20 February 2020

An evidence-based approach

Does the Rural Urban Boundary impose a price premium on land inside it?

FINAL REPORT

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Executive Summary

We calculate the price premium on developed residential land inside the Rural Urban Boundary relative to farm and lifestyle land outside the boundary. We find the boundary is likely to add a price premium of at most ***5.2% to developed residential land inside the boundary compared to*** farmland ***outside, and*** at most ***4.2% compared to*** lifestyle ***land outside. These premiums are substantially lower than estimates in previous studies, and are before accounting for any social costs of more expansive development not included in market prices, such as increased congestion or emissions.***

Housing affordability remains a challenge for many in Auckland. The finger of blame often points at land use rules, such as the old Metropolitan Urban Limit (MUL) or current Rural Urban Boundary (RUB) in Auckland. If the boundary results in a premium that materially increases the cost of housing, then given Auckland's housing affordability challenge, there would be an argument for removing the boundary.

Keeping or removing the boundary is fundamental to Auckland's future shape, infrastructure needs, transport patterns and community outcomes.

No studies on growth boundaries have considered whether there is a price premium on land inside Auckland's RUB since the Unitary Plan was implemented – the biggest change in zoning rules in New Zealand's history. Previous studies have other limitations too, such as excluding bulk infrastructure costs in greenfield areas, or assuming all land is geographically identical (i.e. location doesn't matter).

Our study asks whether the RUB imposes a price premium on residential land inside it, compared to farm or lifestyle land outside the RUB if that land were developed into similar residential development. We account for characteristics of the dwelling, location and land to isolate the impact of being inside or outside the RUB. We account for net usable land and bulk infrastructure costs to convert farm and lifestyle land outside the RUB into residential-use sections similar to those inside the RUB.

This allows us to estimate the ***RUB factor***. The RUB factor is the price premium on developed residential land inside the RUB when compared to farm or lifestyle land outside the RUB, after accounting for infrastructure, amenities, location and net usable land area. It is expressed as a ***percentage of the price of the average developed residential property inside the RUB attributable to the RUB***.

We find that converting farmland or lifestyle blocks outside the RUB into bulk-infrastructured residential sections similar to those inside the RUB would be unlikely to deliver land to the market substantially more cheaply.

Using low estimates of the cost of bulk infrastructure to convert ***farm-sized land*** outside the RUB into residential land, we find the ***RUB factor*** for residential land inside the RUB is at most 1.6% to 5.2% of the value of the average residential ***property*** inside the RUB. Compared to ***lifestyle-sized*** land outside the RUB, the RUB factor on residential land inside the RUB is at most 0.6% to 4.2% of the value of the average residential ***property*** inside the RUB. These premiums are dramatically smaller than suggested by previous work, which relied on pre-Unitary Plan data and had other limitations.

At higher estimates of infrastructure costs, land ***inside*** the RUB may be priced at a ***discount*** compared to outside, suggesting the taxpayer and ratepayer subsidy in greenfield areas may be inflating land prices outside the RUB.

There are various social impacts associated with development not captured in market prices, such as congestion, emissions, viability of public transport and optimal use of existing infrastructure. It is beyond the scope of this work to determine whether these relative costs and benefits justify the relatively small premium on residential land inside the RUB.

Key definitions

The RUB factor

The RUB factor is the price premium on residential land inside the RUB when compared to farm and lifestyle-sized land outside the RUB, after accounting for infrastructure, amenities, location and net usable land area. It is expressed as a percentage of the price of the average developed residential property inside the RUB attributable to the RUB.

The MUL, the RUB and the FUZ

- ***Metropolitan Urban Limit***: The MUL was the urban growth boundary in place before the RUB. It was significantly smaller than the RUB and relatively inflexible in terms of opportunities for expansion.
- ***Rural Urban Boundary***: The RUB replaced the MUL. It defines the extent of urban development over 30 years and areas likely to be kept rural. It is about 30% bigger than the MUL, can be changed by private plan change, and includes development capacity for over two million additional dwellings in existing urban areas and inside the FUZ.
- ***Future Urban Zone (FUZ)***: The FUZ is land inside the RUB, set aside for urban expansion over the next 30 years. The sequencing for development of the FUZ is set out in the Future Urban Land Supply Strategy and allows for around 137,000 new dwellings on approximately 13,000 hectares.

Property, improvement, land and "un-amenitied, a-spatial" land values

- ***Property value***: The total value of a property, including its land and improvement value.
- ***Improvement value***: The value of all improvements (e.g. dwellings, sheds, fences).
- ***Land value***: The value of unimproved land with no dwellings, sheds or fences.
- ***Un-amenitied, a-spatial land value***: The value of land stripped of the improvements, amenities, location, and non-size attributes of the land, allowing us to fairly compare pieces of land across locations.

Residential, lifestyle and farm-sized land

The fundamental question this paper answers is whether cutting up farm or lifestyle-sized land outside the RUB into residential-sized sections similar to infrastructured residential properties inside the RUB would deliver cheaper land to market. Our analysis needs to include land that is zoned for residential, lifestyle or farm use inside or outside the RUB, regardless of its current use.

There is no set definition of what constitutes these three categories. Looking at other parts of New Zealand and testing multiple different combinations yielded the following definitions:

- ***Residential-sized land***: Land inside or outside the RUB zoned residential, countryside living or rural, but under 4,000 square metres (0.4 hectares or roughly one acre) in size.
- ***Lifestyle-sized land***: Land inside or outside the RUB zoned residential, countryside living or rural, from 4,000 to under 40,000 square metres (0.4 to four hectares or roughly one acre to 10 acres) in size.
- ***Farm-sized land***: Land inside or outside the RUB zoned residential, countryside living or rural, but 40,000 square metres (four hectares or roughly 10 acres) or bigger in size.

These definitions also allow that on a per-square-metre basis, the value of un-amenitied a-spatial land varies by the overall size of the section.

Bulk and local infrastructure

- ***Bulk infrastructure:*** Large-scale provision of highways, railway lines and stations, and social infrastructure like schools and hospitals (by central government); arterial roads, public transport, water supply, wastewater and stormwater networks and social infrastructure such as community facilities and parks (by local government).
- ***Local infrastructure:*** Usually provided by the developer, this includes local and connector streets, and the local pipe network.

Why are we posing this question?

Housing affordability remains a challenge for many in Auckland. The finger of blame often points at land use rules, such as the old Metropolitan Urban Limit (MUL) or current Rural Urban Boundary (RUB) in Auckland. If the boundary results in a premium that materially increases the cost of housing, then given Auckland's housing affordability challenge, there would be an argument for removing the boundary.

The validity of this argument is fundamental to the shape of Auckland as it grows, its infrastructure provision, and economic and social outcomes. This means any policy to contain or expand development should be based on even-handed, defensible evidence.

Several papers have been written in New Zealand on the topic of growth boundaries, as we detail later. Some studies have significant strengths. But they all have one limitation in common: none of them consider whether there is a price premium on land inside Auckland's RUB post-Unitary Plan implementation.

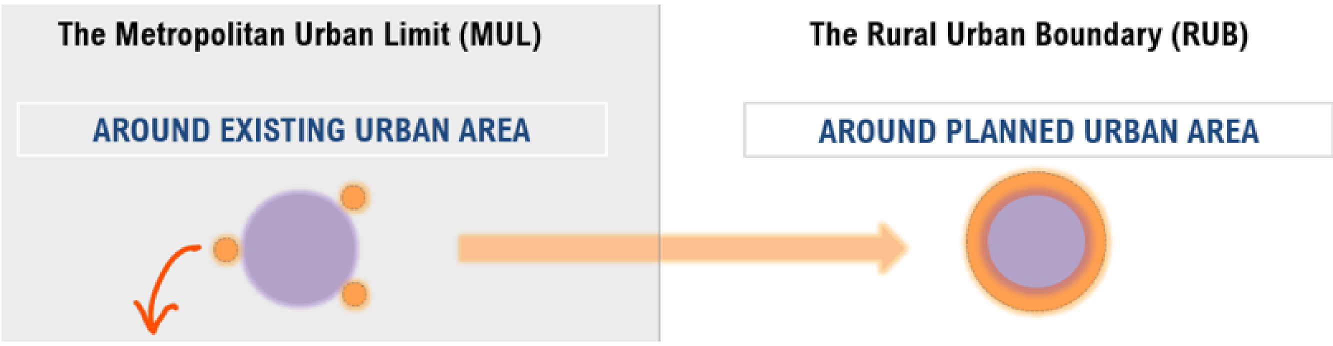
Auckland Unitary Plan renders previous studies largely obsolete

Auckland's Unitary Plan, which became operative on 15 November 2016, was the biggest change in zoning rules in New Zealand's history. It consolidated the sometimes sharply different zoning rules in the various legacy plans of the councils that amalgamated to form the new Auckland Council in 2010. It also provided substantially more development capacity:

- It simplified the number of residential zones in Auckland to six (four in urban areas), from around 100 in the legacy council plans.
- It made the most common zone the Mixed Housing Suburban zone, allowing widespread development of terraced housing, and much denser development in some places.
- It increased development capacity in urban areas by a factor of at least 10.
- It increased physical development capacity by around two million extra dwellings, or 40 times Auckland's current housing shortfall and several times its projected housing demand over the next 30 years.
- It replaced the MUL with the more flexible RUB, which includes 30% more land.

It stands to reason then, that this dramatic change would affect land markets. Yet prior to our work, no evidence existed post-implementation of the Unitary Plan on whether the RUB imposes a price premium on land inside it.

Figure 1 Comparing the MUL and the RUB



The Metropolitan Urban Limit (MUL)

- Uncoordinated, unplanned, few efficiencies
- Required infrastructure not planned for
- Ad-hoc urban form outcomes
- Could only be shifted by the Regional Council

The Rural Urban Boundary (RUB)

- 30% bigger than the MUL
- 30+ year view for growth in 13,000 hectares of Future Urban Zone (FUZ) areas inside RUB
- Flexible boundary through a plan change process
- Sequenced land release

What we are and are not asking

The headline question posed is whether the RUB imposes a premium on land inside it. A more meaningful policy-oriented way to ask the question is:

Would converting farm or lifestyle land outside the RUB into infrastructured residential sections similar to already developed sections inside the RUB deliver land to market more cheaply?

Because this is our policy question, we do not focus on the following.

- a comparison of the RUB policy to the old MUL policy it replaced. We explicitly do not use a "difference in difference" modelling approach. This study focuses on how the land market operates today, since the Unitary Plan and RUB were introduced.
- whether the RUB is a "good" or "bad" policy. Our focus is simply on what land price premium it may impose once amenities, location, bulk infrastructure and other characteristics of dwellings or land have been accounted for.
- whether the specific location of different types of residential zoning inside the RUB is optimal. It is only concerned with whether the RUB acts as a constraint that inflates land prices inside it relative to farm and lifestyle land outside it.

The broad and specific roles of the Chief Economist Unit

The mandated role of the Chief Economist Unit is to provide impartial, objective advice in the interest of Aucklanders. Our independence means that sometimes our views may be at odds with staff or elected representatives at Auckland Council, but it is a role we take seriously and defend vigorously.

For two years, we have been gathering data with immediate application but that we also knew would be useful in answering the bigger question of whether the RUB imposes a price premium on land inside it.

We have conducted our own dispassionate analysis and reached our own evidence-based conclusions. It is the results of this work that we publish here.

Review and other assistance

We have not completed this work in a vacuum.

We worked with a range of experts throughout the process, whose insights and suggestions on the modelling were invaluable. They also hold views that don't always align with ours or with each other, which made our job more challenging but also meant a robust outcome. ***Their assistance on this work does not necessarily imply an endorsement of its results***.

Stuart Shepherd, MCA, An economist with more than 20 years in the economics of infrastructure, Stuart spent 18 years at Sapere Research Group. He also served on the Independent Hearings Panel for the Unitary Plan. This placed him well to understand the strengths and weaknesses of the current zoning regime, what the RUB is and its limitations. Stuart provided input during the model design, testing of initial assumptions and results, and a review of the draft report.

Doug Fairgray, PhD, With over 30 years of consulting and research experience, Doug established Market Economics in 2001. His focus over the last 15 years has been on urban economies, and the contribution of urban spatial form to community wellbeing and enablement, and sustainability. Doug provided input during the model design, testing of initial assumptions and results, and a review of the draft report.

Peter Nunns, MA, Principal Advisor at Wellington City Council, formerly provided secretariat support to the Mayoral Housing Taskforce. He reviewed our draft report and provided valuable technical suggestions for sensitivity testing the model and clarifying the presentation of results.

Ryan Greenaway-McGrevy, PhD, Director of the Centre for Applied Research in Economics at the University of Auckland, provided invaluable input during the model design and testing phase.

Michael Rehm, PhD, Senior Lecturer in Property at the University of Auckland Business School, provided several upfront insights on how urban boundaries may interact with property prices.

Lucy Groenhart, PhD, of Auckland Council's Research and Evaluation Unit (RIMU), provided internal economic review and estimated the cost of bulk infrastructure across the Future Urban Zone (FUZ).

Shyamal Maharaj of the Chief Economist Unit evaluated previous work completed on the FUZ zones and natural hazards, assisted in gathering data and provided an internal review of the draft report.

A lot of the data we have used in our modelling has been developed with invaluable support from ***Chad Hu***, ***Mario Fernandez, PhD*** and ***Kyle Balderston***, all of whom were in RIMU at the time.

Previous Auckland studies and gaps

Three studies that consider urban growth boundaries in Auckland are most relevant to the current work. The Results section and Appendix discuss international studies that are also relevant to our current work.

Spatial determinants of land prices: Does Auckland's MUL Have an Effect? – Grimes and Liang (2009)

Grimes and Liang find that land just inside the MUL is valued approximately 10 times higher than land just outside. This work is often cited when discussing the implications of an urban growth boundary on land prices.

The study considers a few key factors that are crucial to a study of the effect of growth boundaries on land prices, including proximity to the CBD, town centres and the coast. Additionally, the model considers the impact of socio-economic variables that are likely to be correlated with land price differentials such as population density, income, and relative deprivation. In the absence of more detailed data, these are reasonable proxies for amenity – higher income areas tend to have more and better amenities than lower income areas.

As with our work, the Grimes and Liang study does not explicitly state whether the MUL is good or bad. Instead, it focuses on whether the boundary imposes a premium.

There are a few limitations to the work, some simply a matter of when it was done. The most obvious is that since amalgamation and the Unitary Plan, Auckland Council has eliminated the MUL and replaced it with the RUB. The RUB is 30% larger in land area than the MUL, captures future urban zones that provide staged infrastructure to greenfield land over time, and allows for massively more development within the boundary. The Unitary Plan also increased development capacity in existing urban areas by a factor of over 10. This renders the Grimes and Liang study largely obsolete.

Second, the report assumes council rates and user fees are predominantly to pay for capital cost of infrastructure on specific properties. This is not the case. Rates and user fees largely cover generalised ***operational*** costs across the region or sub-region, and some portion of the generalised (rather than property-specific) infrastructure capital costs not covered by development contributions an infrastructure growth charges paid by developers on a specific property. Rates and user fees also do not cover the cost of infrastructure provided by central government. As a result, the report overestimates the gap in land values across the MUL.

Third, the paper concludes that land values inside the MUL are roughly 10 times the value of land outside the MUL on average. But no dollar value is provided, so it is not evident whether the 10 times ratio implies a substantial impact on land prices. Ten times a small number is immaterial, while 10 times a large number is highly material. This matters in evaluating whether, when social impacts of expansive or intensive development are considered, there is a net benefit to removing the growth boundary. The absence of a dollar value also makes it impossible to compare to the cost of the infrastructure required to service land either side of the boundary.

Fourth, the study relies on valuations rather than actual sales prices. Using valuations probably yields a stronger statistical relationship (technically, a higher adjusted R^2), but this is because the model models a mass appraisal model, rather than observed sales with the values people place on those sales. This was possibly the result of data limitations of the time.

Finally, results are presented at a meshblock rather than a disaggregated level, possibly the result of limited computing power at the time.

Quantifying the impact of land use regulation: Evidence from New Zealand – Lees for Superu (2017)

The Superu report studies the costs of land use regulation, to some extent replicating work by Edward Glaeser in the US. It concludes that 15% to 56% of the average ***property*** value, not land value, in major New Zealand cities is due to land use regulation. The figures presented for Auckland are up to 56% or $530,000 of the average property value.

The work has several limitations. First, it uses data from before the Unitary Plan became operative, which for the reasons already established, makes the report largely obsolete.

Second, the report underestimates or excludes the cost of bulk infrastructure to service undeveloped land, as in the Grimes work.

Third, and in contrast to Grimes and to Glaeser, the study makes no explicit allowance for proximity to the CBD or jobs in Auckland – though it does for several other cities in the study. It is not clear why this is not included and / or reported in the model for Auckland. As Grimes, Glaeser, and our models later will show, proximity to the CBD/jobs is a major driver of land value.

Fourth, the methodology includes a Census Area Unit (CAU) dummy variable, which is reasonable on its own. This helps account for the amenities that make land in some parts of the city more valuable than others. Amenities such as access to goods and services, or "good" schools are part of what make land valuable.

By including these dummy variables, the report is estimating the per square metre value of land once it is stripped of nearby amenities. But this un-amenitied value is then compared to the sale price of land (which intrinsically includes this amenity value). In other words, the report appears to compare the value of land stripped of its amenities to the sale price of amenitied land, and then to assign the difference to land use regulation.

Fifth, the Superu model of property prices (and, in fact, any standard hedonic regression model) estimates the log-transformed value of a property using an equation fit through the means of all the variables. Due to the nature of the housing price distribution, the log of the average house price and the average of the logged house price are not equivalent[1]. By using the average land value for the average log-price property, and subtracting this value from the average property price, the gap – which is then assigned to overregulation – is likely to be overestimated.

Finally, the report uses valuations rather than actual sales prices, and uses an approach that estimates the cost to "rebuild" dwellings on existing sites to determine a land value, which it compares to the un-amenitied land value it calculates. The estimate of the cost to build is based on dollars per square metre data calculated from building consent applications at the time. This measure is known to be a substantial underestimate of the actual cost to deliver houses. This underestimate in build costs (tens of thousands of dollars per dwelling on average) was assigned to land use regulation.

NPS-UDC: price efficiency indicators technical report: rural-urban differentials – MBIE and MfE (2017)

The national policy statement on urban development capacity (NPS-UDC) requires local governments to give effect to price efficiency indicators to help determine housing and business development capacity in relation to urban planning. The NPS-UDC sets out four measures of price efficiency, one of which is the rural-urban land price differential, the subject of this particular Ministry of Business, Innovation and Employment and the Ministry for the Environment (MBIE/MfE) report.

[1] For example, in our residential property price dataset, the average price of a property sold in 2018 was $1,048,802. If we log-transform each property's sale price, and take the mean, we get a value of 13.775. When this is transformed back into dollars, we get $959,946. Since a model that uses the log of property price as the dependent variable was used to estimate the land price, this should be the value that is used to estimate how much of the property price is "left-over" after accounting for land.

Rural-urban differentials were calculated for Auckland by comparing prices within two kilometres of the MUL on either side. The study controls for proximity to CBD, town centres and major beaches; slope; flooding and natural hazard impacts; the costs of subdivision including development contributions for public infrastructure, but not bulk infrastructure paid for by other taxpayers or ratepayers. It concludes there is a price differential of 3.15 between land inside and outside the MUL once these factors have been accounted for.

One limitation of this analysis and its application to Auckland is that it uses 2014 valuations data, which pre-dated the Unitary Plan, and not actual sales data post-implementation.

Second, as already mentioned, the study does not account for the costs of bulk infrastructure not paid for by the developer. As we point out later, this can be as much as two-thirds or more of bulk infrastructure costs in greenfield areas.

A third limitation is that by only looking at land within two kilometres of the MUL, which helps control for proximity differences, the comparison is mostly urban versus peri-urban or lifestyle land rather than a comparison with farmland. The impact this has on the results is unclear.

A summary of gaps

As a result of reviewing previous work, as well as discussions with local and central government stakeholders, we identified several gaps we sought to overcome in the current work. In summary, we needed to:

- use post-Unitary Plan land market data
- use the RUB, not the MUL
- use actual sales, not valuations, which negates the need to estimate rebuild costs for properties with dwellings more accurately than in previous work
- select and group appropriate comparator properties inside and outside the RUB
- consider net usable land when comparing residential, and farmland and lifestyle-sized blocks of land
- account for amenities more comprehensively and acknowledge that is why some land is more valuable
- account for bulk infrastructure costs not borne by the developer
- account for natural hazards – specifically proneness to flooding.

Methodology

In line with the approaches used by many authors in New Zealand and internationally – including all three reports reviewed in the previous section – we use standard hedonic pricing econometric modelling techniques to explain property prices as a function of the dwelling (if any), land, and location. More formally, we use hedonic price models with spatial error disturbances to explain prices in farm, lifestyle and residential properties.

The goal of the modelling is to isolate the un-amenitied a-spatial value of developed land inside the RUB (which has infrastructure) and undeveloped farm and lifestyle land outside the RUB (which does not have infrastructure).

We do not use a "difference in difference" modelling approach, as we are not asking how the RUB affects land market prices relative to the MUL, but rather how the land market operates today, since the Unitary Plan and RUB were introduced.

Moreover, we would argue that the results of a difference in difference analysis could almost certainly not be meaningfully interpreted in this instance. For example, if land included in the FUZ inside the RUB, but that was outside the old MUL increased in value from the change in policy, it would likely be impossible to say whether the rise in value implied a positive or negative policy change. The value change may imply acknowledgement that infrastructure is on its way (announcement effect) but whether the scale of this change was reasonable would be subjective in part because of differences in infrastructure timing within the FUZ areas.

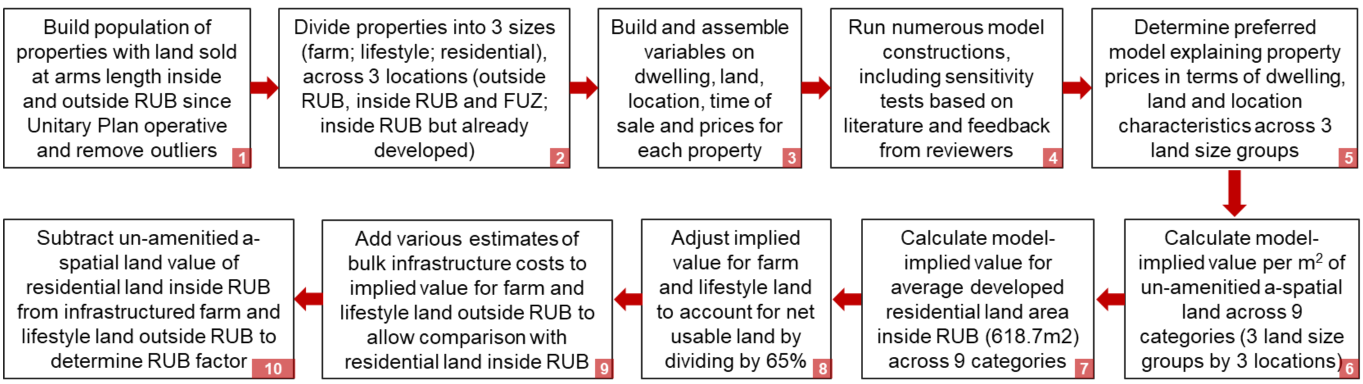
Another tool that has been used to examine growth boundaries is regression discontinuity design (RDD). However, the nature of the RUB and the FUZ, and the data available, limits the feasibility of RDD. While it may have been a straightforward analysis under the old MUL, it is not obvious how it would work with the RUB. The border between land inside and outside the RUB is clear, but for land inside the RUB that is zoned FUZ, there are many gradients. Some land is already being provided with infrastructure, while other land is 30 years away, for instance. Thus, it becomes unclear where the second discontinuity in the data would take place, or, indeed, how many discontinuities there are.

This is also why, although we include data throughout for FUZ land for the sake of completeness, we do not comment on the un-amenitied a-spatial land price differential between land in the FUZ and land in developed residential areas.

Post-modelling, we apply real-world data on the ratio of net usable land to gross farm or lifestyle land and bulk infrastructure costs to develop farm and lifestyle land, to determine whether there is a premium on land inside the RUB. We call this premium, expressed as a share of the average residential property price inside the RUB, the RUB factor.

Our methodology is summarised in Figure 2. Throughout the report we will reference the step numbers in this figure so readers can follow along the process of estimating the RUB factor.

Figure 2 Methodology



Building our sample (steps 1 and 2)

The Auckland Unitary Plan became "operative in part" on 15 November 2016. On this day, the biggest change in zoning rules in New Zealand's history came into effect in Auckland.

Because the RUB did not exist before the Unitary Plan became operative and we are interested in determining if and how the current boundary affects land prices, we use only data post-Unitary Plan implementation.

The bulk of the data used came from the sales audit file of the District Valuation Roll (DVR) for Auckland. The information contained in the DVR data is standardised across all territorial authorities in New Zealand and outlined in the Rating Valuations Rules 2008 published by Land Information New Zealand (2010).

These data contain, among other things, the address of a property, the size, slope, zoning, and use of the land, and a variety of attributes of the dwelling (if any).

For a sale of a property to be included in our dataset, several criteria must be met.

- The sale must have taken place after the Unitary Plan became operative in part on 15 November 2016.
- Sales of properties on Waiheke, Great Barrier Island, or any other Hauraki Gulf island were excluded. While these areas are within Auckland, they are not subject to the Unitary Plan.
- Sales must have been at arms-length. We exclude sales where a property is transferred to a family trust or a parent sells to a child, for example, as these are not market sales.
- Only sales of free-hold properties were considered. This eliminates sales of lease-hold properties or sales where only part of a rating unit is transferred.
- Because we are interested in ***land*** that could potentially be used for ***housing*** development, we included only sales of properties that are ***zoned*** for residential, rural (including countryside living), or future urban purposes, regardless of use.
- Because the focus of this research is the price of ***land***, only properties that include land were considered. This excludes apartment blocks or other intensive developments where individual dwellings have no land associated with the title. While apartments usually include an interest in the land that the building sits on, the value of land attributable to individual units is difficult to infer from the data.
- Any properties with more than 500 square metres of total living area (e.g. retirement villages on one title or incorrectly entered data such as a greenhouse wrongly identified as a dwelling) were removed.
- The top and bottom 2.5% tails of the sales price distribution were removed for all three property types. This accounts for data entry errors (for instance, the sale of an approximately 100 square metre house on less than 250 square metre of land was recorded as being sold for $110 million) and outlier sales (e.g. mansions or farms with specialised equipment like hydroponics), which are not indicative of the overall market.

This data cleaning process leaves us with 36,722 sales that took place between the Unitary Plan becoming operative and the end of the first quarter of 2019.

As defined earlier, properties are split into three groups based on their land size – residential (less than 4,000 square metres), lifestyle (4,000 square metres to less than 40,000 square metres), and farm-sized (40,000 square metres or more). Within each of these groups, there are properties within and outside of the RUB, and for those inside the RUB, there are properties in developed areas and in the FUZ. This yields a total of nine possible property categories:

- farm-sized outside RUB
- farm-sized inside RUB, FUZ
- farm-sized inside RUB, developed
- lifestyle-sized outside RUB
- lifestyle-sized inside RUB, FUZ
- lifestyle-sized inside RUB, developed
- residential-sized outside RUB
- residential-sized inside RUB, FUZ

- residential-sized inside RUB, developed

Table 1 shows the average size and number of observations in each category.

Table 1 Average land size, price, and number of observations by category

	Average Land Size (square metres)	Number of Observations
Farm-sized, outside RUB	150,876	599
Farm-sized, inside RUB, FUZ areas	63,585	32
Farm-sized, inside RUB, already developed areas	44,523	23
Lifestyle-sized, outside RUB	15,188	1,502
Lifestyle-sized, inside RUB, FUZ areas	16,497	207
Lifestyle-sized, inside RUB, already developed areas	9,157	162
Residential-sized, outside RUB	1,124	2,700
Residential-sized, inside RUB, FUZ areas	1,230	70
Residential-sized, inside RUB, already developed areas	619	31,427

Creating new variables (step 3)

Next, we created variables that describe a property's proximity to amenities. For each property, the driving or walking distance to the nearest golf course, arterial road, primary school, park, water (and whether this water is a beach), and rapid transit station are calculated. We also calculated the linear distance to the city centre and the nearest town centre as defined in the Unitary Plan. These distances allow us to account for amenities that most other studies only proxy with variables like median income of the neighbourhood.

Additionally, there are variables that describe a property's access to jobs and services – based on Statistics New Zealand's Business Demography dataset. To develop reasonable catchments, we identified the centroid of each census area unit (CAU) and drew circles with 2km radii. If another centroid fell within this circle, its CAU was in the catchment.

Figure 3 shows an example catchment calculation for the Mt St John CAU. This CAU's catchment is made up of the 10 CAUs with centroids within the 2km radius. For Mt St John, this is Mt Eden East, Epsom North, Central, and South, Remuera West and South, Mt Hobson, One Tree Hill Central, Waitaramoa, and Mt St John itself. This process was repeated for all the CAUs in Auckland.

For every property in the dataset, the number of jobs located in their catchment was calculated and used as a measurement of local access to jobs. Similarly, the number of establishments (geographic units) in the catchment was calculated for a variety of business types. We included petrol stations, food retailers, other stores, restaurants and cafes, financial institutions, real estate businesses, tertiary education providers, hospitals, medical and healthcare establishments, performing arts, sports and recreation, repair, and personal and other services.

Figure 3 CAU catchment calculation example

We further created other variables to describe characteristics of the property that are otherwise unaccounted for. We flagged whether the property was inside a special character area. We also calculated the percentage of the land that is in the 100-year flood plain, the highest decile school that is zoned to the property, and a measure of a property's development intensity (improvement value divided by capital value).

To account for the effects of being located very close to certain amenities, we identified properties that are within 100 linear metres of railroad tracks, arterial roads, schools, or golf courses. This distance is a reasonable estimate of how far away you would have to be to avoid the bulk of the noise associated with transport and schools. We would expect a negative effect on properties located "too close" to roads, schools, and railroad tracks, and possibly a positive effect on properties that are close to a golf course.

Summary of variables

There are many variables that are included as a matter of course in the DVR data, as well as the many that we created, as described in the previous section. A summary of these variables is in Table 2.

These variables fall into four general categories. Firstly, there are those that describe the dwelling. These variables include decade of construction, wall material, roof material, whether the dwelling is associated with being leaky (i.e. monolithic cladding and built in the 1990s or 2000s), number of garages (whether separate or integrated), total living area, and whether there is a deck.

Secondly, there are variables that describe the land. These include square metreage; contour; views; percentage of land that is in the 100-year flood plain, noting the non-random way the RUB was drawn to broadly avoid flood zones; and the intensity of existing development on land.

Thirdly, there are the variables that describe the location. These include distance to the various amenities, FUZ zoning, special character area, school zones, access to jobs, and access to local businesses.

Finally, there are variables that describe the sale. These are the quarter and year of the sale, and the sale price.

Our preferred model (steps 4, 5 and 6)

Our preferred model is a standard hedonic price model with the log of the sale price on the left-hand side and the characteristics of properties on the right-hand side. We estimate separate models for each of our land size categories (farm, lifestyle, and residential), though the functional form is identical. Equation 1 is a representation of the models.

Equation 1 Representation of our hedonic price model

$$\ln(P) = \alpha + D\beta + L\gamma + M\delta + T\theta + \varepsilon$$

where, P is a vector of the sale prices of the properties, D is a vector of characteristics that describe the ***dwelling*** associated with each property, L is a vector of characteristics that describe the ***land*** associated with each property, M is a vector of variables that describe the ***neighbourhood*** where each property is located, T is a vector of dummy variables for each quarter (i.e. time fixed effects), and ε is an error term.

To control for spatial autocorrelation, we estimate the models as spatial error models which correct for non-spherical error variance. We use a spatial weights matrix based on the four nearest neighbours. More details on this can be found in the appendix.

Model for residential-sized properties

Residential-sized properties make up the bulk of the observations in our dataset. Recall that of the 36,722 observations in our dataset, 34,197 of them are of properties on residential-sized sections inside or outside the RUB.

Due to computing power limitations, a 25% (8,549 observations) proportionately stratified random sample of the full residential dataset was used to estimate the models, similar to Mathur (2014) and Grimes and Liang (2009). The strata are whether the properties are within or outside the RUB so that the proportion of inside / outside RUB properties is the same in our sample and in the full dataset. Like Mathur, we find that the ordinary least squares (OLS) results are robust and the results for the OLS model on the full dataset and the 25% sample are similar.

The model structure described previously is estimated on the sample of residential-sized properties using standard OLS. We use the global Moran I test (which is a statistical measure of spatial autocorrelation) for regression residuals.

Table 2 Summary statistics of included variables

Dwelling Characteristics	Min	Farm -sized Mean	Lifestyle -sized Mean	Res -sized Mean	Max
Freestanding garages	0	0.732	0.816	0.480	14
Integrated garages	0	0.583	0.826	1.020	20
Total living area	0	151.6	163.7	140.0	500
Possibly leaky	0	0.021	0.046	0.039	1
Has deck	0	0.564	0.647	0.569	1
Land Characteristics					
Square metres	12	142,864	14,811	660	1,384,089
Proportion in flood plain	0	0.128	0.104	0.094	1
Development intensity	0	0.234	0.322	0.303	0.820
Location Characteristics					
FUZ Zoned	0	0.049	0.111	0.002	1
Inside RUB	0	0.084	0.197	0.921	1
Closest water is beach	0	0.043	0.050	0.2	1
Special Character	0	0	0	0.046	1
Maximum zoned school decile	1	7.4	7.9	7.1	10
Jobs in catchment	12	914	1,355	9,146	185,622
Businesses in catchment					
Petrol stations	0	0.97	1.44	4.46	18
Food retailers	0	3.14	6.43	44.96	285
Other stores	0	11.11	18.55	104.43	1,188
Restaurants / cafes	0	8.81	15.51	101.38	1,230
Financial	0	31.93	38.22	176.55	3,054
Real estate	0	110.44	132.43	535.47	5,649
Tertiary Education	0	0.79	0.74	3.11	84
Hospitals	0	0.00	0.08	0.83	15
Medical / healthcare	0	8.39	13.81	99.22	786
Heritage	0	1.39	1.01	0.97	12
Performing arts	0	2.99	3.47	27.72	399
Sports / recreation	0	6.35	7.19	21.56	153
Repair	0	10.44	12.65	47.55	198
Personal and other services	0	8.48	11.92	70.21	726

Location Characteristics	Min	Farm -sized Mean	Lifestyle -sized Mean	Res -sized Mean	Max
Within 100 linear metres of:					
Golf course	0	0.0000	0.0010	0.0003	1
Arterial road	0	0.025	0.067	0.153	1
School	0	0.0031	0.0027	0.0131	1
Railroad tracks	0	0.000	0.000	0.012	1
Distance to CBD (linear metres)	863	36,689	32,284	17,026	81,363
Within 4,000 linear metres of town centre	0	0.174	0.288	0.878	1
if within 4,000m, how far (linear metres)?	78	2,784	2,559	1,607	4,000
Within 4,000 linear metres of golf course	0	0.254	0.318	0.647	1
if within 4,000m, how far (walk / drive metres)?	86	5,167	5,042	3,568	20,305
Within 4,000 linear metres of park	0	0.963	0.980	0.9998	1
if within 4,000m, how far (walk / drive metres)?	8	2,760	2,131	319	34,796
Within 4,000 linear metres of arterial road	0	0.454	0.636	0.980	1
if within 4,000m, how far (walk / drive metres)?	17	3,616	2,726	790	22,132
Within 4,000 linear metres of primary school	0	0.772	0.838	0.986	1
if within 4,000m, how far (walk / drive metres)?	37	3,691	3,181	1,011	21,422
Within 4,000 linear metres of water	0	0.525	0.619	0.927	1
if within 4,000m, how far (walk / drive metres)?	29	3,297	3,126	1,791	16,042
Within 1,500 walk / drive metres of rapid transit stop	0	0.002	0.007	0.176	1
Sales Characteristics					
Date of sale	2016 Q4	2017 Q4	2017 Q4	2017 Q4	2019 Q1
Price (1,000s)	$325	$2,227.6	$1,531.1	$1,049.8	$24,285
# of observations		654	1,871	34,197	
List of qualitative variables					
Decade of dwelling construction					
Contour of land					
Roofing material					
Roof condition					
Walls material					
Walls condition					

This test indicates that spatial autocorrelation is an issue (i.e. the regression residuals are non-random and are correlated spatially), with a z-value of 45.40 and a p-value < 1×10^{-15}. However, Moran's I does not identify the cause or nature of the underlying spatial process. It is a general test for detecting autocorrelation but gives no indication of how to correct for it.

Consequently, we use Lagrange Multiplier (LM) tests to see what type of spatial dependence is exhibited by the models – spatial lag or spatial error. The null hypothesis of these tests is that there is no spatial lag or spatial error process.

For the residential-sized property model, we reject the null hypothesis for both the standard spatial error dependence and the standard spatial lag dependence tests. This indicates that either the error could be best modelled by assuming a spatial lag model or a spatial error model. As recommended by Anselin (2005, p. 199), we then look to the robust forms of the LM tests. These indicate that the spatial dependence is best controlled for with a spatial error model as we reject the null hypothesis for spatial error (p-value < 1×10^{-15}) and cannot reject the null hypothesis for spatial lag (p-value = 0.17).

Model for lifestyle-sized properties

There are 1,871 lifestyle-sized properties in our dataset. Because there are fewer lifestyle properties, there are no computing power issues with this model.

Again, the model structure described previously is estimated on the lifestyle data using OLS. Using the global Moran I test for regression residuals, we see that spatial autocorrelation is an issue, with a z-value of 19.85 and a p-value < 1×10^{-15}.

The LM tests are only significant for the spatial error model (p-value < 1×10^{-15}), and this is confirmed by the robust versions of the tests.

Model for farm-sized properties

There are 654 farm-sized properties in our dataset. There are no computing power issues with this model. The model structure described previously is again estimated on this data using OLS. We use the global Moran I test for regression residuals which indicates that spatial autocorrelation is an issue, with a z-value of 638 and a p-value < 8.6×10^{-11}.

The standard LM tests are statistically significant for both the spatial lag and spatial error model. We then look at the robust forms of these LM tests. Both are significant, but as the test statistic for the spatial error model is orders of magnitude more significant (a p-value of .000002 versus a p-value of .0003), we use the spatial error model as recommended by Anselin (2005).

Interpreting hedonic model results

These hedonic models give us a way to isolate the un-amenitied, a-spatial land price component of property prices. However, simply looking at the price of un-amenitied, a-spatial farm or lifestyle-sized land versus residential land is not a valid comparison for at least two reasons.

Account for net usable land (steps 7 and 8)

The first reason is that when farm or lifestyle-sized land is converted to residential use, a large share of that land will be converted into roads, stormwater run-off, parks and other uses from which no financial return will be made by the developer. This means the value per square metre of raw land needs to be adjusted ***upward*** based on an assumption about how much of the land will be used for non-recoverable purposes once converted to residential use.

Three recent Structure Plans in the Auckland context provide a range for these values – Warkworth (Auckland Council, 2019c) in the north, and Drury-Opāheke (Auckland Council, 2019a) and Pukekohe-Paerata (Auckland Council, 2019b) in the south. In these three Plans, an estimated 57%, 55% and 58% of land respectively are estimated to be ***un***available for development. This is after accounting for areas not for development, including flood plains, streams, wetlands, existing open space, heritage, existing roads, and significant ecological areas. It is also after roads and areas for other uses such as parks, schools and community facilities are excluded.

To err on the side of conservatism (i.e. to over rather than underestimate any premium on land inside the RUB), and to consider the argument some might make that some of these areas should not be protected, we assume ***only 35%*** of land is ***un***available for building due to roads and other uses. In other words, we assume the farm or lifestyle land price would need to be recovered from 65% of its land if it were to be converted into residential uses, compared to an average of around 43% in three recent Structure Plans.

Account for bulk infrastructure (step 9)

The second reason comparing the price of un-amenitied, a-spatial farm or lifestyle-sized land and residential-sized land inside the RUB is not valid, is the cost of bulk infrastructure to convert farmland into residential-sized sections similar to those inside the RUB. Only the MBIE/MfE study makes an explicit allowance for bulk infrastructure, by considering the costs borne by the developer in a greenfield development, which includes development contributions (DCs) and infrastructure growth charges (IGCs) for infrastructure paid by developers. It also makes an allowance for local infrastructure costs borne by the developer. However, the analysis does not cover bulk infrastructure costs of growth that are currently borne by the taxpayer or ratepayer.

These costs not fully covered by the developer comprise various forms of ***ratepayer*** funded bulk infrastructure including arterial roads, storm, fresh and wastewater trunk and treatment provision, and community facilities such as pools, parks and other open space. ***Taxpayer***-funded costs not fully recovered from developers include highways, arterial roads, train stations, schools, police stations or healthcare facilities among others.

We need to account for how much infrastructure is required to convert farm or lifestyle-sized land outside the RUB into residential-sized land with infrastructure levels similar to that of already developed land inside the RUB.

These bulk infrastructure costs (excluding DCs and IGCs of about $39,200 per dwelling in FUZ areas on average) are ***in addition*** to the cost of infrastructure borne by the developer onsite. Local infrastructure costs borne by the developer may include local/connector roads and onsite stormwater management.

We cannot know with absolute certainty what future infrastructure costs will be in areas ***outside*** the RUB. However, the Future Urban Land Supply Strategy (FULSS) work on the expected costs of infrastructure in FUZ areas (which are inside the RUB) provides useful ***lowerbound*** estimates. They are lowerbound estimates for at least four reasons.

First, they exclude all central government spending other than transport infrastructure – all schools, health facilities and the like are left out.

Second, the process for determining the FUZ included eliminating a lot of land that carries significant geological risk, such as (but not limited to) proneness to flooding, that would significantly increase the cost of infrastructure provision.

Third, the further from the RUB (and existing urban areas) the greater the likely cost per dwelling to deliver additional bulk infrastructure for new developments as there is seldom connecting infrastructure available nearby.

Fourth, ***local*** infrastructure costs in greenfield areas, which are borne by the developer and excluded from our analysis, will often be higher than in brownfield areas, where a lot more infill occurs. Thus, the need for connector roads and other infrastructure to be provided by the developer may be larger in greenfield areas.

We would note that these infrastructure costs also do not include other costs of subdivision such as surveying, resource consents, legal fees, and Land Information New Zealand fees.

To estimate lowerbound bulk infrastructure costs outside the RUB, we used infrastructure cost estimates from the FULSS. For commercial reasons, detailed estimates for the cost of each project in the FULSS (which includes council-provided infrastructure and central government-provided transport infrastructure) cannot be published. However, this data did allow us to estimate the infrastructure cost per new dwelling delivered in the FUZ by broad area, caveated by the points made earlier that these are all likely to be low estimates of actual infrastructure costs to develop these areas.

We adjusted the FULSS data as follows:

1. All infrastructure estimates were expressed in today's dollars (2019$).
2. An allowance for the infrastructure cost to serve businesses rather than housing was made based on the share of land set aside for business (10.5%) and subtracted from total infrastructure costs to be borne by residential development.
3. FUZ areas were disaggregated into nine development areas as well as three rural areas expected to stay rural, and the stripped back infrastructure costs estimated in (1) and (2) above were assigned across development areas likely to directly benefit from the new infrastructure.
4. The cost of the share of all infrastructure applied to each development area was divided by the estimated number of future dwellings in each area to determine an estimate of infrastructure costs.

Across the nine development areas, the lowest estimated bulk infrastructure cost is $72,600 per dwelling. The costliest area is around $208,600 per dwelling. The average is $115,200. These figures constitute lower, average and upperbound ***lowerbound*** estimates.

As a result of expressing all values in today's dollars, excluding business land and so on, our average of $115,200 per dwelling implies a total cost across the FULSS areas of under $16 billion, substantially lower than the $20 billion total figure in the FULSS report, which is itself an underestimate.

Arguments can be made for whether the full cost of bulk infrastructure should be added to the cost of each residential-sized section converted from farm or lifestyle land in our analysis thus far. One such argument is whether all the benefits of new infrastructure accrue to the new development. Some would say that there would be benefits to existing network users through service level upgrades or perhaps reduced congestion from new infrastructure.

But it's also hard to contend that these infrastructure improvements would occur ***without growth***, and thus it could be suggested appropriate to assign these bulk infrastructure growth costs fully to the expected number of new dwellings. Still, to allow for a view that some benefit accrues to existing network users, the results section includes a scenario of the RUB factor when 30% of the cost of new bulk infrastructure accrues to them. This scenario is included in our reported range of upperbound values for the RUB factor.

Given the signalling the RUB and FUZ provide about where development is anticipated over the next thirty years, we expect that land outside the RUB (with no promise of infrastructure) will have no advance speculative uplift in value. This would suggest that the full estimated cost per dwelling of the bulk infrastructure should be added to the price of each residential-sized section on farm or lifestyle land outside the RUB to get the actual likely price of that land once infrastructure has been accounted for.

That said, on land very close to the RUB, it is possible that some of the subsidy for infrastructure from taxpayers and ratepayers may be priced into land outside but adjoining the RUB, based on speculation that zoning changes may be possible there. To test this assumption, we replicate a model by US researcher Mathur (see the Appendix). While our work shows adjoining the RUB does ***not*** have a statistically significant impact on price, we nevertheless model a scenario where 15% of the subsidy at the average lowerbound bulk infrastructure cost is priced into land prices outside the RUB already. This scenario is also included in our range of upperbound RUB factor estimates.

Sensitivity tests (step 4)

To determine the most sensible preferred model, we performed a number of tests.

To begin with, there were several ways to correct and / or account for spatial autocorrelation and several ways to calculate spatial weights matrices. The appendix sets out how we went about this process and how different spatial weights affect results.

We also performed the following sensitivity tests:

- including neighbourhood median income
- including the zoning of each property
- including a RUB dummy variable in addition to the RUB and FUZ dummy variables interacted with land size
- including a RUB and a FUZ dummy variable in addition to the RUB and FUZ dummy variables interacted with land size
- using different thresholds for determining residential, lifestyle, and farm-sized land
- using capital valuation instead of sale price
- using the 95% confidence intervals for land value coefficients
- running one combined model instead of three separate models on each of the land size categories
- log-transforming the land size variable

The results of these tests are found in the appendix.

External review and assistance

In formulating the list of gaps in previous analysis, we spoke to several local and central government officials to get their perspectives.

We also spoke to several academic and private sector experts with differing views on whether the RUB was likely to impose a premium on land inside it. Once we had a draft model, we walked several experts through the model to get their feedback on what we may have missed or whether there were better ways to proxy certain variables or to run robustness tests.

We incorporated their suggestions where possible, and some also reviewed the draft report to provide feedback. Their input has been invaluable in progressing our work and subjecting it to independent review. Their assistance does not necessarily imply an endorsement of our results.

Results

Overall comments on model results

The results of the spatial error model for residential, lifestyle and farm-sized properties are shown in Table 4.

Not all coefficients were able to be estimated for all three models. For instance, there are no farm-sized parcels of land within 100 metres of a school, so there is no coefficient for "school within 100 linear metres". Throughout Table 4, where this is the case, the coefficients have been left blank. And because of the smaller number of observations for the farm and lifestyle-sized property models, fewer coefficients were statistically significant.

But in general, the modelled coefficients fit nicely with what would be expected. Distance from the CBD, steeply sloped land, lower decile school zones, a dwelling associated with the leaky building era, and being too close to railroad tracks reduce prices. Wide water views are valuable.

Time fixed effects were mostly statistically insignificant, and when they were significant, fell within a narrow band as prices were relatively flat through the period of analysis.

Although some of these coefficients are interesting on their own, we focus on the coefficient for land outside the RUB (i.e. land that has no promise of future development).

The model fits all have pseudo-R^2 values above 0.7 and the spatial error models have better fits (lower Akaike Information Criterion or AIC values) than the non-spatially adjusted models.

Interpreting and using the models

We evaluate each model at the mean of its dataset. We estimate the expected sale price of the average property, which is a composite of all the properties in the dataset, for each model.

By evaluating each model at its mean values, we can derive the average cost per square metre of un-amenitied a-spatial land inside and outside the RUB. The process is as follows:

1. Calculate the mean "composite" property for each property size (farm, lifestyle, and residential-sized)
2. Calculate the expected sale price of these composite properties excluding their un-amenitied a-spatial land component, and including the average amount of un-amenitied a-spatial land inside or outside the RUB / FUZ for each land category.
3. The difference between these calculations is the price of the average amount of un-amenitied a-spatial land inside or outside the RUB / FUZ for each land category.
4. Divide this number by the average section size to get the average price per square metre price of un-amenitied a-spatial land inside and outside the RUB / FUZ for each land category.

An example of these calculations for farm-sized properties is shown in Table 3.

Table 3 Calculation of per square metre land price for farm-sized properties outside the RUB

Modelled value of farm-sized section ***including*** average amount of land, ***outside*** RUB	$1,532,232
Modelled value of average farm-sized section ***excluding*** land, ***outside*** RUB	$1,271,520
Modelled value of average amount of un-amenitied, a-spatial land, ***outside*** RUB	$260,712
Average square metre of farm-sized sections, ***outside*** RUB	150,876
Average value per square metre of un-amenitied, a-spatial land, ***outside*** RUB	$1.73

The calculated average price of a square metre of un-amenitied, a-spatial land is only $1.73. However, bear in mind that this is the price of land once it is ***stripped of amenity value*** from the things that it is near. This does not mean that one can buy a hectare of land in rural Auckland for $17,300. Instead, this is the value of land as though it is located near nothing – no schools,

Table 4: Regression results (step 5)

	Farm-sized				Lifestyle-sized				Residential-sized			
	Estimate	Std. Error	Pr(>|z|)		Estimate	Std. Error	Pr(>|z|)		Estimate	Std. Error	Pr(>|z|)	
Intercept	13.409	0.314	< 2.2E-16	***	13.485	0.146	< 2.2E-16	***	13.038	0.069	< 2.2E-16	***
Pre-1920 Dwelling	0.166	0.114	0.1466		0.012	0.055	0.8304		0.135	0.018	1.82E-14	***
1920s Dwelling	0.173	0.133	0.1912		0.020	0.051	0.6942		0.115	0.016	3.11E-13	***
1930s Dwelling	-0.112	0.133	0.3970		-0.067	0.055	0.2263		0.066	0.019	0.0007	***
1940s Dwelling	-0.039	0.126	0.7577		0.023	0.054	0.6743		0.016	0.017	0.3508	
1950s Dwelling	0.002	0.095	0.9809		-0.056	0.037	0.1235		-0.006	0.012	0.6223	
1960s Dwelling	0.016	0.103	0.8764		-0.083	0.048	0.0860	.	-0.074	0.011	6.90E-11	***
1970s Dwelling	-0.092	0.100	0.3572		-0.084	0.039	0.0316	*	-0.105	0.011	< 2.2E-16	***
1980s Dwelling	-0.001	0.086	0.9861		-0.060	0.034	0.0823	.	-0.091	0.012	4.44E-15	***
1990s Dwelling	-0.082	0.080	0.3010		-0.067	0.030	0.0270	*	-0.079	0.010	1.18E-14	***
2000s Dwelling	-0.037	0.079	0.6352		-0.029	0.028	0.2980		-0.040	0.009	1.11E-05	***
No Dwelling	0.516	0.241	0.0324	*	0.141	0.097	0.1445		0.379	0.041	< 2.2E-16	***
Unknown construction decade	0.002	0.098	0.9798		-0.035	0.044	0.4219		-0.049	0.013	0.0002	***
Land contour - Steep fall	-0.157	0.110	0.1543		-0.108	0.038	0.0043	**	-0.082	0.012	2.13E-11	***
Land contour - Steep rise	-0.071	0.104	0.4952		-0.009	0.043	0.8278		-0.050	0.016	0.0023	**
View, Other moderate	-0.065	0.045	0.1491		-0.034	0.019	0.0768	.	0.010	0.008	0.2159	
View, Other slight	-0.028	0.053	0.5981		-0.016	0.022	0.4806		0.020	0.006	0.0023	**
View, Other wide	-0.047	0.078	0.5434		-0.023	0.029	0.4298		0.006	0.018	0.7209	
View, Water moderate	0.016	0.116	0.8891		0.024	0.044	0.5811		0.068	0.012	2.36E-08	***
View, Water slight	0.022	0.147	0.8802		0.019	0.053	0.7209		0.065	0.010	1.23E-10	***
View, Water wide	0.262	0.151	0.0818	.	0.235	0.050	2.82E-06	***	0.157	0.015	< 2.2E-16	***
1 Freestanding garage space	-0.108	0.063	0.0857	.	0.004	0.027	0.8730		0.017	0.007	0.0225	*
2 Freestanding garage spaces	-0.029	0.043	0.4952		0.052	0.019	0.0063	**	0.034	0.008	1.65E-05	***
3+ Freestanding garage spaces	0.084	0.069	0.2230		0.052	0.030	0.0820	.	0.019	0.018	0.3022	
1 Integrated garage space	-0.074	0.087	0.3897		-0.066	0.043	0.1265		0.025	0.007	0.0008	***
2 Integrated garage spaces	0.035	0.047	0.4558		0.033	0.022	0.1386		0.072	0.008	< 2.2E-16	***
3+ Integrated garage spaces	0.195	0.086	0.0237	*	0.116	0.033	0.0004	***	0.113	0.017	1.52E-11	***
Roof Material, mixed / unknown	0.081	0.124	0.5151		-0.082	0.070	0.2390		0.042	0.017	0.0149	*
Roof material, other	0.109	0.141	0.4399		0.044	0.073	0.5448		0.015	0.021	0.4712	
Roof material, tile	0.033	0.041	0.4293		-0.002	0.019	0.9121		0.008	0.005	0.1107	
Roof condition, mixed	0.308	0.249	0.2166		0.014	0.421	0.9728		0.076	0.066	0.2499	
Roof condition, average	0.005	0.407	0.9902		-0.231	0.293	0.4316		0.047	0.049	0.3443	
Roof condition, fair	-0.204	0.471	0.6658		-0.169	0.310	0.5851		0.017	0.054	0.7504	

Roof condition, good	-0.030	0.434	0.9443		-0.279	0.299	0.3499		0.060	0.050	0.2308	
Walls construction, mixed / unknown	0.119	0.062	0.0537	.	-0.025	0.024	0.3089		-0.018	0.006	0.0048	**
Walls construction, metal	0.066	0.180	0.7152		-0.038	0.051	0.4543		-0.059	0.031	0.0535	.
Walls construction, brick and stone	-0.016	0.054	0.7675		0.008	0.024	0.7474		-0.009	0.006	0.1506	
Walls construction, concrete	-0.062	0.097	0.5189		0.067	0.056	0.2249		-0.101	0.016	7.01E-10	***
Walls construction, fibre cement	0.056	0.054	0.2958		-0.051	0.027	0.0634	.	-0.025	0.008	0.0022	**
Walls construction, rubber and plastic	-0.428	0.213	0.0446	*	0.009	0.085	0.9179		-0.014	0.029	0.6301	
Walls construction, roughcast	0.028	0.178	0.8743		0.005	0.058	0.9355		-0.065	0.018	0.0002	***
Walls condition, mixed / unknown					0.119	0.404	0.7690		0.148	0.068	0.0287	*
Walls condition, average	0.438	0.346	0.2052		0.319	0.280	0.2543		0.112	0.052	0.0323	*
Walls condition, fair	0.618	0.411	0.1320		0.104	0.295	0.7251		0.114	0.057	0.0455	*
Walls condition, good	0.596	0.376	0.1132		0.388	0.285	0.1731		0.147	0.053	0.0054	**
Possibly leaky building	0.121	0.204	0.5513		-0.069	0.065	0.2887		-0.050	0.021	0.0155	*
Total living area (square metres)	9.04E-04	2.35E-04	0.0001	***	0.001	1.23E-04	< 2.2E-16	***	0.002	5.34E-05	< 2.2E-16	***
Development intensity	0.371	0.165	0.0244	*	0.522	0.062	< 2.2E-16	***	0.145	0.018	8.88E-16	***
Has deck	-0.006	0.043	0.8938		-0.005	0.019	0.8008		0.004	0.005	0.3740	
Low (1-4) decile school zone	-0.012	0.086	0.8847		0.132	0.053	0.0133	*	0.004	0.017	0.8011	
Medium (5-7) decile school zone	0.047	0.065	0.4660		0.099	0.042	0.0186	*	0.044	0.017	0.0086	**
High (8-10) decile school zone	0.219	0.070	0.0018	**	0.173	0.044	7.10E-05	***	0.091	0.016	1.85E-08	***
Golf course within 100 linear metres									-0.179	0.104	0.0849	.
Road within 100 linear metres	-0.140	0.167	0.3998		-0.004	0.041	0.9269		-0.014	0.007	0.0426	*
School within 100 linear metres									-0.005	0.019	0.7975	
RR tracks within 100 linear metres									-0.092	0.023	5.93E-05	***
Closest golf course 0 - 2000m					-0.088	0.063	0.1600		0.025	0.011	0.0165	*
Closest town centre 0 - 200m									0.157	0.048	0.0010	***
Closest town centre 200 - 1000m	-0.151	0.223	0.4978		0.289	0.072	6.49E-05	***	0.035	0.011	0.0013	**
Closest town centres 1000 - 2000m	-0.143	0.114	0.2127		0.199	0.042	2.80E-06	***	0.019	0.009	0.0374	*
Closest park 0 - 400m	-0.058	0.081	0.4724		0.039	0.023	0.0892	.	0.015	0.006	0.0112	*
Closest arterial road 0 - 500m	0.255	0.145	0.0792	.	0.047	0.040	0.2433		0.047	0.012	0.0001	***
Closest arterial road 0 - 2000m	0.160	0.058	0.0058	**	0.004	0.026	0.8777		0.043	0.011	0.0001	***
Closest primary school 0 -400m					0.013	0.066	0.8383		-0.002	0.009	0.8582	
Closest water 0 - 400m	0.193	0.107	0.0719	.	0.069	0.041	0.0897	.	0.049	0.011	2.68E-06	***
Closest water 400 - 2000m	0.124	0.047	0.0087	**	0.107	0.024	1.08E-05	***	0.028	0.008	0.0004	***
Closest RTN station 0 - 500m									-0.029	0.026	0.2701	
Closest RTN station 500 - 1500m									-0.015	0.010	0.1317	
Proportion of land in flood plain	0.034	0.089	0.7061		-0.109	0.038	0.0043	**	-0.014	0.010	0.1329	
Closest water is beach	-0.175	0.078	0.0246	*	0.038	0.033	0.2578		0.010	0.006	0.0794	.

Distance to CBD (linear metres)	-7.15E-06	2.50E-06	0.0042	**	-1.02E-05	1.35E-06	4.31E-14	***	-9.84E-06	4.96E-07	< 2.2E-16	***
Petrol stations	-0.005	0.017	0.7652		-0.002	0.006	0.7951		-0.004	0.001	0.0052	**
Food retailers	0.011	0.010	0.2798		0.007	0.004	0.0564	.	0.001	3.32E-04	0.0257	*
Other stores	0.002	0.004	0.5570		-0.003	0.001	0.0029	**	-2.29E-04	1.35E-04	0.0897	.
Restaurants / cafes	0.023	0.007	0.0021	**	0.007	0.002	0.0009	***	-4.96E-04	2.11E-04	0.0188	*
Financial	0.011	0.003	0.0001	***	0.005	0.001	9.44E-08	***	3.88E-05	6.25E-05	0.5347	
Real estate	-0.005	0.001	0.0002	***	-0.002	4.58E-04	0.0003	***	3.66E-04	4.84E-05	3.82E-14	***
Tertiary Education	-0.039	0.023	0.1000	.	-0.014	0.011	0.2099		-0.004	0.001	0.0020	**
Hospitals	-0.201	0.187	0.2827		-0.044	0.030	0.1473		-0.010	0.003	0.0014	**
Medical / healthcare	-0.003	0.008	0.7181		-0.004	0.002	0.0292	*	1.60E-04	1.52E-04	0.2927	
Heritage	0.005	0.018	0.7832		0.009	0.009	0.3278		0.007	0.003	0.0097	**
Performing arts	-0.010	0.007	0.1388		0.002	0.003	0.5372		0.001	1.68E-04	4.53E-05	***
Sports / recreation	0.009	0.006	0.1114		0.001	0.003	0.7854		0.003	0.001	9.53E-07	***
Repair	0.003	0.007	0.7295		-0.003	0.002	0.0360	*	-2.93E-05	2.02E-04	0.8849	
Personal and other services	-0.018	0.006	0.0049	**	0.005	0.002	0.0376	*	-0.002	3.92E-04	1.37E-05	***
Catchment employment, logged	-0.004	0.034	0.9114		-0.003	0.016	0.8292		-0.008	0.007	0.2102	
Sale in 2016 Q4	0.160	0.093	0.0853	.	-0.007	0.044	0.8747		-0.030	0.013	0.0199	*
Sale in 2017 Q1	0.072	0.087	0.4079		0.016	0.042	0.7008		-0.018	0.012	0.1405	
Sale in 2017 Q2	0.085	0.085	0.3176		0.079	0.043	0.0635	.	-0.021	0.012	0.0747	.
Sale in 2017 Q3	0.138	0.091	0.1275		0.021	0.043	0.6225		-0.026	0.012	0.0264	*
Sale in 2017 Q4	0.075	0.089	0.3989		0.041	0.043	0.3319		-0.018	0.012	0.1283	
Sale in 2018 Q1	0.096	0.093	0.3003		0.077	0.044	0.0777	.	-0.005	0.012	0.7032	
Sale in 2018 Q2	0.081	0.090	0.3672		0.031	0.043	0.4760		-0.013	0.012	0.2817	
Sale in 2018 Q3	0.086	0.092	0.3488		0.057	0.044	0.1944		0.004	0.012	0.7232	
Sale in 2018 Q4	0.104	0.091	0.2516		0.033	0.044	0.4548		-0.006	0.012	0.6211	
Inside special character area									0.084	0.016	2.35E-07	***
Land (square metres), outside RUB	**1.24E-06**	**8.85E-08**	**< 2.2E-16**	*******	**1.07E-05**	**8.67E-07**	**< 2.2E-16**	*******	**1.22E-04**	**1.02E-05**	**< 2.2E-16**	*******
Land (square metres), inside RUB, FUZ	**1.59E-05**	**1.41E-06**	**< 2.2E-16**	*******	**3.35E-05**	**1.65E-06**	**< 2.2E-16**	*******	**1.74E-04**	**2.99E-05**	**6.32E-09**	*******
Land (square metres), inside RUB, already developed	**3.60E-05**	**2.72E-06**	**< 2.2E-16**	*******	**4.65E-05**	**2.74E-06**	**< 2.2E-16**	*******	**2.40E-04**	**8.20E-06**	**< 2.2E-16**	*******
Pseudo R^2			0.764				0.709				0.766	
AIC			535.8				774.3				-3887.0	
AIC for non-error model			569.2				1089.4				-2346.9	
Statistical significance codes: '***' 0.001; '**' 0.01; '*' 0.05; '.' 0.1												

no arterial roads, no city centre, no stores, no restaurants and so on. By accounting for these amenities separately, we can fairly compare pieces of land in different parts of the region with different access to amenities.

We note that this land value is roughly what farmland can be purchased at in far-flung parts of New Zealand not close to many of the amenities that add value to property.

We do this calculation for each set of models and get an un-amenitied, a-spatial value of land per square metre for each category of land. The results of these calculations are shown in Table 5.

Table 5 Value of un-amenitied, a-spatial land per square metre, by category of land, not allowing for net usable land or infrastructure (step 6)

	Farm-sized	Lifestyle-sized	Residential-sized
Outside RUB	$1.73	$12.04	$108.56
Inside RUB, inside FUZ	$34.90	$46.38	$160.34
Inside RUB, already developed areas	$113.30	$60.16	$214.43

The results demonstrate the expected pattern. Land outside the RUB has the lowest value in each size category. Inside the FUZ, where land has the promise of infrastructure, some of the value is in land prices. In already developed areas inside the RUB, where infrastructure already exists, the land values are highest.

We then use these values to estimate the un-amenitied a-spatial land value of 618.7 square metres of land, the average size of residential properties inside the RUB, as shown in Table 6.

Table 6 Value of 618.7 square metres of un-amenitied, a-spatial land by category of land, not allowing for net usable land or infrastructure (step 7)

	Farm-sized	Lifestyle-sized	Residential-sized
Outside RUB	$1,069	$7,447	$67,164
Inside RUB, inside FUZ	$21,594	$28,695	$99,203
Inside RUB, already developed areas	$70,098	$37,222	$132,665

Accounting for net usable land (step 8)

Having estimated a value for un-amenitied, a-spatial land, we adjust farm and lifestyle-sized land for net usable land. As discussed in the methodology section, we assume each square metre of farm or lifestyle land converts into 0.65 square metres of net usable residential land.

On average, already developed residential-sized properties inside the RUB with an identifiable land component have a land area of 618.7 square metres. To get a residential section of that size, we estimate approximately 952 square metres of farm or lifestyle-sized land is required, with the rest going to roads, parks, stormwater drainage and other non-recoverable purposes. We note again that recent structure plans suggest that much more land is likely to be needed in most cases to produce properties similar to the average residential-sized property inside the RUB.

Multiplying the per square metre value of un-amenitied a-spatial land by the square meterage needed for an average residential section yields the un-amenitied a-spatial land value per residential section. Results are shown in Table 7.

Table 7 Value of un-amenitied, a-spatial land per already developed inside-RUB residential section equivalent, not allowing for infrastructure (step 8)

	Farm-sized	Lifestyle-sized	Residential-sized
Outside RUB	$1,645	$11,457	$67,164
Inside RUB, inside FUZ	$33,221	$44,146	$99,203
Inside RUB, already developed areas	$107,843	$57,265	$132,665

This provides a price gap compared to residential land inside the RUB, ***before accounting for bulk infrastructure required***, of:

- $131,020 between farm-sized land outside the RUB divided into residential sections similar to those inside the RUB, not yet allowing for infrastructure
- $121,208 between lifestyle-sized land outside the RUB divided into residential sections

similar to those inside the RUB, not yet allowing for infrastructure.

Accounting for infrastructure (step 9)

Having calculated the difference in value of un-amenitied, a-spatial residential-sized sections on farmland and lifestyle land outside the RUB compared to those inside the RUB, we subtract the bulk infrastructure costs required to develop that land. This allows a clearer picture of whether there is a price differential between farm or lifestyle land outside the RUB and residential land inside the RUB.

Table 8 shows a range of results using various assumptions of bulk infrastructure costs:

- No allowance for infrastructure, as assumed in some other reports, which we believe to be an inadequate view and is included for comparison only
- A lower lowerbound estimate of bulk infrastructure costs of $72,600
- An average lowerbound estimate of bulk infrastructure costs after removing 30% of costs to account for potential value and benefit to existing users ($80,640)
- An average lowerbound estimate of bulk infrastructure costs with 15% of the taxpayer and ratepayer infrastructure subsidy priced in, as you may observe close to but outside the RUB ($103,800)
- An average lowerbound estimate of bulk infrastructure costs ($115,200)
- An upper lowerbound estimate of bulk infrastructure costs ($208,600).

The RUB factor (step 10)

We express the price differential for infrastructured residential-sized sections inside the RUB versus farm and lifestyle land outside the RUB in dollar terms, and as a percentage of the average already developed residential property price inside the RUB in Table 8. The most defensible ***upperbound*** estimates of the RUB factor are in the dark grey columns.

Previous studies have reported estimates of the price differential as a multiple (e.g. land inside the boundary is 10 times more expensive than land outside) or a share of the average price of a property (e.g. 56%), or a dollar value (e.g. $530,000). Because reporting the differential as a multiple does not give any indication of the premium's magnitude, we report it primarily as a percentage of the property price.

The modelled price of the average residential sized property in our dataset is $959,652. We use this value to determine the RUB factor in percentage terms.

The ***RUB factor*** expressed as a share of the price of the average developed residential property there. This is ***at most*** likely to be ***1.6% to 5.2%*** when compared to ***farm-sized land*** outside the RUB.

The RUB factor on residential land inside the RUB compared to ***lifestyle-sized land*** outside the RUB is ***at most*** likely to be between ***0.6% and 4.2%*** of the price of an average already developed residential property with land inside the RUB.

Table 8 RUB factor range for farmland and lifestyle land

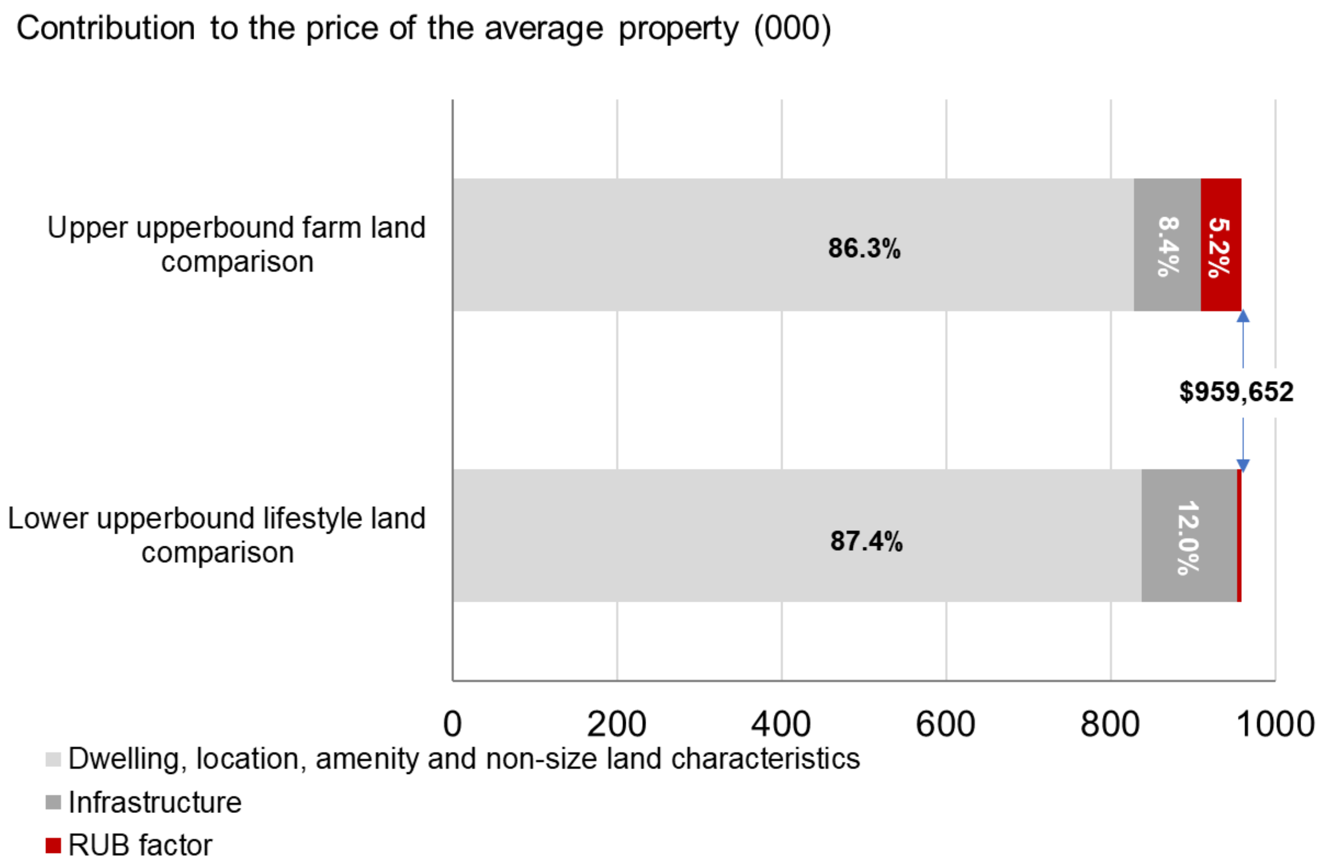
Property location	Higher estimate of bulk infrastructure costs	Average estimate of bulk infrastructure costs	Average estimate of bulk infrastructure costs, 15% of subsidy priced into land	Average estimate of bulk infrastructure costs, 30% of value to existing users	Lower estimate of bulk infrastructure costs	No allowance for infra-structure costs
Farm-sized land outside RUB	-$77,580 (-8.1%)	$15,820 (1.6%)	$27,220 (2.8%)	$50,380 (5.2%)	$58,420 (6.1%)	$131,020 (13.7%)
Lifestyle-sized land outside RUB	-$87,392 (-9.1%)	$6,008 (0.6%)	$17,408 (1.8%)	$40,568 (4.2%)	$48,608 (5.1%)	$121,208 (12.6%)

These premiums compare to premiums of up to 56% of the value of a property or $530,000 estimated in previous work, which seemingly did not account for bulk infrastructure costs or proximity to the city centre and used data from before the Unitary Plan was implemented. Our analysis shows that even if no allowance was made for infrastructure, the premium would be no more than 13.7%, but a more ***defensible upperbound range is between 0.6% and 5.2%*** of the price of an average already developed residential property with land inside the RUB.

To demonstrate what this means in explaining residential property prices inside the RUB, we can show the relative share of a property price accounted for by the components of what adds value: the dwelling, location, amenities, and non-size characteristics of the land; infrastructure; and the RUB factor.

We show two bar charts in Figure 4, representing the 0.6% and 5.2% RUB factor estimates, both upperbound estimates of the likely impact of the RUB on developed land prices inside the RUB.

Figure 4 Contribution to average modelled developed residential property price inside the RUB



Source: Chief Economist Unit, Auckland Council

Conclusions

The results of the econometric modelling and accounting for net usable land and bulk infrastructure costs indicate that the actual impact of the RUB on land prices is likely to be small. This suggests that, at present, the RUB is acting as a tool for sequencing development without impeding growth.

The analysis shows that the differential could even be a discount for residential-sized land inside the RUB when compared to farm or lifestyle-sized land outside the RUB, depending on assumptions about infrastructure costs, and considering that the infrastructure figures used in this study are likely to be underestimates.

These findings suggest that debate post-Unitary Plan implementation that continues to suggest that the RUB imposes a large price premium on land inside the RUB is baseless. The premiums appear to be at most 1/10th the size of those previously reported with regard to Auckland's old urban growth boundary, once bulk infrastructure, location and amenities are taken into account.

Nevertheless, the question of whether the RUB imposes a substantial premium on land inside it should be revisited every five to six years to ensure that it continues not to play a big role in setting land prices.

Our work also highlights that, to ensure market realities reflect actual costs and benefits, there is a lot of room for reducing the bulk infrastructure subsidy from ratepayers and taxpayers to new development, such that new developments pay more of their own development costs.

One further point to consider is that even if the price of infrastructure were fully borne by new development, this pricing would not overcome a number of social costs often associated with more expansive development. These typically include, but are not limited to:

- greater congestion
- greater emissions
- reduced viability of public transport
- (sub)-optimal use of existing infrastructure
- risks to viability of new communities.

It is beyond the scope of this study to determine whether the ***upperbound estimates of a 0.6% to 5.2% RUB factor*** on residential-sized land inside the RUB relative to farm and lifestyle-sized land outside is justified given these social costs associated with more expansive development. However, this question should be answered before bold recommendations are made on the RUB's future.

It is clear that the impact of the RUB on land prices inside it is at most a small fraction of what has previously been estimated with regard to earlier urban growth boundaries in Auckland.

Appendix: Other models and tests

We ran numerous sensitivity tests in addition to the preferred model presented in the Results section. For each test, the coefficients were estimated to five decimal places.

Spatial weights matrices

In the main text, we report our results based on spatial error models with four nearest-neighbour spatial weights matrices. However, there is no way to know which spatial weights matrix is the "proper" one to use. To account for this, we estimated the three models non-spatially adjusted, and with various k-nearest-neighbour spatial weights matrices.

Recall that the model specification is

$$\ln(P) = \alpha + D\beta + L\gamma + M\delta + T\theta + \varepsilon$$

where, P is a vector of the sale prices of the properties, D is a vector of characteristics that describe the dwelling associated with each property, L is a vector of characteristics that describe the land associated with each property, M is a vector of variables that describe the neighbourhood where each property is located, T is a vector of dummy variables for each quarter (i.e. time fixed effects), and ε is an error term.

For all model permutations, the Global Moran I test for regression residuals indicated spatial autocorrelation and the Lagrange Multiplier diagnostics for spatial dependence indicate there is spatial error dependence. These conclusions were reached using the flowchart from Anselin (2005, pp. 199), an adapted version shown here as Figure 5. The results of these tests are shown in Table 9 through Table 11. The grey shaded boxes in these tables indicate which tests showed the spatial error model to be preferred using Anselin's rationale from the flowchart and the recommendation to "estimate the spatial regression model matching the most significant statistic" when both tests are significant and one test is orders of magnitude more significant than the other.

Figure 5 Flowchart adapted from Figure 23.24 from Anselin's Exploring Spatial Data with GeoDa™: A Workbook

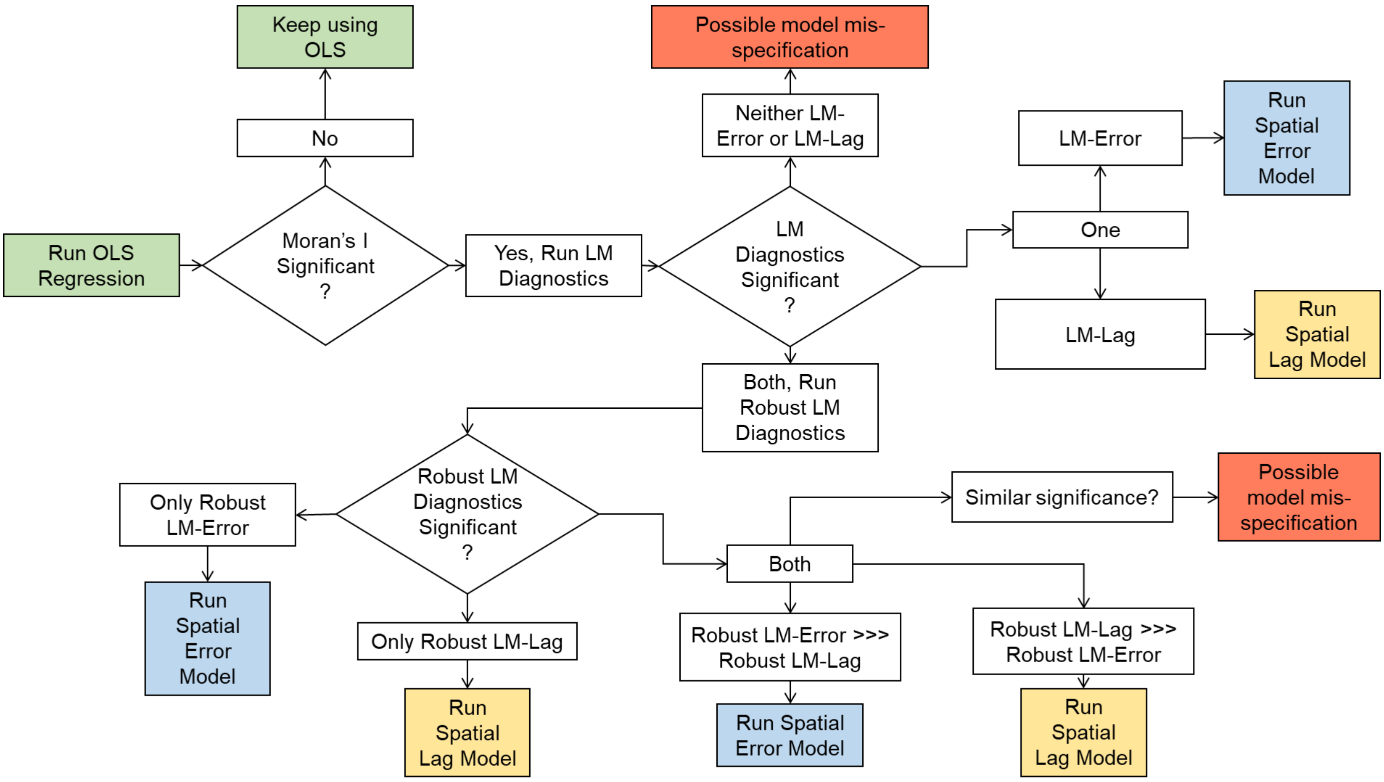


Table 9 Tests for spatial autocorrelation for farm-sized properties, various spatial weights matrices

Nearest Neighbours	4	6	8	10	12
Moran's I	6.0324	7.0898	7.1343	7.9389	8.2936
p-value	8.08E-10	6.71E-13	4.86E-13	1.02E-15	2.20E-16
Lagrange Multiplier Test (error model)	21.585	28.106	25.78	31.166	32.326
p-value	3.39E-06	1.15E-07	3.83E-07	2.37E-08	1.30E-08
Lagrange Multiplier Test (lag model)	15.576	5.1468	7.9885	9.8157	10.952
p-value	7.92E-05	0.023	0.005	0.002	0.001
Robust Lagrange Multiplier Test (error model)	19.111	26.584	23.965	28.969	30.118
p-value	1.23E-05	2.52E-07	9.81E-07	7.36E-08	4.07E-08
Robust Lagrange Multiplier Test (lag model)	13.102	3.6253	6.1734	7.618	8.7441
p-value	2.95E-04	0.057	0.013	0.006	0.003

Table 10 Tests for spatial autocorrelation for lifestyle-sized properties, various spatial weights matrices

Nearest Neighbours	4	6	8	10	12
Moran's I	19.847	21.969	23.011	23.467	24.818
p-value	2.20E-16	2.20E-16	2.20E-16	2.20E-16	2.20E-16
Lagrange Multiplier Test (error model)	344.23	408.44	434.9	439.54	480.74
p-value	2.20E-16	2.20E-16	2.20E-16	2.20E-16	2.20E-16
Lagrange Multiplier Test (lag model)	0.021065	3.091	4.6064	3.6516	3.8636
p-value	0.885	0.079	0.032	0.056	0.049
Robust Lagrange Multiplier Test (error model)	346.04	414.43	441.73	445.52	486.75
p-value	2.20E-16	2.20E-16	2.20E-16	2.20E-16	2.20E-16
Robust Lagrange Multiplier Test (lag model)	1.8321	9.0831	11.434	9.6295	9.874
p-value	0.176	0.003	0.001	0.002	0.002

Table 11 Tests for spatial autocorrelation for residential-sized properties, various spatial weights matrices

Nearest Neighbours	4	6	8	10	12
Moran's I	45.404	51.492	56.48	60.815	64.293
p-value	2.20E-16	2.20E-16	2.20E-16	2.20E-16	2.20E-16
Lagrange Multiplier Test (error model)	1978.4	2519.5	3004.2	3454.1	3829
p-value	2.20E-16	2.20E-16	2.20E-16	2.20E-16	2.20E-16
Lagrange Multiplier Test (lag model)	11.798	11.263	11.85	13.175	11.981
p-value	0.001	0.001	0.001	2.84E-04	0.001
Robust Lagrange Multiplier Test (error model)	1968.5	2509.7	2993.8	3442.7	3818.4
p-value	2.20E-16	2.20E-16	2.20E-16	2.20E-16	2.20E-16
Robust Lagrange Multiplier Test (lag model)	1.8838	1.3868	1.4407	1.7738	1.3593
p-value	0.170	0.239	0.230	0.183	0.244

These results effectively mean that the model specification is

$$\ln(P) = \alpha + D\beta + L\gamma + M\delta + T\theta + \varepsilon$$

$$\varepsilon = \lambda W\varepsilon + v$$

where W is the spatial weights matrix, λ is an estimated spatial parameter, ε is a vector of spatially autocorrelated error terms, and v is a vector of i.i.d. errors.

Unfortunately, without testing every single possible spatial weights matrix, it is impossible to know which one is the correct one, which is why we tested all the permutations previously. In fact, for residential-sized properties, we tested various k-nearest-neighbour matrices of up to k=40.

Sensitivity testing the spatial error models

The AIC for each of the models can give us an indication of which spatial error model is the best fitting for each of the land categories. In all cases, the smallest AIC value indicates the model with the best fit. It should be noted that AICs can only be compared within a model, not across. The AICs for farm-sized properties cannot be compared to AICs for residential-sized properties, for instance.

The AIC for each of the models tested is shown in Table 12. These AIC values indicate that for the farm-sized property model, a 10-nearest-neighbours spatial weights matrix gives the best model fit; for the lifestyle-sized properties, six-nearest-neighbours is best; and for residential-sized properties, 16-nearest-neighbours gives the best fit.

It is worth noting that the biggest changes in AIC come from recognising that spatial autocorrelation is an issue, with massive improvements in model fits coming from the unadjusted model to the four-nearest-neighbour spatial error models. In fact, the difference between any of the spatial error models is immaterial. To be consistent with Mathur (2014) and to allow similar comparison across land types, we use the four-nearest-neighbour spatial error model as our preferred model.

Table 12 Akaike information criterion for various spatial error models

AIC	Not adjusted	4	6	8	10	12	16	20	25	30	40
Farm-sized	590.29	560.84	554.38	556.96	550.31	550.61					
Lifestyle-sized	1089.4	774.29	746.32	754.38	764.88	760.13					
Residential-sized	-2346.9	-3887	-4031.6	-4116.8	-4181.2	-4219.5	-4286.7	-4282	-4245.9	-4255.9	-4268.7

But if our results in Table 7 are replicated for the 10, six, and 16 nearest neighbour spatial weights matrix models respectively, they change very slightly and do not alter any of our conclusions. The values of un-amenitied, a-spatial land per already developed inside-RUB residential section equivalent are as follows: For farm-sized properties outside the RUB, the value varies from $1,645 to $1,654, a difference of $9. For lifestyle-sized properties outside the RUB, the value varies between $11,457 and $11,442, a difference of -$15. Finally, for residential properties in already developed areas, the value varies from $132,665 to $137,600, a difference of +$4,935 or 0.5% of the modelled price of an average residential-sized property in already developed areas (~$960,000).

If, for the sake of generating unreasonably conservative estimates (i.e. overstating the premium on land inside the RUB if any), we used the models with the absolute lowest estimates for the un-amenitied a-spatial value of farm and lifestyle-sized properties outside the RUB and the absolute highest estimates of un-amenitied a-spatial residential-sized land values inside the RUB, these figures would be $1,637, $11,334, and $138,620 respectively.

This means that the RUB premium would vary by no more than about $6,000 from our estimates in Table 7 regardless of which model specification is used. Recalling that the reference property has a modelled price of approximately $960,000, this means that the RUB factor estimates are robust to within 0.6% of the value of the reference property, regardless of the spatial weights matrix used.

Preferred models with median income

Many other studies on this topic include median income among their regressors – for instance three of the studies we reference specifically in this paper use median income (Grimes and Liang, Mathur, and MBIE and MfE). Often this is used as a proxy for the “desirability” of a neighbourhood. In our preferred model, we do not include this factor for two reasons. First, we include other measures of neighbourhood desirability such as access to jobs, access to businesses / services, and measured distances to many amenities. Second, the school decile variable is highly related to household income. Nevertheless, we estimated the models both with and without median income as a variable.

For farm-sized properties, when median income is included, it is statistically insignificant, and the penalty for including another regressor is larger than the gain in model fit. However, we have included these results for completeness.

For lifestyle-sized properties, when median income is included, it is statistically significant, and model fit is improved slightly. For practical purposes, however, it makes little difference. The lifestyle-sized property model including median income estimates the per square metre price of land outside the RUB to be $0.05 higher than the model without median income. This amounts to roughly $50 per residential-equivalent property and would lower our estimate of the RUB factor for lifestyle-sized land.

For residential-sized properties, when median income is included, it is barely statistically significant and model fit is improved infinitesimally. Like with the lifestyle-sized properties, since we believe the model without median income is superior, we test to see how much the model changes with it included. Including median income as a regressor makes almost no difference. The estimate of the per square metre price of land in already developed areas inside the RUB decreases by about $0.04 when median income is included. This is roughly $26 per property.

All told, we believe that the models that exclude median income are better because income of a neighbourhood is generally a proxy for the things in that neighbourhood (good schools, services available, access to jobs and so on) that we have already tried to explicitly account for. While it appears that including median income may *slightly* improve model fit – at least for lifestyle-sized properties – we do not include it in our preferred model to avoid any double counting of the amenities that median income is a proxy for. Regardless, whether the term in included or not makes practically no difference to the estimates of the variables we are primarily interested in – and estimates that do vary by more than a few dollars are the estimates with the least precision, as there are the fewest observations in those categories (Farm-sized, inside the RUB, both FUZ and already developed).

Preferred models with zoning variables

We considered including zoning dummy variables in our model. However, zoning is highly correlated with whether a property is inside or outside the RUB. We are concerned, for instance, that properties zoned rural can only be located outside the RUB and that 99.9% of terrace housing and apartment building zoned land is located inside the RUB. This could muddle the interpretation of the RUB variable as it would be difficult to determine how much of the difference is due to the RUB and how much is due to the different zoning.

With zoning included, we found that, while the results change a bit from those of our preferred models, the implied RUB factors vary just a bit with the range changing from 0.6% to 5.2% with the preferred model to 1.9% to 6.5% in the model with zoning. However, there is no way to know how much of the calculated premium is attributable to the existence of the RUB itself versus the types of zoning available inside and outside the RUB. Given this interpretation challenge, the minor changes to the calculated numbers, and no material change in the overall results of our study, we retained the preferred model results.

Preferred models with RUB dummy variable

One external reviewer suggested that our preferred model should include a RUB dummy variable. We note that we already include a RUB dummy variable interacted with the square metres of land. The addition of this variable is effectively an intercept term. That is, regardless of the land size, being inside or outside the RUB has an impact. Then there is an additional marginal impact per square metre of land. This is a totally reasonable approach to consider.

When this approach was adopted, the results from our preferred model did not change much. We found that our estimated RUB factors fell by a little more than $4,000. Since this is a smaller premium than we get from our preferred model, we err on the side of conservatism by keeping our initial estimates. Another interesting point to note is that with the RUB dummy variable, residential-sized sections both inside and outside the RUB have almost identical prices – in fact, this is about the only meaningful change.

Preferred models with RUB dummy variable and FUZ dummy variable

Similarly, it was suggested that our preferred model could include a RUB dummy variable and a FUZ dummy variable in addition to our already included RUB and FUZ dummies interacted with the square metres of land. Again, these effectively add an intercept term with a similar explanation for the FUZ dummy as the RUB dummy in the previous section.

When this approach was adopted, most of the results were similar to the results with only the RUB dummy variable added. Residential-sized land in the FUZ sees quite a large decrease in value, though as we discuss in the main text, there is no basis on which to decide which of these figures is correct. Since the difference in the variables of interest (i.e. already developed residential-sized sections, and outside RUB farm- and lifestyle-sized sections) are quite small, this is one reason we retain our preferred model.

These results also show that residential-sized un-amenitied, a-spatial land both inside already developed areas and outside the RUB have very similar prices. For our calculated RUB factors, they are approximately $4,000 smaller than those estimated by the preferred model in the paper. Again, to err on the side of conservatism, we keep our estimates from the preferred models.

Preferred models with different thresholds for residential, lifestyle, and farm-sized land sizes

Our definitions of the land size categories are not based on any legislative or specific policy framework, so we have tested alternate definitions. Recall that we used 4,000 square metres and 40,000 square metres for the breakpoints between residential and lifestyle-sized, and lifestyle and farm-sized land respectively. These were based on loose definitions used in other council documents (there is no set definition), as well as qualitative research of the New Zealand real estate market, focusing on typical lifestyle property sizes.

As an alternative, we used a "fisher-style" algorithm (Bivand, 2019) to estimate where the "natural" breakpoints could be. This algorithm suggests that the optimal breakpoints are 8,296 square metres and 33,284 square metres. The results from our preferred models with these alternative breakpoints yield RUB factors that are much smaller than those generated by our original models. The estimated value of farm-sized land outside the RUB is nearly identical to our original estimates, whereas the estimated value of residential-sized land in already developed areas is more than $40,000 lower. This would take the RUB factor to an upperbound range of -3.7% to +0.8%. Again, we stick to the more conservative estimate.

Combined model versus the preferred three separate models

We had initially considered having one model that described the sale price of all types of properties. A drawback of this approach is that it implies that attributes like floor area, construction type, or distance to various amenities will affect all types of properties equally. This is one of the reasons for moving to the three-model approach that we adopted. However, we did estimate two versions of a single model to see how that might affect results.

First, we estimated a single model that did not include dummy variables for land size category interacted with the log of land size. This effectively treats all properties in Auckland identically, with the exception of where they are located in relation to the RUB. As expected, this model gives a slightly worse fit to the data because it implicitly assumes that dwellings, location, and amenities are similarly valued on very small parcels of land and very large ones, which attenuates the land value estimates.

It also introduces another complication. Because the land outside the RUB includes farmland as well as land that has already been chopped into residential-sized sections, it is not clear how much of the value of this land includes its own infrastructure. Similarly, it is not clear how much of the land inside the RUB would need to be further broken down into residential-sized categories, as there are larger tracts of land in this area.

Given that the question we are trying to address requires a comparison between land inside the RUB being used residentially now and large tracts of land outside the RUB that could be broken into residential-sized sections in the future, the comparison possible from this model is not as useful to answer the question that we've posed.

Nevertheless, the RUB factor estimate for the combined model with no land size dummy variables is around $100,000 lower than for the three-model approach. This would equate to a RUB factor up to 10.1 percentage points lower than our preferred model calculates and suggests that land ***inside*** the RUB sells at a 4.8% to 8.3% ***discount*** relative to land ***outside*** the RUB.

The second combined model we estimated was identical to the first, but with the inclusion of dummy variables for land size category interacted with land size. This allows for a square metre of land on a large tract of land (farm) to be valued differently than a square metre on a residential-sized section, as in our preferred model, but requires the remaining attributes of land, dwellings, location, and amenities to be valued the same way across all properties in Auckland. This model results in a RUB factors about $40,000 less than our preferred models. This implies an upperbound RUB factor estimate of between -3.7% and +0.9%.

Log of land size as independent variable

During our research, it was suggested that we test a log-transformed land size variable or a quadratic term. Quadratic terms are often used for amenities where proximity is valued but being either "too close" or "too far" is less desirable than being somewhere in between. For instance, many people probably do not want to live next door to a train station. Living an easy five-minute walk would potentially be desirable and living several kilometres away would give little or no value (or possibly even negative value). In this instance, a quadratic term on distance would allow the amenity value to be low nearest to the train station, increase up until a point, then decrease again. There is no reason to believe, however, that this would be true of land size. While one could expect each additional unit of land to be worth ***less*** than the one before it, there is no evidence that an additional unit of land would be ***negative*** and decrease the value of a property.

More plausible is that the value of land could be a logarithmic function – that is, increasing at a decreasing rate with larger land size. Theory could suggest that the minimum land size needed for a feasible dwelling would have a massive value because it has the option of being built upon. Then, each subsequent square metre of land would have much less value because those square metres add only "backyard amenity" rather than the ability to add another dwelling. If every single property in Auckland was zoned for single-house dwellings, this could be a good descriptor.

However, post Unitary Plan implementation, around three quarters of residential-sized sections are zoned for denser usage than a single house. This means that every additional square metre of land leads to more development potential and a higher probability of being able to add a dwelling. The implication is that land prices should not necessarily follow a logarithmic pattern, and if one is applied to them, we could end up mis-estimating the value of land – see Figure 6 for an illustration.

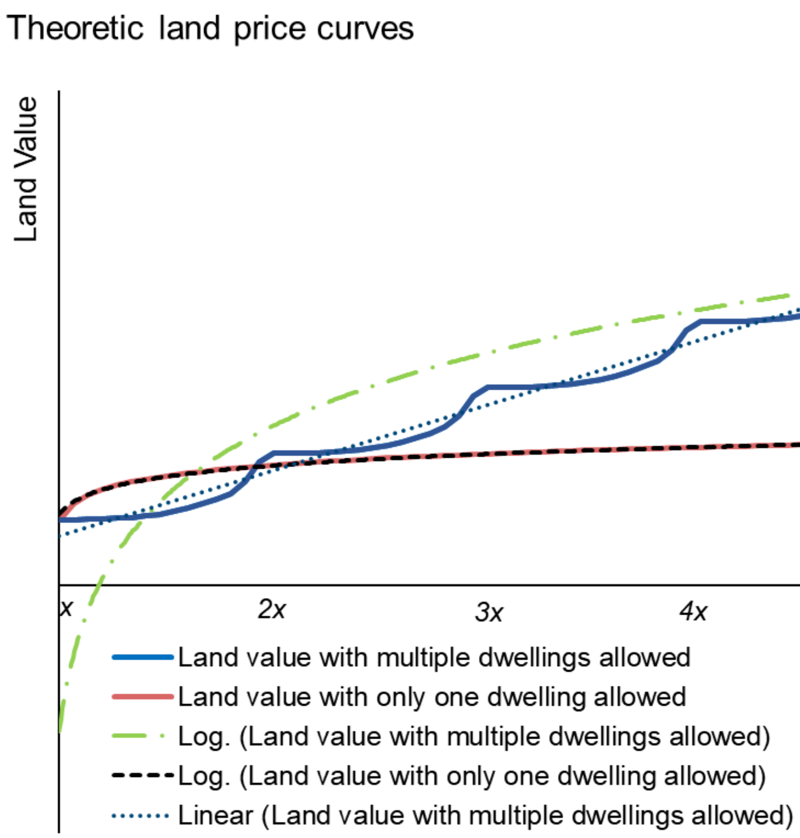
This illustration shows theoretic land price curves. The solid red line is indicative of a property that is zoned for only a single dwelling. Here, it makes sense that the vast bulk of the land value is accumulated as soon as the land is big enough to accommodate a dwelling. Once this threshold, *x*, is reached, the remainder of the land can only provide backyard amenity and has no development potential.

In contrast, the solid blue line is indicative of land that is zoned for multiple dwellings, as is the case for most residential land in Auckland. In this theoretic case, adding roughly an additional *x* square metres of land is enough to trigger the next dwelling. As the size of a section approaches a multiple of *x*, the value of the land jumps as the probability of another dwelling being permitted increases rapidly.

In the case of the single-dwelling zoned land, it is reasonably clear that the value of the land is probably best estimated with a logarithmic function (the black dashed line). However, in the case of multiple-dwelling zoned land, a linear function (the blue dotted line) is a much better fit than a logarithmic function (the green dash-dot line). While these curves are purely theoretic, they do illustrate that a logarithmic function is not necessarily the best fit for the land value – land size relationship. This remains true even in the case when price is logarithmically transformed as well, as in our preferred model.

Three options are available to include log-transformed land. First, we could use a combined model, which simply models the price of a property as a function of the log of the land size. This would make no allowance for disaggregating land across the three size categories we have used. It is precisely because

Figure 6 Possible shapes of land price curves



Source: Chief Economist Unit, Auckland Council

different land size categories represent different levels of development and use that our preferred approach uses a separate model for each of the three categories. This better accounts for how they value amenities and property characteristics differently from other land sizes.

Second, we could use a combined model with dummy variables for land size category interacted with the log of land size. This would effectively be the same as the first model but allow for different sized tracts of land to have different marginal land values. This would overcome the problem with the first model approach but would add another. We have already explained why a linear model may be the best approximation for land size increases, but it is hard to argue that the next square metre of farm land (and possibly lifestyle land) will be less valuable in its current use than the last square metre. This is what a log-log model implies. There is no reason to believe that the next square metre of farm-sized land will be less productive, and thus less valuable than the last.

Finally, we could use a three-model approach for the log-log model based on land size category as we do for our preferred model. This would overcome the problem with the combined model approach but would add another. This would, in theory, be a more accurate version of the second model, but suffers from the same issues with regard to explaining the value of an additional square metre of land, especially for farmland and potentially lifestyle land.

Regardless, we tested the three log-log models defined above. Using a log-log specification and a single model of property prices with no land size categories, the differential between a residential-sized section in already developed areas and one outside the RUB is approximately $159,000. While this figure is almost $30,000 higher than in our preferred model, we find that it is impossible to interpret because this combined model makes no allowance for the level of development of different properties on either side of the RUB implicit in different land size categories. Nevertheless, the implied upperbound RUB factor range of the combined log-log model with no land size categories is between 4.5% and 8.0%.

Using a log-log specification and a single model of property prices with land size categories, the differential between a residential-sized section in already developed areas and a farm-sized section outside the RUB is approximately $160,000 and the differential between a residential-sized section in already developed areas and a lifestyle-sized section outside the RUB is approximately $148,000. These differentials result in an upperbound RUB factor range between 3.3% and 8.1%.

Finally, we used the three-model approach with log transformed land size. These models yield a RUB factor of approximately $176,000 between residential-sized sections in already developed areas and farm-sized land outside the RUB and $162,000 between residential-sized sections in already developed areas and lifestyle-sized land outside the RUB. These figures are approximately $30,000 to $45,000 higher than our preferred model and would result in a range of upperbound RUB factors from 4.8% to 9.7% as compared to our preferred model range of 0.6% to 5.2%.

Preferred models with capital value rather than sale value

Using capital valuation (CV) data, as previous models by other authors have done, has a couple of advantages over using actual sales. Firstly, CV data is available for every property in a region, whereas a property must have been sold for it to show up in the sales dataset. Secondly, all properties theoretically have their CV estimated at the same time. This means the econometrician needn't control for time in the regressions. Lastly, models that use CV data often have better R^2 values and other measures of model fit.

However, there are at least two reasons why, despite these advantages, using actual sales data is better. Firstly, sales prices reflect the actual values that market participants place on properties rather than the best estimate of an appraiser.

Secondly, the models estimated with CVs rather than sales would be expected to have higher R^2 values because they are models of a model. CVs are often generated by a mass appraisal model, which means that any model using CVs is fitting a model to a set of fitted values rather than actual values. By using fitted values, an unknown portion of variance in sale prices is unaccounted for.

The number of sales in our sample is more than adequate to generate meaningful statistical relationships. With around 550,000 properties located in Auckland, our sample of sales was nearly 37,000.

Nevertheless, we fitted our preferred models from the paper to CVs rather than sale prices to determine the impact. As expected, the model fits are generally better (apart from farm-sized properties). The R^2 for the lifestyle and residential-sized models increased materially. Curiously, the model fit for farm-sized properties was worse for the CV model than the actual sales model. This may suggest that the CVs for very large sections of land do not accurately capture their true market value.

The results from the CV-based models are, like our other sensitivity tests, consistent with the results from our preferred model. In the case of the CV models, the estimated value of farm and lifestyle-sized land is lower than for the models based on sales price, though still in the same range. The CV-based RUB factor comparing residential land inside the RUB and farmland outside would be at most 1.4 percentage points higher than in our preferred model. However, for the reasons set out above and the immaterial impact of moving to the CV-based model, we stick with our preferred model.

Confidence interval sensitivity testing of the preferred model

The upperbound RUB factor estimates of 0.6% to 5.2% of the value of a developed residential property inside the RUB are based on point estimates of the land value coefficients in our preferred model. We further sensitivity tested these results using the 95% confidence intervals for these coefficients. We find the range of RUB factor estimates widens from -0.6% to 6.3%. This shows that the point estimates of land value are accurate enough that our RUB factor varies only by about +/- 1 percentage point when the confidence interval is used instead.

Summary of sensitivity tests

Our sensitivity tests broadly show that our preferred model results presented in the paper are robust to various changes in the modelling methodology. Where the results change, it is no more than a few thousand dollars up or down on the modelled price of an average property of about $960,000. The exception to this is the fisher-style" algorithm for determining breakpoints for lifestyle-sized properties, which yields a RUB factor around $40,000 lower than our preferred model.

When we run models with different ***specifications***, the range of RUB factors widens somewhat, to a ***range of upperbound RUB factors from -8.3% to +9.7%***, with a midpoint estimate of approximately 1%. Recall again that these are ***upperbound*** estimates of the RUB factor (that is, the true premium is likely to be ***lower***) for all the reasons outlined throughout the report.

Mathur's model of land prices outside an Urban Growth Boundary

Mathur (2014) looked at the impact of a RUB-like boundary on land prices around Seattle, Washington, USA using four models. He notes the importance of "assured urban-level infrastructure and services" being capitalised into land prices inside the Urban Growth Boundary (UGB). His "Model 2" hypothesises that *vacant* lots outside but adjacent to the UGB could be priced higher than those further outside the UGB. In particular:

> *For lots outside the UGB, the effect of the 'distance from the UGB' variable primarily depends on the expectation of UGB expansion. If UGB expansion is expected, the lots closer to the UGB should be priced higher than those farther away to capitalize the future stream of revenues boundary expansion might confer on these lots. Conversely, the distance to the UGB should not impact lot prices if UGB expansion is not expected.*

He finds that for his area of analysis, the coefficient on the distance to the UGB is not statistically significant and there is, consequently, little expectation of UGB expansion. He notes that this is reasonable as the UGB had been in effect for over 25 years and had only seen minor changes during that time.

In Auckland, the RUB is quite new. It has only existed since late 2016 and there is no precedent for how often and how far the RUB will move, if at all. To determine if, outside the RUB in Auckland, there is any anticipatory effect on land prices, we estimated a model similar to Mathur's Model 2, of the following form:

$$\ln(PPSM) = \alpha + L\gamma + M\delta + T\theta + \varepsilon$$

$$\varepsilon = \lambda W\varepsilon + v$$

where, $PPSM$ is a vector of the sale price per square metre of the land parcels, L is a vector of characteristics that describe the land, M is a vector variables that describe the neighbourhood where the land is located, T is a vector of dummy variables for each quarter (i.e. time fixed effects), and ε is an error term. Like the other models, this one shows symptoms of spatial autocorrelation that is best accounted for with a spatial error model. Thus, the error term, ε, is a function of the spatial weights matrix.

The results of this model are shown in Table 13. Like our other estimates, these coefficient estimates are robust to the choice of spatial weights matrix.

Similar to Mathur, we find that distance to the RUB / UGB is statistically insignificant. However, even if we treated this variable as significant, it would imply a 12.8% price premium on land located immediately adjacent to the RUB (i.e., Distance to RUB = 0) over land located the average distance to the RUB, which is roughly 8km. This gives us a reasonable point estimate of how much of the infrastructure subsidy could be priced into land prices just outside the RUB. Like our other estimates, these coefficients are robust to the choice of spatial weights matrix.

Table 13 Results of "Mathur's Model 2" for Auckland

	Estimate	Std. Error	Pr(>|z|)	
Intercept	2.379	0.492	1.35E-06	***
Distance to RUB (km)	-0.015	0.010	0.1530	
Land contour - various / unknown	-0.685	0.115	2.95E-09	***
Land contour - Easy fall	-0.013	0.124	0.9146	
Land contour - Easy rise	0.006	0.110	0.9530	
Land contour - Steep fall	0.003	0.372	0.9926	
Land contour - Steep rise	0.684	0.592	0.2482	
View, Other moderate	0.003	0.130	0.9808	
View, Other slight	0.082	0.123	0.5086	
View, Other wide	0.056	0.214	0.7931	
View, Water moderate	0.054	0.197	0.7844	
View, Water slight	-0.053	0.202	0.7946	
View, Water wide	0.721	0.230	0.0017	**
Low (1-4) decile school zone	-0.013	0.212	0.9526	
Medium (5-7) decile school zone	-0.068	0.163	0.6790	
High (8-10) decile school zone	0.158	0.177	0.3722	
Closest water 0 - 400m	0.260	0.151	0.0858	.
Closest water 400 - 2000m	0.194	0.100	0.0528	.
Closest golf course 0 - 2000m	-0.424	0.266	0.1105	
Closest town centre 200 - 1000m	-0.177	0.612	0.7726	
Closest town centres 1000 - 2000m	-0.073	0.318	0.8180	
Closest park 0 - 400m	0.292	0.102	0.0040	**
Closest arterial road 0 - 500m	0.411	0.187	0.0278	*
Closest arterial road 0 - 2000m	0.523	0.116	6.77E-06	***
Closest primary school 0 -400m	0.338	0.457	0.4605	
Proportion of land in flood plain	-0.030	0.158	0.8512	
Closest water is beach	-0.034	0.103	0.7411	
Petrol stations	-0.029	0.035	0.4186	
Food retailers	0.026	0.023	0.2625	
Other stores	-1.79E-04	0.008	0.9824	
Restaurants / cafes	0.010	0.012	0.4182	
Financial	0.015	0.006	0.0113	*
Real estate	-0.006	0.003	0.0231	*
Tertiary Education	-0.120	0.066	0.0673	.
Hospitals	-0.138	0.153	0.3647	
Medical / healthcare	0.008	0.017	0.6473	
Heritage	0.044	0.040	0.2689	
Performing arts	-0.034	0.014	0.0131	*
Sports / recreation	0.023	0.014	0.1077	
Repair	-0.003	0.019	0.8623	
Personal and other services	-0.001	0.016	0.9331	
Distance to CBD (m)	4.60E-07	4.99E-06	0.9264	
Lifestyle-sized section	1.753	0.095	< 2.22E-16	***
Residential-sized section	3.082	0.127	< 2.22E-16	***
Catchment employment, logged	-0.009	0.076	0.9032	
Sale in 2016 Q4	-0.113	0.186	0.5431	
Sale in 2017 Q1	-0.018	0.181	0.9211	
Sale in 2017 Q2	-0.142	0.178	0.4256	
Sale in 2017 Q3	-0.113	0.186	0.5421	
Sale in 2017 Q4	0.023	0.188	0.9009	
Sale in 2018 Q1	0.047	0.182	0.7959	
Sale in 2018 Q2	-0.042	0.183	0.8189	
Sale in 2018 Q3	0.020	0.185	0.9134	
Sale in 2018 Q4	0.066	0.185	0.7206	
Pseudo-R2	0.845			
Statistical significance codes: '***' 0.001; '**' 0.01; '*' 0.05; '.' 0.1				

Although our replication of Mathur's Model 2 shows land on the RUB has no statistically significant premium in value, in estimating the RUB factor, we run a scenario that allows for 15% of the infrastructure subsidy from ratepayers and taxpayers to be priced into land prices outside the RUB. This provides a sense of scale as to what the impact could be close to the boundary if subsidies were bidding up land prices there.

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