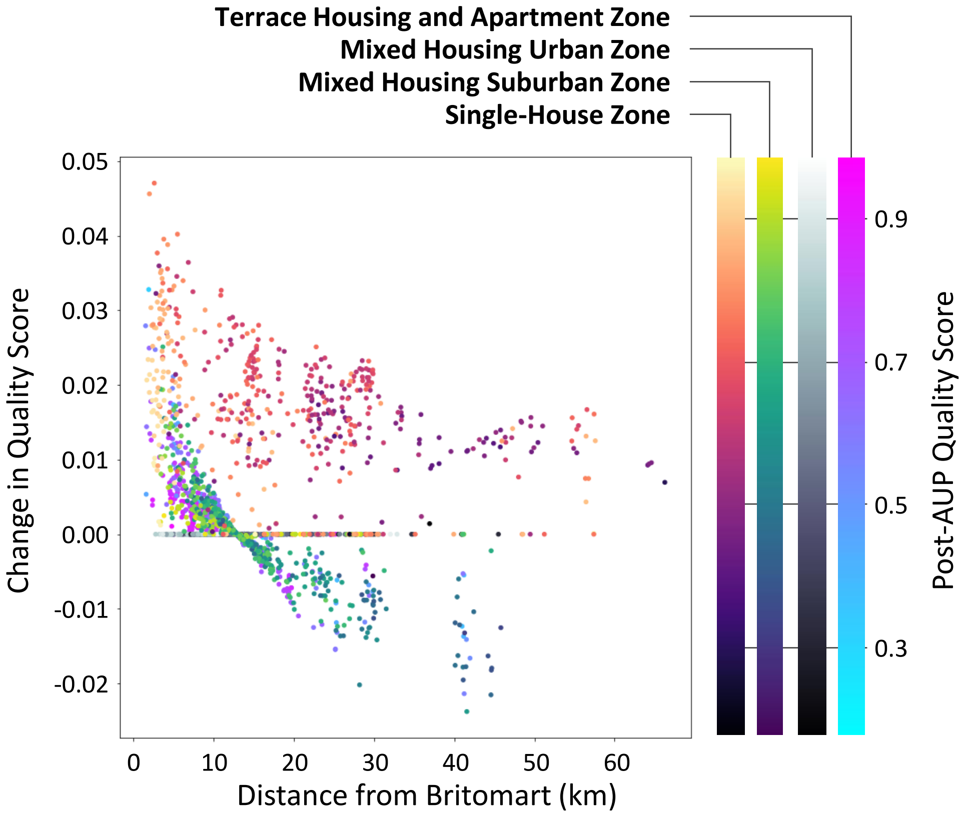


Source: Authors' analysis.
Note: The chart shows a random sample of 500 plots from each zone.

The four colour ramps in the figure represent the post-AUP quality scores for the four AUP zones in our data. In the scatter plot, notice that the grey colour ramp shows no land-value shock at any distance from Britomart. This is because the MHU is our proxy zone for the MDRS, so no simulated up-zoning takes place for those parcels. For the other zones, the change in land value is driven by the same regression results shown in Figure 11 above. In that figure, wherever the blue line for the MHU shows a higher or lower land-value than a parcel's current zone, our simulated shock is the difference in land-value change between the two lines. This means that at some distances from the city centre, we forecast a decrease in land values as a result of the upzoning. This is consistent with the AMM model framework described in Section 2.2.1.

The simulated land value changes are applied to the post-AUP quality score calculations to reflect the impact of the zone change on demand for each property. The resulting changes in quality score for Auckland are shown in Figure 20.

Figure 20: Simulated post-MDRS quality score shocks in Auckland by zone and pre-shock quality score



Source: Authors' analysis.
Note: The chart shows a random sample of 500 plots from each zone.

The simulated quality score shocks in Auckland and in the other Tier 1 urban areas are consistently small compared to each observation's pre-shock scores. This implies that the land-value shock from the policy (Step 1) will have only a minor influence on a property's likelihood of development compared to that property's existing development demand conditions (Steps 2 and 3).

Step 2: Probability of adding at least one dwelling

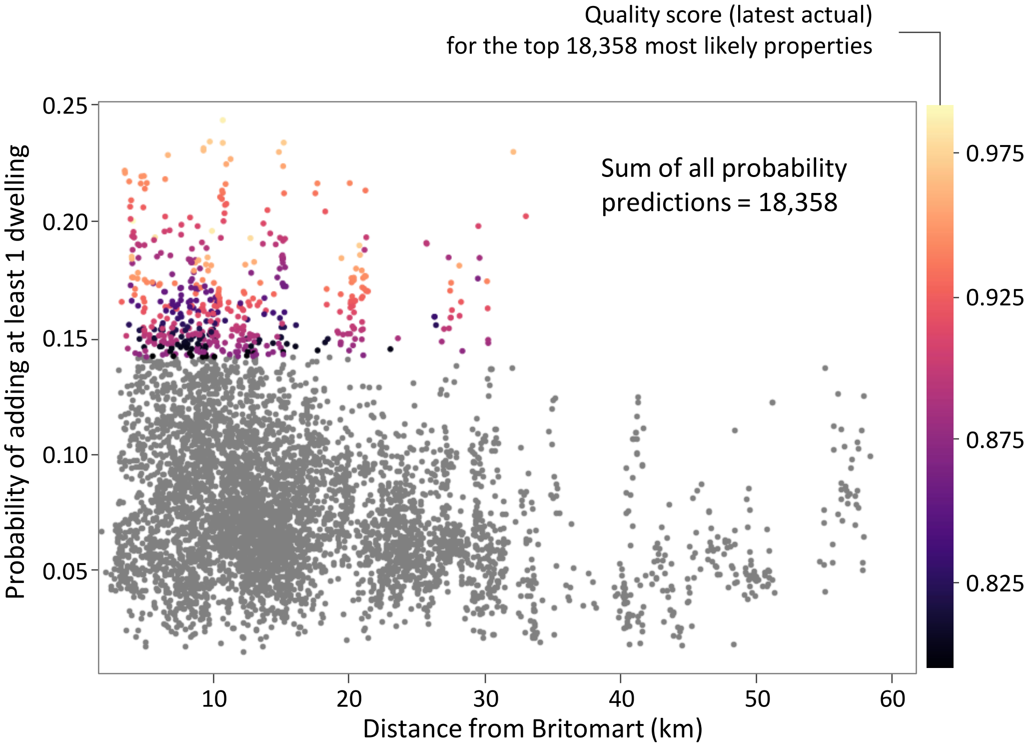
As the property-level quality score increases, the probability of adding at least one dwelling also increases. This is true for all zones. However, this is most prominent for the MHU and MHS zones. Our model uses the fitted coefficients for each zone, pre-AUP quality score, special character status, and distance from Britomart, and applies them using updated zone and special character status and updated quality scores, including the simulated shock from Step 1.

Each property is assigned a probability of adding at least one dwelling based on the fitted coefficients and updated model variables. This is done once without the policy effects (quality score shock, special character effects, and zone change) and once with the policy effects.

To simulate the selection of parcels that add at least one dwelling following the new policy, we first sum the predicted probabilities for all policy-eligible residential parcels (the four zones, less any parcels within the NPS-UD 6-storey catchment areas). We use this sum of probabilities as our estimate for the total count of development events for the forecast scenario.

To select properties for further estimations of dwelling counts, building dimensions, costs, and benefits, we rank the properties in order of their predicted probabilities and take the top *n* most likely properties, where *n* is the total count of development events described above.

Figure 21: Plot selection based on probability predictions: Auckland Base Case – without policy

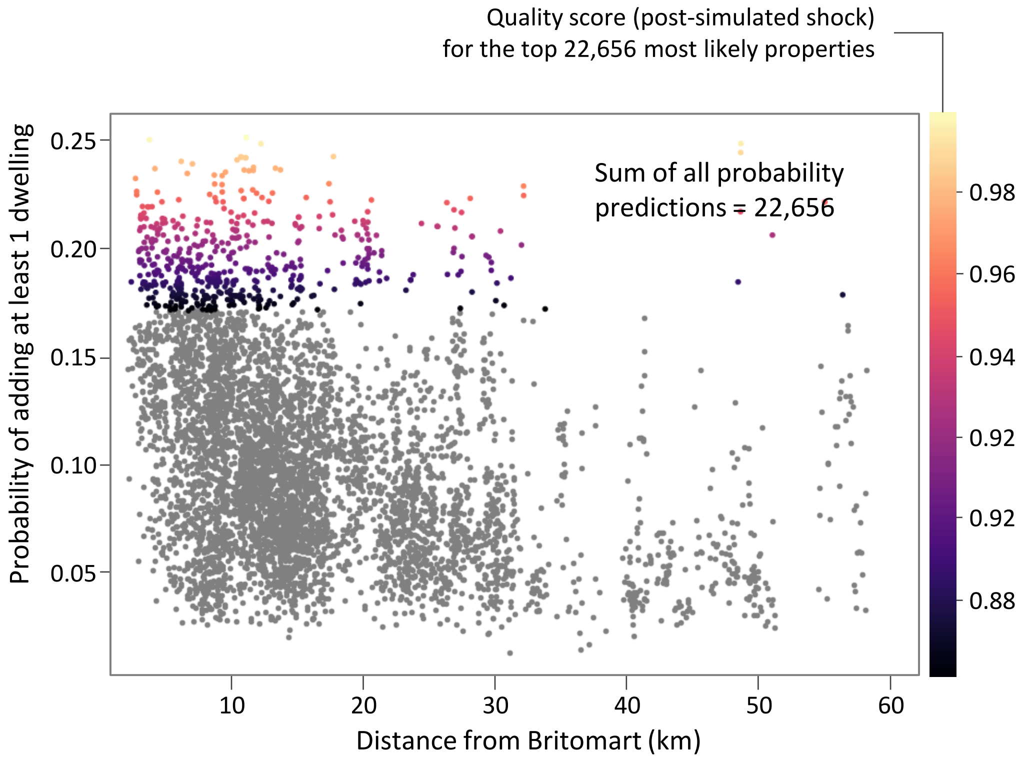


Source: Authors' analysis.

Note: Plotted parcels above are a sample of 5,500 out of 218,430 policy-eligible residential parcels. Model calculations use the full population of parcels.

We repeat this process in each scenario and each city for both the with- and without-policy case, comparing the results to estimate the impact of the policy. Figure 21 and Figure 22 show sampled results from this process for the Auckland Base Case.

Figure 22: Plot selection based on probability predictions: Auckland Base Case – with policy



Source: Authors' analysis.
Note: Plotted parcels above are a sample of 5,500 out of 218,430 policy-eligible residential parcels. Model calculations use the full population of parcels.

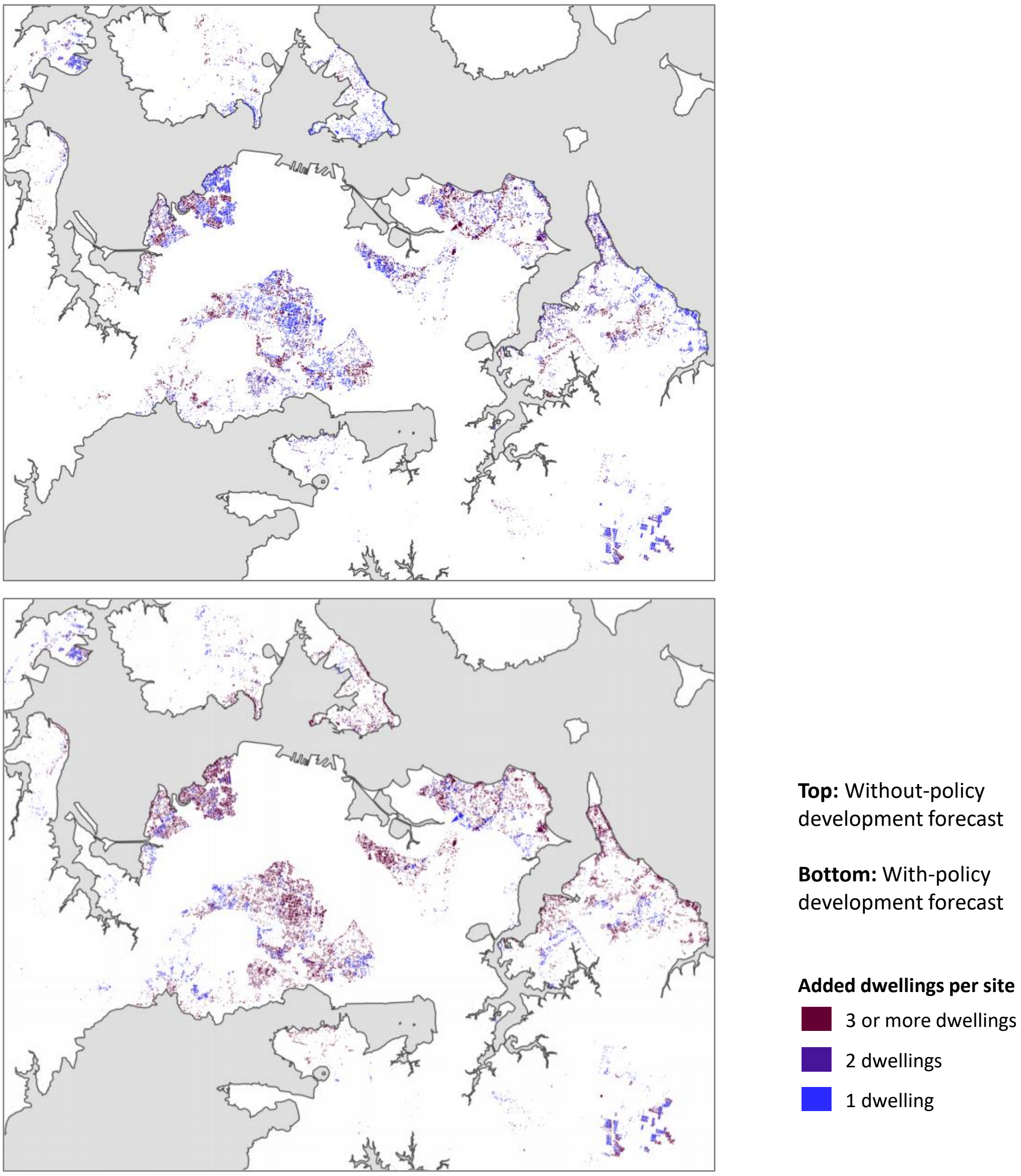
The sum of all probability predictions is about 4,300 greater in Figure 21 than in Figure 22. This is driven by the increases in probabilities from modelled changes in zone, quality score, and special character status. In aggregate, this implies an estimated 4,300 more development events in the with-policy case than in the without-policy case. This is significant, but small compared to the increase in dwellings estimated in Step 3, as the more significant driver of more dwellings is the greater added floor area from the 18,300 parcels that would have added at least one dwelling even without the policy but choose to add more under the more permissive MDRS.

Step 3: Floor area ratio increase conditional on adding at least one dwelling

For each property selected in the previous step using ranked probabilities, we estimate the increase in floor-area-ratio expected based on the property's quality score, zone, and land area. To do this, we apply the fitted coefficients from the AUP data, which generate a prediction like the one shown in Figure 18 above but adjusted for the simulated shocks to quality score and zone, as in Step 2.

Figure 23 below illustrates our base case scenario projections for the with- and without-policy cases. This spatial arrangement results from modelling dwelling increases for the statistically highest-probability parcels according to our model. In practice, it is likely that many of the statistically most likely parcels as predicted by quality scores and zone status will not add dwellings for reasons unrelated to our modelled variables. It is also likely that many other dwellings showing lower probability in the model will add dwellings. Our results are not intended as a spatial prediction for where Auckland's future development will take place, but rather as a set of illustrative hypothetical scenarios for how the predicted quantities of dwellings would be arranged under each scenario's assumptions.

Figure 23: Base-case projected development with and without the MDRS



Top: Without-policy development forecast

Bottom: With-policy development forecast

Source: Authors' analysis.

Dwelling impact results for Auckland

Without the MDRS, we forecast a 40,609 increase in the number of dwellings in policy-affected areas. With the MDRS, we forecast a 79,776 increase in the number of dwellings in policy-affected areas. Thus, we forecast the increase in dwellings due to the MDRS in Auckland is 39,167, or almost double the number of dwellings added than would be expected without the MDRS.

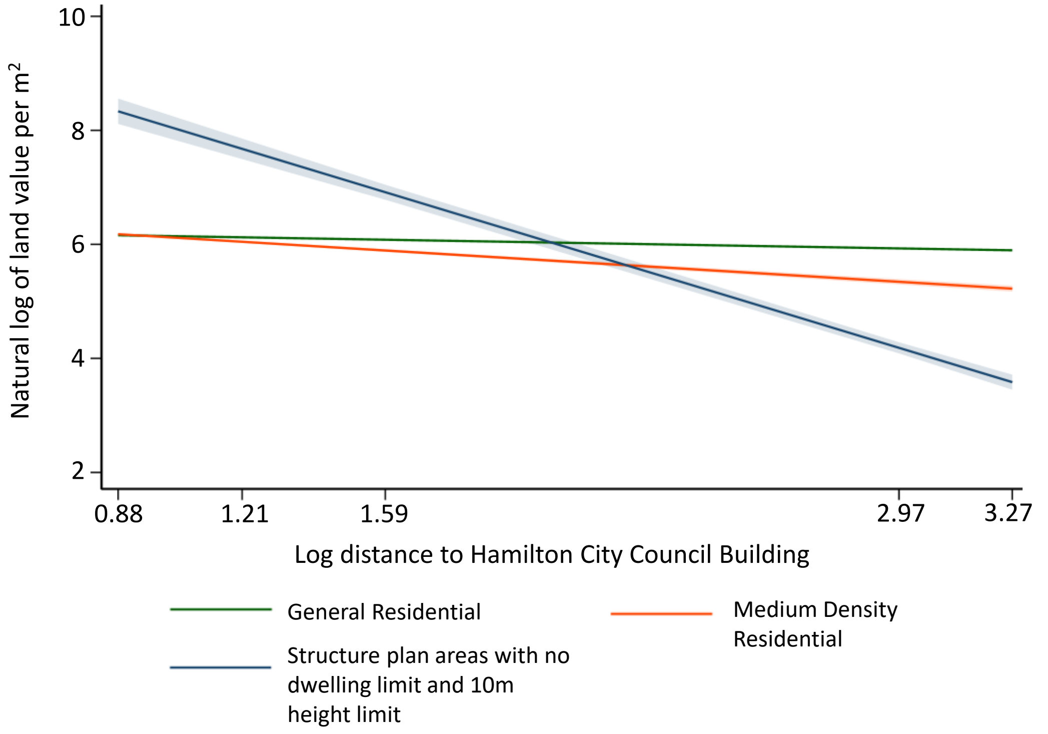
2.3.2. Other Tier 1 urban areas

Since we do not have a natural experiment in other Tier 1 urban areas, we adjust the model to align with local demand and constraints as described in the approach section above. The following subsections present model outputs for the four non-Auckland Tier 1 urban areas.

Hamilton

In Hamilton, land values show less variation by distance to the centre than in other urban areas. Most of the residential areas are in the General Residential and Medium Density Residential zones. To simulate the land-value shock from the MDRS, we use a subset of zones with characteristics closer to the new policy than to Auckland's SHZ. This subset comprises the structure plan areas on the edges of Hamilton and in outlying towns that have no listed dwelling limit and a height limit of 10 metres. Figure 24 shows the discontinuity in land values by zone grouping.

Figure 24: Land value by zone and distance to city centre - Hamilton

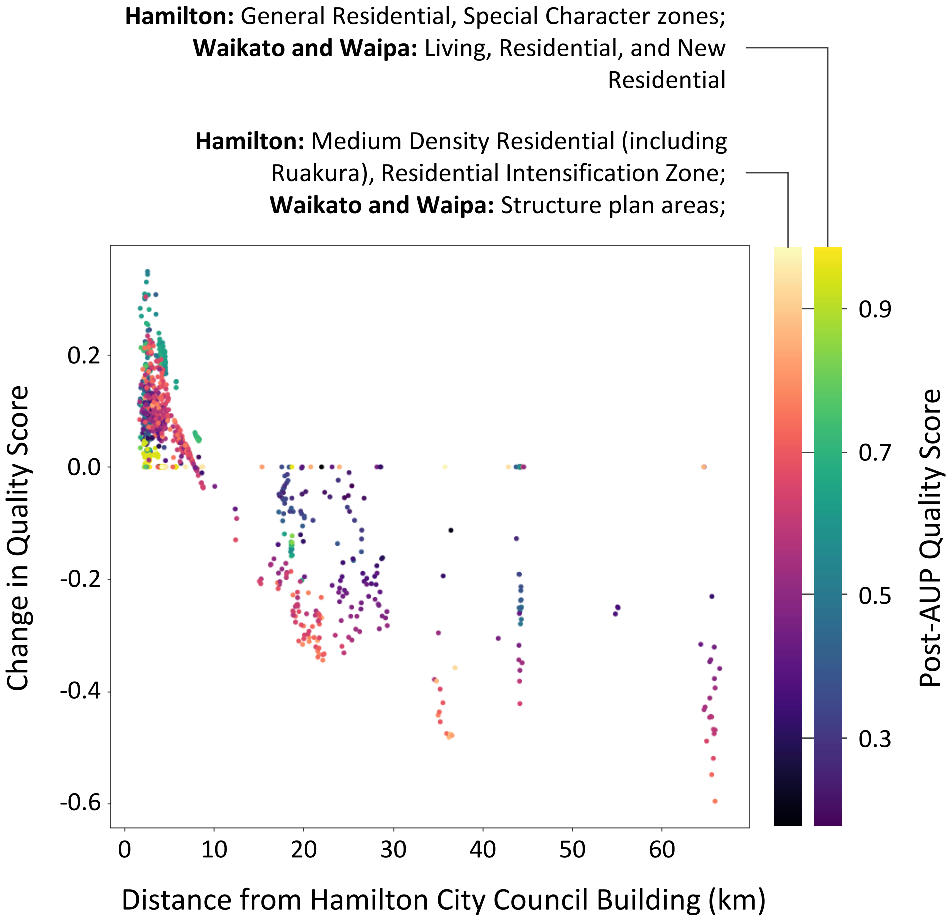


Source: Authors' analysis.

In our land value regressions, the special character zones to the East of Hamilton's city centre are grouped with the General Residential zone, along with the Living, Residential, and New Residential zones from Waikato and Waipā. The Medium Density Residential group includes Hamilton's Medium Density Residential zone including Ruakura and the Residential Intensification Zone, as well as some structure plan areas in Waikato and Waipā.

The observed discontinuity pattern means that most of the properties forecast to see a positive land value shock from up-zoning are in Hamilton City rather than the neighbouring districts. This is consistent with the AMM model to the extent that nearby towns are a substitute for living in Hamilton City—relaxing constraints in the centre leads to a decrease in land value for substitute locations farther away. This is clear in Figure 25, where positive quality score shocks are exclusively in the distance range below 10 km from Hamilton City Council.

Figure 25: Simulated quality score shock from MDRS – Hamilton

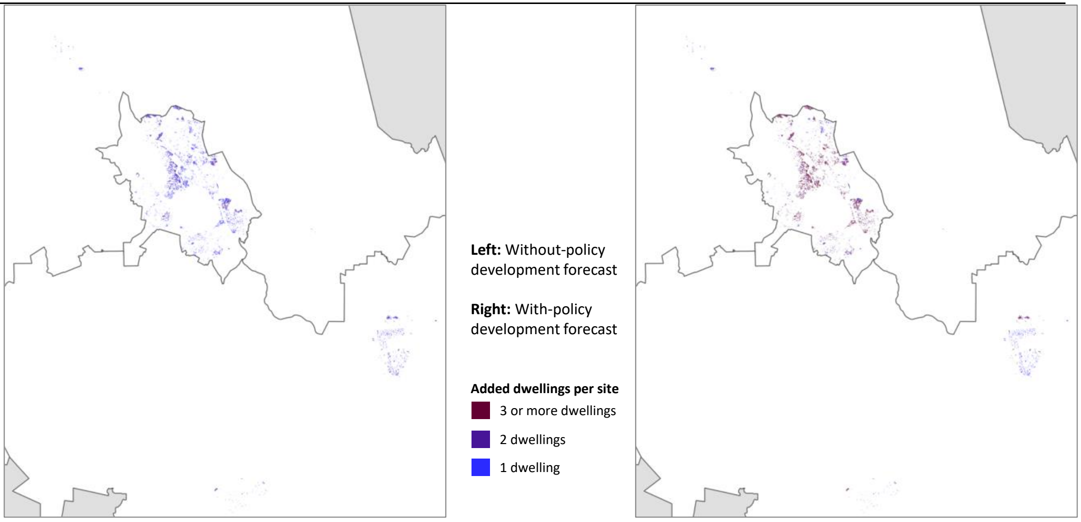


Source: Authors' analysis.

We use these adjusted quality scores as inputs to steps 2 and 3 of our model, which forecast the location and quantity of likely development of new dwellings in Hamilton over the five-to-eight years following the enactment of the MDRS.

Figure 26 below shows our base case with-and without-policy comparison. The left panel shows the simulated medium-term development outcomes without the MDRS and the right panel shows the outcomes over the same period with the MDRS.

Figure 26: Simulated medium-term development outcomes with and without the MDRS – Hamilton



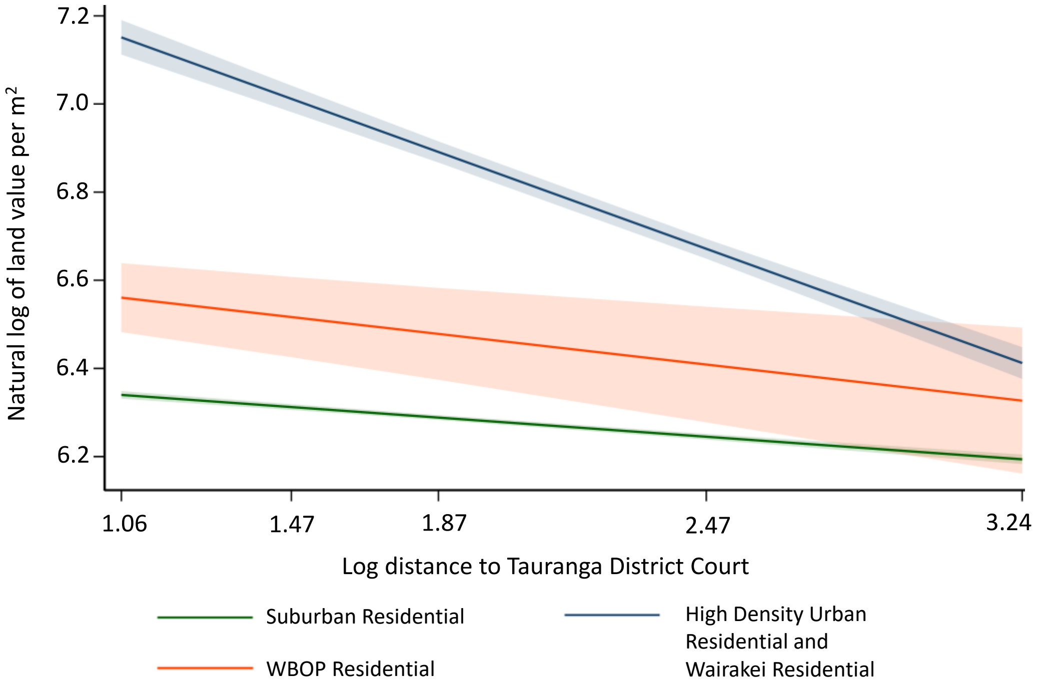
Source: Authors' analysis.

Without the MDRS we forecast a 9,509 increase in the number of dwellings in policy-affected areas. With the MDRS, we forecast a 17,769 increase in the number of dwellings in policy-affected areas. Thus, we forecast the increase in dwellings due to the MDRS in Hamilton is 8,260.

Tauranga

Land values in Tauranga show a clear and significant statistical difference by zone at all distances to the city centre. This suggests that much of the city may face constraints to development. Figure 27 shows the discontinuities in land values in Tauranga post-MDRS by zone. The wide shaded band around the linear estimate for Western Bay of Plenty residential areas indicates a smaller sample size and lower statistical confidence for the estimated relationship for that group.

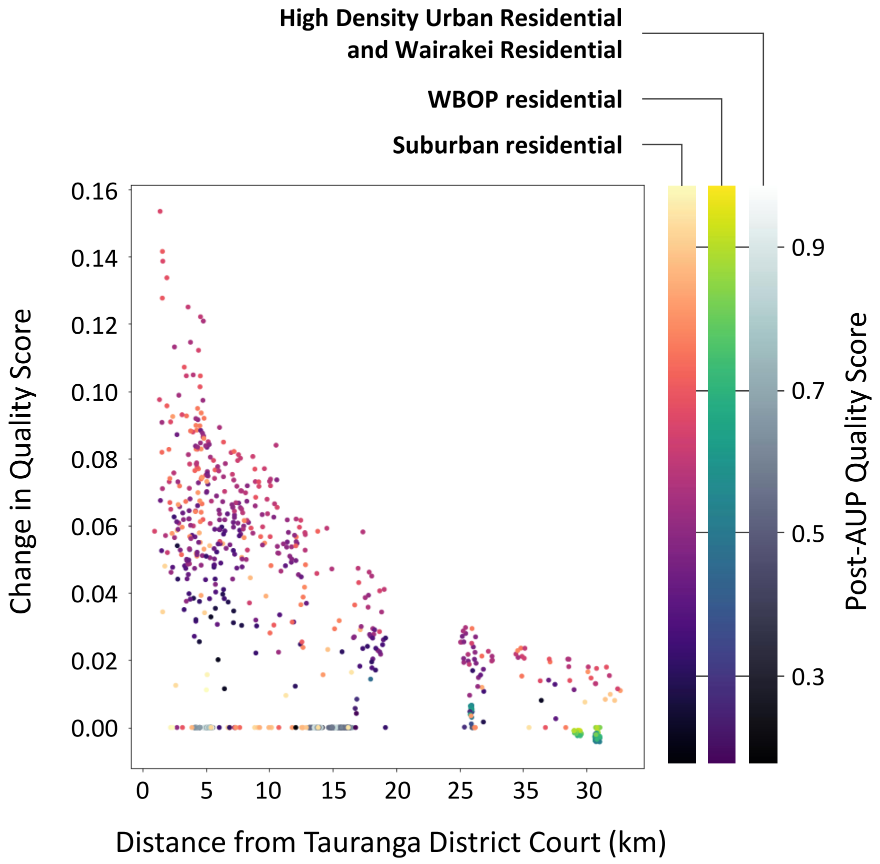
Figure 27: Land value by zone and distance to city centre - Tauranga



Source: Authors' analysis.

Unlike in Hamilton, Tauranga's simulated land value and quality score shocks are positive at nearly all distances from the centre. These are shown for a sample of parcels in Figure 28 below.

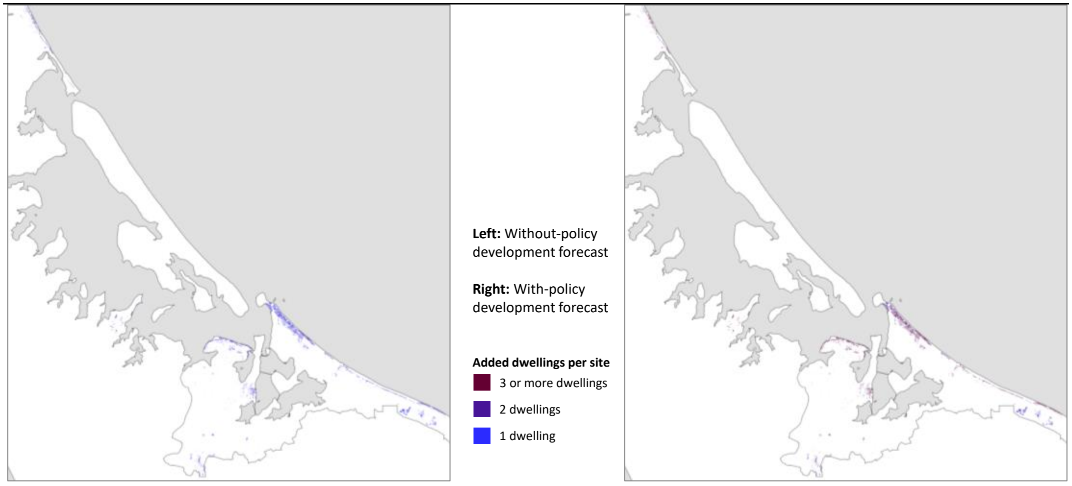
Figure 28: Simulated quality score shock from MDRS – Tauranga



Source: Authors' analysis.

As in the other urban areas, we use the shocked quality scores to estimate likelihood, location and quantity of development with and without the policy. The left panel in Figure 29 below shows the simulated medium-term development outcomes without the MDRS and the right panel shows the outcomes with the MDRS in Tauranga.

Figure 29: Simulated medium-term development outcomes with and without the MDRS – Tauranga



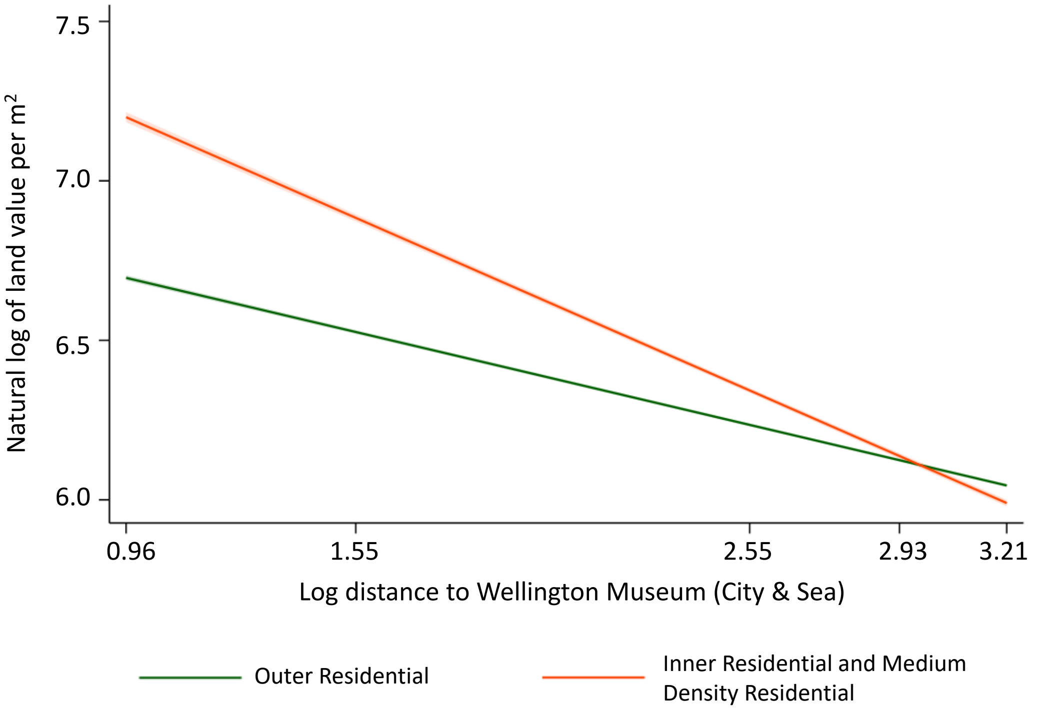
Source: Authors' analysis.

Without the MDRS, we forecast a 4,500 increase in the number of dwellings in policy-affected areas. With the MDRS, we forecast a 10,318 increase in the number of dwellings in policy-affected areas. Thus, we forecast the increase in dwellings due to the MDRS in Tauranga is 5,818.

Wellington

In Wellington, the Inner Residential zone and Medium Density Residential zone show very similar land value patterns. While their names imply that the latter might be more permissive, both permit one dwelling and up to 50% building coverage. The Inner Residential zone also has special character protections in many neighbourhoods. These two zones have been grouped together, along with the Medium Density Residential Activity Area in Lower Hutt and the Suburban Zone in Porirua, each of which are more permissive than the Wellington City zones. Figure 30 shows the discontinuity in land values in Wellington post-MDRS by zone.

Figure 30: Land value by zone and distance to city centre – Wellington

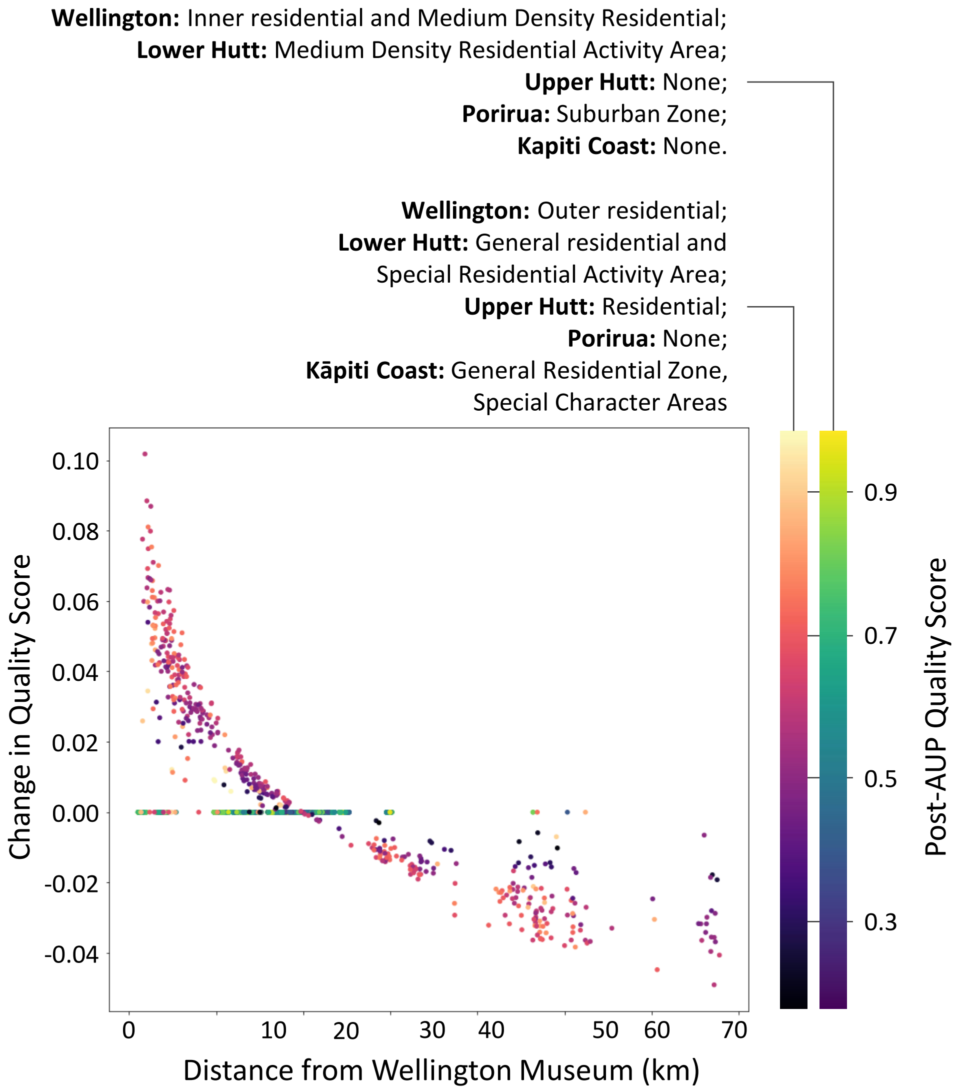


Source: Authors' analysis.

The Outer Residential zone in Wellington has been grouped with the General Residential and Special Residential Activity Area zones in Lower Hutt, the Residential zone in Upper Hutt, and the General Residential zone and Special Character Areas in Kāpiti Coast. The land value discontinuity patterns imply that a broad release of development capacity may lead to rising land values in Wellington City but falling land values in the more distant residential zones.

This pattern is simulated in our modelled quality score shocks, a sample of which are shown in Figure 31 below.

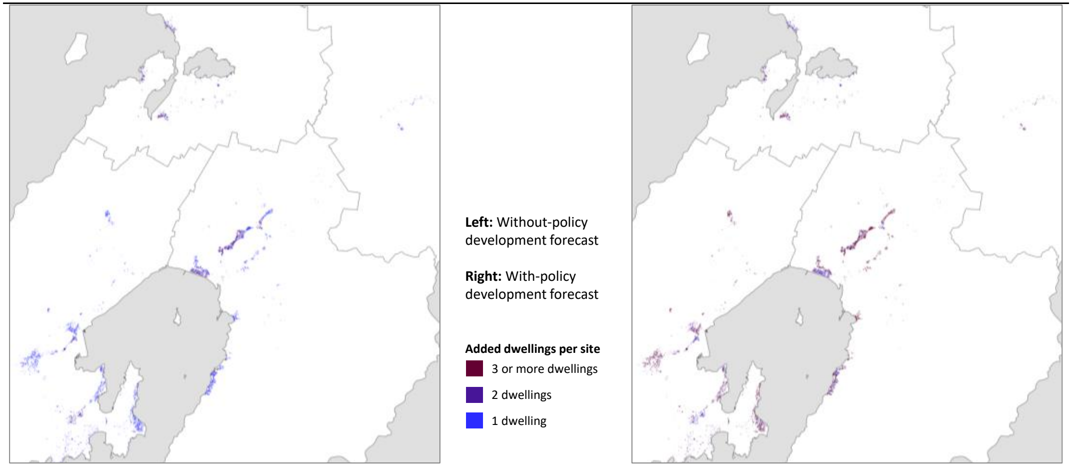
Figure 31: Simulated quality score shock from MDRS - Wellington



Source: Authors' analysis.

The forecast pattern of development is more dispersed in Wellington than in the other cities, reflecting that the NPS-UD catchment areas in Wellington cover much more of the urban core. The left panel in Figure 32 shows the simulated medium-term development outcomes without the MDRS and the right panel shows the outcomes with the MDRS in Wellington.

Figure 32: Simulated medium-term development outcomes with and without the MDRS – Wellington



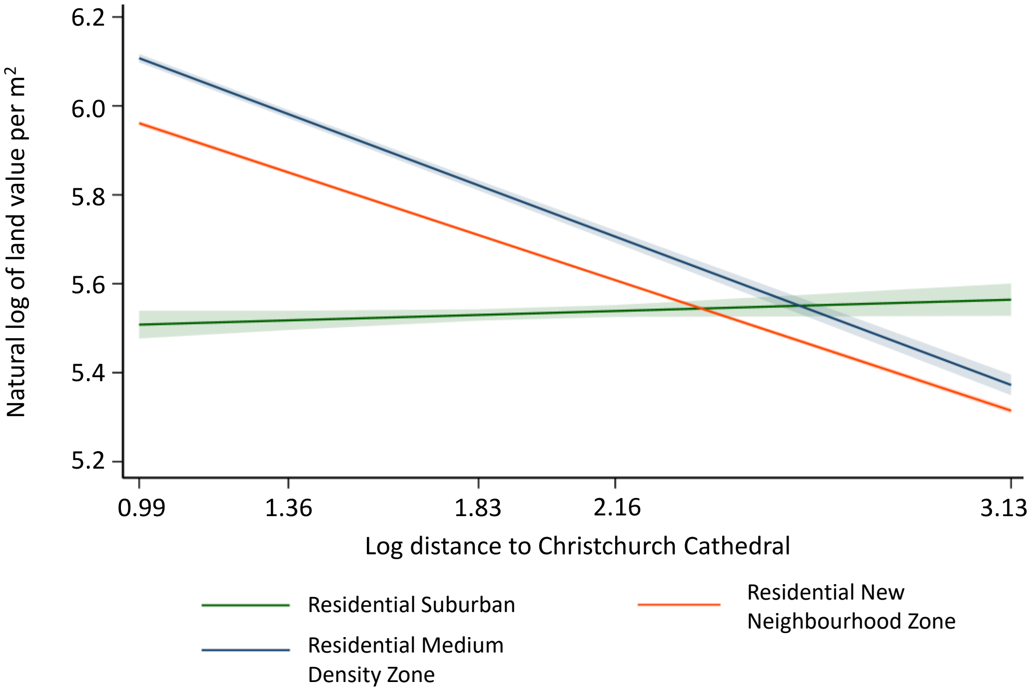
Source: Authors' analysis.

Without the MDRS, we forecast a 7,249 increase in the number of dwellings in policy-affected areas. With the MDRS, we forecast a 17,082 increase in the number of dwellings in policy-affected areas. Thus, we forecast the increase in dwellings due to the MDRS in Wellington is 9,833.

Christchurch

Christchurch shows a significant difference between zones in the relationship between distance from the city centre and land value. Our regression results for land value discontinuity between zones are shown in Figure 33 below.

Figure 33: Land value by zone and distance to city centre – Christchurch

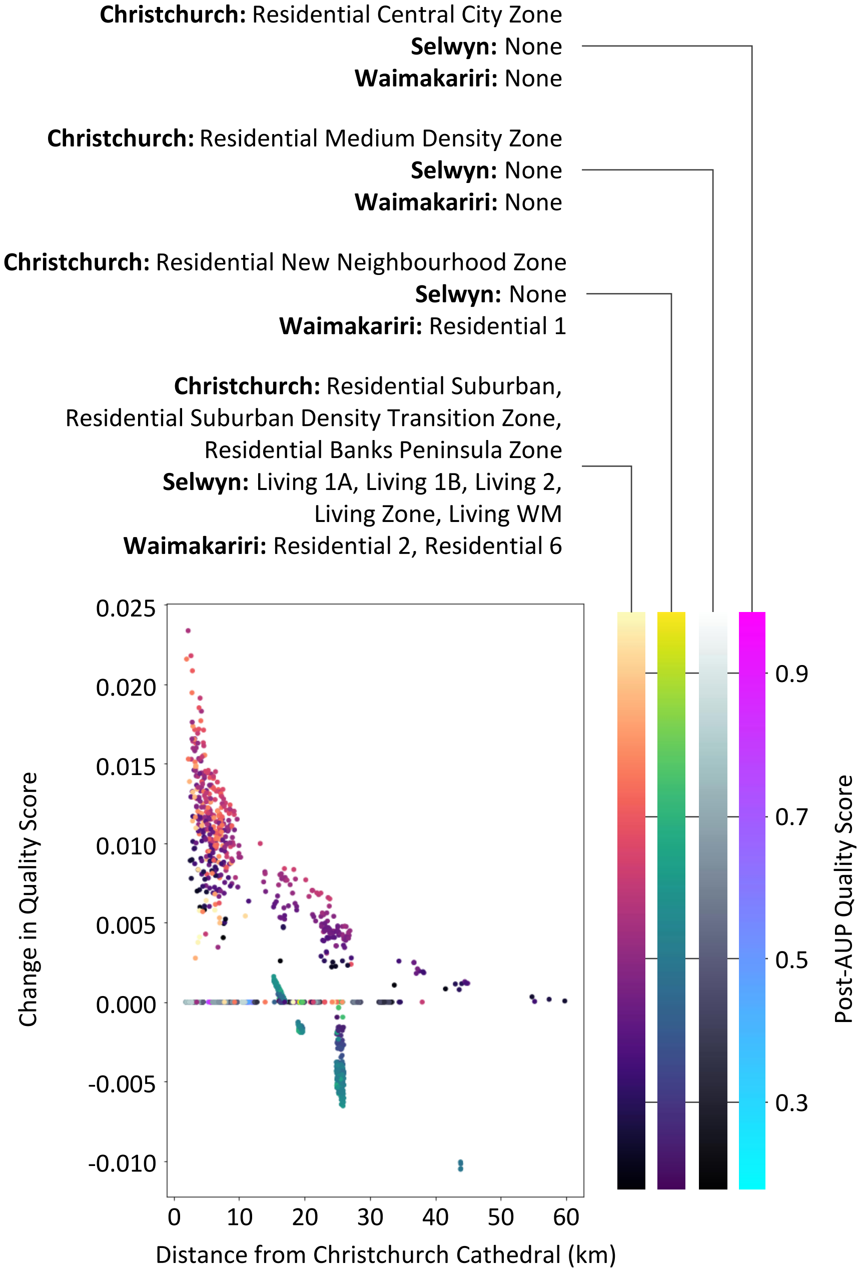


Source: Authors' analysis.

The zones shown in the figure represent groupings according to zone characteristics. The 'Residential Suburban' zone includes the Residential Suburban, Residential Suburban Density Transition, and Residential Banks Peninsula zones in Christchurch; the Living 1A, Living 1B, Living 2, Living Zone, and Living WM zones in Selwyn; and the Residential 2 and Residential 6 zones in Waimakariri.

Based on these observed discontinuities, our land value and quality score shocks are much more significant for parcels currently zoned as Residential Suburban or similar than for other zones. The quality score shocks are shown for a sample of parcels in Figure 34 below.

Figure 34: Simulated quality score shock from MDRS – Christchurch



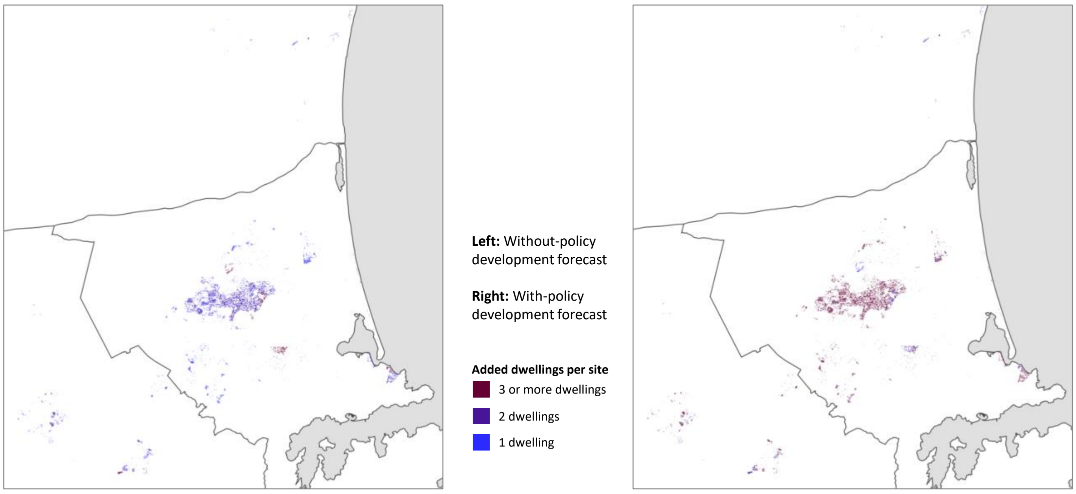
Source: Authors' analysis.

Note: Zone alignments for land-value shocks are chosen based on local land-value discontinuities and may differ slightly from the alignments used for floor area changes in Step 3.

We use these adjusted quality scores as inputs to steps 2 and 3 of our model, which forecast the location and quantity of likely development of new dwellings in Christchurch over the five-to-eight years following the enactment of the MDRS.

Figure 35 below shows our base case with-and without-policy comparison. The left panel shows the simulated medium-term development outcomes without the MDRS and the right panel shows the outcomes over the same period with the MDRS in Christchurch.

Figure 35: Simulated medium-term development outcomes with and without the MDRS – Christchurch



Source: Authors' analysis.

Without the MDRS, we forecast a 14,100 increase in the number of dwellings in policy-affected areas. With the MDRS, we forecast a 25,601 increase in the number of dwellings in policy-affected areas. Thus, we forecast the increase in dwellings due to the MDRS in Christchurch is 11,501, a high impact relative to population compared to the other urban areas.

In terms of our model, the impact in Christchurch is strong because historical consents have been strong and quality scores are high. Conceptually, Christchurch is unique among the Tier 1 urban areas in that its prices have been more stable over the last decades. No other Tier 1 urban area had a median house price as a multiple of median income that was no higher in April 2020 than it was in April 2014.[12] This may be due to the unusual demand conditions created by the devastating 2011 Christchurch Earthquake, after which building consents spiked during reconstruction, but population growth slowed for several years and housing preferences appear to have shifted toward less densely developed areas.[13]

Since mid-2020 however, the price-income multiple has begun to climb. Population growth has also recovered to pre-earthquake levels after a period of decline from 2011 to 2013. Land values in the city centre have recovered well relative to improvement values, implying lower average opportunity cost of redevelopment compared to the other city centres. Together, these factors provide insight into the difference in data inputs that have led to a stronger modelled policy response in Christchurch.

---

[12] REINZ and Stats NZ data.

[13] PwC 2020, Stats NZ.

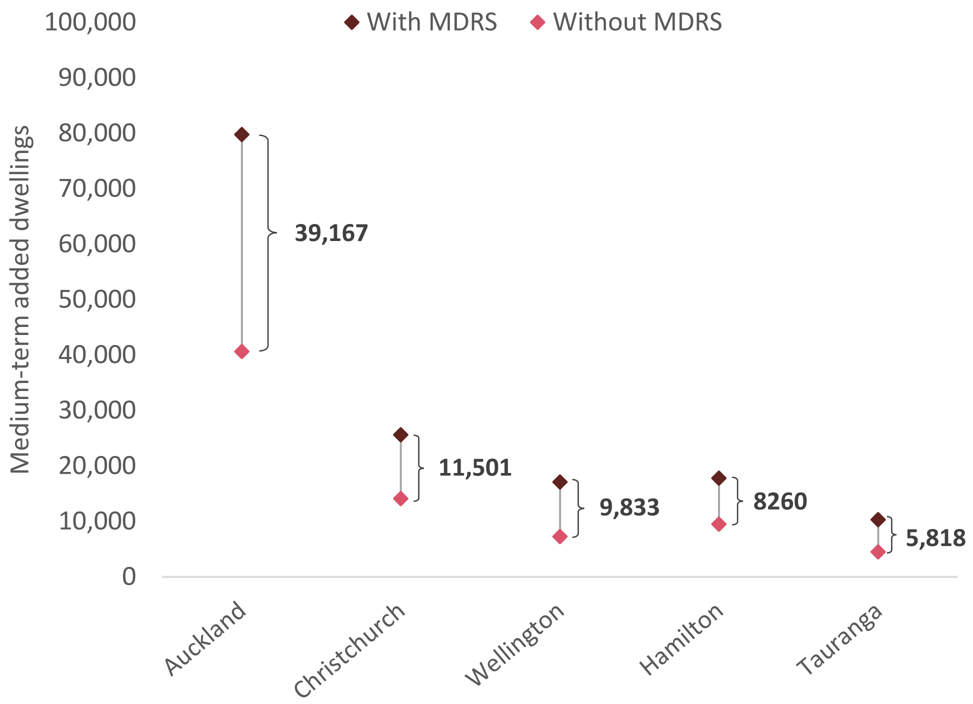
In other words, the policy can be more effective than average in Christchurch because where other urban areas have a housing crisis to address, Christchurch is in the enviable position of having a housing crisis to prevent.

2.3.3. Summary of Results

In our base case, we assume that in the without-policy case, the NPS-UD will already accomplish both a neutralisation of the bias toward fringe expansion observed under the AUP and a nullification of the effect of special character protections on likelihood of development.

The impact observed in the with-policy case, summarised in Figure 36, is driven by the change in zone and associated change in land values, and their interaction with parcel-level quality scores.

Figure 36: Summary of MDRS impact on dwellings added in the medium-term (5 to 8 years)



Source: Authors' analysis.

Note on treatment of qualifying matters

Both the NPS-UD and the MDRS include provisions that allow councils to exempt specific properties from minimum upzoning requirements according to a list of "qualifying matters," including consideration of the provisions of other National Policy Statements, potential interference with nationally significant infrastructure, and several others.[14]

To apply an exemption under one of the qualifying matters, councils must demonstrate their case based on site-specific analysis, including what characteristics of the site make the level of directed

---

[14] See NPS-UD 2020, Section 3.32 and 3.33.

development inappropriate, why those characteristics justify limiting development in light of the national significance of the policy's urban development objectives.

This is a stark departure from the status-quo for exemptions to allowable development before the NPS-UD, where typically the case had to be made for development rather than against it. Because the burden of demonstration for qualifying matters applies to specific sites and falls on councils in their planning process, our assumption is that only a few sites with clear cases for exemption will be put forward under qualifying matters. Most sites will therefore be subject to the new minimum standards. We model our base case forecasts accordingly and test sensitivity to this assumption in Section 2.5.

2.4. Robustness checks

As robustness checks for our spatial econometric model, we tested three alternate model specifications to examine their effects on the primary relationships that drive our forecast results. These are described in the subsections below.

2.4.1. Spatial autocorrelation

In plain language, we tested and found that the estimated relationships between quality score and both likelihood of development and quantity of development are not random in the way the errors (differences between fitted model expected values and actual observations) are spatially distributed. We conducted an alternate method of estimating these errors that is robust to this kind of spatial dependence to understand whether the spatial clustering or anti-clustering (dispersion) in the data harms the accuracy of our estimates of the key model relationships and concluded that it does not.

In more technical language, we conducted a Moran's I test for spatial autocorrelation in regression residuals for both the logit and Ordinary Least Squares (OLS) steps. We found that residuals are spatially correlated, with index values of 0.022 for the logit and 0.016 for the OLS. Moran's Index values near zero imply that we observe both non-random spatial clustering and non-random dispersion in the residuals.

To test whether the presence of spatial autocorrelation affects the statistical significance of our coefficient estimates, we use the Conley standard errors method (Conley 1999) to correct for spatial autocorrelation, finding no relevant effect on the significance of our coefficient estimates. Further technical details of these test results are provided in Appendix A.

2.4.2. Neighbourhood-level fixed effects

We tested both the logit and OLS models with neighbourhood-level fixed effects for Auckland and found that the general relationship between quality score and both the likelihood to develop and quantity of development were unchanged, including in terms of differences in slope between zones. That is, higher quality scores were still associated with higher likelihood and quantity of development, and this relationship was more pronounced for the MHS and MHU zones than for SHZ.

While the specific estimates of slopes and intercepts were altered by the presence of neighbourhood-level fixed effects, we decided to omit these from the final model to avoid overfitting our forecasts to observed neighbourhood-level patterns in the past, which the policy intends to alter.

2.4.3. Single-step approach to the dwellings-added estimate

We also tested a single-step model, directly estimating the average FAR increase across the city in each zone as predicted by the quality score. This provided similar results in terms of zone-quality score relationships and city-wide average FAR increases.

However, this method disperses modelled increases in floor area across all observations as predicted by their quality score, zone, land area, and distance from the city centre. Consequently, it does not provide insight into potential scenarios for how development might be spatially arranged throughout a city, as the two-step model does. Because we need to simulate actual development locations to estimate the costs of the policy from factors such as overshadowing and traffic congestion, we favour the two-step estimation for our forecasts.

2.5. Sensitivity tests for dwellings added forecasts

We test the sensitivity of our forecasts to four types of input changes:

- The **range of statistical uncertainty** for model coefficients associating input factors with likelihood to develop. Here we test the forecast impact if each coefficient is incremented by one standard error above and below its original estimate.
    - Our sensitivity tests for standard errors substitute the likelihood model coefficients for each model variable with the coefficient ± one standard error, to examine the effects on the predicted count of parcels that add at least one dwelling in the medium term.
    - To derive the difference in dwellings from this variation in parcels adding at least one dwelling, we look at the ratio of numbers of dwellings added per site (with and without the policy) around the central estimate and hold these constant. We then multiply the number of sites at ± one standard error with the ratio of the number of dwellings added per site to get the number of dwellings added in each sensitivity test.
- The **effect of the chosen adjusted distance predictor** on the regression constant. Because we replace each property's distance with a single constant distance to (in Auckland) neutralise the bias toward urban fringe expansion in the AUP data and (in other cities) align the overall likelihood of redevelopment level with local trends in building consents, this has the effect of turning the distance parameter into an adjustment to the regression constant (ie it applies equally to all properties regardless of other input values). Here we test the forecast impact of incrementing the adjusted distance scalar by one decile in the distribution of distances for Auckland's properties. In Auckland for example, the base case uses the median distance, so our sensitivity tests use the 40th and 60th percentiles.
- The **use of the adjusted distance factor** to neutralise the bias toward urban sprawl observed in the AUP data (Auckland only). As described above, our base case simulates what it might look like if the MDRS and NPS-UD succeed in unlocking development where demand is strongest, closer to the centre of the city. The sensitivity tests show the forecast impact if we assume that this does not take place (by using each parcel's actual distance instead of adjusted distance as a predictor) either under the NPS-UD alone (our without-policy case), under the MDRS, or both.
- The **removal of the special character effect** (Auckland only). Our fitted model shows a negative effect on development likelihood associated with special character status for a

property, all else equal. Our base case assumes that the MDRS policy will nullify this effect, making properties with special character status just as likely to develop as others. Here we test the impact if this assumption is varied in both the with- and without-policy cases.

Note that the statistical impact of special character status in our model may overlap with the impact associated with distance from the city centre. Additional regression tests more focused on special character show that its effect varies with both quality score and distance, becoming more severe at higher quality scores and lower distances. This nuance is not captured in our forecast model, which applies a uniform effect for special character across distances. Auckland has about 17,000 residential parcels with special character status, but only around 8,000 of them are in our study area, which excludes the NPS-UD walkable catchments as discussed in Section 1.2. Compared to 218,000 affected parcels, this is a small factor overall.

Finally, supply constraints could limit the number of dwellings that are delivered by the MRDS. Box C suggests if current growth rates are sustained, the sector can deliver the new dwellings enabled by the MRDS. However, these growth rates require significant new labour to be added to the construction sector.

Box C: Supply-side constraints

The MDRS enables substantial capacity in New Zealand’s tier 1 cities and Auckland in particular. Any benefits of the policy require the additional capacity to be realised and put in place by the residential construction sector, supported by improved civil infrastructure.

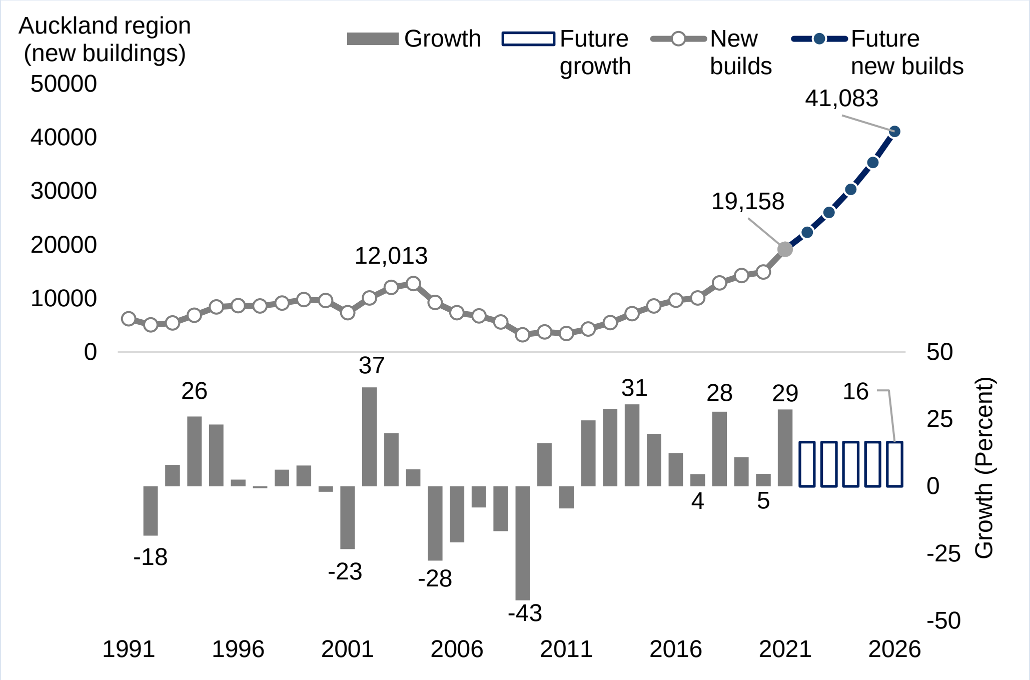
The construction sector has seen very large swings and the very low lows during recessions, and the Global Financial Crisis has driven high employee churn. This made it difficult to plan through the cycle. Incentives tend to favour maximising profits in the short run rather than investing in training for the long term, because historically, the good times have not always lasted.

We conduct a simple test the feasibility of the sector to meet additional demand enabled by the MDRS. We focus on Auckland, since not all construction activity is likely to be fungible across New Zealand and Auckland provides the most enabled growth.

Auckland has experienced strong growth in residential construction. We simply take the typical growth in construction activity over the past ten years to show an implied build profile in

Figure 37.

Figure 37: Sector will need to continue to ramp up to support implied construction profile
New builds implied by projecting average growth rate of the past 10 years (16 percent)



Under this profile our preferred central scenario of 39,167 builds suggests one-in-four (25.3%) residential builds would be supporting the MDRS, under the low scenario of 27,927 builds, less than one-in-five (18.0%) and about one-in-three (34.6%) for the high scenario of 53,683 new builds.

This suggests that the sector can meet the expected increases in demand for construction but only by continuing the strong rates of growth experienced in recent years. This requires continued strong demand for training and bringing labour into the sector – both internally and internationally.

Supply chain constraints in the building and construction sector, such as labour and materials, would be expected to become less binding over time.

2.5.1. Auckland

Sensitivities to standard error ranges and the adjusted distance parameter

Results for Auckland (Table 4) show that the impact estimate is sensitive to changes in the fitted model coefficients for likelihood of a parcel to add at least one dwelling. Variation by one standard error across all coefficients (quality score, zones, interactions, log distance, and special character flags) results in a range of potential policy impact from around 28,000 to 54,000 dwellings. However, Auckland results are less sensitive to the choice of adjusted distance parameter.

Sensitivities to unadjusted distance and special character assumptions

Our without-policy case in each scenario must make certain assumptions about the effects of the NPS-UD, which is already enacted but has not yet shown results in the data. Our choice of assumptions about what the NPS-UD will accomplish in the counterfactual case affects our estimates of policy impact. To understand how much these assumptions influence our impact estimates, we include some sensitivity tests that change the without-policy assumptions.

One key assumption we test is how our model treats the tendency observed in the post-AUP data for high-demand residential areas with high development potential (implying high quality scores) that is close to the city centre to show lower rates of development than parcels farther from the centre. For our base case, we have assumed that under the NPS-UD, this tendency will be nullified in general, across both NPS-UD catchment and other residential areas, as is intended by that policy.

We also test the sensitivity of our results to keeping the statistical effects of special character zones in our forecast versus nullifying them (replacing the dummy variable with zero in our fitted estimate equations) to reflect the intent of both policies to lower barriers to intensification. In our base case, we have assumed that special character effects remain in place for the areas affected primarily by the MDRS (outside the NPS-UD 6-storey catchment areas) but is nullified by the MDRS policy.

The results of these tests are shown in the third section of Table 4. For example, in the scenario labelled ‘S3a’, the NPS-UD doesn’t reverse the bias toward urban fringe expansion observed in the AUP data (“sprawl bias”), but the MDRS both does so and nullifies the effects of special character on likelihood to develop. Under these assumptions, the model forecasts 32.2% more dwellings added due to the MDRS compared to the base case.

Table 4 below shows the results of the sensitivity tests described above for the estimated medium-term policy impact on dwellings added for Auckland.

Table 4: Sensitivity tests for medium-term added dwellings – Auckland

	With policy dwellings added	*Without policy dwellings added*	*Policy impact*	*Change in impact vs. base case*
Sensitivity to the standard error range for development likelihood estimates				
***S1a**. Base - 1 standard error*	59,068	31,141	27,927	-28.70%
Base case	79,776	40,609	39,167	+0.00%
***S1b**. Base + 1 standard error*	106,368	52,685	53,683	+37.06%
Sensitivity to the choice of adjusted distance parameter				
***S2a**. Distance constant at 11.6 km (Base - 1 decile)*	71,349	36,449	34,900	-10.89%
Base case (Distance constant at 13.2 km)	79,776	40,609	39,167	+0.00%
***S2b**. Distance constant at 14.8 km (Base + 1 decile)*	89,234	45,167	44,067	+12.51%
Sensitivity to unadjusted distance and special character assumptions				
Base case (NPS-UD reverses sprawl bias, MDRS nullifies special character)	79,776	40,609	39,167	+0.00%
***S3a**. NPS-UD doesn't reverse sprawl bias, MDRS does and nullifies special character*	79,776	27,996	51,780	+32.20%
***S3b**. NPS-UD doesn't reverse sprawl bias, MDRS does but special character remains*	77,962	27,996	49,966	+27.57%
***S3c**. NPS-UD reverses sprawl bias, special character remains*	78,549	40,609	37,940	-3.13%

Source: Authors' analysis.

2.5.2. Hamilton

Forecast sensitivities for Hamilton show an impact range from 5,200 to 12,200 for sensitivity to development likelihood coefficients. As in Christchurch, the impact range is similar for sensitivity to the one-decile range of adjusted distance inputs, but with fewer added dwellings both with and without the policy compared to the coefficient sensitivity scenario.

Table 5: Sensitivity tests for medium-term added dwellings – Hamilton

	With policy dwellings added	*Without policy dwellings added*	*Policy impact*	*Change in impact vs. base case*
Sensitivity to the standard error range for development likelihood estimates				
***S1a**. Base - 1 standard error*	13,367	8,165	5,202	-37.02%
Base case	17,769	9,509	8,260	0.00%
***S1b**. Base + 1 standard error*	23,240	11,049	12,191	47.59%
Sensitivity to the choice of adjusted distance parameter				
***S2a**. Distance constant at 15.1 km (Base - 1 decile)*	7,742	4,353	3,389	-58.97%
Base case (distance constant at 17.6 km)	17,769	9,509	8,260	0.00%
***S2b**. Distance constant at 23.4 km (Base + 1 decile)*	21,415	11,280	10,135	22.70%

Source: Authors' analysis.

2.5.3. Tauranga

In Tauranga, our forecasts are more sensitive to the single standard error range for model coefficients (impact of 3,800 to 8,500) than to the one decile range for adjusted distance (impact of 4,800 to 7,300). Differences between cities in these sensitivity ranges are driven by the differing variation in quality scores across zones and number and sizes of potentially up-zoned properties in each city.

Table 6: Sensitivity tests for medium-term added dwellings – Tauranga

	With policy dwellings added	*Without policy dwellings added*	*Policy impact*	*Change in impact vs. base case*
Sensitivity to the standard error range for development likelihood estimates				
***S1a**. Base - 1 standard error*	7,670	3,851	3,819	-34.35%
Base case	10,318	4,500	5,818	0.00%
***S1b**. Base + 1 standard error*	13,714	5,252	8,462	45.44%
Sensitivity to the choice of adjusted distance parameter				
***S2a**. Distance constant at 15.7 km (Base - 1 decile)*	8,324	3,491	4,833	-16.93%
Base case (distance constant at 19.5 km)	10,318	4,500	5,818	0.00%
***S2b**. Distance constant at 24.9 km (Base + 1 decile)*	13,286	5,984	7,302	25.51%

Source: Authors' analysis.

2.5.4. Wellington

Wellington is an outlier in terms of historical consents. Where the other four urban areas added between 25 and 30 new dwellings per thousand existing households in 2020, Wellington added only 15. Our forecasts align the without-policy case for the base-case scenario to this historical rate of residential development, making Wellington an outlier in terms of base case adjusted distance as well. Where Christchurch, Hamilton, and Tauranga align at around the 70-75th percentiles of distance for Auckland parcels, Wellington's historical consents align at the 40th percentile.

Table 7 below shows the sensitivity tests for Wellington. In all cases, the policy impact is greater than double the without-policy case. Mechanically, this is because lower adjusted distance effects make the quality score and zone interaction a proportionally stronger driver. Conceptually it reflects that if residential supply is more constrained in Wellington than the other urban areas, we expect a stronger reaction to a relaxation of constraints.

Table 7: Sensitivity tests for medium-term added dwellings – Wellington

	With policy dwellings added	*Without policy dwellings added*	*Policy impact*	*Change in impact vs. base case*
Sensitivity to the standard error range for development likelihood estimates				
***S1a**. Base - 1 standard error*	12,786	6,105	6,681	-32.05%
Base case	17,082	7,249	9,833	0.00%
***S1b**. Base + 1 standard error*	22,609	8,607	14,002	42.40%
Sensitivity to the choice of adjusted distance parameter				
***S2a**. Distance constant at 9.7 km (Base - 1 decile)*	11,625	5,109	6,516	-33.73%
Base case (distance constant at 11.6 km)	17,082	7,249	9,833	0.00%
***S2b**. Distance constant at 13.2 km (Base + 1 decile)*	20,360	8,550	11,810	20.11%

Source: Authors' analysis.

2.5.5. Christchurch

For Christchurch, model forecasts show a range of policy impact from 7,200 to 17,200 dwellings when testing sensitivity to altering the development likelihood model coefficients by one standard error. For the adjusted distance alignment to historical consent levels in Christchurch, we see a similar impact range, from 6,500 to 15,200. These tests are summarised in Table 8 below.

Table 8: Sensitivity tests for medium-term added dwellings – Christchurch

	With policy dwellings added	*Without policy dwellings added*	*Policy impact*	*Change in impact vs. base case*
Sensitivity to the standard error range for development likelihood estimates				
***S1a**. Base - 1 standard error*	19,242	12,009	7,233	-37.11%
Base case	25,601	14,100	11,501	0.00%
***S1b**. Base + 1 standard error*	33,704	16,539	17,165	49.25%
Sensitivity to the choice of adjusted distance parameter				
***S2a**. Distance constant at 15.7 km (Base - 1 decile)*	14,130	7,595	6,535	-43.18%
Base case (distance constant at 19.5 km)	25,601	14,100	11,501	0.00%
***S2b**. Distance constant at 24.9 km (Base + 1 decile)*	34,133	18,973	15,160	31.81%

Source: Authors' analysis.

3. Estimation of housing market benefits

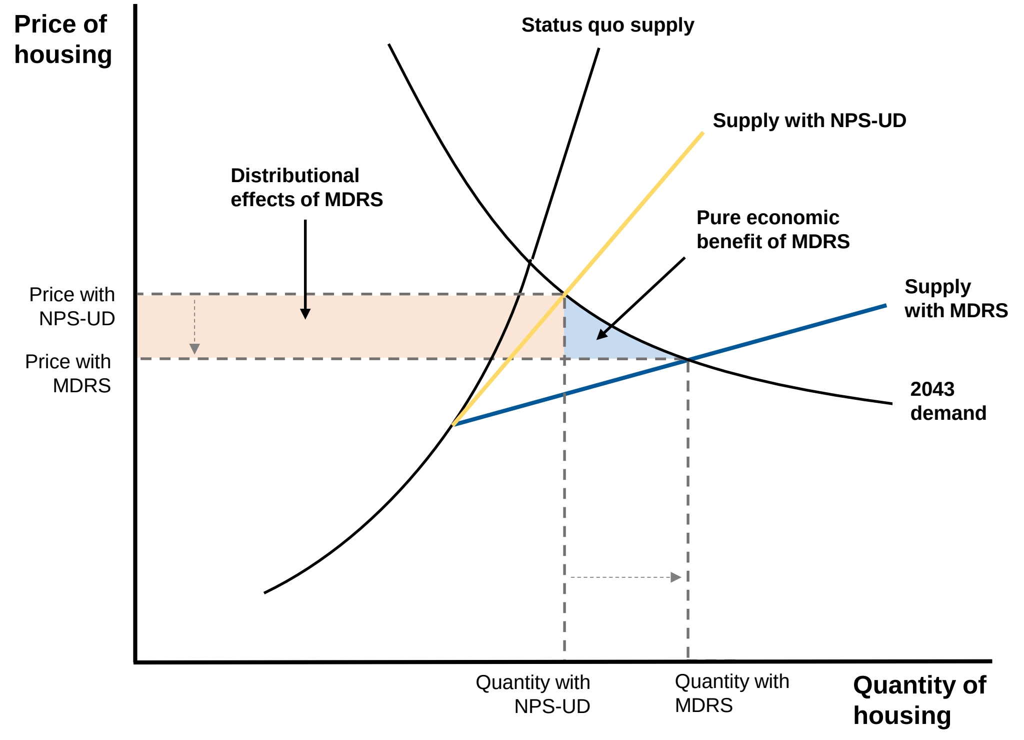
3.1. Approach

To quantify the benefits of our forecast policy impacts on housing supply, we use the same comparative statics approach used for the CBAs for both the NPS-UD and its predecessor the NPS-UDC. Where both of those CBAs derived estimates of supply impact by assuming statistically unremarkable shifts in supply elasticity, we rely instead on our fitted model forecasts.

The comparative statics approach uses a 'shock' framework, comparing the allocations of value among market participants for two alternate scenarios at the same future point. Our comparison is between the projected NPS-UD price and quantity (using the less conservative scenario from that study, updated to reflect our long-term population forecasts) as a counterfactual, and the price and quantity implied by our supply impact forecasts given the demand assumptions described below.

The comparison of these two price-quantity pairs allows us to calculate both pure economic benefits and transfers of value between market participants, as described in Figure 38 below.

Figure 38: Comparative statics approach to measuring the benefits of a housing supply shock



Source: Authors' illustration.

We model the price elasticity of demand for housing based on the NPS-UD modelled projections for high demand responsiveness to price, which used the Hyslop et al (2019) New Zealand-wide estimate of -0.516 plus one standard error—a base-case demand elasticity of -1.21 for the modelled NPS-UD impact levels.[15] Note that assuming a higher price elasticity will produce a more

---

[15] See PwC 2020 page 116 for details on this choice.

conservative estimation of the benefits of the MDRS, as the same change in quantity will imply a smaller decrease in price.

We adjust the projected demand growth from 2021 to 2043 using our population forecast model. This creates minor changes in modelled demand elasticity according to the supply elasticity assumptions in each city, as well as in the price-quantity pairs for the without-policy scenario.

We then derive a demand curve using a log-linear functional form from the status quo and 'with NPS-UD' price-quantity pairs, and project along that curve to find the price level implied by our supply impact forecasts under the MDRS.

This method improves on the NPS-UD method in two ways:

- The demand growth forecasts improve on Statistics New Zealand projection models by providing a better framework for modelling migration, the key driver of growth in New Zealand's population over the past 10 years. The method used for these forecasts is described in Appendix C.
- The log-linear form is closer to actual price response behaviour in housing markets than the linear demand curve used in previous CBAs, as it allows for quantity response to price to increase at an increasing rate as prices decrease.

Because price elasticity is not constant at different starting levels of price and quantity except in certain stylised functional forms, our log-linear demand curve will imply new estimates for expected elasticity in each city. These numbers are driven by the interaction between the estimated NPS-UD impact vs. status quo, the choice of log-linear form (leading to a more conservative price impact estimate than linear form), and our projected MDRS impacts. Table 9 shows our implied price elasticity of demand for each urban area.

Table 9: Estimated demand elasticity in Tier 1 urban areas at forecast policy impact levels

Tier 1 urban area	*Implied price elasticity of demand for policy impact*
Auckland	-1.761
Hamilton	-0.990
Tauranga	-1.210
Wellington	-0.739
Christchurch	-1.332

Source: Authors' analysis

3.2. Results and discussion

We estimate real benefit and distributional values in 2019 dollars to align with the NPS-UD CBA model, which we use for our without-policy projections. These values are informed by updated current prices and population projections, assumptions about the sustainability of changes in supply responsiveness that result from the policy, the way demand responds to price changes, and our modelled supply response forecasts described above.

We see the strongest impact in proportion to the total housing supply without the MDRS in Auckland and Tauranga. However, price impacts are greatest in Wellington and Tauranga. This reflects Auckland's higher price elasticity of demand, which is influenced by a high expected policy response in proportion to projected population growth rates. Another way to say this is that Auckland has the most severe modelled constraints to development, as our weaker evidence in other cities had led to conservative choices for model inputs.

3.2.1. Economic benefits from housing market impacts

The primary source of economic benefits arising from lower housing prices come from the transactions that take place which otherwise would not have under a higher price level. For these transactions, the difference between the price paid and the maximum willingness to pay for each purchaser represents a gain in value above what they pay for the house.

The theoretical total of this surplus across all such transactions makes up the economic benefit of the policy. In practical terms, this takes the form of higher disposable income among those new homebuyers and renters who would not have otherwise purchased or rented their dwellings. The total pure economic benefit of the MDRS, cumulatively from enactment to 2043, is estimated at $14.5 billion in 2019 dollars. Table 10 summarises our estimates of benefits and transfers by city.

Table 10: Summary of policy benefits and distribution effects as of 2043

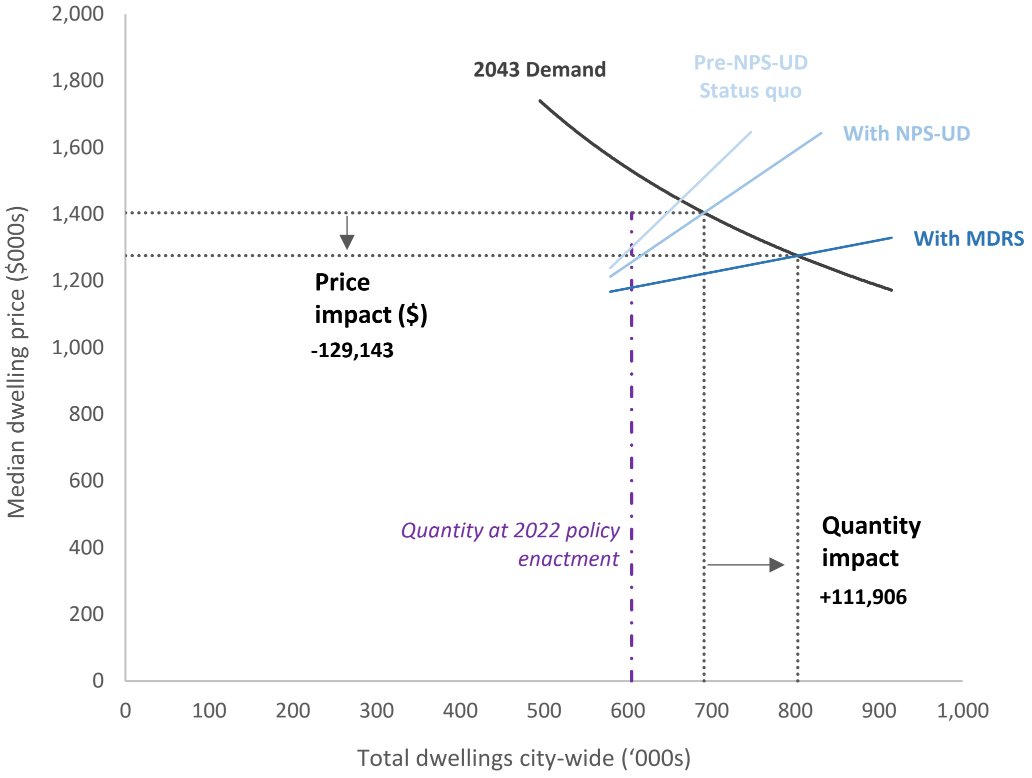
	Auckland	***Hamilton***	***Tauranga***	***Wellington***	***Christchurch***	***Total***
Without-policy total dwellings (‘000s)	691	160	105	237	269	1,462
Policy impact on dwellings (‘000s)	112	24	17	28	33	213
With-policy total dwellings (‘000s)	803	183	122	265	302	1,675
Implied housing supply impact vs. without-policy supply	16.2%	14.8%	15.8%	11.9%	12.2%	*14.6%**
Without-policy price forecast ($000s)	1,404	1,119	1,395	1,092	880	*1,225**
With-policy price forecast ($000s)	1,275	951	1,213	917	799	*1,093**
Price impact ($000s)	-129	-167	-182	-175	-81	*-133**
Pure economic benefits ($m)	**7,226**	**1,972**	**1,513**	**2,460**	**1,324**	**14,496**
Total transfers ($m)	**89,227**	**26,671**	**19,168**	**41,494**	**21,703**	**198,264**

Source: Authors’ analysis.

*Note: Without-policy levels include projected NPS-UD impacts as modelled in the cost-benefit analysis for that policy (PwC 2020), updated using 2021 baseline prices and population forecasts described in Appendix C. *Figures for all urban areas shown in italics are averages weighted by 2043 household numbers in each city.*

The figures below show projected supply under three scenarios, with implied prices at projected 2043 demand characteristics for each city. For Auckland, the forecast increase of 111,900 dwellings due to the MDRS is expected to result in median housing prices (2019 dollars) about $129,100 lower than they would be in 2043 without the policy (Figure 39).

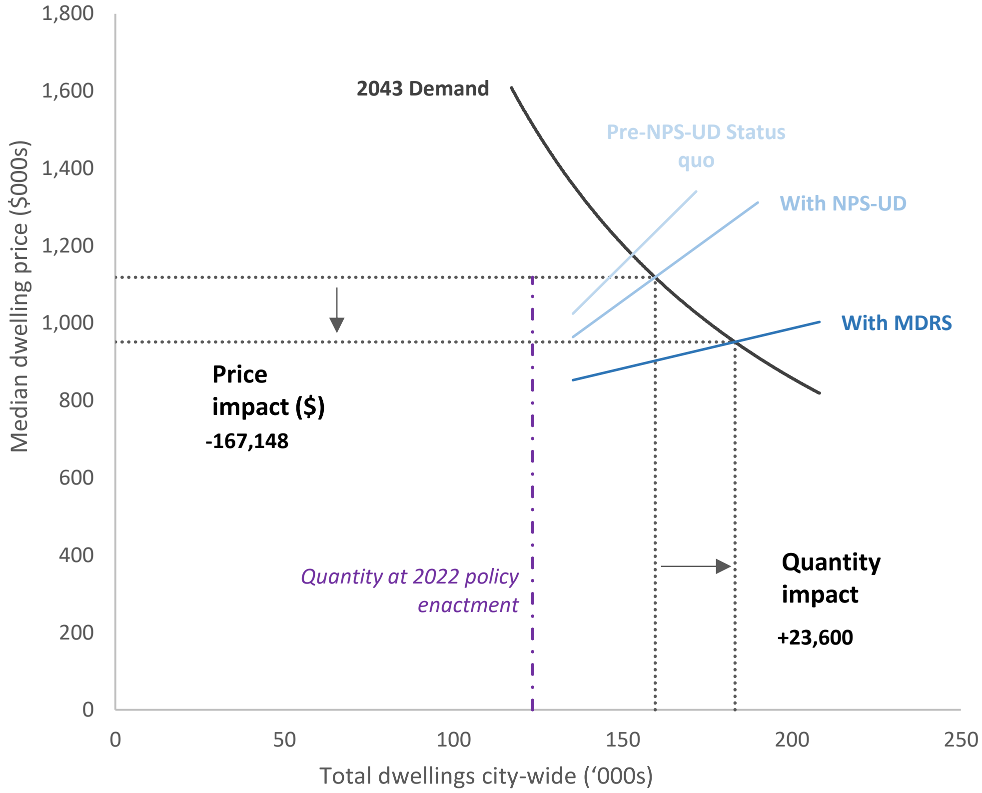
Figure 39: Cumulative housing price and quantity impacts to 2043: Auckland



Source: Authors' analysis.

In Hamilton, the forecast increase of 23,600 dwellings due to the MDRS is predicted to decrease 2043 median dwelling prices by $167,100 in 2019 dollars (Figure 40).

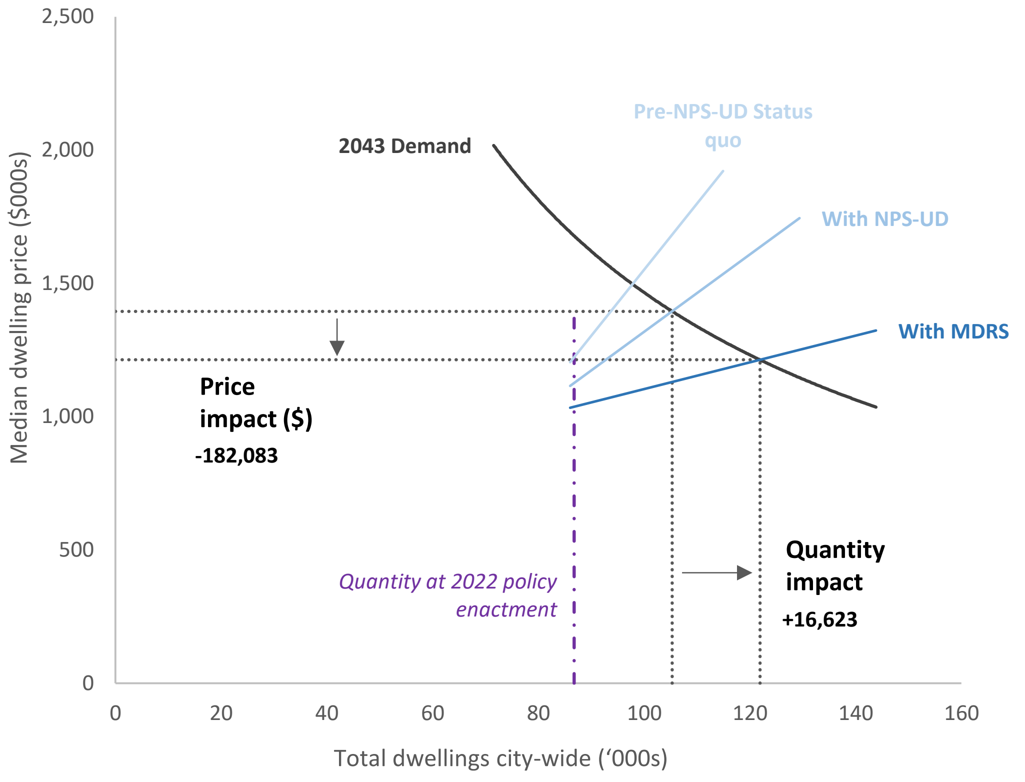
Figure 40: Cumulative housing price and quantity impacts to 2043: Hamilton



Source: Authors' analysis.

The forecast increase of 16,600 dwellings in Tauranga due to the MDRS is predicted to result in median dwelling prices about $182,000 lower in 2043 than they would be without the policy (Figure 41).

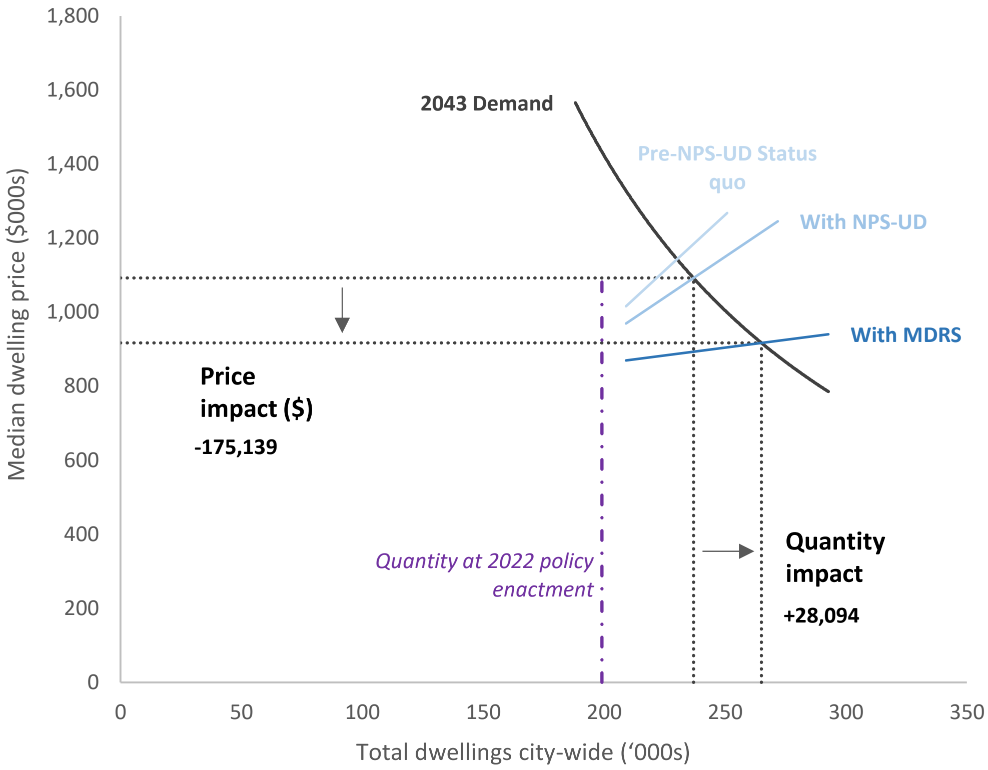
Figure 41: Cumulative housing price and quantity impacts to 2043 - Tauranga



Source: Authors' analysis.

In Wellington, the forecast increase of 28,100 dwellings by 2043 due to the MDRS is predicted to lead to median dwelling prices around $175,100 lower than they would be without the policy.

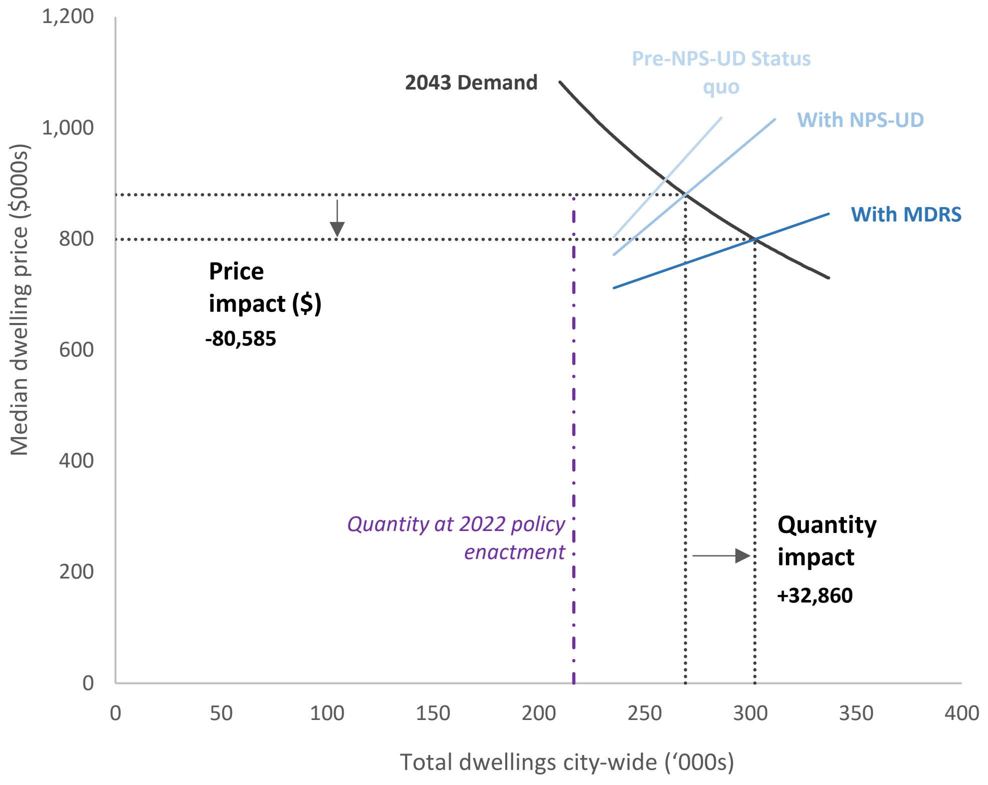
Figure 42: Cumulative housing price and quantity impacts to 2043 - Wellington



Source: Authors' analysis.

In Christchurch, the forecast increase of 32,900 dwellings due to the MDRS is predicted to result in median dwelling prices in 2043 around $80,600 lower than they would be without the policy (Figure 43).

Figure 43: Cumulative housing price and quantity impacts to 2043 - Christchurch



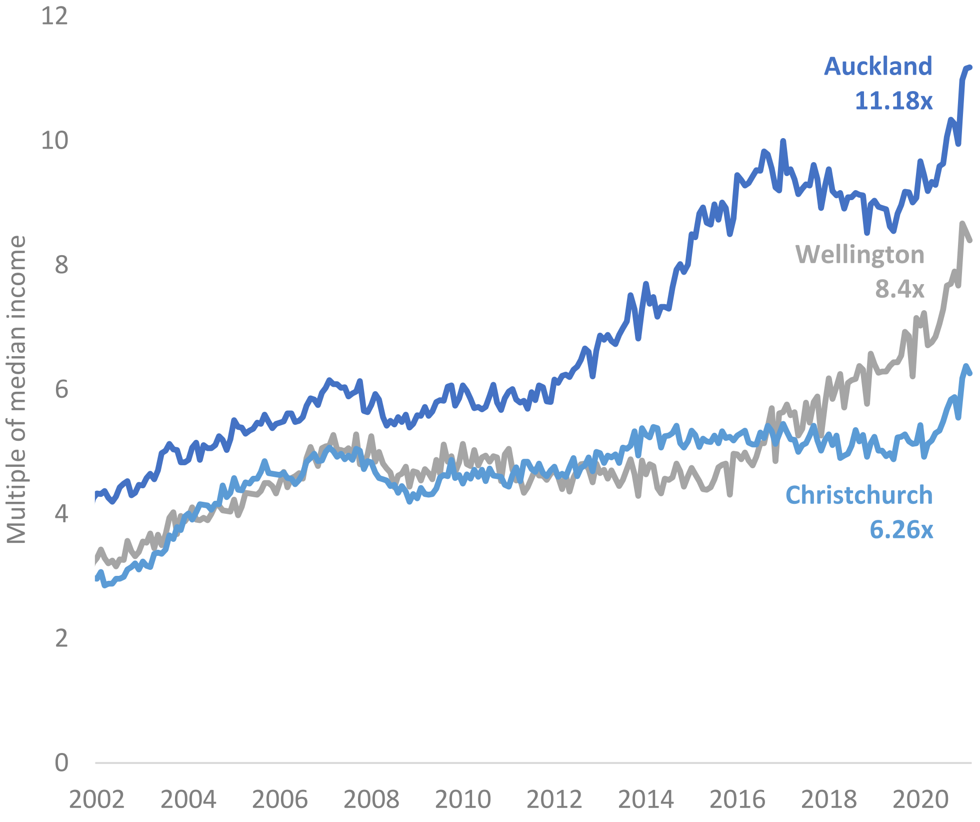
Source: Authors' analysis.

3.2.2. Transfers

Economic transfers arising from the policy are driven by the slowing-down of housing price increases over time. When the price of housing in a city rises faster than real wages in that city, the housing market slowly transfers wealth from non-homeowners to the owners of real estate over time.

For most non-homeowning households, this means reducing disposable income over time, leading to greater inequality of income and of quality of life in urban society. This has been the case in Tier 1 urban areas on average for the last 20 years. Figure 44 shows three examples of this.

Figure 44: Median house price as a multiple of median annual household income



Source: REINZ, Stats NZ data, as of April 2021.
Note: According to interest.co.nz, as of September 2021, Hamilton has a multiple of 8.4 and Tauranga of 10.7.

The housing supply increase enabled by the MDRS reduces this transfer of wealth over time by narrowing the gap between the rate of real wage growth and the rate of housing price growth. We refer to this policy effect as a 'transfer' or 'distributional impact', though it is more accurately described as a reduction in the ongoing transfer of wealth from non-owners to owners described above.

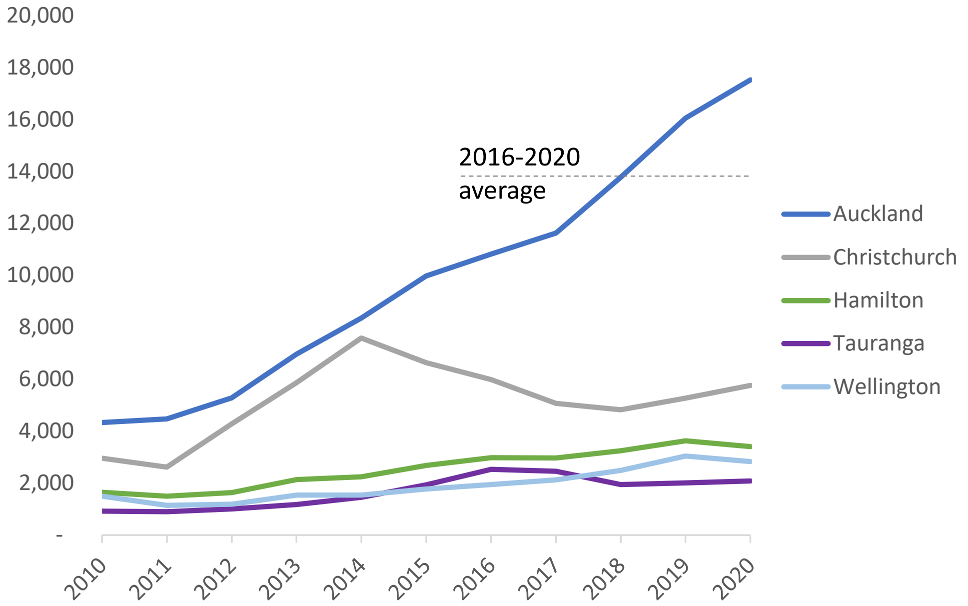
The total cumulative value of this transfer, estimated as of 2043, is about $198 billion, or about $161,000 per household present in the five cities at the time of policy enactment in 2022—enough for a deposit on a home. This $198 billion is the value of the forecast price impact multiplied by the total expected households in the without-policy case, in each urban area. This corresponds to the peach-shaded area in Figure 38.

In this way, the policy addresses housing affordability on two fronts, both directly by slowing the rise of home prices, and indirectly by slowing the reduction of disposable income and savings capacity of households who do not own their home.

3.3. Sensitivity tests

While we expect our forecasts for medium-term housing supply impact to occur over a five- to eight-year period, we convert this to a specific annualised estimate for the sake of extending our forecasts to the long-term. For the estimation of long-term benefits, we have assumed that it will take seven years for the number of dwellings added to reach our medium-term quantity impact forecast. For Auckland, this means that we assume Auckland will add an additional 5,595 dwellings annually, compared to the without-policy scenario. We then project this level of annual impact if it were maintained until 2043. Note that this implies a lower long-term annual impact than that expected at the peak around years 4-6 of the policy as modelled after the observed AUP pattern, shown in Figure 45.

Figure 45: Building consents – Dwelling count trends in Tier 1 urban areas



Source: Stats NZ.

For the sensitivity tests, we vary the assumption on the number of years it takes for the number of dwellings added to reach our medium-term quantity impact forecast.

In the optimistic scenario, we assume that it will take five years for the number of dwellings added to reach our medium-term quantity impact forecast. For Auckland, this means that we assume the medium-term forecast of an additional 39,167 dwellings will take place over 5 years (7,833 dwellings per year), and the long-term trend will settle around that average.

In the pessimistic scenario, we assume that it will take 10 years for the number of dwellings added to reach our medium-term quantity impact forecast. For Auckland, this means that we assume the medium-term forecast of an additional 39,167 dwellings will take place over 10 years (3,917 dwellings per year) rather than five to eight, and the long-term trend will settle around that average.

We also estimate the benefits in a low supply impact and high supply impact scenario, based on the range of sensitivity tests conducted for our medium-term supply forecasts.

For each scenario, we estimate the total cumulative economic benefits and distributional effects to 2043, in 2019 dollars (aligning with NPS-UD estimates).

Results for Auckland are summarised in Table 11.

Table 11: Summary of sensitivity tests for benefits and distributional impacts - Auckland

Years to reach medium-term quantity impact	*5 years*	*7 years*	*10 years*
Implied annual impact in dwellings (compared to without-policy)	7,833	5,595	3,917
Total Transfers ($m)			
Low Supply Impact	$89,088	$65,808	$47,282
Base Supply Impact	$119,417	$89,227	$64,707
High Supply Impact	$154,887	$117,289	$86,011
Consumer Surplus ($m)			
Low Supply Impact	$7,202	$3,800	$1,911
Base Supply Impact	$13,539	$7,226	$3,668
High Supply Impact	$24,069	$13,019	$6,683

Source: Authors' analysis.

Sensitivity test results for Hamilton are summarised in Table 12.

Table 12: Summary of sensitivity tests for benefits and distributional impacts - Hamilton

Years to reach medium-term quantity impact	*5 years*	*7 years*	*10 years*
Implied annual impact in dwellings (compared to without-policy)	1,652	1,180	826
Total Transfers ($m)			
Low Supply Impact	$16,285	$11,921	$8,503
Base Supply Impact	$35,364	$26,671	$19,484
High Supply Impact	$47,954	$36,910	$27,428
Consumer Surplus ($m)			
Low Supply Impact	$692	$362	$181
Base Supply Impact	$3,661	$1,972	$1,009
High Supply Impact	$7,328	$4,029	$2,096

Source: Authors' analysis.

Sensitivity test results for Tauranga are summarised in Table 13.

Table 13: Summary of sensitivity tests for benefits and distributional impacts - Tauranga

Years to reach medium-term quantity impact	*5 years*	*7 years*	*10 years*
Implied annual impact in dwellings (compared to without-policy)	1,164	831	582
Total Transfers ($m)			
Low Supply Impact	$17,808	$13,187	$9,492
Base Supply Impact	$25,477	$19,168	$13,977
High Supply Impact	$34,296	$26,287	$19,469
Consumer Surplus ($m)			
Low Supply Impact	$1,292	$683	$344
Base Supply Impact	$2,816	$1,513	$772
High Supply Impact	$5,513	$3,019	$1,565

Source: Authors' analysis.

Sensitivity test results for Wellington are summarised in Table 14.

Table 14: Summary of sensitivity tests for benefits and distributional impacts - Wellington

Years to reach medium-term quantity impact	***5 years***	***7 years***	***10 years***
Implied annual impact in dwellings (compared to without-policy)	1,967	1,405	1,150
Total Transfers ($m)			
Low Supply Impact	$38,873	$28,797	$20,733
Base Supply Impact	$55,121	$41,494	$30,262
High Supply Impact	$72,911	$55,893	$41,379
Consumer Surplus ($m)			
Low Supply Impact	$2,138	$1,131	$570
Base Supply Impact	$4,575	$2,460	$1,256
High Supply Impact	$8,618	$4,719	$2,445

Source: Authors' analysis.

Sensitivity test results for Christchurch are summarised in Table 15.

Table 15: Summary of sensitivity tests for benefits and distributional impacts - Christchurch

Years to reach medium-term quantity impact	***5 years***	***7 years***	***10 years***
Implied annual impact in dwellings (compared to without-policy)	2,300	1,643	1,150
Total Transfers ($m)			
Low Supply Impact	$17,625	$12,889	$9,187
Base Supply Impact	$29,216	$21,703	$15,663
High Supply Impact	$40,901	$30,872	$22,573
Consumer Surplus ($m)			
Low Supply Impact	$855	$447	$223
Base Supply Impact	$2,495	$1,324	$669
High Supply Impact	$5,214	$2,811	$1,439

Source: Authors' analysis.

4. Agglomeration benefits

Agglomeration in consumption

But cities are not just labour markets. Individual preferences matter and can create amenity value that attracts people to cities. When people have different preferences for a range of goods and services, such as going out for dinner and listening to live music, these goods and services are more easily accessed within cities.

But we can also think about a hierarchy of preferences –preferences for not just listening to live music but listening to heavy metal and listening to subgenres of heavy metal like doom metal or sludge metal.

Cities support variety in the consumption of goods and services, allowing residents to access a deeper diversity of preferences across goods and services.

Agglomeration in consumption is difficult to measure. Travelling to gain access to niche goods and consumption is the alternative to cities. Driving times have been used to assess the utility of the variety of consumption options provided by cities but there are no New Zealand studies of agglomeration in consumption, and we do not quantify these effects but note they are likely to add some small upside benefits to the MDRS.

Agglomeration in production

Agglomeration benefits can occur when people and firms are brought closer together.[16] When economic distance between firms and workers is reduced several dynamics can be important:

- Labour markets deepen, allowing better and more productive matches between firms and workers.
- When labour markets deepen, workers can specialise in niche occupations that bring benefits to workers and firms alike
- knowledge transfer facilitated by workers interacting in the same space can boost productivity.
- Firms can reduce costs by relying on economic scale and network effects when firms cluster together in dense locations.

Estimates of agglomeration in production

There is considerable uncertainty on the size of agglomeration impacts the differs across countries, regions and sector of the economy. Estimates from Maré and Graham 2009 suggest an economy-wide estimate of 0.069. MR Cagney et al. 2006 use a lower estimate of 0.04.

Given the uncertainty across estimates we proceed by combining:

1. 10,000 draws from a uniform distribution bounded by the lower estimate of 0.04 and the upper estimate of 0.069
2. Changes in the relative city sizes implied by the improvement in housing supply in Tier 1 cities.

---

[16] See Melo et al. 2009 and Ahlfeldt and Pietrostefani 2019 for example.

To calculate the agglomeration benefits we use the standard equation:

$$\Delta Productivity = \left(\frac{New\ city\ size}{Old\ city\ size}\right)^{elasticity}$$

where we draw the elasticity from the uniform distribution that runs from 0.04 to 0.069. Again, we produce estimates for each of the low, medium and high housing supply scenarios.

While we draw from the same distribution across each New Zealand region (rather than apply regional specific estimates to our Tier 1 areas that do not neatly match estimates available for regional political boundaries) we approximate current GDP for each region with regional GDP estimates from Statistics New Zealand.[17] Table 16 summarises the results. We present the expected value of the distribution of estimates.

Table 16: Agglomeration benefits are substantial

Variable	*GDP per capita*	*Low*	*Medium*	*High*
		Change in productivity		
Auckland		0.04%	0.09%	0.15%
Christchurch		0.08%	0.21%	0.34%
Hamilton		0.07%	0.29%	0.46%
Tauranga		0.15%	0.27%	0.43%
Wellington		0.10%	0.18%	0.29%
		Increase in productivity for existing residents ($millions)		
Auckland		$49.9m	$110.2m	$187.2m
Christchurch		$27.4m	$68.3m	$113.3m
Hamilton		$13.2m	$51.9m	$82.2m
Tauranga		$18.1m	$32.2m	$50.2m
Wellington		$35.1m	$67.6m	$107.8m
Total		$143.9m	$330.2m	$540.6m
		Increase in GDP per added resident		
Auckland		$1,278	$2,008	$2,489
Christchurch		$1,681	$2,369	$2,639
Hamilton		$1,437	$2,326	$2,496
Tauranga		$1,969	$2,299	$2,474
Wellington		$2,150	$2,748	$3,077

Source: Authors' analysis.

---

[17] Regional GDP: Auckland $71,978, Waikato $56,664, BOP $56,623, Wellington $74,785 and Canterbury is $62,323.

5. Estimation of costs

5.1. Identifying costs

Likely cost elements of the MDRS are identified in the Regulatory Impact System that is consistent with existing literature on conducting cost-benefit analysis of changes in land use regulation[18] These costs relate to externalities not internalised into house prices between buyers and sellers and fall into 7 categories:

1. Blocked views or other nuisances to neighbouring residents in intensified areas
2. Overshadowing of properties by taller buildings
3. Congestion costs including slower trips and trip avoidance
4. Impacts on water quality from changes in the concentration of impervious surface area
5. Externalities to network infrastructure not recovered through development contribution charges
6. Intensified use of open spaces and community facilities
7. Implementation costs of the policy.

Note on implementation costs

It is difficult to assess the net costs and benefits of implementation of the MRDS for local councils.

On one hand, the appeals process will be simplified, and councils have standing teams that undertake plan changes to enable development. In the long-run, it will be difficult to distinguish the impact of the MRDS on council activity relative to other policies, including the NPS-UD for example.

However, in the short-term, the MRDS will increase the need for Tier 1 councils to consider funding and financing of infrastructure to enable development. Councils could increase resources to fund these new activities or reallocate existing activity towards how to fund and finance infrastructure. On balance, we include $2 million in total for the implementation costs of the MDRS across all Tier 1 councils.

Note on urban intensification and pandemic risks

While it may be tempting to suspect that urban density increases the risk of infection during pandemics given the experience of Auckland versus other New Zealand cities with the COVID-19 pandemic, this conclusion is not borne out by the emerging worldwide evidence.

Recent studies have found:

- that density is not linked to rates of COVID-19 infection, after controlling for metropolitan area population, socioeconomics, and health care infrastructure (Hamidi et al 2020a)
- no association between high population density and per capita COVID-19 cases across 35 global cities, and that public health interventions can completely overcome contagion risk due to higher density (Adlakha and Sallis 2020)
- that many metropolitan areas that with triple or higher the density of Auckland, such as Singapore, Hong Kong, Tokyo, and Seoul, more effectively contained the spread of COVID-19 compared to lower-density cities (Adlakha and Sallis 2020)
- that COVID-19 death rates are lower in denser counties and higher in less dense counties, at a high level of statistical significance, likely due to better access to health care facilities

---

[18] See MR Cagney et al. 2016 and PwC 2020.

and easier management of social distancing interventions such as sheltering in place (Hamidi et al 2020a)

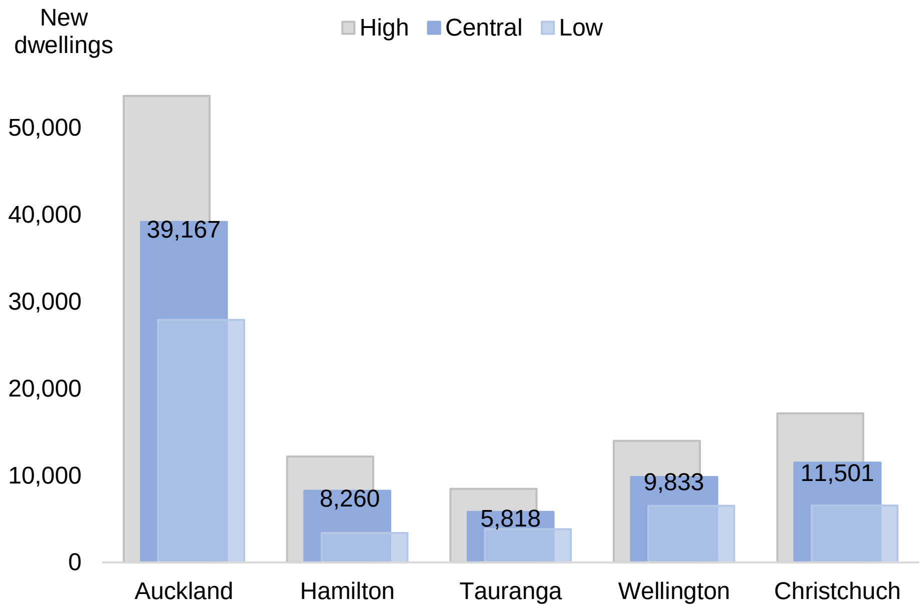
- that connectivity matters more than density in the spread of COVID-19 and more dense areas show lower mortality rates (Hamidi et al 2020b)

Based on this evidence and to avoid attempting to predict the nature of future pandemics, we omit consideration of pandemic risks from this study.

5.2. Quantifying costs

To quantify costs from a disparate set of elements, we take as a starting point the number of new dwellings added by the policy, shown in Figure 46.

Figure 46: New dwellings added under the proposed MDRS trends in Tier 1 urban areas

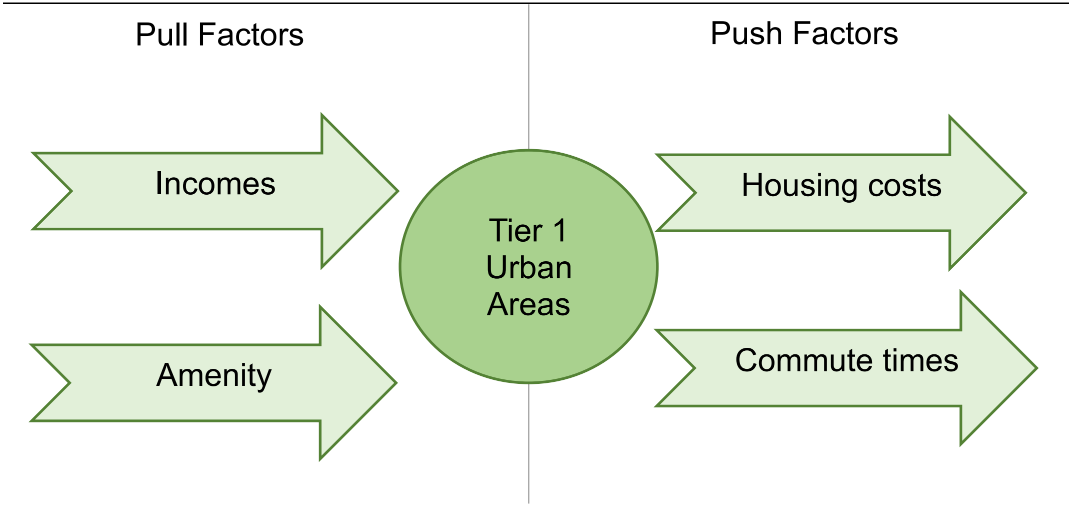


Source: Authors' analysis.

The dwelling numbers serve as a starting point to help uncover the types of population movements that can generate the costs across each of the 7 categories we analyse.

One of the foundations of our approach – and indeed, previous cost-benefit analysis of land use policies – is the concept of spatial equilibrium. We expect people to respond to additional supply by moving locations until factors that attract residents to Tier 1 urban areas are balanced by the factors that push people away from New Zealand's fastest growing urban areas.

Figure 47: New dwellings added under the proposed MDRS trends in Tier 1 urban areas



Source: Derived from Glaeser 2007

6. Loss of views

6.1. Interpreting possible impacts

Views are widely understood to be an important driver of amenity. The MDRS has the potential to block views or parts of views, so we assess expected costs.

Applied empirical research typically uses hedonic price models to provide some guidance on likely effects and size of impacts: [19,20,21]

- Kask and Maani 1992 – sea views can have significant positive impacts on house prices using Auckland data
- Bourassa et al. 2004 – suggests potentially large impacts of wide water views on Auckland (old territory authority) data
- Fillipova 2009 – region wide models can mask local market impacts, but a wide water view can add 18 percent to a home’s value in Auckland
- Rohani 2012 estimates that a view of the Hauraki Gul is associated with a 15-50 percent higher property valuation
- Nunns, et al. 2015 suggest water views add 8.3 percent to house prices but views over land actually take a little off house prices
- Fleming, et al.2018 suggest views may be correlated with other features of housing markets and argue a view does not make much difference once neighbourhood choice is made

MR Cagney 2016 also present estimates for externalities for development options. Their CBA suggests loss of views in high urban intensification developments of $10,219 per dwelling in 2016 prices.

6.2. Our approach

Since we have specific information on the nature of the policy intervention (three storeys), likely sites from our spatial econometric modelling and a range of property information for particular sites, we make our own assessment of the impact of the policy. We then integrate this work with the MRCagney et al. 2016 estimate to produce a likely range of estimates on views.

- Step one: Locate sites of interest
- Step two: Assess likely impacts on views
- Step three: Assess likely impacts of property value
- Step four: scale up to properties across the 5 Tier 1 urban areas

Step 1: Locate sites of interest

We use a stratified sample of just under 8,000 properties across all five Tier 1 urban areas to assess views. This data includes information on the height of the property from the ground and the

---

[19] See Rosen 1974.

[20] Bourassa, Hoesli and Sun 2005 note the impact of the real estate cycle on estimates of amenity from hedonic pricing models.

[21] See also Samarasinghe and Sharp 2008.

height of the property relative to sea level and additional fields we use in our estimates of overshadowing.

In addition, this sample dataset has information on property characteristics used for local council valuation purposes, including if the property has: (i) a view of water or land; (ii) if any view is slight, moderate, or wide.

Relative few properties have either water views or wide views (see Table 17).

Table 17: Relatively few urban properties have expansive water views

Stratified sample, 7,789 properties

Variable	*None*	*Other*	*Water*	*Total*
None	62.3%		0.1%	62.4%
Slight	0.1%	10.3%	10.0%	20.4%
Moderate	0.1%	6.4%	9.9%	16.3%
Wide		0.2%	0.6%	0.8%
Total	62.5%	16.9%	20.6%	100.0%

Source: Authors' analysis.

Step 2: Qualitative assessment of likely impacts on views

Since we have address data on likely sites from the housing supply modelling, we use a combination of the height data (from LiDAR), Google maps and local council data to assess the likelihood of impaired views along a 5-point scale:

1. no impairment (0%)
2. slight impairment (5%)
3. low probability of impairment (10%)
4. moderate probability of impairment (15%)
5. high probability of impairment (25%).

We applied this procedure to 60 properties in Auckland, placing a putative development on each address and assessing impacts on views. We exclude properties with no views from this exercise.

Several points are worth noting from this largely qualitative exercise:

- There are few houses with wide views of water. These properties tend to be expensive, but elevated, such that few developments are likely to impair the views of these properties.
- Properties with moderate views of the water are more common. These properties often tend to be moderately elevated, such as on the upper side of a road that provides the elevation for a view but also provides some modest protection from loss of views. These properties sometimes include corner properties that are less likely to be built out.
- Locations with slight views of the water can be difficult to assess. On the one hand, a single development is unlikely to block a slight view of water. On the other hand, a single development is likely to block the entire view of water rather than have a partial effect.
- On average, the properties in our sample are relatively expensive compared to REINZ, particularly for Auckland. This in part reflects the PWC modelling that identifies the most likely targets for redevelopment where underlying amenities are high.

Step 3: Assess likely impacts of property value

To assess likely impacts on property values we use the impacts from Bourassa et al. 2004 provided for Auckland city that we show in Table 18.

Table 18 Wide waters views can have large impacts on property values

View type	Narrow view	Medium view	Wide view
Water views			
At coast	0%	33%	59%
1,000 metres from coast	0%	13%	18%
2,000 metres from coast	0%	11%	14%
Other views	4%	5%	6%

Source: Bourassa et al. 2004

Although these impacts appear large, properties with wide, water views are few and far between. Moreover, these areas tend to have sufficient height to preclude large impacts on views. We then combine our qualitative assessment of the impacts on loss of view with the impacts assessment of Bourassa et al. 2004.[22]

Combining these two factors suggest suggests impacts oof wide, water views of up to 5-10 percent of the property. Much smaller impacts on views accrue to properties that do not contain water and are only narrow water views. These are the lion's share of properties.

Step 4: scale up to properties across the 5 Tier 1 urban areas

We use nominal house price data and the number of new dwellings in each Tier 1 urban area to establish the value of the change in the existing stock across each Tier 1 urban area. Table 19 summarises the analysis.

Table 19: Impacts of the MDRS on views range from $295 million to $604 million

Urban area	Dwellings			View impact		
	Low	*Medium*	*High*	*Low*	*Medium*	*High*
Auckland	27,927	39,167	53,683	$239,694,773	$336,166,619	$460,756,060
Hamilton	3,389	8,260	12,191	$6,992,441	$17,042,658	$25,153,395
Tauranga	3,819	5,818	8,462	$4,583,659	$6,982,909	$10,156,304
Wellington	6,516	9,833	14,002	$14,896,303	$22,479,336	$32,010,135
Christchurch	6,535	11,501	17,165	$29,055,361	$51,134,767	$76,317,562
Total	48,186	74,579	105,503	$295,222,537	$433,806,288	$604,393,455

Source: Authors' analysis.

Our estimate suggests on average a $5,816.74 impact on views. This is much lower than the view impacts suggested in MR Cagney et al. 2016 that discuss impacts of between $11,020 and $23,964 (in 2020 dollars). But these estimates are for a much higher building – 7 storeys – which is likely to have a materially higher impact on view for an individual property.

---

[22] Since we have very few properties and details on distance to the coast, we average across the distance to the coast impacts.

7. Congestion

7.1. Access to transport networks

Overview

Congestion of the road network is related to intensity of use across number of users, number of trips, length of each trip and timing of use. Because of congestion, two things happen:

1. traffic speeds decline and road users spend more time in transit across the city
2. potential road users avoid travelling altogether or travel at less convenient times.

Congestion of the road network is typically non-linear, increasing in the rate of change of population growth, such that marginal increases in population have larger increases in congestion at the margin.

At a base level, the MDRS induces increases in dwellings in Tier 1 cities: Auckland, Christchurch, Hamilton, Tauranga and Wellington. To attribute costs and benefits of the policies, it is important to understand where the demand comes from across two dimensions: (i) location; and (ii) density.

Areas with high housing costs are traded off for low commute times. Highly desired locations with local amenities are also associated with higher housing costs. People prefer locations that provide high incomes and amenity (not just parks and open space, but opportunities with friends and family networks) and will seek a balance between higher housing costs and longer commute times to reap these benefits.

The MDRS increases choice and reduces the cost of housing in Tier 1 cities. We distinguish three potential cases of demand by location:

1. Case 1: supressed demand internal to each Tier 1 city
2. Case 2: external demand from Tier 2 cities and other New Zealand locations
3. Case 3: international demand.

Case 1: Supressed internal demand

Conceptually, under case 1, new dwellings are populated from families within each city region that are either living with families or renting.[23] This supressed demand is reflected in average household sizes for our most populated regions that are higher than national averages and higher than suggested by demographic characteristics alone.

To estimate congestion under case 1, the conceptual challenge is to think through how location choice interacts with trip generation and congestion. Several factors are likely to be important:

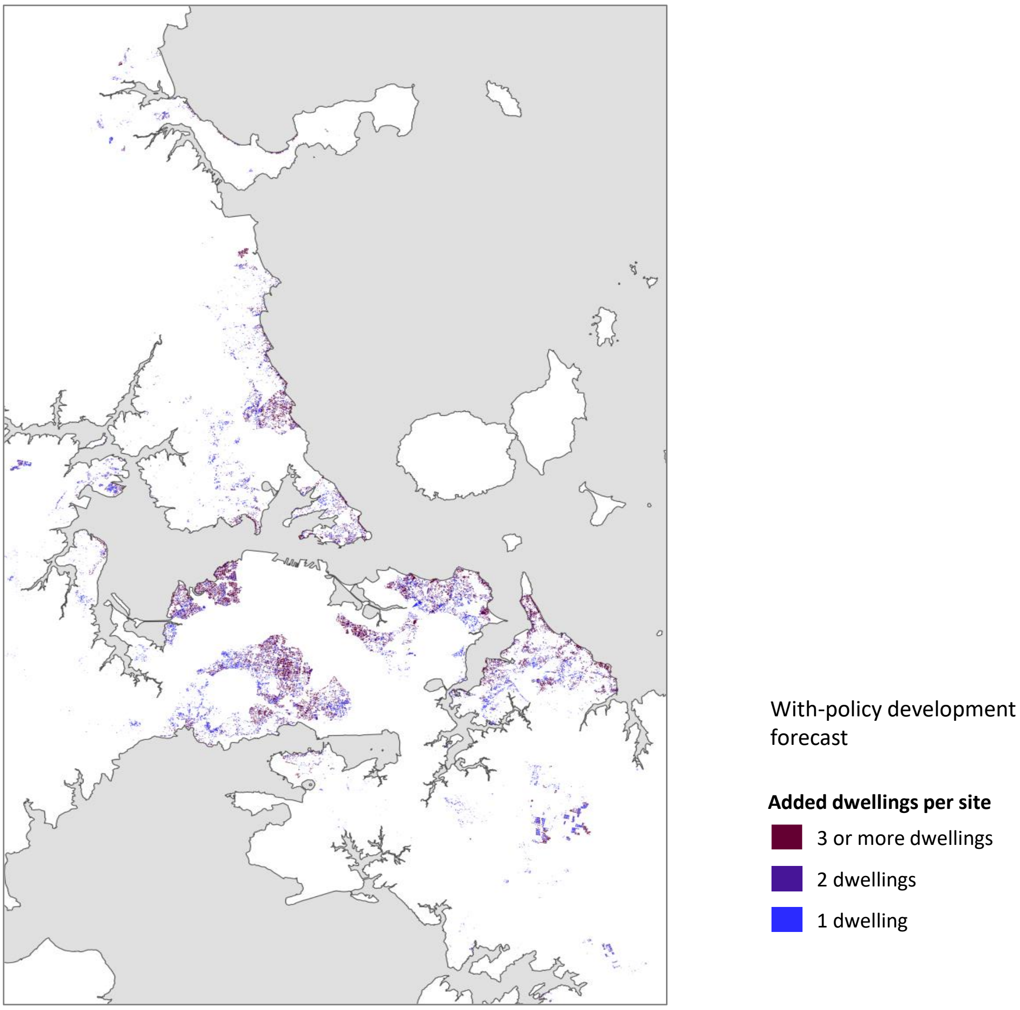
- The middle-income profile is likely to favour public transport over households with higher incomes that have been able to own or rent in these areas.
- The fall in the cost of housing generates an income effect: this could increase trip generation and increase the likelihood of travel by car over public transport.
- Age demographic is likely to be supportive of public transport over travelling by car.
- Additional trips are expected from distributing the same population across a larger number of households.

---

[23] See Greenaway-McGrevy et al. 2019.

In addition, the location of congestion could change. Likely added development locations tend to be in the middle of Auckland but outside the city centre (see Figure 48). We might expect more shorter trips that could increase local congestion but reduce demand, at least initially, on the motorway.

Figure 48: Housing supply assessment suggests development could be centrally located



Source: Authors' analysis.

On balance, it is difficult to assess the likely net effects of each factor. But what could help, is knowing the existing patterns of travel for residents in the suburbs that are identified as likely developable locations verses the travel pattern of Auckland in general.

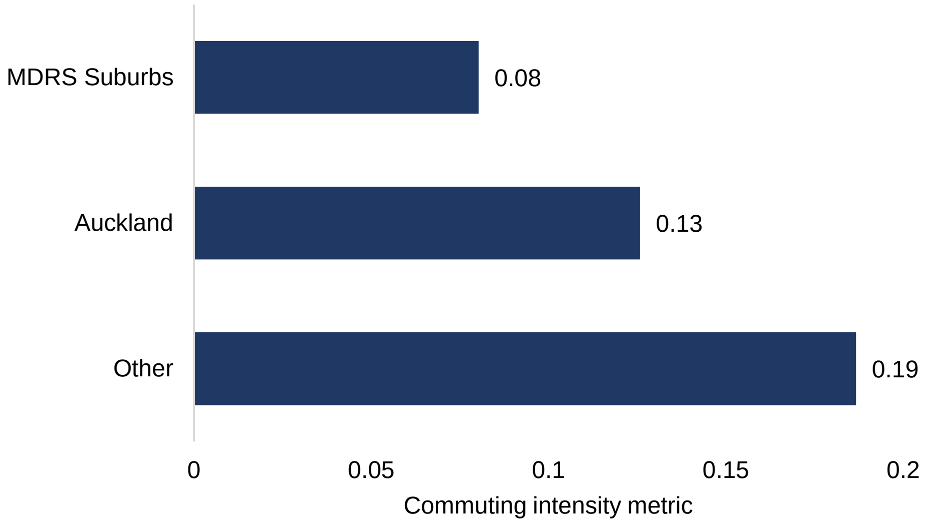
While we have limited data on local trips, we have data on commuting patterns and the model of transport from the 2018 census. Comparing the suburbs where development is likely to other suburbs in Auckland can provide a high-level indicator of the relative commuting (and by implication congestion) intensity of each area.

To compare each suburbs' congestion intensity, we use the following steps:

1. Population by suburb that lives and works with the Auckland urban area
2. Obtain the number of people that drive a car relative to total work trips
3. Approximate the average work journey by calculating the average distance between the residential suburb (SA2) and the workplace
4. Multiply the distance travelled by the ratio of drivers to total work trips
5. Calculate the weighted average for the total suburbs (313) versus the total number of suburbs (547).

Applying this process Figure 49 shows that these MDRS likely suburbs are about 35 percent lower in commuting intensity than other Auckland suburbs. This suggests that if all extra demand is realised from supressed internal demand, then congestion costs could decrease (at a regional level) as a result of the policy.[24]

Figure 49: MDRS suburbs are less commuting intensive that other Auckland suburbs



Source: Authors' analysis.

We quantify this decrease by applying the lower commuting intensity to households that move to suburbs likely to be developed according to the housing supply assessment modelling. Table 20 shows likely impacts of congestion across the low, medium, and high housing scenarios.

---

[24] Ahlfeldt and Pietrostefani 2019 discuss the connection between density and congestion. Density can generate high congestion and lower road speeds but shorter trips. Donovan and Munro 2013 report modest impacts of urban form on transport outcomes, although vehicle ownership and drive alone share are affected.

Table 20: Case 1: supressed demand within Auckland is likely to lower congestion a little

Auckland		***Congestion impact: case 2***		
	Current state	*Low*	*Medium*	*High*
Population	1,717,500	1,717,500	1,717,500	1,717,500
Internal moves		78,196	109,668	150,312
Status quo congestion	$1.596bn			
New state congestion costs		$1.495bn	$1.455bn	$1.404bn
Net costs		-$0.101bn	-$0.141bn	-$0.192bn
Percent improvement		6.7%	9.7%	13.4%

Source: Authors' analysis. Status quo congestion based on MR Cagney et al 2016.

The case for improvements in congestion costs from a reallocation of demand is not so apparent in other Tier 1 cities. For these cities, the MDRS sites are not so significantly different to the average pattern of development. Nor are congestion costs for these cities as material as for the Auckland region. Auckland alone also accounts for over the half the population movements. So, we do not calculate any change in congestion costs for other Tier 1 cities.

Case 2: external demand from Tier 2 cities and other New Zealand locations

Under the MDRS, housing costs in New Zealand's Tier 1 cities decrease relative to other locations. So, we expect internal migration dynamics to drive an increase in Tier 1 cities from other New Zealand locations. We explore these impacts using a three-step process:

- Step 1: Assess likely populations in Tier 1 cities and the rest of New Zealand
- Step 2: Estimate per capita congestion costs
- Step 3: Calculate likely congestion costs based on 1 and 2.

Assess likely populations

The MDRS relaxes land use regulation across all Tier 1 cities, attracting more New Zealanders to live in these locations that have lower housing costs than locations outside Tier 1 cities.

To assess costs and benefits we need to understand the likely changes in population that might occur. Housing markets are assumed to be in equilibrium, that is, the push and pull factors are such that no household has any incentive to move location.

Then, as a first approximation, we assume that these flows between Tier 1 cities net out so that in aggregate, there are no net flows between these Tier 1 cities. Instead, since Tier 1 cities are now relatively more affordable, residents are attracted from elsewhere in New Zealand, that is, Tier 2 cities and other locations.

We use the existing distribution of population as a guide to where flows in each Tier 1 city originate. We use the population weights of each Tier 2 city and then a catch-all – other locations as a guide. Since we assess congestion costs for Tier 2 cities but apply zero congestion costs to other New Zealand locations, we are not interested in any other location information.

Before calculating likely congestion costs, we calculate per capita congestions costs.

Some preliminaries: estimating per capita congestion costs

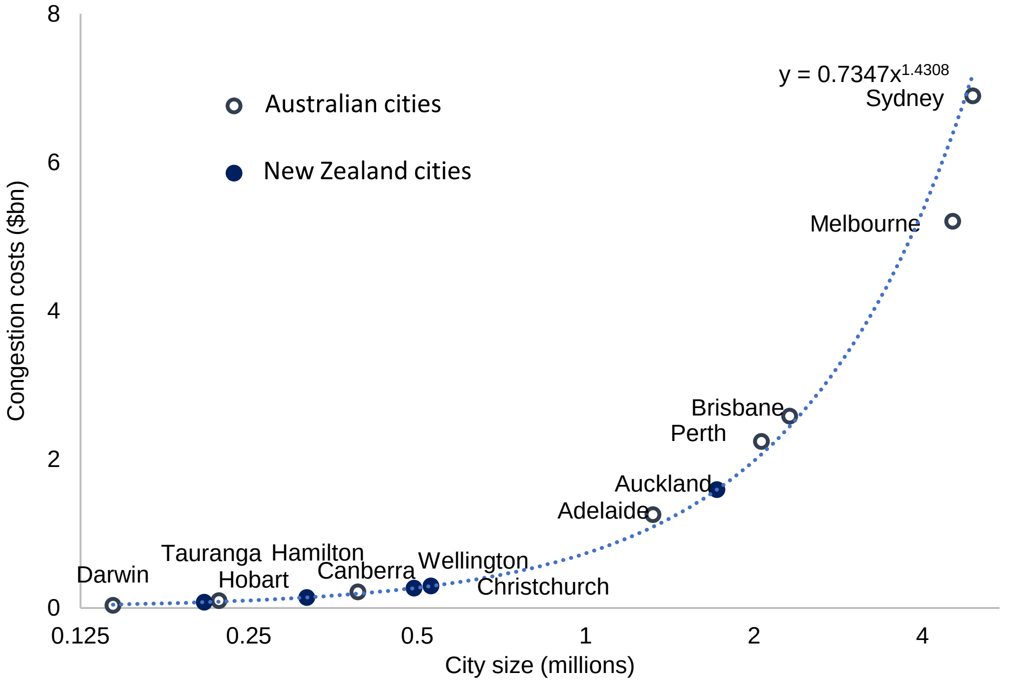
Estimates of per capita congestion costs are not widely available.[25] We draw on an existing approach,[26] that uses estimates of congestion costs per capita for major Australian cities,[27] to estimate likely congestion costs for New Zealand cities.

Our method differs by focusing on congestions costs for 2015 only – the latest available year in the BITRE study – but expanding the range of cities on congestion costs to include Darwin, Hobart and Canberra that are likely to be important for assessing per capita congestion costs for smaller New Zealand cities.

Figure 50 shows the estimation alongside computed costs for New Zealand cities based on the estimated relationship for Australian cities. We adjust data to current year New Zealand dollars.

Figure 50: We estimate congestion costs using data from Australian cities

Avoidable congestion costs, Australia data and New Zealand city estimates (Tier 1)



Source: MR Cagney et al. 2016, BITRE 2015, authors' analysis.

Our estimates for Auckland are in line with previous estimates for congestion used in cost-benefit analysis of urban development.[28] But New Zealand cities are unlikely to be precisely represented by Australian data and geographic factors and other idiosyncratic features are not captured by our model, which produces the per capita costs of congestion across each city that we show in Table 21.

---

[25] Booz Allen Hamilton 2004 is one exception but this is from a much early time period. Grimmond 2017 provides estimates of congestion costs for the Wellington region only.

[26] See MRCagney et al. 2016.

[27] Bureau of Infrastructure, Transport and Regional Economics (BITRE) 2015.

[28] See MRCagney et al. 2016.

Table 21: We map out per capita congestion costs for both Tier 1 and Tier 2 cities

New Zealand dollars 2021 Year

Urban area	*Tier*	*Population*	*Household size*	*Congestion Costs ($m)*	*Per capita costs ($)*
Auckland	Tier 1	1,717,500	2.8	$1,593	$927.48
Christchurch	Tier 1	529,100	2.5	$295	$558.48
Wellington	Tier 1	493,100	2.5	$267	$541.78
Hamilton	Tier 1	317,200	2.7	$142	$448.01
Tauranga	Tier 1	207,900	2.4	$78	$373.46
Napier-Hastings	Tier 2	115,300	2.5	$33	$289.70
Dunedin	Tier 2	106,200	2.4	$30	$279.62
Palmerston Nth	Tier 2	81,500	2.5	$20	$249.48
Rotorua	Tier 2	58,500	2.5	$13	$216.27
New Plymouth	Tier 2	57,600	2.4	$12	$214.83
Whangārei	Tier 2	54,400	2.4	$11	$209.61
Nelson-Tasman	Tier 2	51,100	2.3	$10	$204.03
Queenstown	Tier 2	47,400	2.5	$9	$197.53

Source: Authors' analysis.

To account for model uncertainty, we take 10,000 draws from the distribution of the parameters in the model that we lay out in Table 22 and calculate the distribution of congestion costs for the current state of each New Zealand city. Then we take the new dwellings implied by our housing supply forecasts (including the low, central and high case that we weight equally) and calculate the costs for each draw from the parameter distribution.

Table 22: Our simple model of per capita congestion based on Australian data

Variable	*Parameter*	*Standard error*	*Significance*
Intercept	-0.3083	0.0624	-4.941**
Log (Population)	1.4308	0.0488	29.318***
R-squared	0.992	F-test	859.6***

Source: Authors' analysis.

Assessing congestion costs – Case 2: internal migration demand

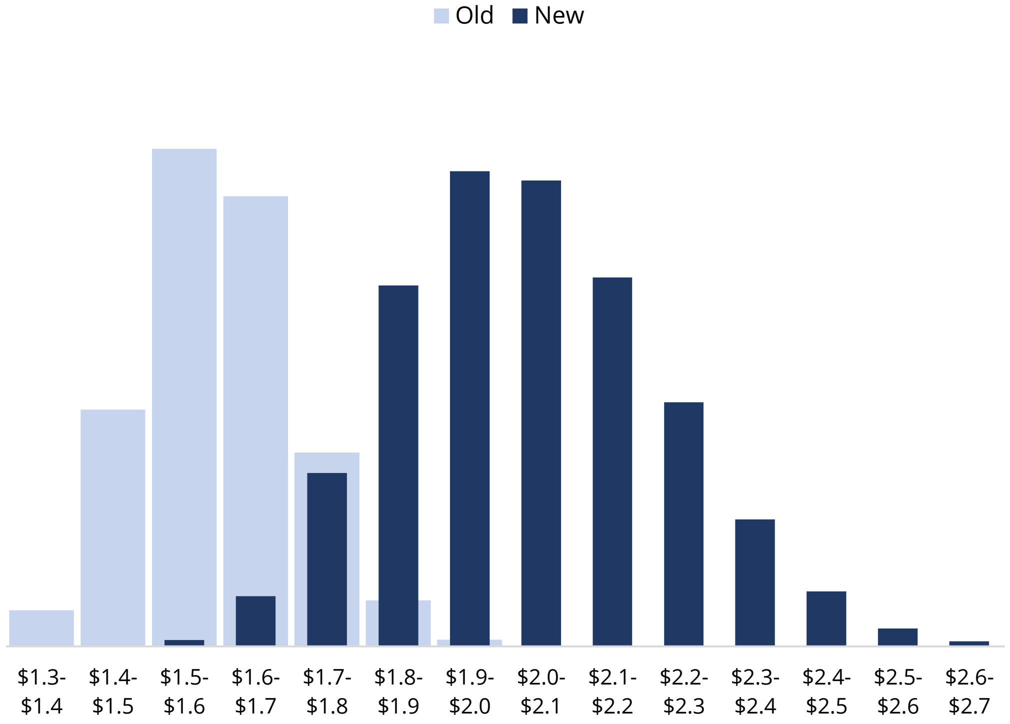
Importantly, we use Table 22 to account for impacts on congestion from both population movements to Tier 1 cities and from Tier 2 cities. Movements to Tier 1 cities add congestion costs while movement away from Tier 2 cities reduce congestion costs in these locations.

Movement to Tier 1 cities also originate in other New Zealand locations, but we do not associate any change in congestion costs from these movements since congestion costs are likely to be small in these locations.

Our simple model suggests marginal costs of congestion at current population levels are higher than average levels. So adding additional residents into New Zealand most populous cities increased congestion costs.

Figure 51: The distribution of case 2 congestion costs for Tier 1 cities shifts higher

Modelled congestion costs for Tier 1 New Zealand cities



Source: Authors' analysis.

Table 23 shows these costs could be substantive. If all demand for new dwellings is accommodated from elsewhere in New Zealand commuting cost could increase by $800 million a year.

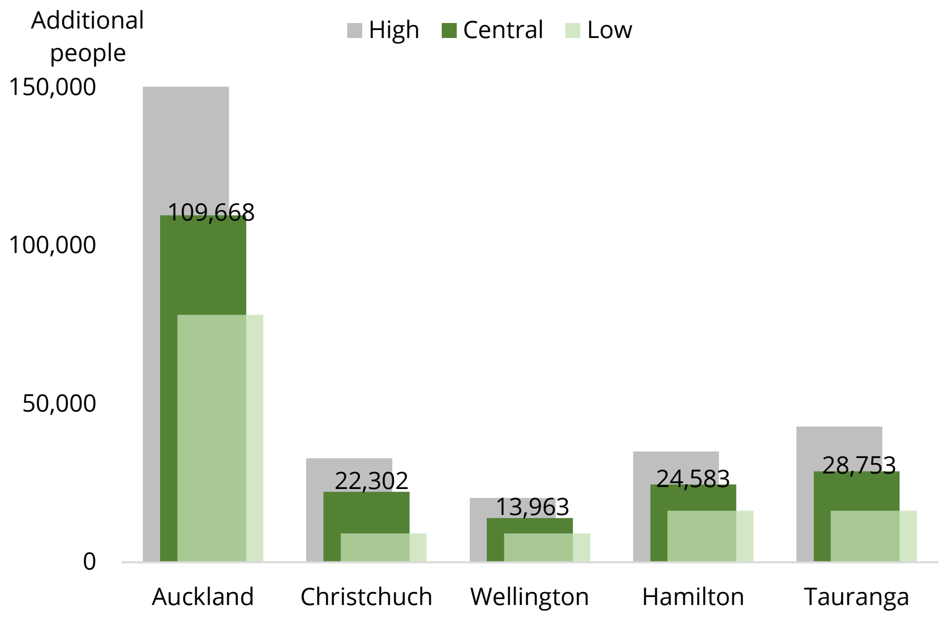
Table 23: Case 2 congestion costs – Internal migration pressures congestion costs higher

Urban area	*Congestion impact: case 2*		
	Low	*Medium*	*High*
Population	129,140	199,269	281,455
Tier 1 costs	$0.393bn	$0.591bn	$0.837bn
Tier 2 costs	-$0.014bn	-$0.021bn	-$0.030bn
Net costs	$0.379bn	$0.570bn	$0.807bn

Source: Authors analysis.

These costs are large but reflect the marginal impact of large population flows (see Figure 52).

Figure 52: Modelling population movement under the MDRS



Source: Authors' analysis.

Assessing congestion costs – preferred scenario

It is difficult ahead of time to assess the relative importance of case 1, where demand arises from within Auckland, against case 2 where external demand comes from elsewhere in New Zealand. So we adopt a pragmatic approach and average over the two scenarios. Table 24 presents the costs from this preferred scenario, which we adopt as our central case in the cost-benefit assessment.

Table 24: Congestion costs, preferred scenario with both internal and regional migration

Annual costs	*Congestion impact: Preferred scenario ($m)*		
	Low	*Medium*	*High*
Tier 1 costs (more people)	$89	$138	$196
Tier 2 costs (fewer people)	-$14	-$21	-$30
Net costs	$75	$117	$166

Source: Authors' analysis.

Case 3: international demand

Housing costs in New Zealand Tier 1 cities are also likely to be lower than otherwise relative to international competitors. However, changes in relative setting drives impacts and quantifying any likely changes in land use regulations for Australian cities is challenging. In addition, Greenaway-McGrevy et al. 2019 note that it is movements in prices in Australian cities that tend to lead New Zealand cities rather than vice versa. So we do not include any international demand in our congestion estimates.

7.2. Access to parks and open space

Hedonic price models often show that proximity to urban parks and open spaces is valued by city residents and typically reflected in house prices.[29]

These models reflect access. Often impacts on house prices are larger the closer homes are to parks and open space.

New Zealand evidence is sparse. But what we do know suggests that parks and public open spaces are widely available, at least in Auckland suburbs. While closeness to parks is reflected in amenity value for apartments, widespread availability of parks means houses do not show the same values, even though residents are likely to value the amenity parks and open space provide.[30]

Many studies also examine the loss of parks and open space to provide housing. [31] Since the MDRS does not require the use of parks or open space, we zero costs in terms of loss of open space. In addition, any congestion of parks and open space are likely to be very small relative to congestion costs of the road network. We omit any costs in terms of congestion of parks and open space.

---

[29] See for example Brander and Koetse 2011, Herath et al. 2015 and Gnagey and Grijalva 2018.

[30] Allpress et al 2016.

[31] See also Crompton 2001, Geoghegan 2002, Daams et al. 2016 and Fan et al. 2016.

8. Network infrastructure

8.1. Our approach

Previous cost-benefit analysis of the costs and benefits of urban development identifies connection to infrastructure network as a possible cost of new development.

Where new developments do not pay for the full marginal costs of connecting to infrastructure networks costs are borne by the rest of the community.

To assess the costs of any impacts of network infrastructure, we use our preferred demand scenario from the congestion cost estimation, where half the demand for new dwellings comes from internal demand and half the demand for dwellings made available by the MDRS comes from other locations in New Zealand.

Pent-up internal demand from Tier 1 cities is modelled as new brownfield developments. We apply network connections charges consistent with low intensity urban development to these properties.

We model the demand for new dwellings in Tier 1 cities from other locations in New Zealand as a shift from a brownfield-greenfield mix (50-50) to all brownfield locations. For some properties this means substituting greenfield network connection charges for brownfield connections charges.

Recovery of connection charges is driven by policies on Development Contributions and Infrastructure Growth Charges. These are operational policies. Changes to these policies are often lumpy in terms of timing and the nature of recovery. Accordingly, these estimates should be considered as indicative costs, given recovery is subject to changes in policy.

To ground our analysis within existing methods, we use the estimates of infrastructure network costs that are not fully recovered from previous costs and benefits of urban development.[32] These estimates are updated to 2021 dollars and presented in Table 25.[33]

The estimates of unrecovered development charges can seem optimistic. Mass transit can cost tens of billions of dollars and recent experiences of Kainga Ora on large-scale renewal projects can show the scale of water infrastructure is not immediately available.

Since the MR Cagney estimates were constructed five years ago there has developed a greater realisation of the costs of development. But at the same time as the costs of development are increasing, there is a greater realisation of what appropriate cost recovery looks like. Thus, these estimates of unrecovered development charges appear more reasonable but are also consistent with costs of development not simply being covered by rates.

---

[32] See MR Cagney 2016.

[33] We use the Statistics New Zealand, PPI (output) for Heavy and Civil Engineering goods to calculate 2021 prices.

Table 25: Unrecovered development contributions and infrastructure growth charges costs

	Urban intensification		*Greenfields*	
	Low	Medium	Low	Medium
Estimated Gross Infrastructure Costs (2021 dollars)				
Transport	$0	$5,000	$13,612	$17,123
Water/wastewater	$14,000	$23,500	$14,000	$32,192
Stormwater	$0	$10,274	$8,167	$10,274
Open space, community facilities	$0	$0	$4,265	$5,365
Total	$14,000	$38,774	$40,044	$64,954
Estimated Development Contributions and Infrastructure Growth Charges				
Transport	$3,641	$6,825	$6,825	$6,825
Water/wastewater	$10,760	$10,760	$10,760	$10,760
Stormwater	$8,684	$8,648	$8,648	$8,648
Open space, community facilities	$2,179	$2,179	$2,179	$2,179
Total	$25,264	$28,412	$28,412	$28,412
External costs not borne by users of infrastructure, 2015 prices				
Transport	$0	$0	$6,787	$10,298
Water/wastewater	$3,240	$12,740	$3,240	$21,432
Stormwater	$0	$1,626	$0	$1,626
Open space, community facilities	$0	$0	$2,086	$3,186
Total	$3,240	$14,366	$12,113	$36,542
As % of total costs	23%	37%	30%	56%
External costs not borne by users of infrastructure, 2021 prices				
Transport	$0	$0	$7,663	$11,626
Water/wastewater	$3,658	$14,384	$3,658	$24,197
Stormwater	$0	$1,836	$0	$1,836
Open space, community facilities	$0	$0	$2,355	$3,597
Total	$3,658	$16,219	$13,676	$41,256

Source: MR Cagney 2016, authors' analysis.

8.2. Costs

We then present costs of the preferred scenario in Table 26. Under case 2, demand comes from elsewhere in New Zealand. So greenfield development contributions are not needed in these locations. Overall, this implies unrecovered development contributions fall under the MRDS (see Table 26).

Table 26: Costs of unrecovered development charges, preferred scenario

Location	Auckland	Hamilton	Tauranga	Wellington	Christchurch	Total
New dwellings						
Low	27,927	3,389	3,819	6,516	6,535	48,186
Central	39,167	8,260	5,818	9,833	11,501	74,579
High	53,683	12,191	8,462	14,002	17,165	105,503
Additional Brownfields dwellings (low urban intensification)						
Low	13,964	1,695	1,910	3,258	3,268	24,095
Central	19,584	4,130	2,909	4,917	5,751	37,291
High	26,842	6,096	4,231	7,001	8,583	52,753
Additional brownfields dwellings costs						
Low	$51,079,914	$6,200,262	$6,986,726	$11,917,671	$11,954,251	$88,138,824
Central	$71,637,714	$15,107,422	$10,641,039	$17,986,246	$21,036,994	$136,409,416
High	$98,187,272	$22,298,994	$15,476,878	$25,609,459	$31,396,370	$192,968,972
Switch from Greenfields/Brownfields mix to brownfields (low urban intensification)						
Low	6,982	847	955	1,629	1,634	12,047
Central	9,792	2,065	1,455	2,458	2,875	18,645
High	13,421	3,048	2,116	3,501	4,291	26,377
Switch from Greenfields/Brownfields mix to brownfields, costs (low urban intensification)						
Low	-$69,943,222	-$8,484,948	-$9,566,854	-$16,318,750	-$16,368,838	-$120,682,612
Central	-$98,092,815	-$20,686,444	-$14,575,679	-$24,623,380	-$28,800,740	-$186,779,058
High	-$134,446,862	-$30,533,793	-$21,197,344	-$35,071,788	-$42,985,730	-$264,235,517
Dwellings with no change in development profile						
Low	6,981	847	954	1,629	1,633	12,044
Central	9,791	2,065	1,454	2,458	2,875	18,643
High	13,420	3,047	2,115	3,500	4,291	26,373
Zero costs for dwellings with no change in development profile						
Low	$0	$0	$0	$0	$0	$0
Central	$0	$0	$0	$0	$0	$0
High	$0	$0	$0	$0	$0	$0
Total costs						
Low	-$18,863,308	-$2,284,687	-$2,580,129	-$4,401,078	-$4,414,587	-$32,543,788
Central	-$26,455,100	-$5,579,022	-$3,934,639	-$6,637,134	-$7,763,745	-$50,369,641
High	-$36,259,590	-$8,234,798	-$5,720,467	-$9,462,329	-$11,589,360	-$71,266,544

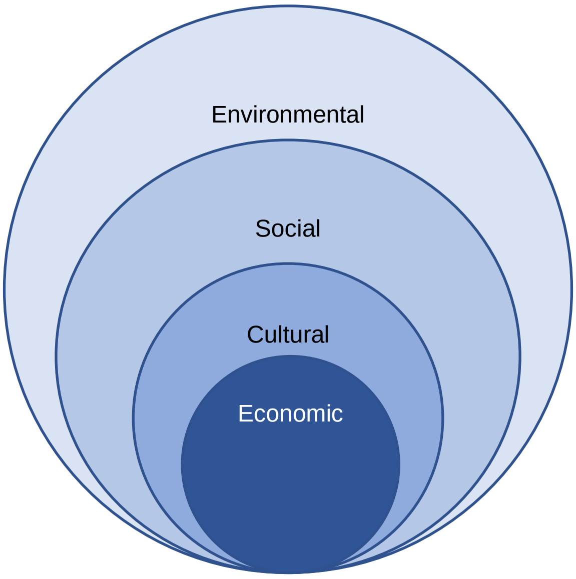
Source: Authors' analysis

9. Environmental impacts

9.1. Approach

Social externalities associated with extra development span not just economic costs but in principle include cultural, social, and environmental costs.

Figure 53: In principle, benefits and costs include social, cultural and environmental factors



Source: Authors.

We have not identified any cultural and social costs. Instead, by reducing housing costs, the MDRS could provide social and cultural benefits by allowing people greater locational choices that facilitate living closer to family and whānau. These benefits should be studied but are not modelled here.

To estimate the environmental costs of the MDRS, not directly borne by added households, we use the estimates provided by MR Cagney et al. 2016 for the NPS-UDC. These estimates were also used by PwC 2020 for the cost benefit analysis of the NPS-UD. We keep our estimates in line with these previous studies, at least partly to preserve comparability across these previous studies.

9.2. Impacts

Previous studies identify 4 key possible environmental impacts:

- Loss of peri-urban land - de Development at the fringe of the city may reduce city residents' amenity by reducing the availability / accessibility of peri-urban open space
- Air quality - intensification can result in higher levels of pollution that can impact on health
- Freshwater quality – can be impacted by stormwater run-off, higher stream temperatures and solid waste from plastic and heavy metals
- Coastal water quality – stormwater run-off can also affect coastal areas.

We use the estimates in MR Cagney et al. 2016 to test the impact of the MDRS on the environmental factors listed above. We use numbers associated with low intensity development since high intensity numbers are associated with properties that are 4-8 stories high. We present the estimates we use (updated for inflation) in Table 27.

Table 27: Costs of urban development associated with environmental factors

Costs	*Brownfield*	*Greenfield*
Loss of peri-urban land		$201.61
Air quality	$289.41	$242.80
Freshwater quality		$135.49
Coastal water quality		$145.25
Total	$289.41	$725.15

Source: MR Cagney et al. 2016, authors' analysis.

We apply the costs in Table 27 to our core scenario that includes both internal demand from within Tier 1 cities and internal migration from across New Zealand. The results suggest relatively narrow differences across low, medium and high population scenarios that range from about $22 million to $28 million. While non-trivial, these costs are an order of magnitude smaller than the congestion cost estimates.

Table 28: New dwellings added under the proposed MDRS trends in Tier 1 urban areas

Number of new dwellings

	Old	*Low*	*Medium*	*High*
Greenfields	254,549	203,932	198,102	191,049
Brownfields	272,885	323,502	329,332	336,385
Ratio	48.3%	38.7%	37.6%	36.2%
Costs	$263,561,553	$241,505,700	$238,965,336	$235,892,061
Savings		$22,055,853	$24,596,217	$27,669,491

Source: MR Cagney et al. 2016, authors' analysis.

10. Overshadowing

10.1. Overview

Urban development creates transfers of sunlight and shade between properties. As cities intensify and buildings are built higher, they inevitably displace how the sunlight naturally falls upon their neighbours.

In practice, these urban development negative 'externalities' have been addressed through inflexible land use regulations that specify allowable building parameters. But until recently we know very little about the costs and benefits of these policies.

Any evaluation of these policies requires three elements:

1. Locations of new developments
2. The value of sunshine to existing residents
3. The likely impact on development from a given land use regulation

We use the modelling form our housing supply impact assessment to identify locations of new developments. Recent research provides estimates of the value of sunshine for Wellington[34] using hedonic pricing methods. We use these values as an approximation to the value of sunshine (in terms of a fraction of the total value of a property).

But there is little direction on 3, so we built 'Icarus', a model that first estimates the impact of a given development on sunshine available to nearby properties and then uses estimates of the value of sunshine to assess the costs of loss of sunshine from the MDRS.

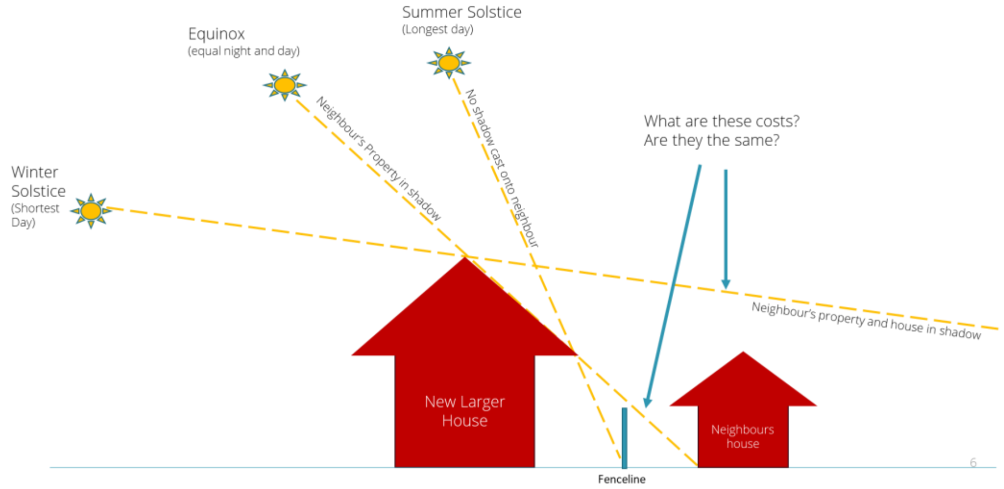
10.2. Modelling approach

Icarus is the first urban development sunshine externality costing model that can support large-scale urban development planning initiatives in New Zealand urban centres. Using geospatial information on building location and height, Icarus tracks the sun at set times of the year and estimates the value of the shade cast by a new development onto its neighbours. Figure 54 provides a stylised example of how Icarus tracks shade from a new development over the year.

---

[34] Fleming et al. 2017 who suggest empirical based methods might support market-based alternative to restrictions which could lead to welfare-improving urban development outcomes.

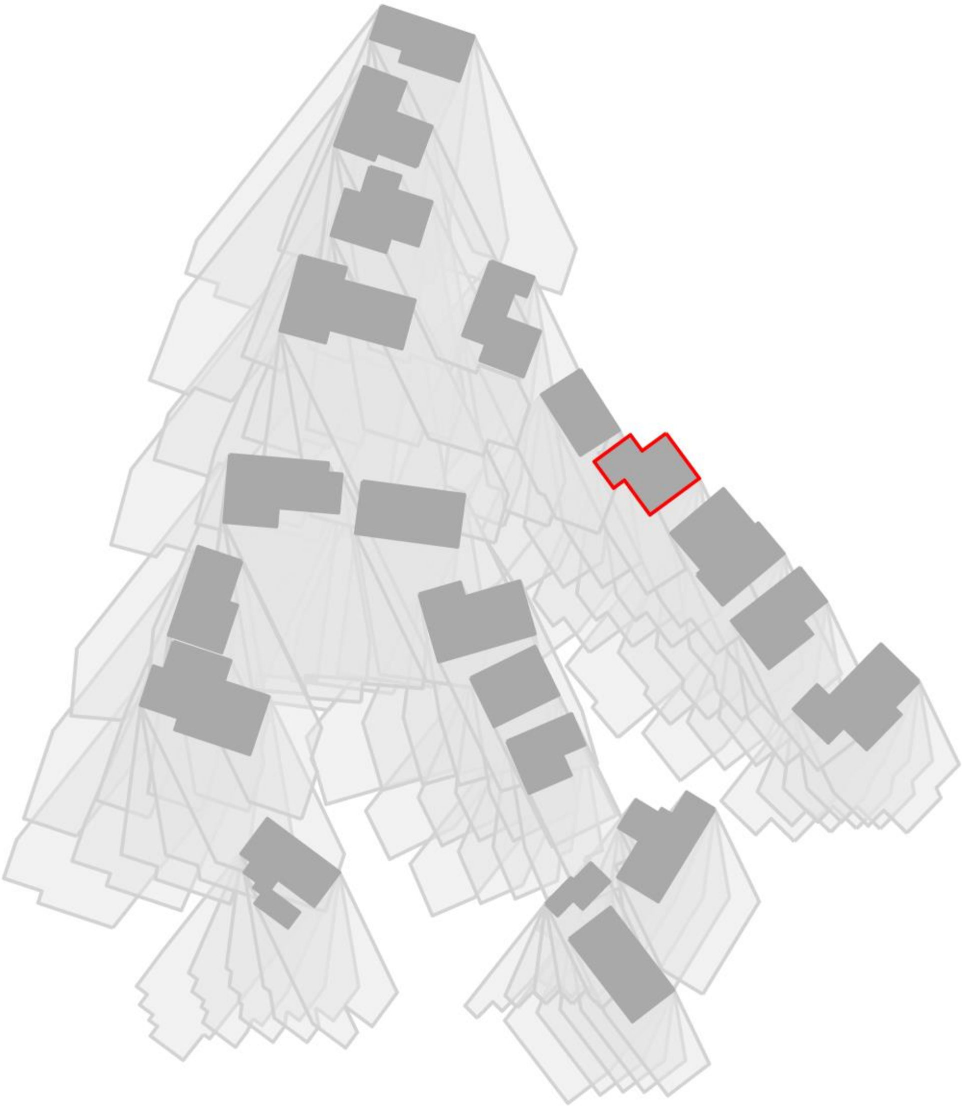
Figure 54: Icarus tracks the impacts of shade from new urban development



Source: Authors' illustration.

This exercise produces a shade pattern for each proposed development. Figure 55 shows an example based on an existing property in Lower Hutt.

Figure 55: Example of shading, existing property, Kelson, Lower Hutt

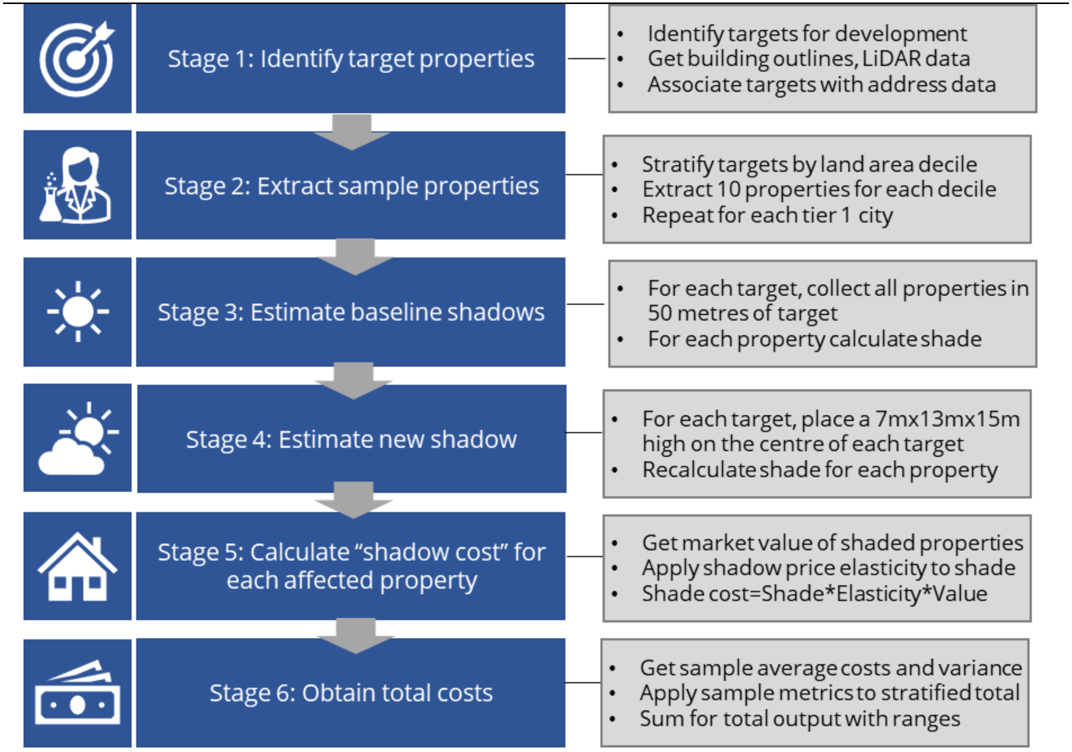


Source: Authors' analysis.

Icarus is data intensive. For a single new development, we need to calculate the impact of the new property on all surrounding properties.

To simplify the analysis, we restrict our analysis to properties within 50 metres of any identified new development. And we restrict ourselves to a stratified sample of 100 targeted developments for each tier 1 city. Figure 56 steps through each of stage of the process to estimate total cost of shading from the MDRS.

Figure 56: We use a six-stage process to estimate the costs of shading from the MDRS



Source: Authors' illustration.

We include further details of each stage of the model in Appendix D.

10.3. Results

Table 29 presents the results of the impacts of the MRDS on views. We evaluate impacts, rating up our estimates for the stratified sample of 100 properties for each city to the total dwelling estimates for each city under the low, medium, and high scenarios. Higher property values and a larger number of sites with view mean most of the impacts fall within the Auckland urban area.

Table 29: Over two-thirds of the loss of sunshine estimates lie in Auckland

Present value of estimated cost of lost sunshine

Major urban area	*Lower bound (90% C.I.)*	*Central estimate*	*Upper bound (90% C.I.)*
Auckland	$212.1m	$316.1m	$420.0m
Christchurch	$39.6m	$59.0m	$80.3m
Hamilton	$22.5m	$32.6m	$78.4m
Tauranga	$41.1m	$60.7m	$80.3m
Wellington	$28.5m	$45.5m	$62.4m
Total	$343.9m	$513.9m	$683.9m

Source: Authors' analysis.

References

Adlakha, Deepti. & James F. Sallis (2020) Activity-friendly neighbourhoods can benefit non-communicable and infectious diseases, Cities & Health, DOI: 10.1080/23748834.2020.1783479

Ahlfeldt, G. M. & Pietrostefani, E. 2019. “The economic effects of density: A synthesis” Journal of Urban Economics, 111(C), 93-107.

Allpress, J., Balderston, K. and Nunns, P. 2016, “How do Aucklanders value their parks? A hedonic analysis of the impact of proximity to open space on residential property values”. Technical report, TR2016/031. Auckland: Auckland Council.

Alonso, W. 1964. “Location and Land Use: Toward a General Theory of Land Rent”, *Harvard University Press, Cambridge.*

Booz Allen Hamilton (2004) Surface transport costs and charges study: road congestion costs. Working paper. Report to Ministry of Transport, Wellington.

Bourassa, S. C., Hoesli, M. and Sun, J. (2004) ‘What’s in a view?’, Environment and Planning A, 36(8), pp. 1427-1450. doi: 10.1068/a36103.

Bourassa, S. C., Hoesli, M. and Sun, J. (2005) ‘The Price of Aesthetic Externalities’, Journal of Real Estate Literature, 13(2), pp. 165-188

Brander, L.M. and M. J Koetse, 2011, “The value of urban open space: Meta-analyses of contingent valuation and hedonic pricing results.” Journal of environmental management. 92(10). pp.2763-2773.

Bureau of Infrastructure, Transport and Regional Economics. 2015. Traffic and congestion cost trends for Australian cities. Canberra: Department of Infrastructure and Regional Development, Available online at https://bitre.gov.au/publications/2015/is_074.aspx

Clough, Peter and Michael Bealing 2018, “What’s the use of non-use values? Non-Use Values and the Investment Statement” Revised NZIER report to The Treasury, February

Conley, T.G. 1999. “GMM estimation with cross sectional dependence,” *Journal of Econometrics*, Volume 92, Issue 1, 1999, pages 1-45.

Crompton, J.L. 2001. The impact of parks on property values: A review of the empirical evidence. Journal of Leisure Research, 33(1), 1.

Daams, M. N., F. J. Sijtsma, and A. J. van der Vlist. 2016. “The Effect of Natural Space on Nearby Property Prices: Accounting for Perceived Attractiveness,” Land Economics, 92(3), pp. 389-410. doi: 10.3368/le.92.3.389.

Donovan, S. and Munro, I. 2013. Impact of urban form on transport and economic outcomes. Wellington, New Zealand Transport Agency, research report 513

Fan, Qin J. Hansz and Xiaoming yang, 2016. “The Pricing Effects of Open Space Amenities," The Journal of Real Estate Finance and Economics, Springer, vol. 52(3), pages 244-271, April.

Filippova, O. 2009. The influence of submarkets on water view house price premiums in New Zealand. International Journal of Housing Markets and Analysis, 2(1), 91-105.

Fleming, D. Arthur Grimes, Laurent Lebreton, David Mare and Peter Nunns. 2018. “‘Valuing sunshine.” Regional Science and Urban Economics. North-Holland, 68, pp. 268-276

Geoghegan, J. 2002 ‘The value of open spaces in residential land use’, Land Use Policy, 19(1), pp. 91-98.

Glaeser, Edward. 2007. The Economics Approach to Cities. NBER Working Paper 13696. Cambridge, MA: National Bureau of Economic Research.

Gnagey, Matthew and Therese Grijalva, 2018. “The impact of trails on property values: a spatial analysis,” The Annals of Regional Science, Springer; Western Regional Science Association, vol. 60(1), pages 73-97, January.

Greenaway-McGrevy, Ryan, Arthur Grimes and Mark Holmes, 2019. “Two countries, sixteen cities, five thousand kilometres: How many housing markets?,” Papers in Regional Science, Wiley Blackwell, vol. 98(1), pages 353-370, February.

Greenaway-McGrevy, R. Pacheco, G. Sorensen, K. 2020. “The effect of upzoning on house prices and redevelopment premiums in Auckland, New Zealand”. *Urban Studies*, Volume 58, Issue 5, 2020, pages 959-976

Grimes, A. Aitken, A. 2010. “Housing supply, Land Costs and Price Adjustment”. Real Estate Economics, Volume 38, Issue 2, pages 325-353.

Grimmond, Dave 2017, “Estimates of costs of road congestion in Wellington”, Greater Wellington Regional Council https://lgwm.nz/assets/Uploads/Estimates-of-costs-of-road-congestion-in-Wellington-Report-v1.pdf, October.

Hamidi, Shima. Sadegh Sabouri & Reid Ewing (2020a). Does Density Aggravate the COVID-19 Pandemic?, Journal of the American Planning Association, 86:4, 495-509, DOI: 10.1080/01944363.2020.1777891

Hamidi, Shima. Reid Ewing, Sadegh Sabouri, (2020b). Longitudinal analyses of the relationship between development density and the COVID-19 morbidity and mortality rates: Early evidence from 1,165 metropolitan counties in the United States. Health & Place, Volume 64, 2020, 102378, ISSN 1353-8292, https://doi.org/10.1016/j.healthplace.2020.102378.

Herath, Shanaka, Johanna Choumert and Gunther Maier, 2015. "The value of the greenbelt in Vienna: a spatial hedonic analysis,: The Annals of Regional Science, Springer; Western Regional Science Association, vol. 54(2), pages 349-374, March.

Hyslop, Dean & Trinh Le & David C. Maré & Steven Stillman, 2019. "Housing markets and migration – Evidence from New Zealand." Working Papers 19_14, Motu Economic and Public Policy Research.

Land Information New Zealand. 2021. “NZ Building Outlines (All Sources).” https://data.linz.govt.nz/layer/101292-nz-building-outlines-all-sources/.

Maré, David C. & Graham, Daniel J., 2013. "Agglomeration elasticities and firm heterogeneity”, Journal of Urban Economics, Elsevier, vol. 75(C), pages 44-56.

Melo, P.C., Graham, D.J. and Noland, R.B. 2009. A meta-analysis of estimates of urban agglomeration economies. Regional Science and Urban Economics, Vol. 39, Issue 3, pp.332- 342

Mills, E.S. 1967. “An Aggregative Model of Resource Allocation in a Metropolitan Area*”, The American Economic Review*, *Papers and Proceedings*, Volume 57, Issue 2, pages 197- 210.

MRCagney, BECA & Covec. Cost benefit analysis of policy options for a National Policy Statement on Urban Development Capacity. Job Number: NZ2052, Prepared for Ministry for the Environment. Auckland: 2016.

Muth, R.F. 1969. “Cities and Housing: The Spatial Pattern of Urban Residential Land Use”, *Third Series: Studies in Business and Society, University of Chicago Press*, *Chicago.*

New Zealand Government. National Policy Statement on Urban Development 2020. Published under Resource Management Act 1991 Section 52(2). https://environment.govt.nz/publications/national-policy-statement-on-urban-development-2020/

NZIER 2018 “What’s the use of non-use values? Non-Use Values and the Investment Statement” Revised NZIER report to The Treasury 1st February

NZTA 2013 The NZ Transport Agency’s Economic evaluation manual, First edition, Amendment 0, Effective from 1 July 2013

Nunns, Peter, Hitchins, Hadyn and Balderston, Kyle 2015. The value of land, floorspace and amenities: a hedonic price analysis of property sales in Auckland 2011-2014. Auckland Council technical report, TR2015/012.

Productivity Commission. (2015). Using land for housing inquiry: Final report. Wellington: Productivity Commission

PwC. 2020. “Cost-benefit analysis for a National Policy Statement on Urban Development”.

PwC. 2021. “The wider costs and benefits of urban growth – methodology report.”

Reda, I., and A. Andreas. 2003. “Solar Position Algorithm for Solar Radiation Application.” National Renewable Energy Laboratory (NREL). https://www.nrel.gov/docs/fy08osti/34302.pdf

Rohani, M. 2012. Impact of Hauraki gulf amenity on land price of neighbourhood properties: an empirical hedonic pricing method, case study North Shore, Auckland. Auckland, Auckland Council

Rosen, Sherwin, 1974. “Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition.” Journal of Political Economy. University of Chicago Press, vol. 82(1), pages 34-55, Jan.-Feb.

Saiz, A. 2010. “The Geographic Determinants of Housing Supply”. Quarterly Journal of Economics. Vol. 125, Issue 3, August 2010, Pages 1253–1296

Samarasinghe, O. E. and Sharp, B. M. H. 2008. “The value of a view: A spatial hedonic analysis.” New Zealand Economic Papers, 42(1), pp. 59-78. doi: 10.1080/00779950809544413

Small, K.A. and Verhoef, E.T., 2007. The economics of urban transportation. Routledge.

Woods, C. and K Dunstan, K., 2014. Forecasting mortality in New Zealand: a new approach for population projections using a coherent functional demographic model (Working Paper No. 14– 01), Statistics New Zealand Working Paper.

Restrictions

This report has been prepared for the Ministry for the Environment and the Ministry of Housing and Urban Development (‘the Ministries’) to set out our estimates of the potential costs and benefits of the proposed Medium Density Residential Standards policy. The purpose of this report is to support preparations and decisions during the policy making process for the proposed amendment to the Resource Management Act 1991. This report has been prepared solely for this purpose and should not be relied upon for any other purpose. While we acknowledge that the report will be made public as part of the legislative process, we accept no liability to any party should it be used for any purpose other than that for which it was prepared.

This draft report has been prepared solely for use by the Ministries and appointed peer reviewers and may not be copied or distributed to third parties without our prior written consent.

To the fullest extent permitted by law, PwC accepts no duty of care to any third party in connection with the provision of this report and/or any related information or explanation (together, the “Information”). Accordingly, regardless of the form of action, whether in contract, tort (including without limitation, negligence) or otherwise, and to the extent permitted by applicable law, PwC accepts no liability of any kind to any third party and disclaims all responsibility for the consequences of any third party acting or refraining to act in reliance on the Information.

We have not independently verified the accuracy of information provided to us and have not conducted any form of audit in respect of the Ministry for the Environment or the Ministry of Housing and Urban Development. Accordingly, we express no opinion on the reliability, accuracy, or completeness of the information provided to us and upon which we have relied.

The statements and opinions expressed herein are based on information available as at the date of the report, have been made in good faith, and have been made on the basis that all information relied upon is true and accurate in all material respects and not misleading by reason of omission or otherwise. We reserve the right, but will be under no obligation, to review or amend our report, if any additional information, which was in existence on the date of this report, was not brought to our attention, or subsequently comes to light.

It is not possible to assess with certainty the implications of COVID-19 on the economy, both generally in terms of how long the current crisis may last and more specifically in terms of its impact on housing supply and demand. We note our advice is subject to significant caveats and caution at this time due to uncertainty that exists for residents and developers including (among other matters) the demand for products or services, access to capital, supply chain disruption, and the extent and duration of the measures implemented by various governments and authorities to contain or prevent spread of COVID-19.

This report is issued pursuant to the terms and conditions set out in our Consultancy Services Order dated 28 June 2021 and the attached Terms of Engagement.

Appendix A. Supplementary technical material for housing supply estimates

A.1 Regression results

The following subsections show regression outputs for our three model steps for each Tier 1 urban area.

A.1.1 Auckland

To avoid multicollinearity among our categorical variables, we have dropped the Single Housing Zone (SHZ) dummy from the regression, making it our base category. The regression outputs for the percentage change in land value are given in Table 30 below.

Table 30: Regression output – percentage change in land value – Auckland

Source	SS	df	MS	Number of observations	217,523
Model	4537.36625	8	567.170782	F-statistic	14.01
Residual	8808296.03	217,514	40.4953062	Probability > F-statistic	0.0000
Total	8812833.4	217,522	40.5146762	R-squared	0.0005
				Adjusted r-squared	0.0005
				Root mean squared error	6.3636

Percentage change in land value	Coefficient	Standard error	t-statistic	p-value	95% confidence interval low	95% confidence interval high
Zone						
MHS	0.067799	0.150576	0.45	0.653	-0.22733	0.362925
MHU	0.401171	0.208059	1.93	0.054	-0.00662	0.808962
THAB	1.361599	0.340106	4.00	0.000	0.695	2.028199
Zone * Log distance						
Log distance (SHZ)	-0.02361	0.040687	-0.58	0.562	-0.10335	0.056135
MHS	0.061411	0.056219	1.09	0.275	-0.04878	0.171598
MHU	-0.06884	0.080836	-0.85	0.394	-0.22727	0.089599
THAB	-0.40484	0.135408	-2.99	0.003	-0.67023	-0.13944
2014 LV/CV	0.660997	0.097445	6.78	0.000	0.470007	0.851986
Constant	0.378911	0.127359	2.98	0.003	0.129291	0.628532

Source: Authors' analysis.

The coefficients for zone are the difference between the constant for the respective zone and the constant for the SHZ. The coefficients for zone * log distance are the differences between the slope for the respective zone and the slope for the SHZ

The coefficient on log distance is not statistically significant. This means that for the SHZ, when no up-zoning took place, we see a general appreciation in the land value (around a 75% increase in three years at the mean value for 2014 LV/CV), with little variation by distance from the city centre.

Whereas, for more permissive zones, especially the Mixed-Housing Urban Zone and Terraced Housing and Apartment Buildings, distance makes a difference. Thus, the up-zoning effect varied by distance, but the general effect did not.

The regression outputs for Step 2, estimating the probability of adding at least one dwelling, are given in Table 31 below.

Table 31: Regression output – likelihood of adding at least one dwelling

Logistic regression					Number of observations	331,105
					Likelihood ratio chi-squared	9693.36
Log likelihood =	-84767.412				Probability > chi-squared	0.0000
					Pseudo r-squared	0.0541
Log odds of adding at least one dwelling	**Coefficient**	**Standard error**	**z-score**	**p-value**	**95% confidence interval low**	**95% confidence interval high**
Quality score (SHZ)	2.035176	0.081777	24.89	0.000	1.874897	2.195455
Zone						
MHS	-0.91135	0.066824	-13.64	0.000	-1.04232	-0.78037
MHU	-0.75265	0.080239	-9.38	0.000	-0.90991	-0.59538
THAB	0.102557	0.127476	0.8	0.421	-0.14729	0.352405
Zone * quality score						
MHS	1.356778	0.104068	13.04	0.000	1.152808	1.560749
MHU	1.468782	0.122659	11.97	0.000	1.228374	1.709189
THAB	-0.39025	0.197592	-1.98	0.048	-0.77752	-0.00298
Special character	-0.67466	0.060959	-11.07	0.000	-0.79413	-0.55518
Log distance	1.00538	0.013873	72.47	0.000	0.97819	1.032571
Constant	-6.4438	0.072636	-88.71	0.000	-6.58616	-6.30143

Source: Authors' analysis.

The coefficients for zone represent the difference between the intercept for the respective zone and the regression constant, which is the intercept for the SHZ. The coefficients for zone * quality score are the differences between the slope for the respective zone and the slope for the SHZ. For logit regressions, coefficient estimates indicate the fitted linear relationship between the modelled predictors and the log of the odds ratio of outcomes for that predictor. This makes it difficult to directly intuit the meaning of logit results in terms of probabilities. See the margin plot shown in Figure 13 in Section 2.2.5 for a graphic presentation of these results in terms of probabilities.

Regression outputs for Step 3, estimating the increase in FAR given that a parcel adds at least one dwelling, are shown in Table 32 below.

Table 32: Regression output – FAR increase conditional on adding at least one dwelling

Source	SS	df	MS	**Number of observations**	**25,398**
Model	1668.1713	8	208.522016	F-statistic	129.62
Residual	4084.3997	25,389	1.60874393	Probability > F-statistic	0.0000
Total	42512.5758	25,397	1.67392116	R-squared	0.0392
				Adjusted r-squared	0.0389
				Root mean squared error	1.2684

Floor area ratio increase	**Coefficient**	**Standard error**	**t-statistic**	**p-value**	**95% confidence interval low**	**95% confidence interval high**
Quality score (SHZ)	0.374482	0.094231	3.97	0.000	0.189783	0.559181
Zone						
MHS	-0.06089	0.078941	-0.77	0.441	-0.21562	0.093838
MHU	0.204171	0.089162	2.29	0.022	0.029408	0.378933
THAB	0.186872	0.135269	1.38	0.167	-0.07826	0.452007
Zone * quality score						
MHS	0.44122	0.121109	3.64	0.000	0.203839	0.678601
MHU	0.454595	0.135119	3.36	0.001	0.189754	0.719435
THAB	0.991064	0.20739	4.78	0.000	0.584567	1.397561
Land Area	-1.99E-06	8.00E-07	-2.49	0.013	-3.56E-06	-4.26E-07
Constant	0.150532	0.060163	2.5	0.012	0.03261	0.268454

Source: Authors' analysis.

The coefficients for zone are the difference between the constant for the respective zone and the constant for the SHZ. The coefficients for zone * quality score are the differences between the slope for the respective zone and the slope for the SHZ.

A.1.2 Christchurch

For Christchurch, we have dropped the dummy indicator for the Residential Suburban Zone (RSZ) from the regression, making it our base category. This means that the coefficient for the quality score is the coefficient for quality score interaction with RSZ and the coefficient for the constant represents the RSZ intercept.

The regression outputs for the percentage change in land value are given in Table 33 below.

Table 33: Christchurch land-value discontinuity regression

Source	SS	df	MS	**Number of observations**	**132,190**
Model	12291.7402	7	1755.96288	F-statistic	5357.04
Residual	43327.3832	132,182	.327785805	Probability > F-statistic	0.0000
Total	55619.1234	132,189	.420754551	R-squared	0.2210
				Adjusted r-squared	0.2210
				Root mean squared error	.57253

Land value/m^2	**Coefficient**	**Standard error**	**t-statistic**	**p-value**	**95% confidence interval low**	**95% confidence interval high**
Log distance (RSZ)	-0.26935	0.002528	-106.53	0	-0.2743	-0.26439
Zone						
RNN	-0.1136	0.013457	-8.44	0	-0.13998	-0.08723
RMD	0.153457	0.010163	15.1	0	0.133538	0.173376
Zone * quality score						
RNN	0.056839	0.008691	6.54	0	0.039804	0.073873
RMD	-0.03729	0.00628	-5.94	0	-0.0496	-0.02498
Latest land ratio	0.649791	0.008707	74.63	0	0.632727	0.666856
Constant	5.898737	0.007288	809.42	0	5.884453	5.913021

Source: Authors' analysis.
Note: RNN is the Residential New Neighbourhood Zone group, RMD is the Residential Medium Density Zone group.

A.1.3 Hamilton

For Hamilton, we drop the dummy indicator for the General Residential Zone (GRZ) from the regression, making it our base category. This means that the coefficient for the quality score represents the coefficient for quality score interacted with the GRZ (ie, the GRZ slope), and the coefficient for the constant represents the intercept for the GRZ.

The regression outputs for the percentage change in land value are given in Table 34 below.

Table 34: Hamilton land-value discontinuity regression

Source	SS	df	MS	**Number of observations**	**68,139**
Model	3946.56811	6	657.761351	F-statistic	2014.85
Residual	22242.1023	68,132	.326456031	Probability > F-statistic	0.0000
Total	26188.6704	68,138	.384347506	R-squared	0.1507
				Adjusted r-squared	0.1506
				Root mean squared error	.57136

Land value/m^2	Coefficient	Standard error	t-statistic	p-value	95% Confidence interval low	95% Confidence interval high
Log distance (GRZ)	-0.13143	0.00226	-58.15	0	-0.13586	-0.127
Zone						
MDR	0.08104	0.016703	4.85	0	0.048303	0.113777
SP	3.939525	0.181074	21.76	0	3.584621	4.294429
Zone * quality score						
MDR	-0.22684	0.01171	-19.37	0	-0.24979	-0.20389
SP	-1.9066	0.073051	-26.1	0	-2.04978	-1.76342
Latest land ratio	-0.05837	0.015207	-3.84	0	-0.08818	-0.02857
Constant	6.340419	0.01114	569.18	0	6.318585	6.362252

Source: Authors' analysis.

Note: MDR is the Medium Density Residential group, SP is the subset of structure plan areas with no dwelling limit and height limits of 10 metres.

A.1.4 Tauranga

In Tauranga, the Suburban Residential Zone (SRZ) is our base category. This means that the coefficient for the quality score is the coefficient for quality score interaction with the SRZ and the coefficient for the constant represents the intercept for the SRZ.

The regression outputs for the percentage change in land value are given in Table 35 below.

Table 35: Tauranga land-value discontinuity regression

Source	SS	df	MS	Number of observations	54,111
Model	2589.36102	7	369.908717	F-statistic	844.65
Residual	23694.0034	54,103	.437942507	Probability > F-statistic	0.0000
Total	26283.3645	54,110	.485739502	R-squared	0.0985
				Adjusted r-squared	0.0984
				Root mean squared error	.66177

Land value/m^2	Coefficient	Standard error	t-statistic	p-value	95% Confidence interval low	95% Confidence interval high
Log distance (SRZ)	-0.07626	0.003872	-19.69	0	-0.08385	-0.06867
Zone						
WBOP	0.242432	0.036885	6.57	0	0.170138	0.314726
HDU	1.064785	0.036535	29.14	0	0.993177	1.136394
Zone * quality score						
WBOP	-0.02912	0.027259	-1.07	0.285	-0.08255	0.024312
HDU	-0.26552	0.015691	-16.92	0	-0.29628	-0.23477
Latest land ratio	0.322454	0.016176	19.93	0	0.290749	0.354159
Total valuations post-2016	-0.03098	0.000575	-53.91	0	-0.03211	-0.02985
Constant	6.336463	0.012487	507.44	0	6.311988	6.360938

Source: Authors' analysis.

A.1.5 Wellington

In Wellington, we use the Outer Residential Area (ORA) as our base category. This means that the coefficient for the quality score represents the slope for the quality score interaction with the ORA and the coefficient for the constant represents the intercept for the ORA.

The regression outputs for the percentage change in land value are given in Table 36 below.

Table 36: Wellington land-value discontinuity regression

Source	SS	df	MS	Number of observations	130,063
Model	19012.0388	4	4753.0097	F-statistic	8970.10
Residual	68914.1649	130,058	.529872556	Probability > F-statistic	0.0000
Total	87926.2037	130,062	.676032997	R-squared	0.2162
				Adjusted r-squared	0.2162
				Root mean squared error	.72792

Land value/m^2	Coefficient	Standard error	t-statistic	p-value	95% Confidence interval low	95% Confidence interval high
Log distance (ORA)	-0.2883	0.002295	-125.63	0	-0.2928	-0.2838
Zone						
MDR	0.740244	0.013393	55.27	0	0.713995	0.766493
Zone * quality score						
MDR	-0.24748	0.005046	-49.04	0	-0.25737	-0.23759
Latest land ratio	0.780849	0.01329	58.76	0	0.754802	0.806896
Constant	6.531676	0.009702	673.25	0	6.512661	6.550691

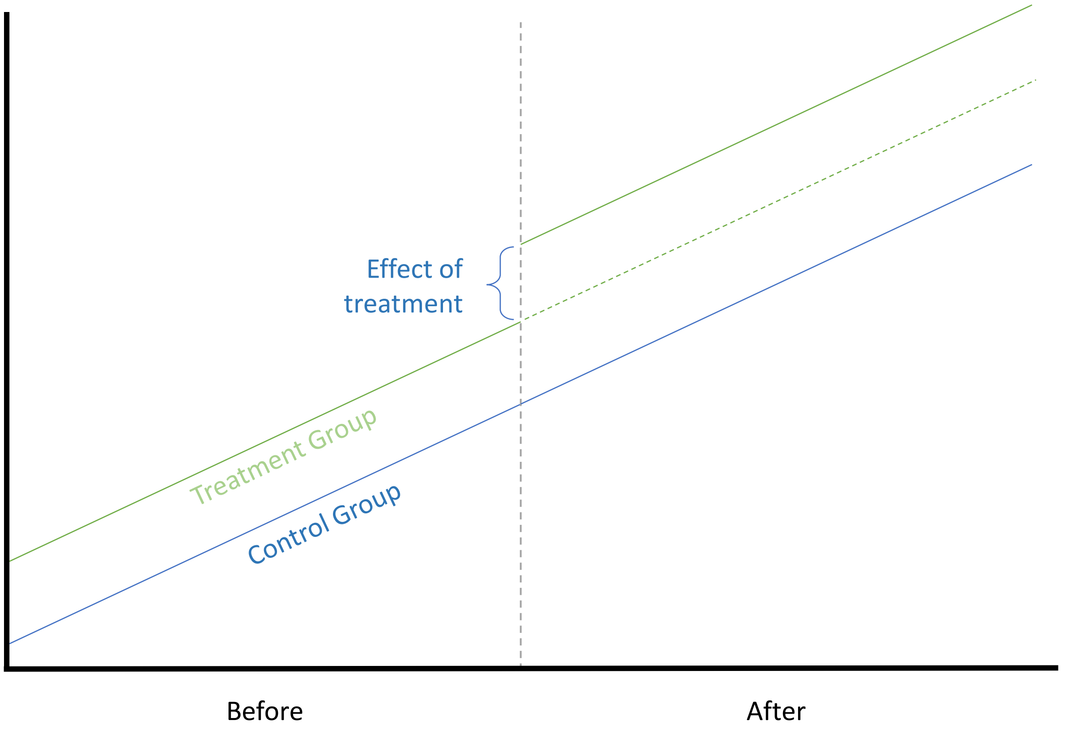
Source: Authors' analysis.
Note: MDR is the Medium Density Residential group.

A.2 Difference in Difference Estimation

Difference in Differences (DiD) is a statistical technique used in econometrics that attempts to measure the impact of a policy intervention or treatment using observational data. DiD analyses often exploit natural or quasi-natural experiments.

Difference in Difference estimation studies the differential effects of a treatment group versus a control group. This is done by comparing the average change of a treatment group, with the average change of a control group. The difference in these average changes gives a causal change due to the treatment.

Figure 57: Difference in Difference Estimation



Source: Authors' illustration.

In Figure 57 above, we have separate trends in a dataset for a treatment group and control group. A DiD estimation examines the difference between the average change in the treatment group and the average change in the control group from before the treatment to after the treatment.

To estimate the change in land value due to the AUP, we can compare the change in land value from parcels that were up-zoned (treatment group) with the parcels that were not up-zoned (control group). The average difference in the land value for parcels that were up-zoned and parcels that were not up-zoned (control group) gives a causal effect of the up-zoning (the treatment).

A.3 Spatial Autocorrelation

A.3.1 Moran's I test for spatial autocorrelation

We test for spatial autocorrelation in the residuals for our modelled estimates in Steps 2 and 3. Results are shown in Table 37 and Table 38 below.

Table 37: Moran's I results – Logit estimation of likelihood to add at least one dwelling

Observed/Moran's I index	0.02223574
Expected index under null hypothesis	-0.000050025
Standard deviation of I under the null hypothesis	0.0002226476
P-value	0.0000

Source: Authors' analysis.

Table 38: Moran's I results – OLS estimation of FAR increase

Computed Moran's I index	0.01640531
Expected index under null hypothesis	-4.29203e-05
Sd	0.0003470399
P value	0.0000

Source: Authors' analysis.

These estimates imply that spatial autocorrelation is present with a high degree of confidence. This is not a surprise, given the model specifications and the geographic distribution of the spatial data employed. Development tends to occur in clusters, especially in areas where land is less scarce, such as the outskirts of Auckland. As a result, the estimates of confidence intervals and significance of coefficients may not be accurately estimated, as the distribution of residuals is non-random or not independent of proximity. We correct the standard errors to account for this spatial dependence in the following section.

A.3.2 Conley standard errors to correct for spatial autocorrelation

In the presence of spatial autocorrelation, the spherical error variance assumption is violated, and so econometric theory would suggest that the estimates of the standard errors are not consistent. Consistency of an estimator means that as the sample sizes gets larger and larger, the value of the estimator gets closer and closer to the true value of the parameter. That is, an estimator is said to be consistent if an estimator converges in probability to the true parameter value. This is often a desirable property as we can assume in large samples that the estimator is approximately its true value.

Conley (1999) presents a method to obtain asymptotically consistent standard errors in the presence of spatial autocorrelation by accounting for spatial dependence. We follow the method described in Conley (1999) for our regression for the probability of adding at least one dwelling and the regression for FAR increase given a property adds at least one dwelling.

The calculation of distance between every possible pair of observations is so computationally intense that it is impractical to run on the full dataset of 331 thousand parcels. Instead, we run the test on a random sample of 40 thousand parcels to understand whether the adjusted standard errors would alter the level of significance for our coefficient estimates of the slopes and intercepts of our estimated relationships between quality score and probability of adding at least one dwelling by zone.

Table 39: Conley standard error estimates for the probability of adding at least one dwelling

Variable	*Coefficient estimate*	*Standard SE*	*Spatial SE*	*Standard Z score*	*Spatial Z-score*	*Standard P-value*	*Spatial P-value*	*Signif. effect*
Intercept (in log odds)								
SHZ	-6.807	0.332	0.523	-20.522	-13.024	0.000	0.000	None
MHS	0.340	0.325	0.292	1.047	1.165	0.295	0.244	None
MHU	-0.266	0.321	0.303	-0.827	-0.878	0.408	0.380	None
THAB	-0.334	0.337	0.300	-0.992	-1.115	0.321	0.265	None
Slope vs. Quality Score								
SHZ	1.837	0.503	0.459	3.650	4.001	0.000	0.000	None
MHS	-0.220	0.539	0.473	-0.408	-0.464	0.683	0.643	None
MHU	0.875	0.526	0.526	1.664	1.663	0.096	0.096	None
THAB	1.395	0.550	0.418	2.536	3.338	0.011	0.001	Higher
Controls								
Log Distance	1.129	0.042	0.111	27.113	10.140	0.000	0.000	None
Special character	-0.742	0.191	0.141	-3.875	-5.258	0.000	0.000	None

Note: Estimates for a random sub-sample of 40,000 observations out of 331,105 parcels and parcel-clusters (where valuations involve multiple parcels) subject to the policy in the four primary residential zones.

As Table 39 shows, the adjustment for spatial autocorrelation has no statistically relevant effect except in cases where it increases the significance of the estimate. Based on this result, we are satisfied to use the original logit model, with the full sample of 331 thousand observations, for our forecast estimates. For the OLS estimate of FAR increase conditional on a property adding at least one dwelling, we run the dependence-adjusted estimate for the full dataset of observations. Results are shown below.

Table 40: Conley standard error estimates for FAR increase given a property adds at least one dwelling

Variable	*Coefficient estimate*	*Standard SE*	*Spatial SE*	*Standard t-score*	*Spatial t-score*	*P-value*	*Spatial P-value*	*Signif. effect*
Intercept								
SHZ	0.088	0.116	0.171	0.764	0.515	0.445	0.607	None
MHS	0.112	0.124	0.172	0.91	0.655	0.363	0.512	None
MHU	0.019	0.123	0.174	0.154	0.108	0.878	0.914	None
THAB	0.162	0.128	0.191	1.264	0.851	0.206	0.395	None
Slope vs. Quality Score								
SHZ	1.848	0.185	0.37	9.988	5	0.000	0.000	None
MHS	-1.495	0.202	0.37	-7.418	-4.04	0.000	0.000	None
MHU	-0.982	0.197	0.375	-4.99	-2.621	0.000	0.009	None
THAB	-0.778	0.205	0.404	-3.791	-1.927	0.000	0.054	Lower
Controls								
Land area	0	0	0	-1.999	-1.577	0.046	0.115	Lower

Note: Estimates use the full sample of 25,398 properties that added at least one dwelling post-AUP.

As with the logit model above, the OLS standard errors show no change in statistical significance when adjusted to account for spatial autocorrelation, except in the case of the slope for the THAB zone and the land area control, which become less significant. As our key coefficient estimates for the slopes and intercepts of the control and treatment zones are unaffected, we conclude that our model results are robust to spatial dependence.

Appendix B. Zone alignment tables

Table 41: Zone alignment for housing supply impact – Hamilton, Waipā, and Waikato

Provisions	**Medium Density Residential Standards**	**Hamilton**							**Waipā**	**Waikato**	
		General Residential	Medium Density Residential	Ruakura Medium Density Residential	Residential Intensification Zone	Special character zones, near inner city	Outlying Residential Development Zones (other structure plans)	Peacockes Structure Plan Area	Residential Zone	**Franklin Section**	**Waikato Section**
										Residential Zones	Living Zone
Dwellings permitted	**3**	1	None	1	None	1	None	None	1	1	1
Building height	**11m**	10m	10m	10m	12.5m	7m	8m to 10m	10m to 12m	9m	8m	7.5m
Height in relation to boundary	**6m + 60°**	3m + 28° to 45°	3m + 28° to 45°	3m + 28° to 45°	3m + 28° to 45° (Where adjoining general residential or special character)	3m + 28° to 45°	3m + 28° to 45°	3m + 28° to 45°	2.7m + 28° to 45°	3m + shortest distance between building and site boundary	2.5m + 37°
Building coverage	**50%**	40%	50%	50%	50%	35%	Up to 40%	8% to 50%	40%	Up to 40%	40%
Treatment		Align to AUP SHZ	Align to AUP SHZ	Align to AUP SHZ	Align to AUP SHZ	Align to AUP SHZ, Special Character Status	Align to AUP SHZ	Align to AUP SHZ	Align to AUP SHZ	Align to AUP SHZ	Align to AUP SHZ

Source: District Operative Plans, MfE, authors.

Table 42: Zone alignment for housing supply impact – Tauranga and Western Bay of Plenty

Provisions	**Medium Density Residential Standards**	**Tauranga City**				**Western Bay of Plenty**	
		Suburban Residential Zone	City Living Zone	High Density Residential Zone	Wairakei Residential Zone	Residential	Medium Density Residential
Dwellings permitted	**3**	1	2	1	1	1	1
Building height	**11m**	9m	9m	9m	9.5m	8m	9m 12m (Waihi)
Height in relation to boundary	**6m + 60°**	2.7m + 45° to 55°	2.7m + 45° to 55°	2.7m + 45° to 55°	2.7m + 45° to 55°	2m + 45°	2m + 45°
Building coverage	**50%**	45% - sites over 500m2 55 % - sites less than 500m2	45% - sites over 500m2 55 % - sites less than 500m2	No limit	No limit	40%	40%
Treatment		Align to AUP SHZ	Align to AUP SHZ	Align to AUP MHS	Align to AUP SHZ	Align to AUP SHZ	Align to AUP SHZ

Source: District Operative Plans, MfE, authors.

Table 43: Zone alignment for housing supply impact – Wellington and Lower Hutt

Provisions	**Medium Density Residential Standards**	**Wellington**			**Lower Hutt**		
		Outer Residential Area	Inner Residential Area	Medium Density Residential Area	General Residential Activity Area	Special Residential Activity Area	Medium Density Residential Activity Area
Dwellings permitted	**3**	2	1	1	2	1	No limit
Building height	**11m**	8m	10m	8m - Johnsonville 10m - Kilbirnie	8m	8m	10m
Height in relation to boundary	**6m + 60°**	2.5m + 45°	2.5m + 45° to 71°	2.5m + 56° to 63°	2.5m + 45°	2.5m + 45°	3.5m + 45°
Building coverage	**50%**	35%	50%	50%	40%	30%	60%
Treatment		Align to AUP SHZ	Align to AUP SHZ, special character status	Align to AUP SHZ	Align to AUP SHZ	Align to AUP SHZ, special character status	Align to AUP MHU

Source: District Operative Plans, MfE, authors.

Table 44: Zone alignment for housing supply impact – Upper Hutt, Porirua, and Kāpiti Coast

Provisions	**Medium Density Residential Standards**	**Upper Hutt**		**Porirua**	**Kāpiti Coast**	
		Residential	Residential (Centres Overlay)	Suburban Zone	General Residential Zone	General Residential Zone with Ōtaki Beach, Raumati, and Paekākāriki beach residential precincts
Dwellings permitted	**3**	1	1	3 (2 share a party wall and one detached)	1	1
Building height	**11m**	8m	8m	8m	8m	8m
Height in relation to boundary	**6m + 60°**	2.7m + 35° to 45°	2.7m + 35° to 45°	3m + 45°	2.1m + 45°	2.1m + 45°
Building coverage	**50%**	35%	45%	35%	40%	35%
Treatment		Align to AUP SHZ	Align to AUP SHZ	Align to AUP MHS	Align to AUP SHZ	Align to AUP SHZ with special character status

Source: District Operative Plans, MfE, authors.

Table 45: Zone alignment for housing supply impact – Christchurch

Provisions	**Medium Density Residential Standards**	**Christchurch**					
		Residential Suburban Zone	Residential Suburban Density Transition Zone	Residential Medium Density Zone	Residential Banks Peninsula Zone	Residential New Neighbourhood Zone	Residential Central City Zone
Dwellings permitted	**3**	1	1	No limit	1	No limit	No limit
Building height	**11m**	8m	8m	11m	7m	8m	8m to 30m
Height in relation to boundary	**6m + 60°**	2.3m + 55°	2.3m + 55°	2.3m + 55°	2m + 45°	2.3m + 55°	2.3m + 55°
Building coverage	**50%**	35%	35%	50%	35%	40% to 45%	No limit
Treatment		Align to AUP SHZ	Align to AUP SHZ	Align to AUP MHU	Align to AUP SHZ	Align to AUP MHS	Align to AUP THAB

Source: District Operative Plans, MfE, authors.

Table 46: Zone alignment for housing supply impact – Selwyn and Waimakariri

Provisions	Medium Density Residential Standards	Selwyn	Waimakariri			
		Living Zones	Residential 1 Zone	Residential 2, 3 and 6 Zones	Residential 6A Zone	Residential 7 Zone
Dwellings permitted	**3**	1	1	1	1	1
Building height	**11m**	8m	8m	8m	10m	8m 9m (Area A)
Height in relation to boundary	**6m + 60°**	2.5m + 30° to 55°	2.5m + 35° to 55°	2.5m + 35° to 55°	2.5m + 35° to 55°	2.5m + 35° to 55°
Building coverage	**50%**	40% approx average in most zones	50%	35%	24% to 38%	40% to 60%
Treatment		Align to AUP SHZ	Align to AUP SHZ	Align to AUP SHZ	Align to AUP SHZ	Align to AUP SHZ

Source: District Operative Plans, MfE, authors.

Appendix C. Population forecasting model

C.1 Approach

We use Sense Partners' population forecasting model to predict future demand.

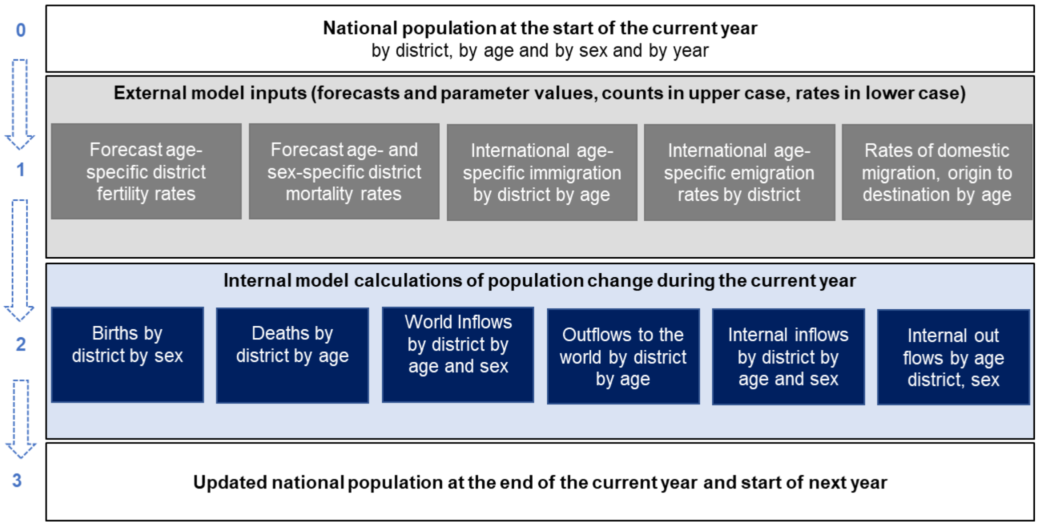
That model uses persistent and predictable structural and compositional characteristics of populations and economies to extrapolate future trends. The methods place a premium on respecting adding-up constraints (for example, domestic migration must sum to zero) and consistency between forecasts. For this reason, the model is a national model, with details for each of the Tier 1 cities.

The forecasts produced should be interpreted as potentials. There are many things that the forecasts do not consider, such as national or local policy changes which can affect actual population and economic growth.

To capture uncertainty around trends we conduct Monte-Carlo simulation, where inputs are varied randomly and repeatedly (500 times) to produce distributions over future values, rather than point estimates. This approach also helps to emphasise the considerable uncertainty that exists about the future and the extent to which this uncertainty grows the further out we look.

The forecasts are based on 4 component models: (i) fertility, (ii) mortality, (iii) international migration, and (iv) national migration. Modelling proceeds in a linear fashion through each of the models.

Figure 58: Population forecast model steps



Source: Authors' analysis.

C.2 Fertility

Fertility model

Births (B) by district (r) by sex (s) are forecast with:

$$B_{r,a=0,s,t} = \frac{B_s}{\sum_s B_s}\sum_a f_{r,a,t}N_{r,a,s=2,t} + \epsilon_t$$

where births (that is age at 0) are a function of:

- A fixed birth rate $\frac{B_s}{\sum_s B_s}$ of 0.513 for males and 0.487 for females
- The size of the population by age $(N_{r,a,s=2,t})$ of females $(s = 2)$ and the forecast age-specific
- fertility rates $(f_{r,a,t})$
- random variation in total births from year to year, using $\epsilon_t \sim N(0, \sigma)$ where the standard error (σ) is estimated from a model used to predict the district births using estimated age specific regional fertility rates.

Fertility Data

The fertility data includes:

- National age-specific fertility rates (Stats NZ, 1980-2019)
- Regional age-group-specific fertility rates (Stats NZ, 1996, 2001, 2006, 2013)
- Regional age-specific fertility rates are estimated using polynomials fitted to the ratio of regional observed age-group rates and national observed age-group rates (see Figure at right for sample of estimated age-specific regional rates)

Forecast method

The functional demographic model used for forecasting regional fertility rates, based on estimated region-specific rates. The functional demographic model is a generalisation of the standard and widely used 'Lee-Carter' model, which decomposes trends in age-specific demographic rates, such as fertility, into components. We include the interaction between age effects and time trends to account for displacement effects such as an increase in fertility rates at age 30 when fertility rates at age 29 decline.

Then, variations in fertility rates across districts estimated with 'fixed effects' (differences in averages) from a model of total birth rates, by district, based on regional fertility rates. Historically fitted fixed effects are assumed to persist in future.

C.3 Mortality

Mortality model

Number of deaths are determined by:

- the size of the population by age $(N_{r,a,s,t})$
- forecast age-specific mortality rates $(f_{r,a,t})$
- random variation in deaths from year to year using $\epsilon_{at} \sim N(0, \sigma_{as})$, where the age- and sex-specific standard error (σ) is based on the average difference between model fitted mortality rates and observed mortality rates.[35]

So deaths (X) by district (r) by age (a) by sex (s) are forecast with the equation:

$$\mathrm{X}_{\mathrm{r,a,s,t}} = (x_{r,a,s,t} + \epsilon_{at}).N_{r,a,s,t}$$

---

[35] We use a national-level model (due to significant smoothing/interpolation in district-level data).

Mortality data

The mortality model uses the following data

- National age- and sex-specific cohort life tables from Statistics New Zealand over 1876-2018.
- Subnational (district) age-group and sex-specific life-tables from Statistics New Zealand for 1996, 2001, 2006, 2013.[36]
- National changes (growth rates) in age-specific mortality rates are used to update the estimates of subnational age and sex-specific mortality rates (to 2018).

Mortality forecast method

A coherent functional demographic model is used for modelling and forecasting district mortality rates.[37]

The mortality model method is very similar to the fertility model method (a functional demographic model) with the addition that the model includes consideration of relative mortality rates across different genders to ensure that forecasts are consistent. That is, they ensure male and female mortality rates do not move too far apart, as reflected by historical ratios of male to female mortality rates.

C.4 International Immigration

The international immigration model

The immigration model forecasts immigration by district, age and year, that is:

$$m_{d,a,t} = m^*(m^*_{t-1}, \alpha_t, \epsilon_t). p(a|m). p(r|a, m)$$

Immigration ($m_{d,a,t}$) by district (r) and age (a) and year (t) is a function of exogenously forecast stochastic growth rates (α_t with error $\epsilon_t \sim N(0, \sigma_{\alpha_t})$) for national immigration (m^*) and fixed probabilities/shares for

- ages of immigrants ($p(a|m)$) and
- district destination conditional on age ($p(r|a, m)$)

The model includes arbitrary ‘shifters’ on immigration that are used to control for e.g. shocks, for example, border closures with the immigration fixed, by year, at a chosen proportion of expected/forecast immigration inflows.

Uncertainty is modelled by varying the national immigration forecast using random selection from $\epsilon_t \sim N(0, \sigma_{\alpha_t})$.

International immigration data

Data in the model includes emigration, departure data, immigration, GDP, exchange rate data and unemployment rates in New Zealand and internationally. All data is pre-COVID and seasonally adjusted where appropriate.

---

[36] Rates for individual ages are interpolated based on splines fitted on age and the log of the mortality rate).

[37] See Woods and Dunstan 2014.

To reduce the dimensionality of the data we use cluster analysis to identify four groups of related countries that form the basis of our forecasts, we label these groups:

- **Commonwealth countries** Non-New Zealander immigration from the United Kingdom, Singapore and India. This groups has a stable upward trend.
- **Growth countries** – dominated by China (non-New Zealand), Australia (non-New Zealand) and New Zealanders returning from the United Kingdom. This is a high growth group.
- **Returning New Zealanders** who are returning from Australia, Samoa, Hong Kong
- **Other** - numerous countries dominated by Non-New Zealand citizen movements. This spiked higher in the 1990s but has flat since this time.

The migration data we use is Stats NZ's 12/16 month rule (labelled Emigration and Immigration at right) with the history of the data back cast using correlations between overlapping 12/16 month rule and permanent and long-term arrivals and departures data.

Observations about data characteristics

We hold constant the age profile of migrants at the most recent age-profile of immigrants. The age profile of migrants is, broadly speaking, highly stable, although in recent years there has been a material increase in the share of migrants aged between 18 and 30 and a decline in the share of immigrants under 18.

The sex of international immigrants is assumed to be 50% male and 50% female.

Modelling national migration

We have several modelling options and choose to average over 5 models:

- Simple vector auto-regression model containing total immigration and emigration, 6 lags and trend and intercept terms
- Univariate time series trend model for aggregate immigration
- Univariate time series trend model for immigration from each of our 4 country groups
- Simple vector error-correction model incorporating total emigration and immigration from each of our country clusters (i.e. 5 endogenous variables)
- Vector error-correction model with macro-economic variables, incorporating total emigration, immigration from each of our country clusters, the Australian and New Zealand unemployment rates and the New Zealand trade-weighted exchange rate.

The average over the models can be based on equal weights on each model (default in the model at right) or through calibration of weights to produce best-fitting overall model (historically).

The forecast standard error σ_{α_t} is calculated based on the lower bound of the forecast confidence interval from the 5 models and the smallest of the upper bounds from the 5 models.

International emigration

There are no up-to-date indicators of international emigration by district and age since Stats NZ/government stopped collecting data on departures by district and age in 2018.

We use Stats NZ data on permanent and long-term departures prior to 2018 to estimate international emigration rates by district.

We adjust our models to account for persistent differences between national total permanent and long-term departures and the more robust 12/16 month rule emigration measure – based on whether travellers spend 12 of the following 16 months out of NZ

- net migration is very similar whether measured by permanent and long-term arrivals and departures or the 12/16 month rule, however
- arrivals overstate immigration and
- departures understate emigration (by ~40% on average in the past 10 years).

Forecasting international emigration

The core of the model is estimated mean rates/propensities of migration by age group and district.

A simple autoregressive model is fitted to rates of emigration by age-group and district, to ensure that emigration dynamics (persistence) are accounted for and so that we can estimate model errors (i.e. for stochastic simulation):

$$e^{w}_{r,a,t} = \mu^{w}_{r,a} + u_{r,a,t} u_{r,a,t} = \rho_{r,a} u_{r,a,t-1} + \epsilon_{r,a,\,t} \epsilon_{r,a,t} \sim N\left(0, \sigma_{\epsilon_{r,a,t}}\right)$$

where $\mu^{w}_{r,a}$ is the mean rate of emigration, the $u_{r,a,t}$ and $\epsilon_{r,a,\,t}$ are error terms (the former being structural deviation from mean and the latter being pure model error) and $\rho_{r,a}$ is the autoregressive term to be estimated.

The means ($\mu^{w}_{r,a}$) and standard errors ($\sigma_{\epsilon_{r,a,t}}$) of the models are adjusted by the mean of the ratio of the national 12/16 month rule emigration to mean permanent and long-term departures (1.35), to account for under-counting of emigration using departures data.

C.5 Domestic migration

The domestic migration model

Internal emigration (E^{i}) between districts (r) by origin and destination (o and d) and age (a) is modelled as a function of:

- district populations ($N_{r,a,t}$)
- emigration rates by origin-destination ($e^{i}_{o=r,\,a,t}$).

$$E^{i}_{r,a,s,t} = \sum_{d} N_{r,a,t} e^{i}_{o=r,\,d,a,t}$$

Age-specific rates of emigration, from an origin to a destination comprise two parts:

$$e^{i}_{o,d,a,t} = p\left(E^{i} \middle| r, a\right) . p\left(E^{i}_{od} \middle| E^{i}\right)$$

- $p\left(E^{i} \middle| r, a\right)$ = district- and age-specific probabilities/propensities that a person will emigrate
- $p\left(E^{i}_{od} \middle| E^{i}\right)$ = district- and age-specific probabilities/propensities that a person will migrate to a specific district (destination), given that they have chosen to emigrate

Domestic immigration is the sum over origins of domestic emigration to a particular destination.

$$M^{i}_{r,a,s,t} = \sum_{o} N_{r=o,a,s,t} e^{i}_{o=r,d,a}$$

Domestic migration data

Domestic migration data includes census domestic migration rates 1991, 1996, 2001, 2006, 2013. These rates are remarkably stable over time, in large measure because they are dominated by predictable/stable life-cycle effects and age-specific rural-urban movements.

Data on origin-destination movements are estimates from administrative data, for 2014-2017. Census data can be used for this purpose however it is very difficult to infer age-specific and year-specific movements solely from cumulative 5-yearly population snapshots. The recent data is also of low quality as concerns domestic migration origin-destination flows.

Forecasting domestic emigration

We use simple average of shares of emigrants from an origin to all potential destination districts/destinations in New Zealand. This is the average over the four years from 2014 to 2017. Matching quality is poor, suggesting that focussing on single years of data is unwise.

Appendix D. Introducing Icarus

D.1 Motivation

As cities intensify and move higher, how sunlight naturally falls upon properties changes. This can create costs from new developments. In practice, these urban development negative 'externalities' have been addressed through inflexible regulatory rules that specify allowable building parameters.[38] So relaxing these rules could generate costs in terms of loss of sunshine.

We assume that new builds have similar shade characteristics to the existing housing stock. This simplification means we do not need to consider the shade profile of new builds.

D.2 The Icarus model

Icarus is an urban development shade pricing model developed in R.[39] The model operationalises the sunshine pricing methodology developed in Fleming et al. 2018 to evaluate the shade costs of new urban developments.

To our knowledge, Icarus is the first urban development sunshine externality costing model that can support large-scale urban development planning initiatives. Using geospatial information on building location and height, Icarus tracks the sun and estimates the value of the shade cast by a new development onto its neighbours. The 'shadow price cost' of shade reflects the loss in house price market value from the increased shade experienced by neighbours surrounding a new urban development.

D.3 Methodology

D.3.1 Economic theory

Using over 5,000 observations on house sales in Wellington, Fleming et al. 2018 estimates a home buyer's willingness to pay for an extra daily hour of sun, on average, across the year.

After controlling for locational sorting and other considerations in a hedonic regression, they find each extra daily hour of sunlight exposure is associated with a 2.4% increase in house sale price. Their estimate was robust to a variety of alternative econometrics modelling specifications.

The authors suggest their results could be used to price negative externalities caused by new development, replacing inflexible regulations designed to address impacts of development on neighbours' sunshine.

D.3.2 A little bit of physics

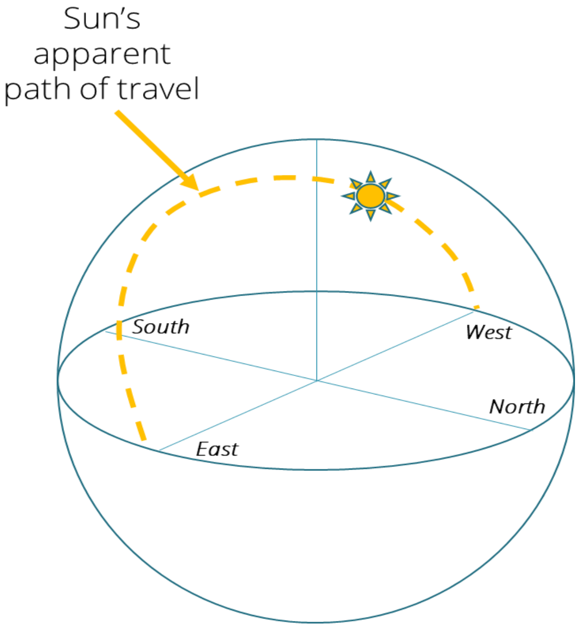
Fleming et al. 2018 estimate the quantum of sun for each property based on modelling the sun at different times of the year for each property location and estimating the impact of buildings as obstacles to sunlight (see Figure 59).

Over the course of the year, as the Earth orbits the sun, the sun's apparent location in the sky changes, so our model needs to track the course of the sun throughout each day over the year.

---

[38] Fleming et al. 2018 on page 1
[39] https://www.r-project.org/

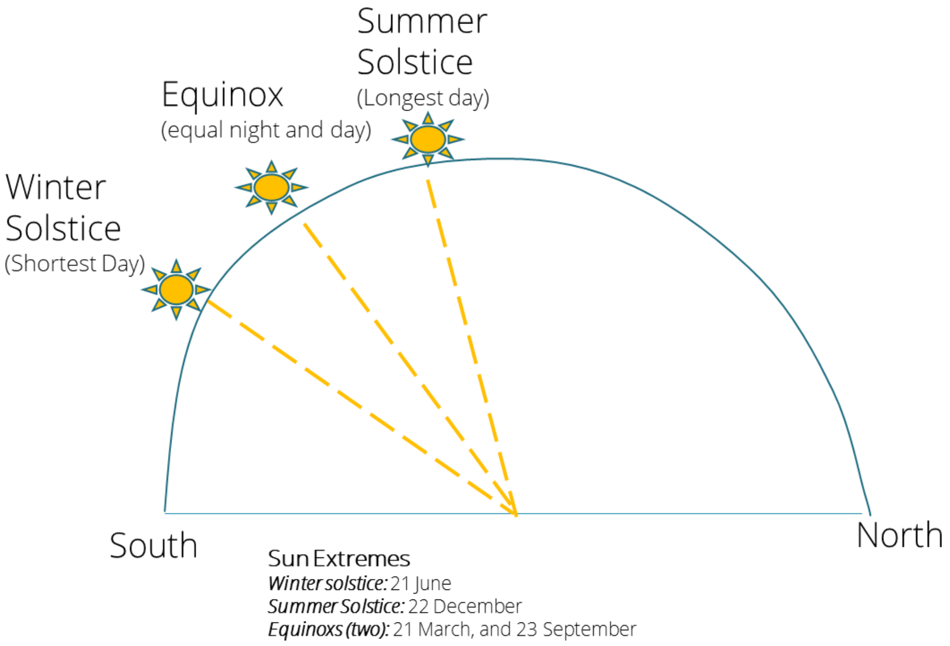
Figure 59: Our model starts by tracing the movement of the sun



Source: Authors.

The sun is highest in the sky, and casts the smallest shadows, on the summer solstice in December each year. It is lowest in the sky on the winter solstice in June, where its shadows are the longest. There are two midpoints each year (the equinox's), when the Earth is returning to the sun (September), or heading away from the sun (March). We evaluate sun at each solstice and for each equinox (see Figure 60).

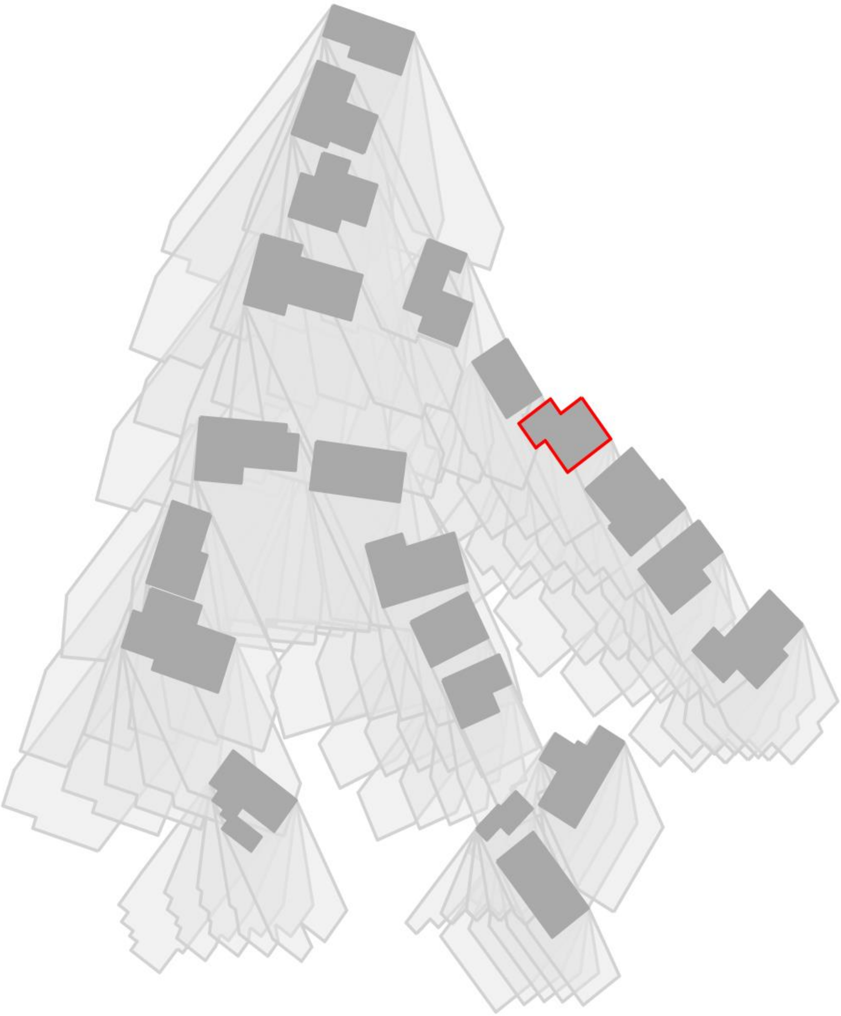
Figure 60: We evaluate shade at the summer and winter solstice and each equinox



Source: Authors.

Even over the course of a day, as the sun's apparent position travels from east to west, the location of its cast shadows change (see Figure 61).

Figure 61: Shadows from a specific building change over the course of the day



Source: Authors.

Icarus estimates the shade on a surrounding building to a property twice on both the solstice's and on an equinox day. Based on these daily estimates, an average quantity of daily sunlight its calculated for each property for each year.

Icarus estimates the *marginal shade* created by new development. For each of the solstice and equinox days, Icarus first estimates the shade falling on the surrounding neighbour properties *in the absence* of any development on the target land.

Secondly, Icarus calculates a fictional three-dimensional building located at the centroid of the target property land, and re-estimates the amount of shade each neighbouring property receives on each of the solstice and equinox days.

The loss in sunlight is calculated as the difference between the average daily shade across the year from each of the two measurement cycles. Consequently, the loss in sun for each neighbouring property between the two estimates is *directly attributable* to the new development occurring on the target property.

Icarus translates the C++ programme of Reda and Andreas (2003) that accurately tracks the sun, requiring only the latitude, longitude and the time of day/year, into R.[40]

D.3.3 Three-Dimensional Building Models

Icarus creates a three-dimensions model of the target property and all buildings within 50 meters of the target properties boundary. Spatial building outline information was derived from Land Information New Zealand (2021) data,[41] which provided latitude and longitude spatial geometric shapes of buildings across New Zealand.

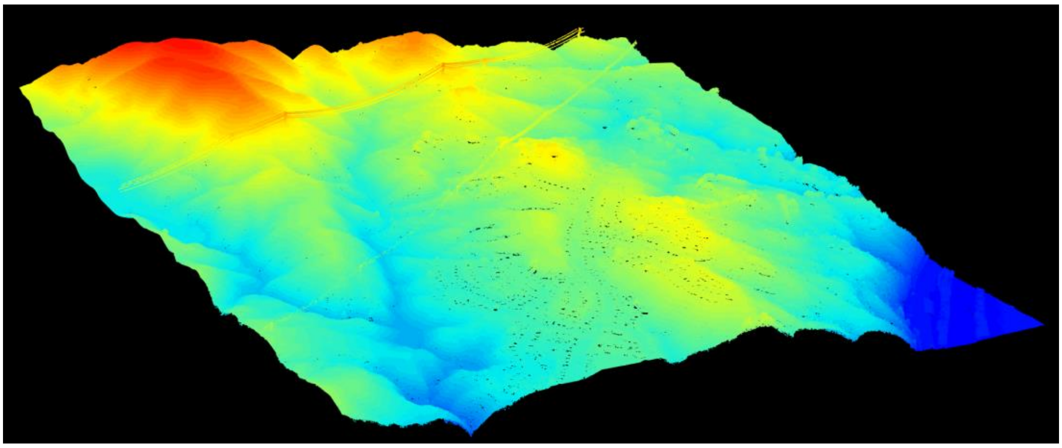
Estimating height from LiDAR

Estimating the height of each building and factoring in underlying slope structure of the ground underneath the properties was undertaken using LiDAR data.

LiDAR[42] is a laser-based method for estimating the contour and shape of land (Figure 61 below).[43] LiDAR is sourced from aerial collection methods where a laser data source is projected onto the ground and return back to a plane flying over land. Based on return times and light intensity LiDAR is able to estimate the ground terrain and the height of objects on the ground.

LiDAR was used to estimate both the level of building above the ground, together with the level of builds relative to sea-level. The sea-level estimate factors into the shadow analysis the potential the cast shadows might be accentuated by the slope of the ground surrounding the properties. For example, in figure 4.3, buildings at the top of the picture are further up a hill compared to buildings at the bottom of the hill, accentuating the shadows they cast over their neighbours.

Figure 62: Example of using LiDAR to measure height over a suburb



Source: Authors' analysis.

---

[40] This is the data source for modelling the sun employed in Fleming et al. 2018.

[41] Released by LINZ under Creative Commons Attribution 4.0 International (CC BY 4.0) with the following Attribution: Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0. For details see https://www.linz.govt.nz/data/licensing-and-using-data/attributing-linz-data

[42] Light Detection and Ranging (LiDAR)

[43] https://en.wikipedia.org/wiki/LiDAR

Estimating Neighbouring Market Value

Fleming et al. 2018 estimate a hedonic regression that explains market transacted house prices as a function of a range of value drivers, like land area and number of bedrooms, together with the volume of shade each house experienced. The market value of the house is derived from historically measured transacted values.

In the absence of historically measured transacted house prices, uses current property values from Homes.co.nz's HomesEstimate.[44] HomesEstimate is Homes.co.nz's estimate of a property's market value, computed using their proprietary formula. The HomesEstimate measure is calculated from public data, registered valuer's valuations, and real estate agent CMA's. Its accuracy depends on the availability and accuracy of council and sales data in an area that we show in Table 47.[45] The estimates appear a reasonable proxy for sales prices.

Table 47: Accuracy of HomesEstimate valuations vs. subsequent sales

Urban Area	*Median error*	*Within 10%*	*Within 20%*
Auckland	9.50%	52.05%	78.41%
Wellington	9.93%	50.00%	78.65%
Tauranga City	6.00%	66.85%	84.27%
Hamilton City	7.97%	61.85%	91.33%
Hutt City	7.34%	68.70%	87.02%
Waimakariri District	11.95%	39.29%	75.00%
Selwyn District	11.84%	40.20%	69.61%
Christchurch	11.93%	41.24%	79.38%
Porirua City	6.53%	65.38%	94.23%
Upper Hutt City	6.07%	78.85%	90.38%

Source: Homes.co.nz.

D.3.4 Shadow cost sensitivities

Results are sensitive to the urban density immediately around the target property. Everything else equal, building in dense residential zones will result in more shadows cast onto neighbours. Properties which are small imply neighbours which are closer and more susceptible to shadows from urban development.

Results are also sensitive to the market value of neighbouring properties. Our elasticity applies the value of the property, meaning shade cast on more expensive properties generates larger costs.

Shadow costs require neighbouring values. Greenfield development - where whole new suburbs are created - are the absence of established existing housing and result in no shadow costs. Consequently, the market value of greenfield development fully incorporates the value of urban density and associated shade into the initial sale price to new homeowners.

D.3.5 Measurement Issues

Geographic-specific Views

Missing from the Icarus model are 'views': the unobscured ability to view aspects of the local geography, unobstructed by the neighbours' property. In the original Fleming et al. 2018 paper, the researchers were unable to quantify the value of being able to see the sea or other significant geographic feature. Undoubtably 'view' value exists, but once house transactions factored in the

---

[44] https://homes.co.nz/homesestimate

[45] Extracted from https://homes.co.nz/homesestimate on the 11 October 2021

spatial location of the property in a suburb, views no longer had a separate statistically significant value from the fixed suburb value affecting all of the properties in a geographical location.

With its three-dimensional data sources, Icarus is suited to incorporating a view dimension subject to price-relevant views being identified. However, more research akin to the original Fleming et al. (2018) paper, but incorporating Icarus's LiDAR data sources, would be needed to quantify a 'view' effect.

Sun Intensity

Icarus treats all sun intensity the same, despite intensity varying significantly across both the day and the year. Conceivably, shadows cast in the morning and the evening, with weaker intensity, are less detrimental to a property's enjoyment, compared to shadows cast at the height of the day.

Fleming et al. (2018) tested whether house prices differentiated between winter and summer shadows, where sun intensity varies significantly, and found no statistically significant price effect. In the absence of indications to the contrary, their findings suggest sun intensity does not significantly affect traded house prices.

Urban Area Specific Shadow Elasticities

Fleming et al. 2018 estimate the value of shade for Wellington. Icarus incorporates the Wellington house price elasticity for estimating the value of shade across the other major urban areas.

Each urban area having the same shadow price elasticity is assumed in the modelling; however, potentially shadows cast in different areas might be priced differently. Fleming et al. 2018 estimate of 2.4% of the value of a Wellington house reflects the characteristics of Wellington's housing market, including its hilly terrain. Conceivably Christchurch and Tauranga, which are flatter areas with differing house characteristics and prices, might possess different shadow price elasticities.

Without extending the analysis in Fleming et al. 2018 into these areas, any geographical differences in shadow house price elasticities are unknown.

Missing data sources

Icarus requires building outline data and LiDAR data to calculate three-dimensional building shapes and estimate cast shadows. Some areas, specifically very new greenfield areas, lack building outline information. We restrict property sampling to properties which meet all of its data requirements. However, excluded properties are factored back into overall cost estimates through the stratified survey process, when the sample of properties is inflated back to reflect the population metrics.

D.4 Costing the MDRS impact

We estimate the decrease in house value of neighbouring properties assuming a three-storied / three-unit building was constructed on a neighbouring site.

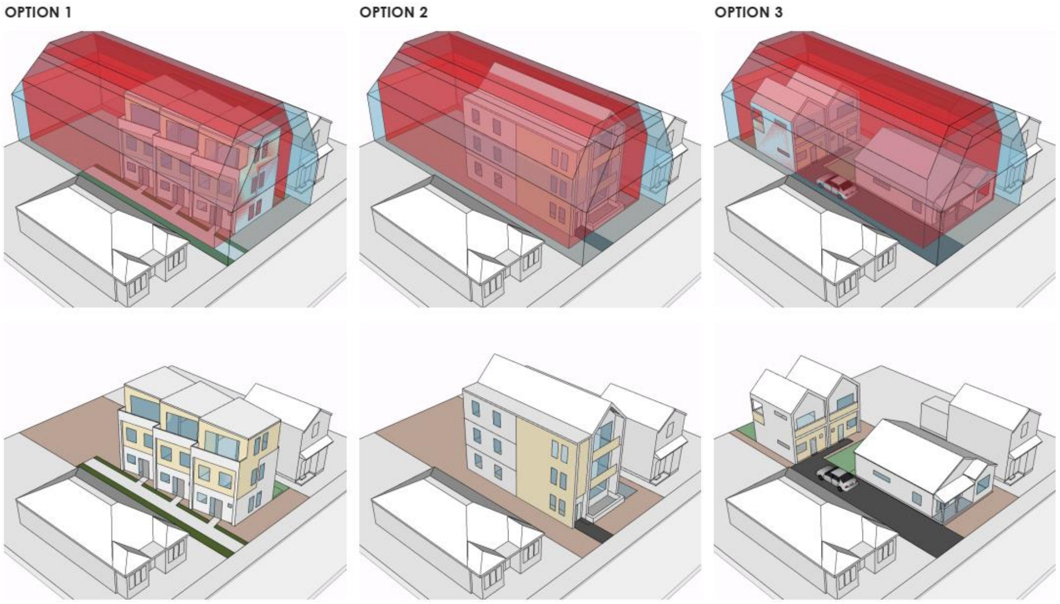
D.4.1 Location of properties

Using our modelled outputs on the potential spatial distribution of added dwellings under the policy we identified a set of sample properties in each urban area as described in the Section D.4.4 of this paper.

D.4.2 Modelled residential development

MfE supplied potential development specifications, shown in Figure 63 below.

Figure 63: Potential Development building prototypes



Source: MfE modelling.

Note that while three-storey buildings are rarely taller than 12 metres, we modelled the quantum and cost of the shadows cast by a 13m long building, 7 meters wide and 15 metres high (red envelope in Figure 63). onto its neighbours as a conservative choice.

D.4.3 Land Area-stratified Simple Random Sample

Icarus estimates the *change in shadows* cast onto neighbours from the erection of a new building built on a target property. Consequently, its methodology estimates shadows *twice*: once before the modelled residential development is build, and secondly, introducing a modelled building onto the property.

Given its double handling of each target location, Icarus is data-processing-intensive. Consequently, a stratified survey sampling approach was implemented to reduce the data processing costs from estimating development for all modelled properties. Target properties within each Tier 1 urban environment were stratified by land area size, with a random sample of 10 properties selected from each stratum (see Table 48).

Table 48: Stratum Land Sizes

Decile Band	*Auckland*	*Christchurch*	*Hamilton*	*Tauranga*	*Wellington*
0% - 10%	0 - 254	0 - 102	0 - 301	0 - 300	0 - 265
10% - 20%	254 - 361	102 - 431	301 - 398	300 - 349	265 - 337
20% - 30%	361 - 417	431 - 501	398 - 430	349 - 390	337 - 393
30% - 40%	417 - 490	501 - 578	430 - 497	390 - 425	393 - 442
40% - 50%	490 - 583	578 - 610	497 - 550	425 - 487	442 - 498
50% - 60%	583 - 652	610 - 638	550 - 611	487 - 592	498 - 518
60% - 70%	652 - 745	638 - 688	611 - 648	592 - 678	518 - 562
70% - 80%	745 - 820	688 - 783	648 - 707	678 - 810	562 - 636
80% - 90%	820 - 993	783 - 904	707 - 809	810 - 854	636 - 781
90% - 100%	993 - Inf	904 - Inf	809 - Inf	854 - Inf	781 - Inf

Source: Authors' analysis.

To estimate the total costs of shadows for all our modelled added dwellings, the decile populations were adjusted to reflect the number of properties *not* covered by building outlines and LiDAR data sources. Consequently, the population values in Table 49 vary for some urban areas and decile sizes. Increasing populations to reflect the full set of added dwellings increases estimate accuracy.

Table 49: Stratum Population Size

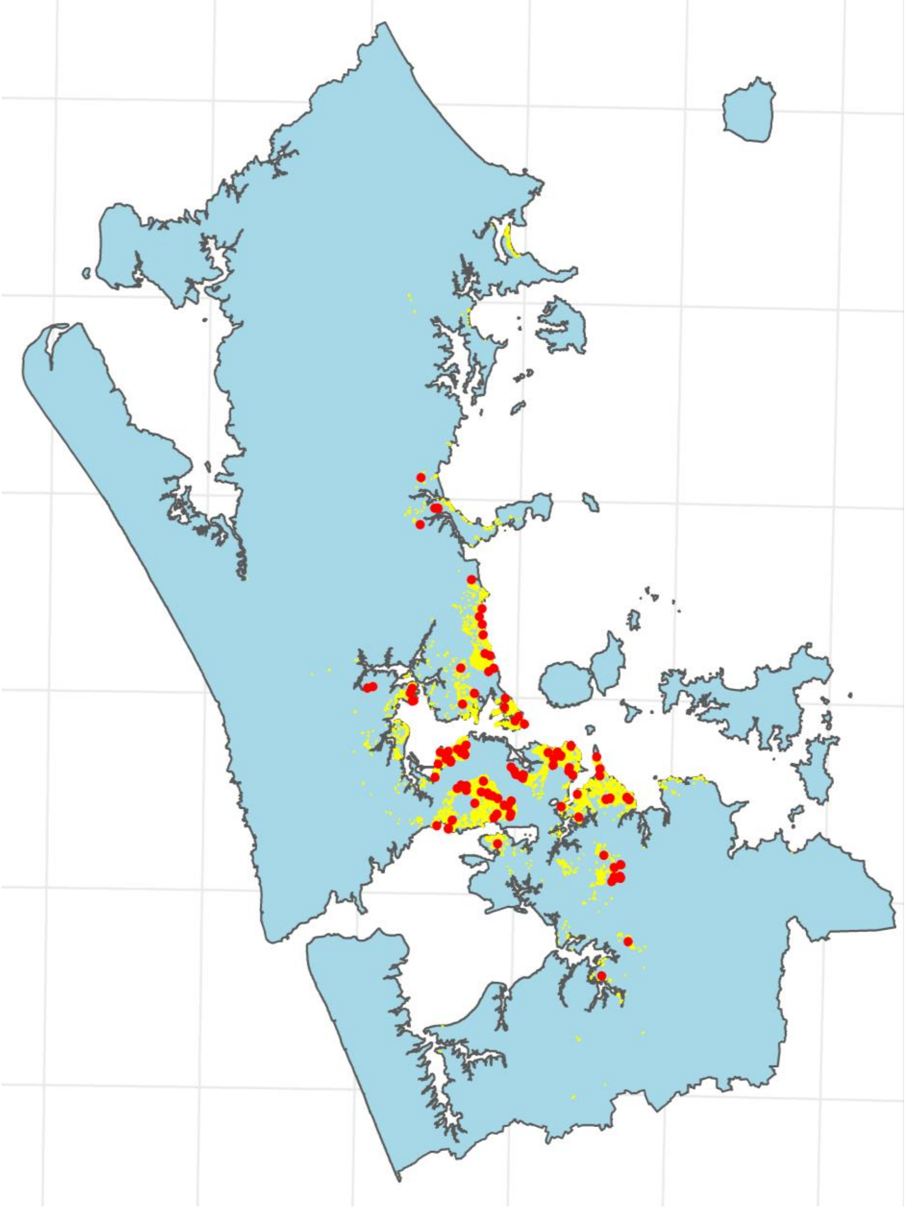
Decile Band	*Auckland*	*Christchurch*	*Hamilton*	*Tauranga*	*Wellington*
0% - 10%	2,698	956	556	420	405
10% - 20%	2,698	1,109	547	449	436
20% - 30%	2,697	992	595	447	694
30% - 40%	2,698	1,011	726	433	566
40% - 50%	2,698	1,002	743	447	605
50% - 60%	2,698	982	907	441	563
60% - 70%	2,698	1,000	680	476	633
70% - 80%	2,697	998	666	471	673
80% - 90%	2,698	1,021	657	473	773
90% - 100%	2,698	1,076	1,053	496	834

Source: Authors' analysis.

D.4.4 Sample coverage

Figure 64 to Figure 69 show the location of target properties from our housing supply forecasts (yellow dots), and the 100-observation random sample drawn for each region.

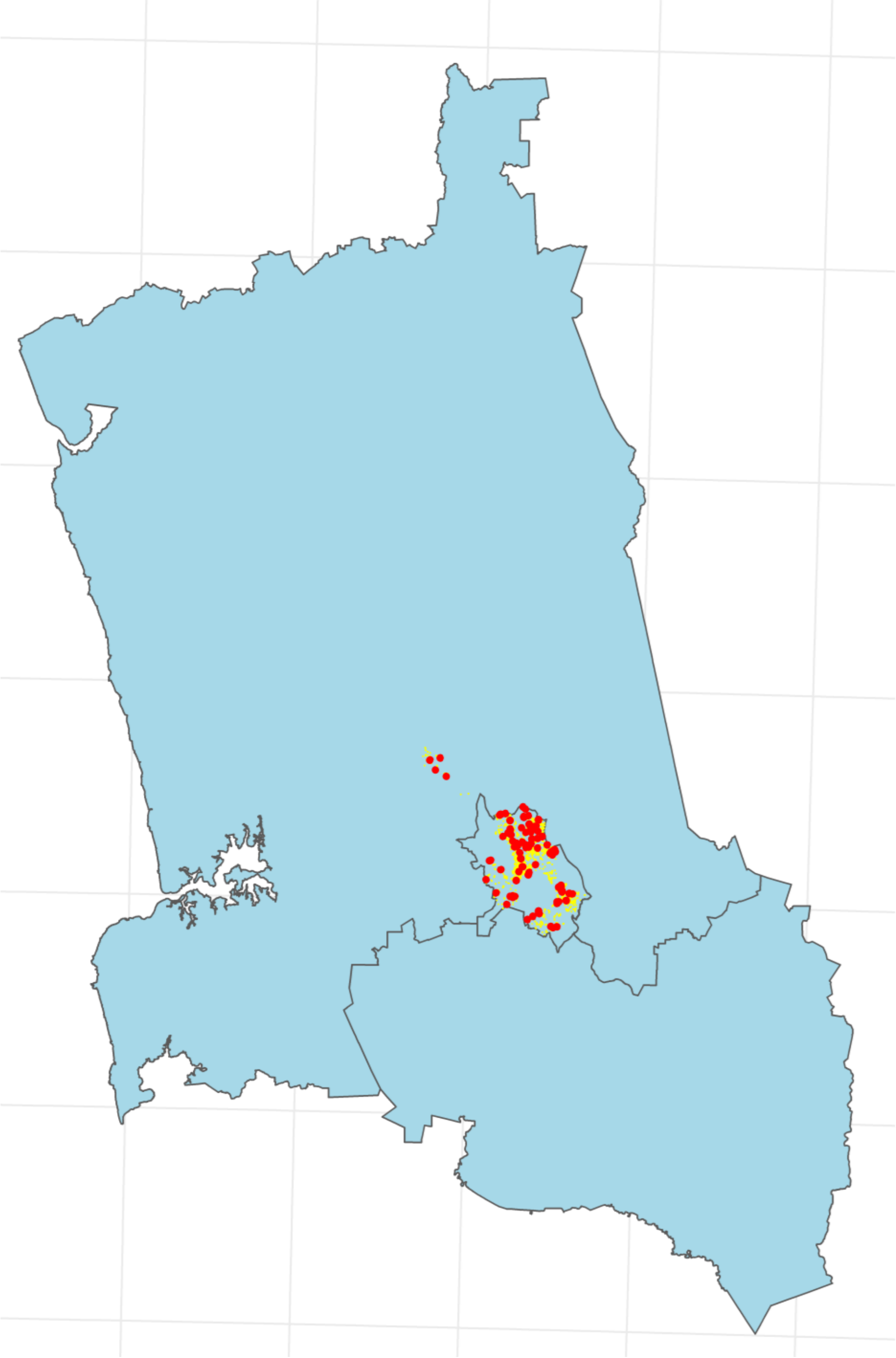
Figure 64: Sampling coverage for Auckland



Source: Authors' analysis.

Note: Simulated with-policy development forecast shown in yellow, sample locations shown in red.

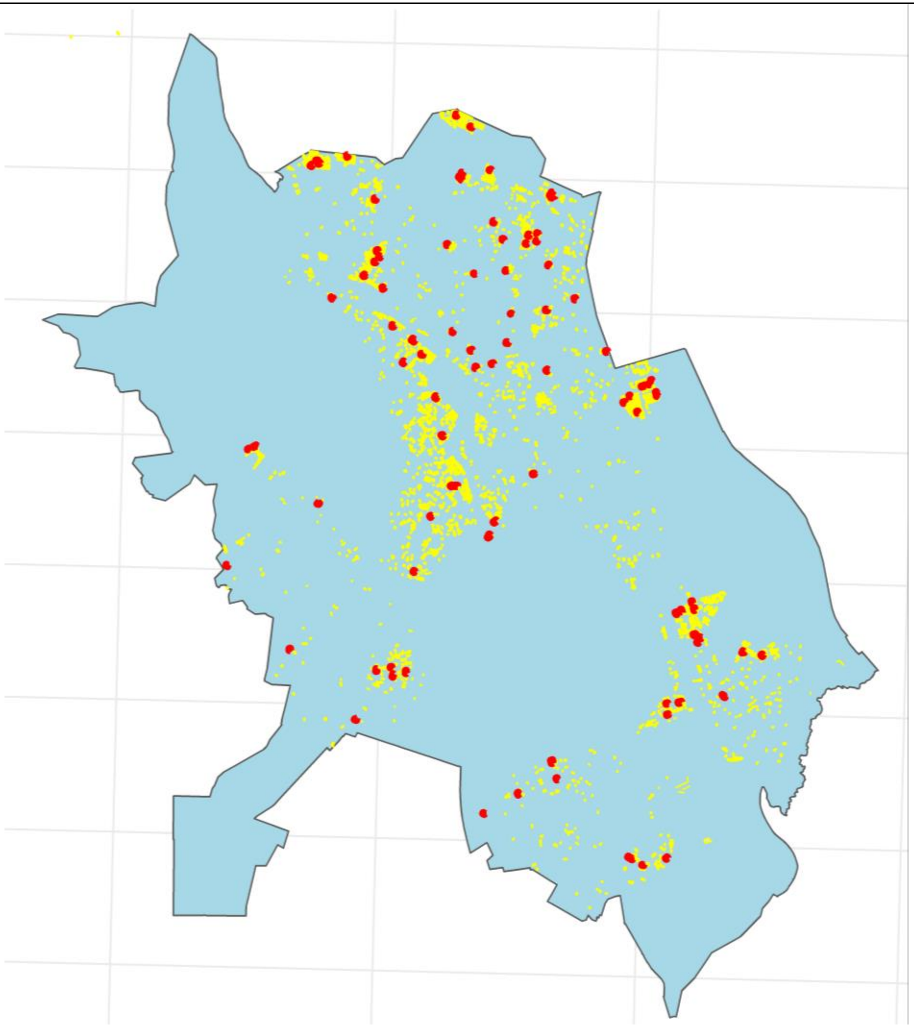
Figure 65: Sampling coverage for Hamilton greater urban area



Source: Authors' analysis.

Note: Simulated with-policy development forecast shown in yellow, sample locations shown in red.

Figure 66: Sampling coverage for Hamilton city



Source: Authors' analysis.

Note: Simulated with-policy development forecast shown in yellow, sample locations shown in red.

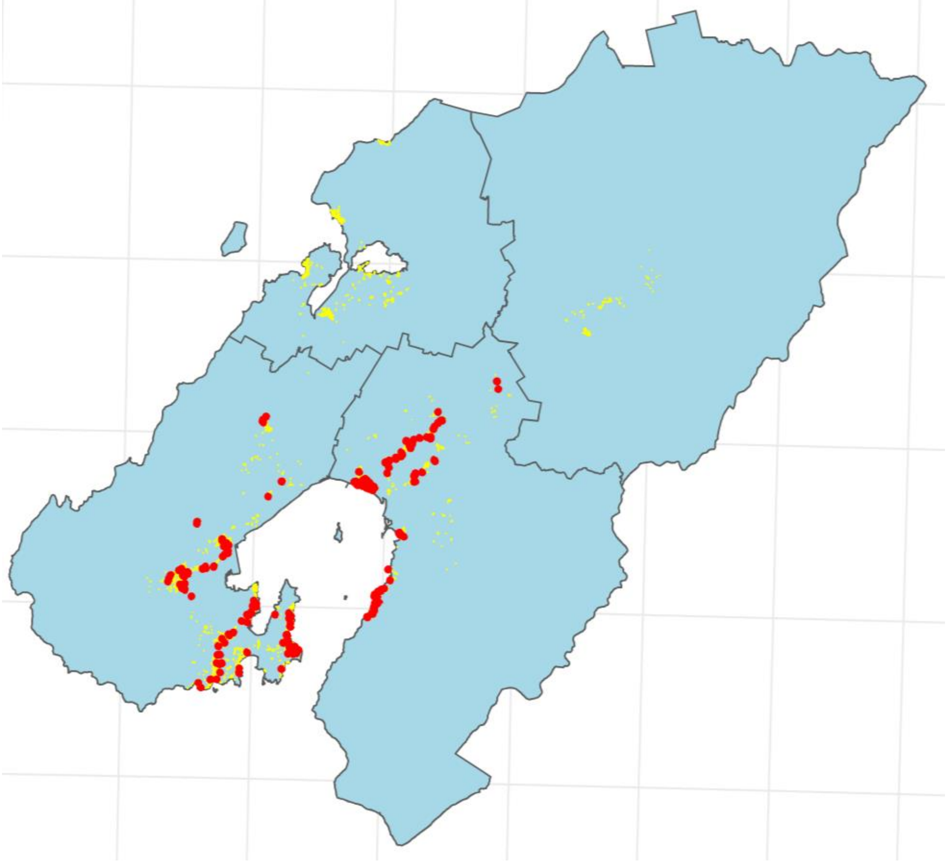
Figure 67: Sampling coverage for Tauranga greater urban area

Source: Authors' analysis.

Note: Simulated with-policy development forecast shown in yellow, sample locations shown in red.

Unfortunately, no LiDAR data was available for Porirua City. Our estimates also set to one side data, that was not developed in time to be deployed for Upper Hutt city. Consequently, while Porirua and Upper Hutt were omitted from the sample, their volumes of target properties were included in the decile population sizes.

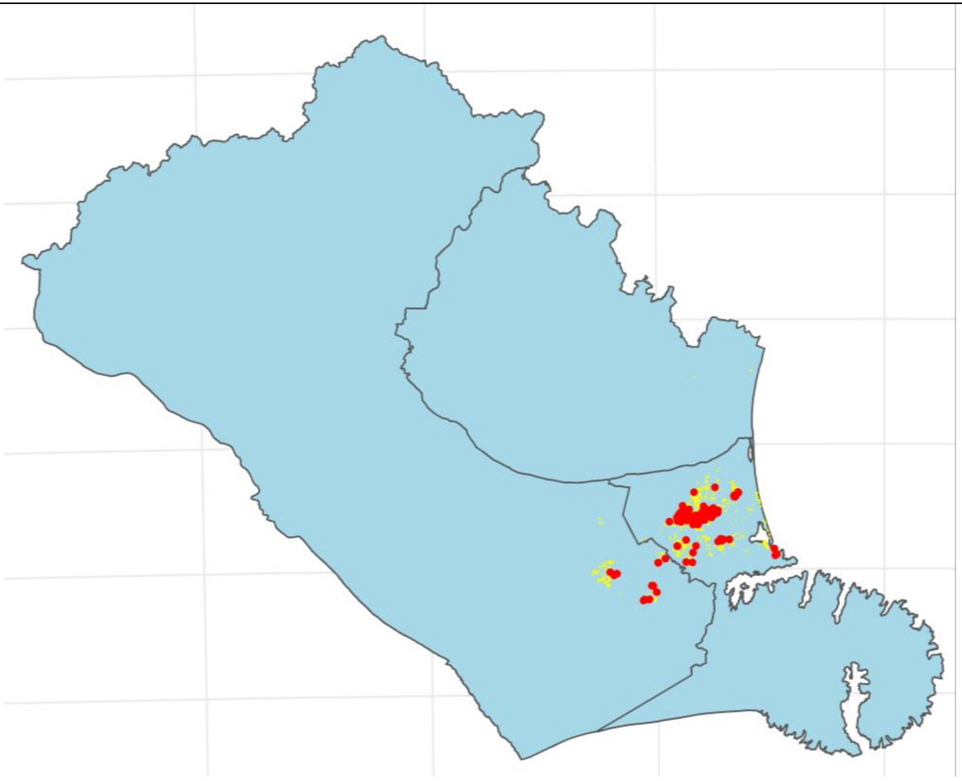
Figure 68: Sampling coverage for Wellington greater urban area



Source: Authors' analysis.

Note: Simulated with-policy development forecast shown in yellow, sample locations shown in red.

Figure 69: Sampling coverage for Christchurch greater urban area



Source: Authors' analysis.

Note: Simulated with-policy development forecast shown in yellow, sample locations shown in red.