TE TAI ŌHANGA
THE TREASURY

Te Tūāpapa Kura Kāinga
Ministry of Housing and Urban Development

Reserve Bank of New Zealand
Te Pūtea Matua

Analysis of availability of land supply in Auckland

Results from improved land efficiency indicators and discussion on their use for policy

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Executive Summary

The Housing Technical Working Group (HTWG) is a collaboration between Te Tūāpapa Kura Kāinga – Ministry of Housing and Urban Development (HUD), the Reserve Bank of New Zealand (Te Pūtea Matua), and The Treasury (Te Tai Ōhanga). It was established in 2021 with the aim of improving our technical understanding of the New Zealand housing system. This paper presents the HTWG's findings on the theory and practice of measuring how restricted land supply is in New Zealand.

The HTWG's first publication[1] suggested that restricted urban land supply in New Zealand affects the behaviour of the housing market. The more that land supply is restricted, the more that financial changes such as movements in interest rates and taxation will be captured as changes in the price of scarce urban land. This contrasts with traditional economic theories that assume an abundance of land and predict that changes in interest rates and taxes would affect rents rather than land prices. The group concluded that the key cause of rising house prices in New Zealand over the past twenty years was a long-term decline in interest rates that, due to restricted land supply, boosted urban land prices. The group placed less emphasis on construction costs and population growth relative to dwelling supply in causing the run up in house prices. However, the HTWG's second piece of published research,[2] found that population relative to dwelling supply is an important determinant of rents in New Zealand.

This paper represents the third phase of the HTWG's work. It attempts to measure how restricted urban land supply is in New Zealand, and how this has changed. We present two empirical pilot-studies that focus on Auckland, and one theoretical background study.

We find direct evidence of restrictions on the supply of urban land in Auckland.[3] For example, these restrictions are estimated to add $378.4 per square metre to the price of urban land immediately inside of the Rural Urban Boundary line in Auckland in 2021. The differential is also smaller in areas that are currently rural but identified by Auckland Council as locations where infrastructure will be implemented. This shows that restrictions on availability of urban land do affect prices – but which restrictions (such as regulation or infrastructure provision), and their degree, varies by area. We find some tentative evidence that the availability of urban land in areas of Auckland improved over the five-year period, following the introduction of the Auckland Unitary Plan, with prices for types of housing in high demand returning closer to the cost of producing those homes.

Interpreting the indicators requires care and nuance. They are highly sensitive to measurement decisions, such as buffer zones around boundaries. There are also limitations to the underlying data, such as delineating new builds from second hand stock, and market prices from administrative valuations. When used thoughtfully, measured over time across and within regions, and considered alongside other evidence, these indicators have multiple policy uses.

The indicators can help with what restrictions policy should seek to target. Clustering regions by indicators allows for the identification of common underlying causes. This can guide which

1 Assessment of the Housing System: with Insights from the Hamilton-Waikato Area, Housing Technical Working Group, August 2022
2 What Drives Rents in New Zealand? National and Regional Analysis, Housing Technical Working Group, August 2023
3 The supply of land refers to; new urban land, typically on the outer limits of cities; redevelopment opportunities on existing urban sites; and intensification opportunities on existing housing sites. Restrictions can include regulatory, infrastructure availability, geographical etc.

interventions are likely to have greater or lesser impact in which regions. Relative scale of restrictions across regions can also be used to determine where additional supply is likeliest to be feasible, the size of potential reduction to restrictions on land supply, and where other interventions will be necessary to achieve desired outcomes. Looking at land metrics within a city can help determine where restrictions limit supply response to different types of demand (e.g. types of home or location) and whether these restrictions are addressable through policy.

The indicators can help determine whether restrictions are loosening or tightening over time. Measuring indicators over time also allows us to observe and evaluate the impact of policy interventions and correlated cyclical factors, like interest rates, that were not distinguishable with previous 'point in time' observations. Timeseries also give a better view of the time taken for changes, such as the Auckland Unitary Plan, to take effect.

Chapter 1 provides an estimate of price-cost ratios for Auckland. The price-cost ratio is a measure of house prices to the cost of constructing a new dwelling. A high ratio suggests there are frictions or regulations that make it difficult for developers to build new dwellings in response to demand. We find that measuring sub-regional price-cost ratios, along with other indicators of demand and amenity, can indicate where supply is avoidably constrained or where further development appears feasible.

Chapter 2 provides new urban rural price differentials based on an updated methodology. This measures the price of land inside an urban boundary relative to the price of land outside the boundary. A high ratio, appropriately corrected for the cost of developing rural land, suggests that house prices could be reduced by easing the constraints to develop across the city (including at the fringe). We present the differential as a time series, rather than point in time, and calculate differentials for multiple boundaries within Auckland. This analysis reveals a significant increase in the price difference between urban and rural land at the city's edge over time, suggesting restrictions on development across the city. We also demonstrate the significant impact the choice of boundary definition has on differential values, which can help identify specific local constraints. For example, the differential between current urban and rural land is higher than at the administrative division between future urban and rural.

Chapter 3 is a theoretical explanation of how price-cost ratios should be expected to respond in different scenarios – such as changes to interest rates, land prices, and construction costs – where there are differing restrictions on the substitutability of housing and land. The model finds that when the above can occur frictionlessly, the price-cost ratio should not alter significantly with changes in land value. In theory, this makes reliable measurement of the ratio between price and cost of dwellings over time an accurate indicator of restrictions on the supply of land for construction.

Chapter 1: Measuring price-cost ratios

The price-cost ratio (PCR) is calculated by dividing the price of a dwelling by how much it costs to build it. As discussed in chapter 3, in theory a PCR is a useful general indicator of how responsive land markets are to demand, relative to construction activity. Where the number and size of sections can be readily adapted to demand, the land component of buying a home should stay relatively static. This ratio was first proposed by Glaeser and Gyourko (2003) and then adapted to the New Zealand housing market by (Lees, 2019). Later, it became one of the recommended indicators in the National Policy Statement for Urban Development - (Ministry for the Environment, 2017) and widely used by councils to assess their performance against the objectives of the policy, in their housing and business capacity assessments. Measuring PCRs is difficult. To do so accurately requires the cost to build each dwelling, how much it sold for when it was first built, and an estimate of its build cost and real sale price for every time it is sold over its lifespan. These data do not readily exist. This chapter examines how effectively PCRs can be measured in New Zealand currently and the implications for their interpretation.

Data sources

Time series data on construction costs and sales price for a dwelling over its time span is not readily available for New Zealand's housing stock. Over the years, different attempts at producing PCRs have used different data sources as a proxy for either of the two variables. These data are often paid for and obtained as snapshot data, that is, without a temporal dimension. The most reproducible PCR calculation is the one performed in the National Policy statement -Urban Development Capacity (NPS-UDC) which uses the following data sources:

- District Valuation Roll (DVR): Record level data owned by local councils according to the Rating Valuations Act 1998 and used as a basis for rating. This data maintained by independent Valuation Service Providers on behalf of Territorial Authorities around New Zealand, and contains information about Titles, parcels, and other physical properties of the record.
- Transactions data from CoreLogic: Private data analytics company CoreLogic commercializes data on the transactions that happen at record level. For this project we use the value of sales for each dwelling over time.
- Stats NZ building consents: Monthly building consents issued data includes the number, floor area and value of planned new dwellings.

Note that DVR and transaction data from CoreLogic are currently only available commercially, at a high cost, which makes these exercise not fully reproducible. HUD has ongoing access to all the above datasets.

Ratio calculation

The ratios are developed by comparing the average price of houses sold in an area (at a $/sqm) with the relevant average building consent values (also at a $/sqm), plus a 25 percent construction cost buffer, and 5 percent for real estate fees and other costs of buying a home. The amount left over is the imputed cost of land (the section). Data on the value of building consents cover most construction costs, including builders' profit (noting it may not include development margin for the developer). However, the construction cost buffer has been added in to adjust for construction costs that building consents' data undercount or exclude, such as land development costs and profit, finance and consultant fees. A 25 percent buffer is used based on advice from quantity surveyors and industry experts (Ministry for the Environment, 2017).

Interpretation

The NPS-UDC guidance to interpret the results of PCRs stated:

1. Ratios below 1 might occur in places or times where there is no growth, with houses selling below the construction cost to replace them.
2. Ratios between 1 and 1.5 (that is, where the cost of an infrastructure serviced section comprises up to one-third of the price of a home) are common where the supply of land and development opportunities are relatively responsive to demand. All New Zealand urban areas had PCRs of between 1 and 1.5 about 20 years ago when land and housing markets delivered more affordable housing, and these ratios are still common in places where homes are cheaper.
3. Ratios above 1.5 signal that the supply of sections and development opportunities is not keeping pace with demand and land prices are materially increasing house prices."

Critiques

When using the PCR to assess the performance of urban land markets, councils have come up with a few problems. These have been highlighted in their Housing and Business Capacity Assessments. For example, the assessment for Queenstown lakes district argues that the PCR has significant limitations, as it does not account for factors like market preferences, planning constraints, and changes in amenities. Moreover, when analysing entire towns or cities, the PCR is dominated by older residential properties and does not accurately reflect the land efficiency of new dwellings. Additionally, the PCR assumes that every residential lot is developed to its maximum potential, which is not the case as, Fairgray argues, over 80 percent of already developed sites have potential for intensification.

Due to these limitations, the authors of the assessment consider the PCR to not have a robust enough basis for interpreting urban markets, and recommend applying it with care when examining new residential properties (Fairgray, Fairgray, & Hampson, 2021).

Age of stock compositional issue

Measurable PCRs can be sensitive to compositional issues if many second-hand houses are being transacted in a particular market, as is the case in New Zealand. This is because the price of the land component of a second-hand property is likely to adjust more quickly than the size of the dwelling component, even if at the margin the size of new dwelling/section combinations reflects contemporary prices. Therefore, Fairgray's *et al.* critique that the PCR is dominated by older residential properties is a valid one.

As a solution to this compositional issue, we have developed a version of the PCRs based only on 'new properties' – dwellings built and sold within the last five years – in the calculation.

Differential land rents implicit in the PCR values

Measured PCRs are affected by desirability and locational differences. The simple calculation in a PCR does not account for any other variables that may affect the price of a property, like distance to amenities, meaning places with higher desirability tend to have higher PCRs. For example, many people have a high willingness to pay to live near a beach; when there is only limited land near a beach, these preferences will lead to higher land prices than elsewhere even if there are no restrictions on land use. Higher PCRs in these areas reflect preferences rather than an ineffective land market; therefore, these factors need to be removed from the calculation.

As a solution to this issue, we suggest calculating PCRs for smaller areas that have 'similar' levels of amenity. This opens a trade-off between choosing a small enough spatial scale while still having enough data points to compute the ratios. In the case of Auckland, we have proposed to compute PCRs at a local board level.

Different housing typologies may have different ideal PCRs

Different housing typologies such as detached houses, townhouses, and apartments, may have different PCRs. This could be due to different household preferences and different production functions of the construction sector. For example, people who like gardening will want a larger section and their PCR will reflect a larger land component relative to dwelling component compared to other people. If apartments don't have gardens, standalone houses will have different PCRs than apartments and attract different owners.

Moreover, the way in which the construction sector can combine labour, capital, materials and technology to produce a dwelling (the production function of the sector) may also differ by typology. This has not been empirically studied in New Zealand but it is not unreasonable to think that apartments require a different combination of the above inputs than detached houses. Because of that, the PCR of the two typologies may also be inherently different.

It follows that using a value threshold of the PCR as an ideal value, (the NPS-UDC guidance and the rest of the literature before used 1.5) and evaluating the efficiency of urban land markets against that value can potentially be misleading if the different production functions are not well known and empirically understood.

Effect of short-term macroeconomic factors on PCRs

PCRs can show steep short-term changes when interest rates change, as land prices change more quickly than the size of the housing stock. Because the PCR is usually presented as a single value, these short-term changes manifest as volatility in the ratio. This volatility can have adverse impacts in the interpretation of the indicator. The policy options required are different if a PCR is increasing because the cost of construction (denominator) is decreasing, rather than if the increase is due to an increase in the sales price of houses (nominator).

To improve the understanding of the drivers behind change in the PCR we suggest presenting the building costs and prices curves separately in a split graph.

Additionally, high PCRs over the long run (for example, over a few cycles of interest rate oscillations or during sufficient time for housing construction to fully respond to prices, which could be decades) indicate issues in the ability to substitute capital for land, but not necessarily due to inefficient land supply alone. In the shorter run, high PCRs may indicate that the market is still in a process of adjustment towards a long-run equilibrium. In summary, the PCR for all homes is not a good indicator of regulatory restrictions but it is better at signalling where development is likely to be most feasible to occur.

Interpretation of measurable price-cost ratios

Even after applying all the improvements detailed in this section to the measurable PCRs, there are some factors that can confound its interpretation. These include the already discussed interest rate changes, but also supply response lags due to capacity constraints of the building sector which create delays in the movement of the value of the ratio, and potential lack of infrastructure development.

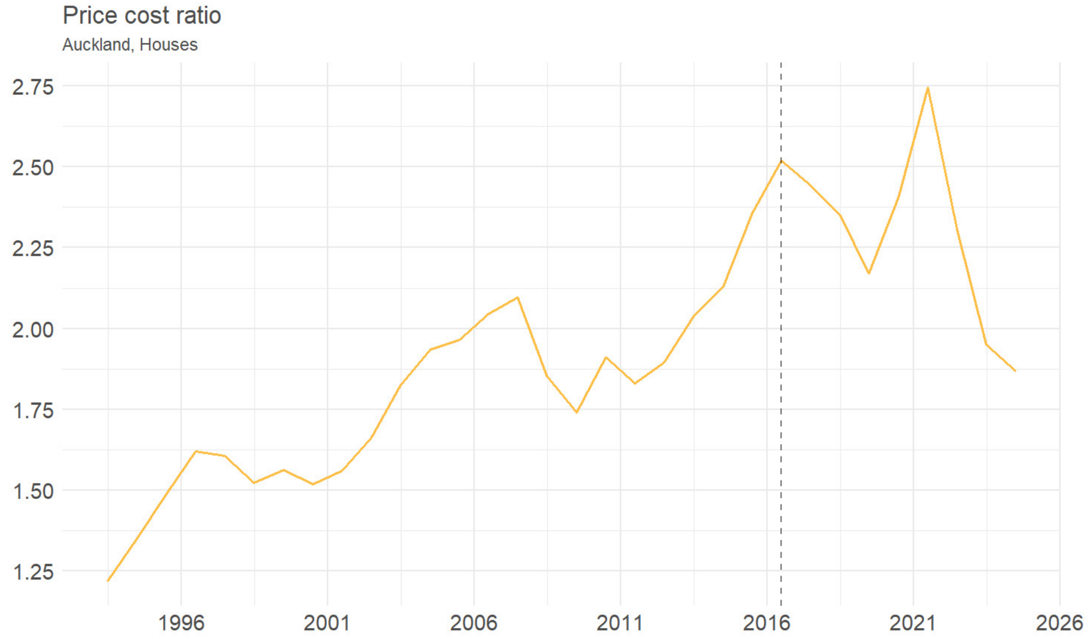
Because of these limitations we suggest additional information is necessary to understand the drivers behind the measurable PCR values for an urban centre. This could include other measures of supply responsiveness, such as the number of consents per 1000 people, or the number and typology of sales in the relevant area. Complimentary qualitative measures include knowledge about specific regulations or events that occurred in the area, which could affect the ability of development to take place.

Example of the measurable price-cost ratio including the improvements suggested by this work

Figure 1 and Figure 2 illustrate the current measurable PCR for Auckland (Figure 1) versus the measurable PCR we propose after applying the improvements suggested in this work (Figure 2). The two figures use the exact same data sources.

As an example, we used Waitematā local board, which includes city centre and fringe retail and commercial areas (including Newmarket) and the inner-city residential suburbs.

Figure 1: Current price-cost ratio information available for Auckland (top) and improved price-cost ratio information for Auckland when using only new builds (bottom)



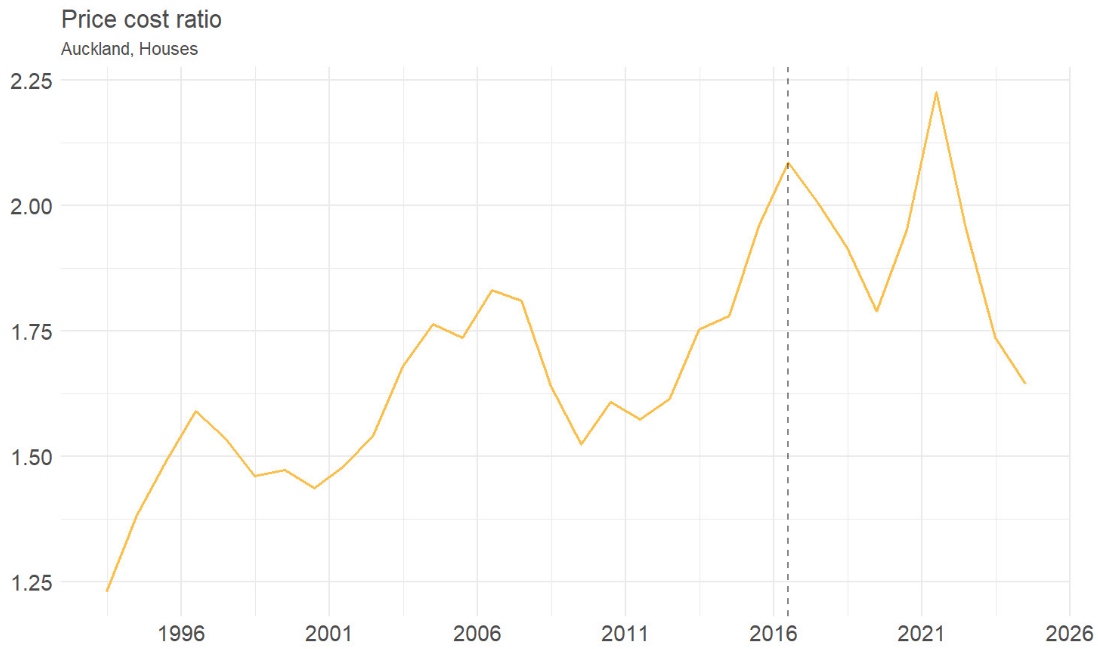
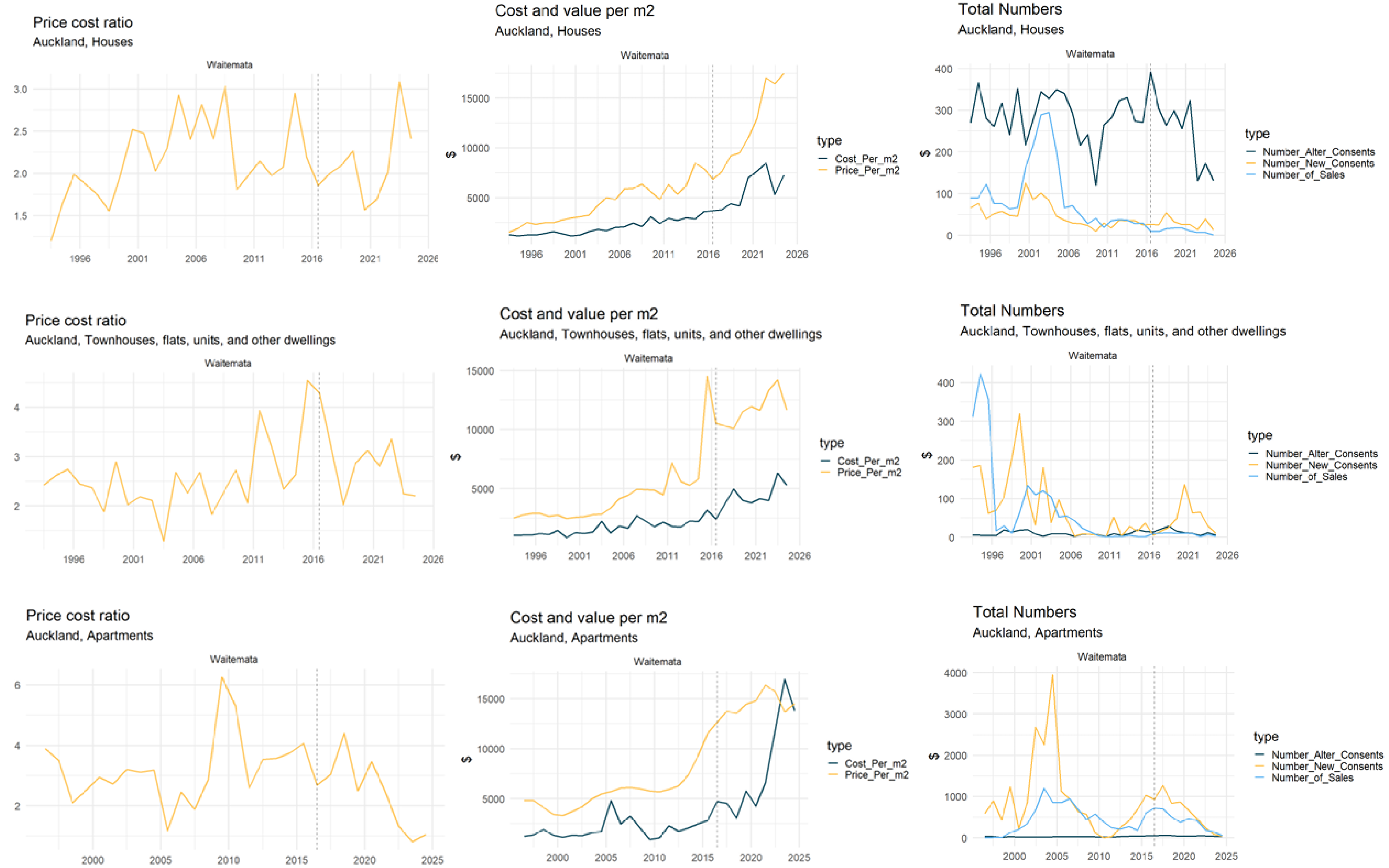


Figure 2: Suite of available price-cost ratio indicators for one Local Board (Waitematā)



Age of stock compositional issue

By removing all the properties in the calculation that were not built and sold in the last five years, Figure 1 bottom shows a more accurate representation of the supply response of the construction sector and demand to the current prices than Figure 1 top. The absolute value of the PCR also decreases significantly, from a peak of 2.75 in the top figure to a peak of 2.23 in the bottom figure. A PCR of 2.75 means that, at the peak (first quarter of 2021) the price per square metre for detached houses was $8695 and the construction cost per square metre was $3166, whereas if we remove from the calculation all the second-hand transactions then we have for that same period, a price per square metre of $7047 and a cost per square metre of $3166.[4] This shows that new detached houses being built have a better ratio of land utilisation than the pre-existing ones that continue being transacted.

Differential land rents implicit in the price-cost ratio values

Figure 1 implicitly assumes that, across Auckland, locations are equally desirable. To mitigate that bias, Figure 2 presents the PCR values for Waitematā local board, which includes city centre and fringe retail and commercial areas (including Newmarket) and the inner-city residential suburbs. The sales prices in Waitematā local board are influenced by the board's central location, and thus it has a higher PCR value that the average of Auckland city.

Different housing typologies may have different ideal price-cost ratios

Figure 2 splits the PCRs into three typologies and shows that the values obtained (left column), the sales price and the building costs (middle column) and the numbers of dwellings consented of each type (right hand side column) are markedly different by typology. This aligns with the theory in section 'Assessment of the critiques' about why different typologies may have different PCRs.

Effect of short-term macroeconomic factors on price-cost ratios

The middle column in Figure 2 shows the different effects that cycles of low interest rates had on the price and in the cost sides of the PCR calculation.

Between 2018 and mid-2021, NZ experienced a strong decline in interest rates (Figure 3). The split PCR shown in Figure 2 depict rapid increases in the price for houses line during that same period, suggesting that prices are heavily influenced by interest rates whereas construction costs are less influenced. For townhouses and apartments that price didn't increase the same, likely reflecting that townhouses and apartments have less land therefore their price is less affected by interest rates. By deconstructing the PCR in the different ways allows us to analyse it in a way we have been unable to in the past.

4 The construction cost remains the same as it is not possible to differentiate the cost of building new versus the cost of replicating second-hand stock.

Figure 3: Floating mortgage rate vs six-month term deposit rate

Case Study: Evidence of localised impacts of the Auckland Unitary Plan

Using the approach outlined above we find tentative evidence of the Auckland Unitary Plan (AUP) relieving the impacts of restrictions for some housing demand. Comparing PCRs for Auckland local boards, by typology (Figures C.1 and C.2), shows a tendency for PCRs for townhouses, flats and other medium/high density dwellings to reduce after the introduction of the AUP, which is not reflected in PCRs for standalone houses. This provides tentative evidence that the AUP was able to reduce the impact of restrictions on areas of high demand.

After the introduction of the AUP PCRs for standalone housing continued to grow in most local boards until interest rate rises began to deflate house prices in 2021. Whereas, in local boards that saw substantial upzoning, PCRs for medium and high-density new builds began to decline after the introduction of the AUP.

Figure C.1: PCRs for standalone new builds

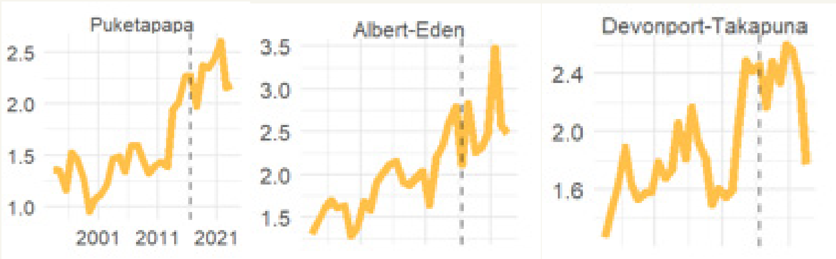
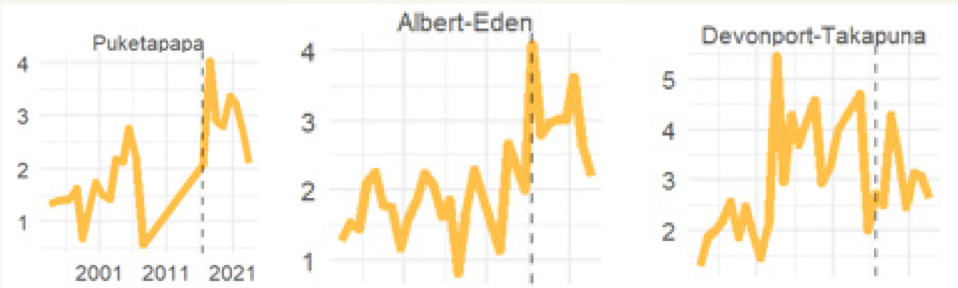


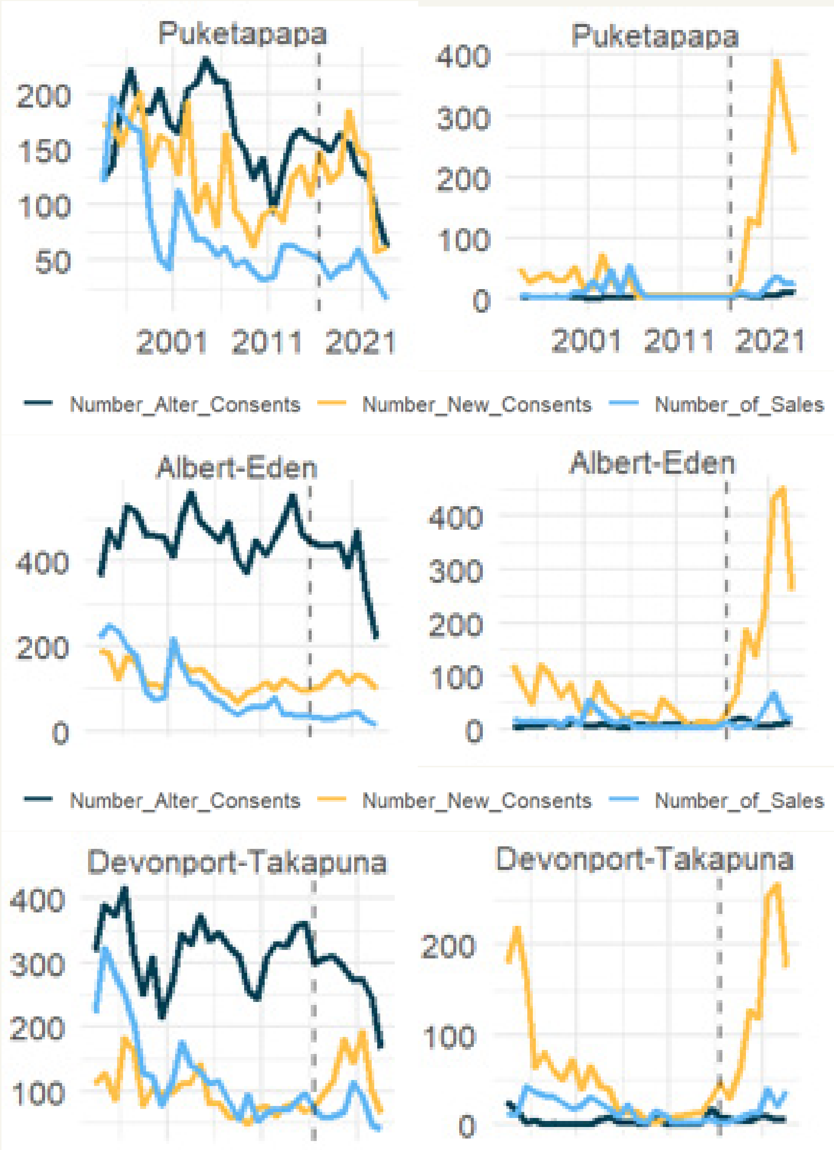
Figure C.2: PCRs for townhouse, flat, apartment etc. new builds



Continually rising PCRs created only a muted increase in the number of new standalone houses being built, suggesting continued restrictions on the ability of supply to meet this demand. However, the volume of medium and high-density building increased substantially (Figure C.3).

This brief analysis does not provide evidence on the net effect of the AUP on Auckland's housing supply. However, it does indicate that the removal of restrictions enabled supply to better respond to areas of high demand and lowered the price of that type of housing relative to the counterfactual.

Figure C.3: Building Consents and Sales of houses (LHS) and townhouses, flats etc (RHS)



Interpretation of improved measurable price-cost ratios

By adding PCR by typology, the split price and cost, and the total number of new consents, alteration consents and sales, we can tell a much more nuanced story of what happened in Waitematā. Waitematā has a higher PCR than the Auckland average, potentially because of its proximity to the CBD. Also, the number of new houses and new town houses built in the local board is quite low, but there are a lot of alteration consents, suggesting that there is a lot of movement of second-hand stock that is renovated. This, together with a subdued effect of the Auckland Unitary Plan on the number of new consents for all typologies seems to indicate that Waitematā is under some significant restrictions or constraints to using land for development and housing, be they regulatory, geographic, or any other type.

These metrics can be easily produced by all the other local boards to identify, within Auckland, where there may be binding constraints.

Using price-cost ratios to understand place

The value of PCRs by different typologies can help us understand regional dynamics at play. Figure 4A and 4B illustrate this by plotting the different Territorial Authorities (TAs) based on their PCR level and the number of consents.

For houses, in the bottom-left quadrant of the plot, we have TAs with low PCR and a low level of consents, such as Tauranga City, Nelson City, or Waitomo District. Despite low numbers of new detached houses being built in these areas, they have low PCR values. Moving to the right, in the bottom-right quadrant, we find places with a high number of houses per thousand built, like Buller, Hurunui, and Ashburton, where many new detached homes are being constructed with low PCR levels. In these locations, there don't seem to be constraints for the development sector to build these typologies.

In the top-left quadrant, we have places with high restrictions (higher PCR values) and very little development of these typologies, including Wellington, Hamilton, Porirua, and Hastings. The upper-right quadrant represents places where there is a significant amount of construction for these typologies, and there may be some restrictions. However, if we consider a PCR threshold of 1.5 in the context of houses, there are only a few places (Auckland, Kaipara, and Hamilton) with a PCR slightly above at 1.6.

For town houses, in the bottom-left quadrant of the plot, we have TAs with low PCR and a low level of consents for townhouses, such as Timaru, Rotorua, and Palmerston. Despite low numbers of new townhouses being built in these areas, they have low PCR values. Moving to the top-left quadrant, we have places with high restrictions (higher PCR values) and very little development of these townhouse typologies, including Wellington, Tauranga, Porirua, Tasman, and Hastings.

The upper-right quadrant represents places where there is a significant amount of construction for townhouse typologies, and there may be some restrictions. Here, we find Auckland, Lower Hutt, Kapiti Coast, Hamilton, Christchurch, and Upper Hutt. In the bottom-right quadrant, we have Buller District, where there is a high number of townhouses per thousand built with low PCR levels, indicating no significant constraints for the development sector to build these typologies.

It is interesting to note that:

- Baseline levels of PCR seem to be higher for townhouses than for houses, which could mean that the two typologies just have inherently different production functions that make building townhouse more expensive. This aligns with some intelligence we have from the development sector.
- Some places are in the same quadrant for both typologies: Wellington (top-left), possibly indicating that the same restrictions that are stopping the sector to develop houses are also stopping them from developing medium density. Christchurch, top-right, doing well developing both low PCR townhouses and low PCR houses. Other places appear in different quadrants depending on the typology, Hamilton goes from top left to top right, Auckland same, suggesting that the restrictions could be binding for one typology but not for the other.

Figure 4A: What can price-cost ratios tell us about regional dynamics (houses)?

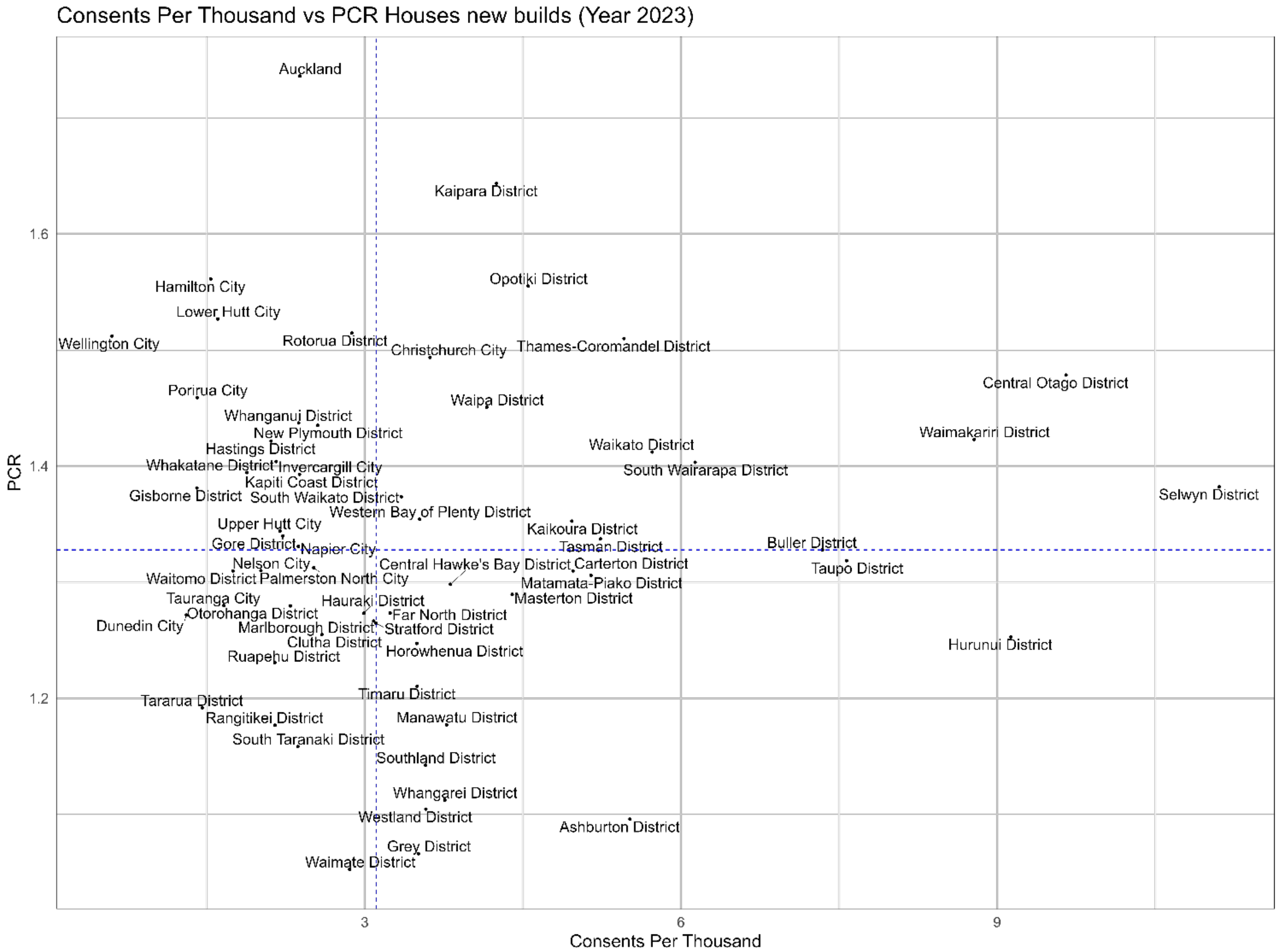
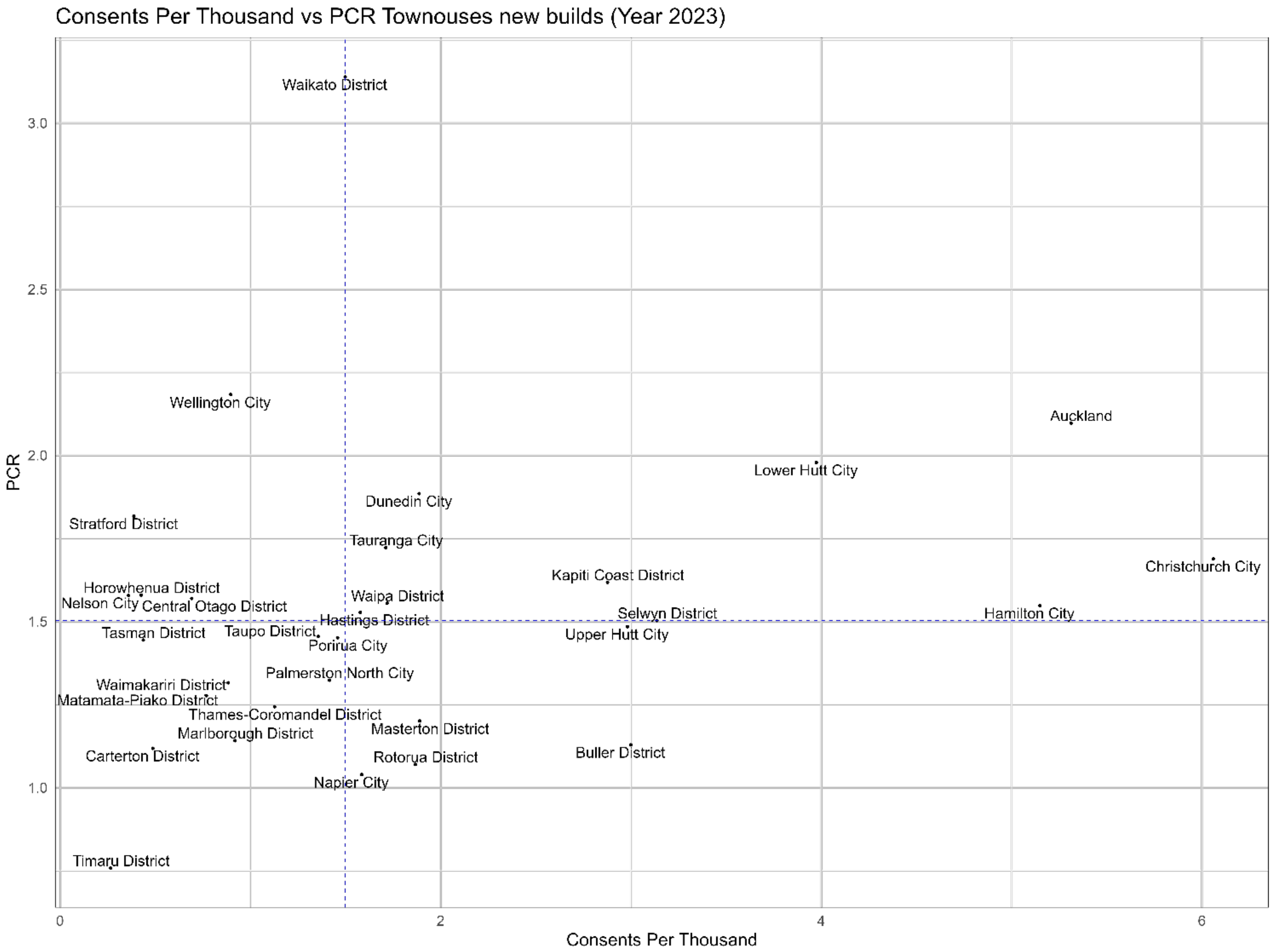


Figure 4B: What can price-cost ratios tell us about regional dynamics (townhouses)?



Chapter 2: Urban fringe price differentials

The urban fringe differential (subsequently called the 'differential') is a measure of the difference in price between urban and rural land at the edge of a city. It should help show the level of extractive land rents in urban areas. Land alike in amenity, once stripped of the value of infrastructure and buildings, should have a similar price whether it happens to be used currently for urban or rural purposes. Any difference in the value of the underlying land should therefore indicate the extent of extractive land rent – the rent extractable because of unmet demand for more urban development.

It is different from and frequently confused with the Auckland Council's Rural Urban Boundary (RUB), which is a planning concept rather than the current edge of development. The value of the differential can reflect:

- natural constraints (e.g. wetlands or steep hillsides),
- regulatory constraints,
- a failure to supply public infrastructure,
- the potential financial benefit gained by postponing investment and
- various other non-regulatory factors that delay land development or redevelopment. Such as the difficulty and cost of redeveloping fragmented land.

All these factors can prevent competitive urban expansion and intensification and explain differences in rural and urban land prices at the fringe, net of development costs.

International research, such as studies by Glaeser and Gyourko (2002), Glaeser and Ward (2009), Lees (2019), Kendall and Tulip (2018), and Denne et al. (2016), have examined these price differences at the urban fringe in various cities. The method has been adapted to standalone homes in several papers (Grimes et al. 2008; Glaeser & Gyourko, 2018; Lees, 2019; Ministry for the Environment, 2017). The urban fringe differentials were recommended alongside PCRs as indicators in the National Policy Statement for Urban Development (Ministry for the Environment, 2017) and are used by councils to assess their performance against policy objectives in their Housing and Business Capacity Assessments. Previous calculations of estimation of these urban fringe differential calculations for New Zealand showed a significant increase in Auckland's differential from 2010 to 2021. Specifically, the estimated ratio increased from 2.08 in 2010 to 4.40 in 2021, or from $176 to $1,274 per square meter (Te Waihanga, 2023).

In the past, the interpretation of this differential has been oversimplified, attributing all the differential simply to the cost of regulations. The NPS-UD evidence and monitoring guide states 'the differential estimates how much urban residential land values are being elevated because of these regulatory constraints'. This definition implies two things, one, that the whole value of the differential is attributable to regulations, and two, that these regulations are local government-imposed regulations, rather than systemic regulations across all cities. Both these implications are misleading. This chapter examines conceptual, methodological and data critiques of urban fringe differentials; provides results of a new differential that attempts to mitigate some of those methodological and data issues; and makes recommendations for how differentials should be interpreted for policy and planning.

Critiques of the Urban fringe differentials

Critiques of the Urban fringe differentials can be grouped into conceptual, data-related, and econometric model concerns.

Conceptually, the most notable critique comes from Douglas Fairgray and Rodney Yeoman's (2019) discussion paper, where they challenge the validity of the metric's conceptual basis. They argue that the concept of inefficient land markets at the urban edge is unsound for two reasons. First, the approach is based on two critical assumptions: (a) land values are not influenced by potential land use, and (b) land values are not influenced by location. These assumptions directly conflict with economic theory and key principles of valuation. As a result, they believe the approach misinterprets the differences between rural and urban values as 'discontinuities' when, in reality (they claim), they are just an outcome of an efficient urban growth process as cities expand into their rural surrounds. They also express concerns about the 2km band applied as a buffer in the calculation, arguing that it is arbitrary and distorts the differential. Furthermore, they note that by including all properties within 2km of the line on the inside, the calculation includes properties developed a long time ago, distorting the calculation of the current market situation.

Data-related concerns not specifically addressed in Fairgray and Yeoman (2019) include the quality and coverage of the underlying data used to produce the differentials, which are limited. The MRCagney version of the differential used in the Infrastructure Commission - Te Waihanga 2023 report (Te Waihanga, 2023) uses DVR rating valuation data from CoreLogic. These data require extensive preprocessing and cleaning steps, including matching the data to Titles to convert rating valuations into spatial information (MRCagney, 2022). During this matching process, a large amount of essential data (approximately 33 percent of DVR records and 17 percent of LINZ titles) needed to be discarded due to inconsistencies between the two data sources.

Additionally, the data available are only point-in-time (snapshot) views of the metric, which risks missing cyclical components of the market. Being able to follow the differentials over time would allow for a better understanding of the drivers behind the high differentials and assess the effectiveness of policies that aim to increase the efficiency of land markets, such as the Auckland Unitary Plan or Going for Housing Growth.

Econometric model concerns arise from differences between studies, such as the one by Martin & Norman (2020), which found a much smaller price differential measure at Auckland's RUB than the one suggested by MRCagney (2018). The main differences between the two papers are the boundary definition and the number of control variables in their respective econometric models. Martin and Norman measure the differential at the RUB, whereas MRCagney measures the differential at the line between what land is currently categorised (for rates valuation purposes) as rural or urban. Furthermore, MRCagney's regression equation controls for a handful of variables (distance to the CBD, distance to body of water, median income of the area, mean slope), whereas Martin and Norman's study uses a much longer list of variables, including closeness to golf courses and the proportion of land in flood plains, among others.

Improved measurement and interpretation of urban fringe differentials

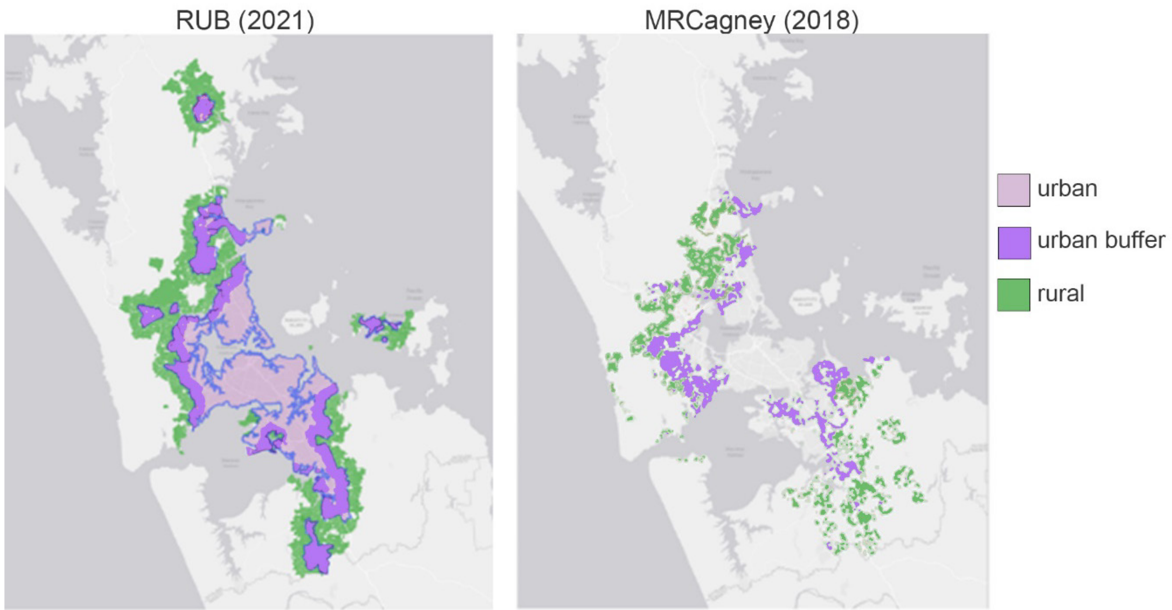
For this study, we replicated the MRCagney 2017 rural-urban differential calculation because that is the measure prescribed in the NPS-UDC for councils to use in their Housing and Business Capacity Assessments and on the NPS-UDC dashboard (www.hud.govt.nz/stats-and-insights/urban-development-dashboard). HUD had a copy of the original New Zealand Land Value Model (NZLVM) code package that had been handed down by MBIE when HUD was created in 2018.

Data

Since HUD does have access to historical data for all the primary sources required to compute these differentials, we created a time series of DVR data that contained historical valuations, planning boundaries and LINZ title parcels.

To do this, we developed a novel method of matching DVR to LINZ titles data that greatly reduced the amount of data loss (more information about the data engineering process in Appendix 2:). The result is a much more comprehensive data coverage than the one used in previous calculations of the differential, and the first and only time series that contains the two dimensions of valuation data (over time and at parcel level).

Figure 5: Differences in data coverage between HUD's RUB data sources (left) and previous MRCagney data sources (right)



The econometric model

The NZLVM is the tool that computes the MRCagney rural fringe differentials (2017 www.mrcagney.com/about/blog/mrcnz15-the-new-zealand-land-value-model). The heart of the NZLVM is a linear regression analysis which looks at, and controls for, the following key factors:[5]

- Land values within 2,000 metres of the RUB
- Whether the properties were urban or rural
- The distance to the main urban centre, the distance to nearest, 'important' water body (e.g. sea in Auckland, lakes in Queenstown)
- Slope
- Natural hazards
- The presence of infrastructure (e.g. water and sewage systems).

The outputs of this model are the price per square metre of being inside and outside of the boundary after all the other factors had been controlled for. The results of the NZLVM have been published in (Te Waihanga, 2023) and are shown in tables 2 and 3 below.

The new econometric model

For this analysis, HUD has redeveloped the NZLVM, taking it from a snapshot view of land values to a timeseries of land values over time starting in 2011, with improved data coverage, and the ability to alter both the boundary and the buffer around it. Details on the technical improvements can be found in Appendix 2:.

Boundary definition

One of the most important changes between the HUD method and the previous MRCagney method is that HUD's new tool allows the user to choose any boundary to calculate the differential. The choice of boundary has very important implications for these differentials and their interpretation.

Auckland has a plan line, the RUB. The council has signalled that any land within the RUB will one day be classed as urban, and therefore all urban development permitted. Inside this RUB there are some areas called Future Urban Zones. These areas have little to no current infrastructure in place, but the council has a release plan for infrastructure provision.

5 At the time of publication the redeveloped HUD NZLVM does not account for natural hazards or the presence of infrastructure.

Figure 6: Auckland's Future Urban Zones inside its Rural Urban Boundary

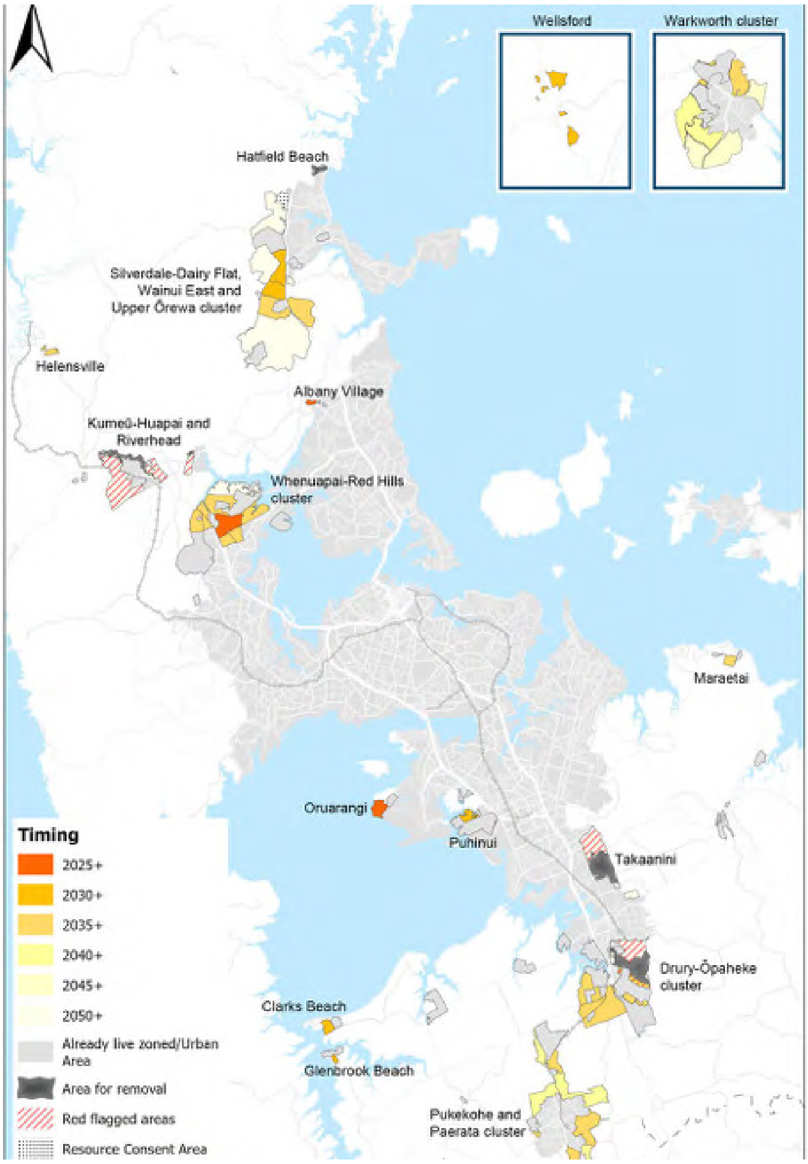
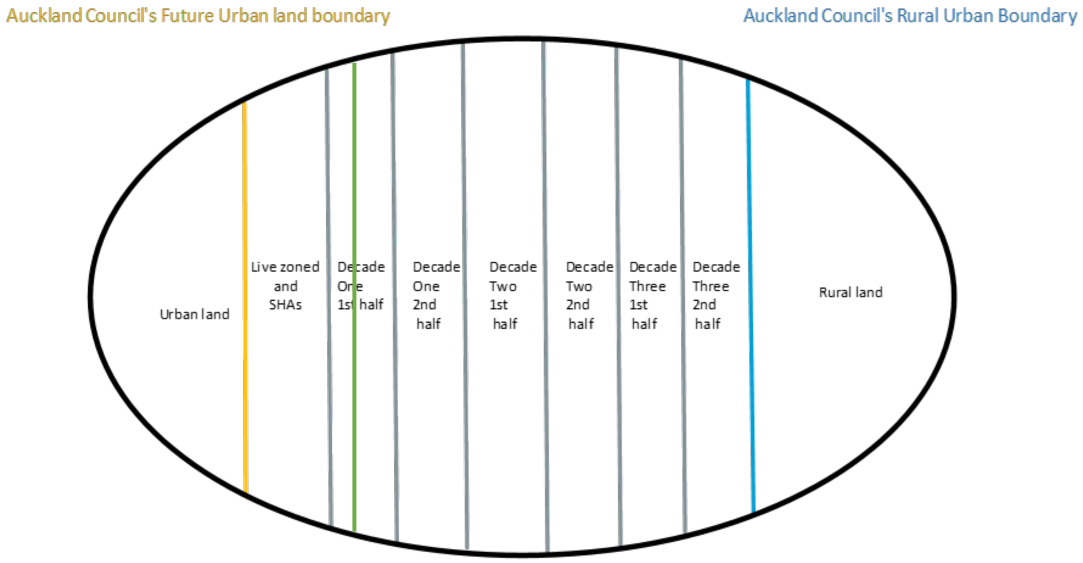


Figure 7: Gradient of boundaries at the fringe of Auckland



The blue line, located on the right-hand side, represents the Auckland Council RUB, which is the planning line outlined in the Auckland Unitary Plan. To the left of this regulatory line is land designated as either urban or future urban, indicating that the council intends to provide infrastructure for these areas at some point in the future. The quite small differential calculated in Shane and Norman's 2021 paper used the blue line.

The yellow line distinguishes land currently used for urban purposes to its left, from land that will either; be zoned as urban in the future to its right, or will likely remain rural (land to the right of the blue line).

The green line separates rural from urban land based on DVR zoning codes. MRCagney's differential calculation utilises these codes. DVR refers to the property rating records that councils use to set property rates, essentially serving as a financial management tool. Independent valuers prepare the content of the DVR on behalf of councils. While the DVR land zoning code is a useful indicator of land use, the Unitary Plan zoning more accurately reflects the potential range of land use for a specific property.

The grey lines represent the divisions between various future urban land releases planned by Auckland Council in their Unitary Plan. Calculating differentials across these lines can be thought about as representing degrees of certainty of development'. The closer to the yellow line, the more certainty development will happen. The further to the right, the more the potential profits from development need to be discounted for the increased uncertainty.

Values of the differential for the whole of Auckland

Table 1: MRCagney urban fringe differential results

2010 Te Waihanga report 2022 (green line figure 5)		2014 NPS-UDC 2017 (green line figure 5)		2021 Te Waihanga report 2022 (green line figure 5)	
urban/rural $/sqm	ratio (urban/rural)	urban/rural $/sqm	ratio (urban/rural)	urban/rural $/sqm	ratio (urban/rural)
$176	2.08	$345	3.15	$1,274	4.4

Table 2: Timeseries of Auckland's urban fringe differential using HUD's new NZLVM

HUD's Fringe differential						
Date	LV per sqm (urban, $)	LV per sqm (rural, $)	Urban fringe differential (Blue line figure 5), $	Urban fringe differential (Blue line figure 5), ratio	Development cost ($ per parcel)	Boundary
1/07/2011	$225.1	$20.0	$133.0	2.4	95,442.91	MUL*
1/07/2014	$309.2	$26.1	$206.3	3.0	106,828.2	MUL*
1/07/2017	$350.5	$28.3	$259.6	3.9	126,369	RUB
1/06/2021	$494.0	$35.6	$378.4	4.3	150,000	RUB

*Metropolitan Urban Limit

Values of the differential for the three Auckland's Growth Areas

Table 3: Snapshot of urban fringe differentials in Auckland's Growth Areas using HUD's new NZLVM

Growth Area identified in Auckland's Future Development Strategy	Urban Rural differential in $/sqm calculated at Auckland Council's Rural Urban Boundary (blue line Fig.5)	Urban Rural differential in $/sqm calculated at Auckland Council's Rural Urban Boundary excluding Future Urban Zoned land on the urban side (left of yellow line and right of blue line Fig.5)
North (Local Boards: Hibiscus and Bays, Rodney)	291.5	555.8
South (Local Boards: Papakura, Franklin)	271.8	471.5
North West (Local Boards: Waitakere, Henderson-Massey, Rodney)	294.4	624.6
Average of all three growth areas	**344.7**	**582.1**

From point to line differentials: The K curve

The results in tables 1-3 seem to show that Auckland has a significant differential in the price of land at several points in its urban fringe. If a differential at the urban fringe is a sign of restrictions to further development of the land, there is a broader question; what other places alongside the Auckland's urban space there is a significant differential?

To do this, we computed the K curve. The K curve is the result of computing thousands of point-differentials in concentric circles starting form Auckland's central business district and expanding the circles out until the edge of the city, as described in Figure 8, and them plotting all these point differentials as a continuous line.

Figure 8: Differential calculated at concentric circles - the K curve

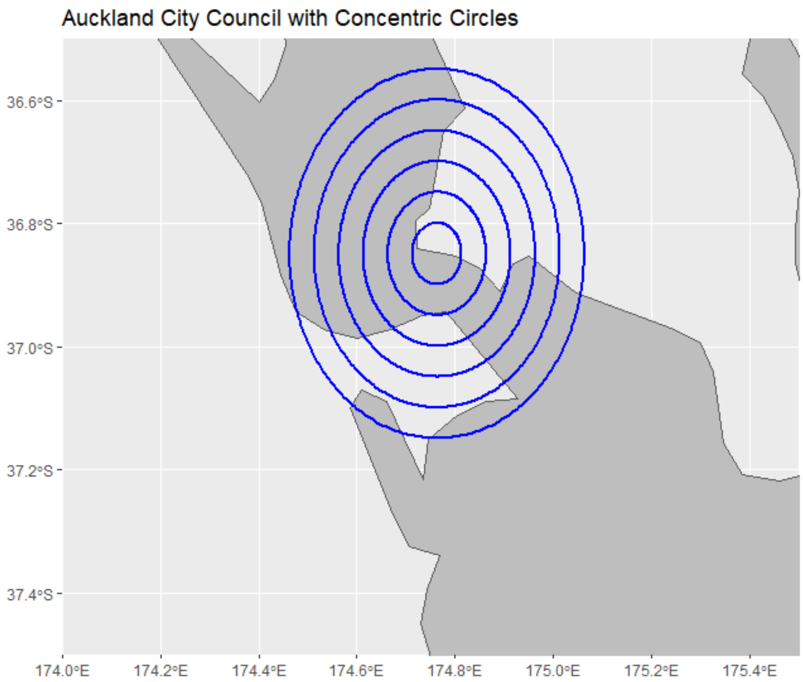
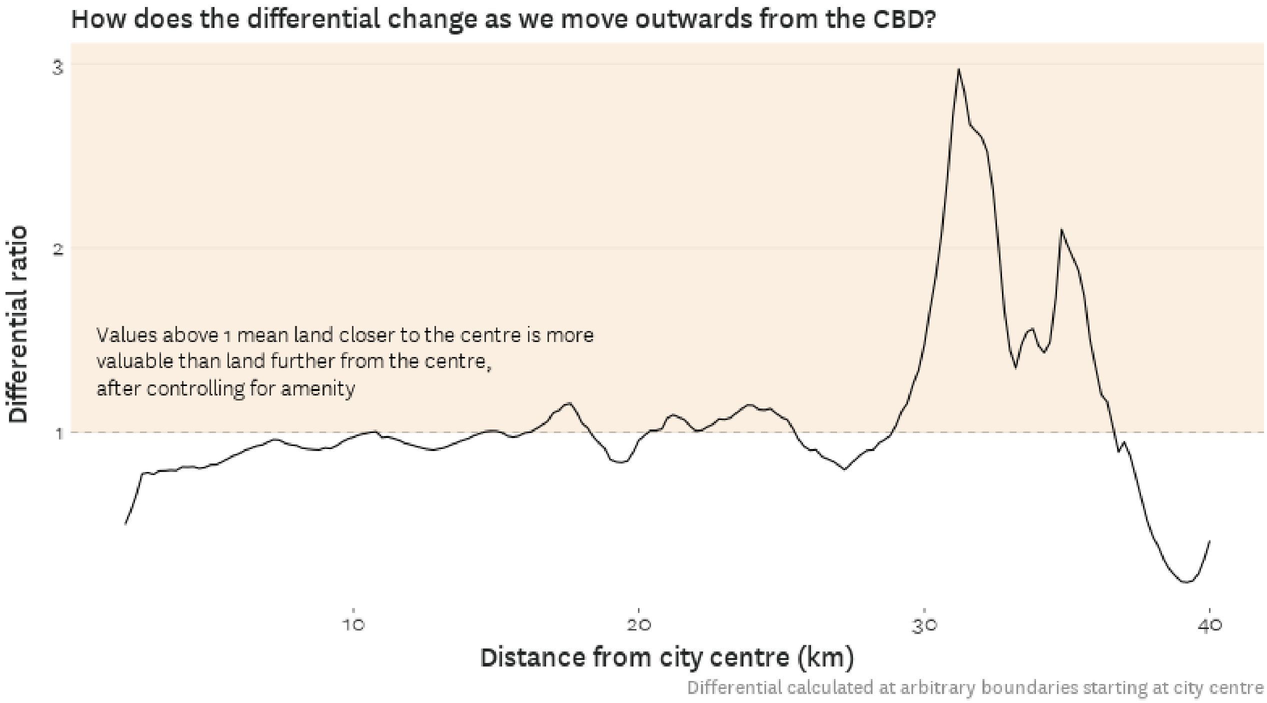


Figure 9: K curve for Auckland in 2021



Interpretation and consolidation of results

The primary insights from this study are: (i) Auckland has a significant urban fringe differential, (ii) the differential has increased over time, and (iii) this suggests that restrictions are hindering development on both sides of the city's existing boundary.

MRCagney's/Te Waihanga previous urban fringe differential calculations showed a considerable increase in Auckland's price difference from 2010 to 2022. HUD's new calculations support the presence of a differential but reveal a more moderate dollar increase from 2011 to 2021. The main distinctions between the two studies stem from the different boundaries measured and the unique questions addressed. MRCagney's differentials are measured at the valuation boundary (green line in Figure 5), while HUD assesses differentials at successive planning boundaries over the years, such as the Metropolitan Urban Limit and the RUB.

When examining the green line, the question being considered is, "Is the urban land at Auckland's fringe currently overpriced compared to the adjacent rural land?" MRCagney's NZLVM differential value answers this query. Conversely, when measuring the blue line in Figure 5, the question being addressed is, "Is the RUB causing a premium on the price of urban land at the boundary's edge?" The HUD NZLVM provides the answer to this question.

Differential for specific parts of the boundary

Table 3 delves deeper into specific sections of the boundary. In this instance, we measured the differential value at the boundaries of particular growth areas. When the NZLVM calculates the differential for Auckland, it computes an average for the entire region (i.e., all properties within a 2km radius inside the boundary's circumference versus all properties within a 2km radius outside the circumference). For Auckland, this encompasses a vast area. By examining specific parts of the boundary, the value is more precise and may better reflect local constraints.

The entirety of Auckland has a differential value at the RUB of $413/sqm, whereas the three growth areas display differential values at the RUB of $314, $334, and $335, respectively. This implies that restrictions on land use for development are less stringent in these areas than in others. It is logical, as these areas are identified in Auckland's Future Land Development Strategy as locations where infrastructure will be implemented.

However, for these areas, when the differential is calculated not at the council planning line but at the divide between current urban and rural classifications (green line in Figure 5), the values are considerably higher: $680, $549, and $729 per square meter. This suggests that there is a significant difference in the value of the differentials.

Conclusions and potential improvements

Enhanced data, alternative boundary definitions, and expert knowledge have contributed to the new calculations, which provide a comprehensive view of Auckland's land price distribution over time. The boundary definition is a crucial aspect of what is being measured. The urban fringe is challenging to define precisely in practice because competitive urban expansion makes the fringe itself porous. New developments often skip over undeveloped land, resulting in scattered and disconnected urbanisation parcels ('leapfrogging'). Three proposed boundary measurements have been presented, which inevitably lead to different $ values of the differentials.

Using the Auckland Unitary Plan RUB is one such method, employed in HUD's calculations. This RUB indicates where the urban area is anticipated and permitted to be in 30 years, with the Auckland Council planning to stage and sequence land release within the RUB during that period. The value of these differentials may lie in comparisons over time or across areas using a set model specification, with data engineering capabilities allowing for adjustments in methodologies such as boundary definition or econometric inclusions.

Improving controlled variables

The variables controlled for in this model are selected because of their importance but also due to data availability. It controls for less variables than Martin & Norman (2020). Including further variables with material links to value could improve the ability to distinguish amenity from constraint.

Using the real option markup as an alternative

Considering high prices outside a city may be influenced by anticipated policy changes or rezoning, a real option markup could be applied to the costs of developing land. This markup would account for the typical increase in rural land prices in peri-urban areas. This approach has not yet been tested.

Incorporating parcel size as a variable in the differential calculation

One aspect that has been overlooked in the rural-urban fringe measurement so far is accounting for the relationship between land value and parcel size. Larger parcels are generally worth less per m^2 than smaller ones as the more sub-division that will occur the higher volume of per unit infrastructure cost associated with it and the greater amount of land used for infrastructure (i.e. roads) than housing. When parcel size increases with distance from the city centre, this can lead to an overstatement of the land price gradient and a potential exaggeration of the RUB differential value.

Additionally, the urban fringe differential analysis might not fully account for the effects of certain planning choices, such as infrastructure. In a well-functioning market, the RUB should be equal to the cost of converting rural land into urban land, including infrastructure costs. While current RUB estimates attempt to incorporate costs paid by developers, some infrastructure expenses might be overlooked. Understanding the relationship between infrastructure and the fringe differential is crucial for assessing market efficiency.

Discussion

No single measure is sufficient to determine if land markets are functioning well. However, if a majority of measures deviate from what we would expect, it is likely that urban land markets are functioning poorly.

The PCR is a valuable indicator for assessing price relative to construction activity. The theoretical PCR model provides new insights into the sensitivity of PCRs to factors such as building height restrictions, minimum lot sizes, and interest rate changes, and validates the metric.

However, there are inherent limitations in measuring PCRs in real life that must be considered when interpreting the results. To address these limitations and improve the accuracy of the PCR, this research suggests focusing on new properties, calculating PCRs for smaller areas with similar levels of amenity, considering different housing typologies, and presenting building costs and price curves separately. Additionally, it is important to account for other factors when interpreting PCRs, such as supply response lags, infrastructure development, and short-term macroeconomic factors.

The PCRs measured in this study have shown that, when complemented with more data like consenting volumes, the metric can demonstrate how different local boards in Auckland have varying degrees of regulatory and non- restrictions on building and development.

We also examined the concept of urban fringe differentials and their implications for land prices and urban development. We highlighted the critiques and limitations of earlier approaches and developed improvements in data coverage, boundary definition, and econometric models that have led to more accurate and comprehensive calculations of these differentials.

Our analysis of the urban fringe differentials in Auckland revealed a significant increase in the price difference between urban and rural land at the city's edge over time, suggesting restrictions on development across the city. We further demonstrated that the choice of boundary definition can significantly impact the differential values and help identify local constraints in specific growth areas.

Both the PCR and the RUB indicate the existence of restrictions on development within the city of Auckland and at its fringe. This finding is consistent with previous HTWG hypotheses that restricted land supply was a driver of the increased house price value observed in New Zealand's past few decades.

However, Auckland implemented a large-scale zoning reform in 2016 that upzoned approximately three-quarters of its residential land, leading to a boom in housing construction. Greenaway-McGrevy found that the zoning reform significantly increased new housing starts, doubled new dwelling permits per capita within five years, and contributed to increased housing supply in the city.

Moreover, the research also investigated the effect of the zoning reform on housing affordability. Six years after the policy's full implementation, rents for three-bedroom dwellings in Auckland were found to be between 22 and 35 percent lower than they would have been without the reform. These findings suggest that the large-scale zoning reforms in Auckland improved the affordability of family-sized housing, as measured by rents (Greenaway-McGrevy).

These supply responses identified in Greenaway-McGrevy are mostly reflected in the PCRs, particularly in the Local Boards that experienced greater easing of restrictions. The impact on the urban fringe differential is more muted, as the differential itself continued to increase. However, considering the influence of cyclical factors, it could be argued that the differential could have increased much more if the reform hadn't occurred (and additional housing had not been built).

One key aspect to consider is that because housing is durable and expensive, the speed at which new construction activity and urban renewal respond to housing shortages can be slow, potentially accentuating these shortages. This point highlights the importance of understanding how to determine whether these indicators can tell us that we are on the right track and suggests a fundamental shift in their interpretation. Previously, before this work, evidence of inefficiency implied regulatory restrictions, but now we have seen indicators may reflect continued restrictions, a construction sector still in the process of transforming housing stock to more efficient use of land, or both.

Our work and improvements to these metrics show that they can display general trends in market restrictions to intensification and extensification. However, discerning the exact restrictions and drivers of these restrictions from the metrics is not straightforward, and their interpretation should be more nuanced than in the past.

Additionally, this work demonstrates that these metrics have some utility in monitoring long-term trends in supply restrictiveness, but their use in policy should be informed by the difficulty of disentangling the drivers behind their values, the lag they incur in responding to policy interventions, and the difficulty in measuring them accurately due to real-world data quality and availability constraints.

Chapter 3: Simulating a price-cost ratio model

The price-cost ratio (PCR) is calculated by dividing the price of a dwelling by how much it costs to build it. It is meant to provide a general indication of how responsive land markets are to demand, relative to construction activity. When the number and size of infrastructure-serviced sections can be easily altered to meet demand, and there is a construction sector capable of developing those sections, land should be a small component of the cost of a home and the price of a home should mostly reflect the cost to build it. Where the number or size of sections cannot be easily altered, then as demand rises the land proportion of the cost of a home would also increase. The PCR is defined as

$$PCR = \frac{Land\ Value + Construction\ Cost}{Construction\ Cost} = \frac{LV + CC}{CC} = 1 + \frac{LV}{CC} \quad (1)$$

For an individual housing unit (property), it can be interpreted as the ratio of the land value to the construction cost of the dwelling. We have developed a mathematical model that explores how the PCR might be expected to change in different scenarios, considering factors like interest rates, land prices, and construction costs. This note creates a simple model of housing demand and supply to explore how the PCR can be expected to change in an idealised setting that captures the main determinants of supply and demand in the housing market.

Initially, the paper examines housing market outcomes when interest rates are constant and the market is frictionless and both demand and supply fully adjust to price signals such as an exogenous change in the price of land or an exogenous change in the price of constructing houses. It then incorporates frictions such as a building-height restrictions to find out the relative importance of these frictions. Lastly, it relaxes the assumption that interest rates are fixed and examines housing outcomes when the land price is endogenous to interest rates. In this case the PCR is calculated in terms of user costs (the monthly mortgage payment required to purchase a house) as well as the upfront dollar costs (the initial dollar payment required to purchase a house).

The PCR depends on the size of the land section and the floorspace size of the dwelling. These values not only depend on the preferences of a household but are endogenous to the price per square metre of land and construction. As the price of floorspace increases, for example, it is reasonable to expect people to demand smaller houses. The model is used to calculate PCRs when households adjust the dimensions of the house and section and their demands in response to prices, and builders adjust the mix of inputs (land, building materials and technologies) they use to construct new properties as costs change. Three main adjustment mechanisms are considered when prices change:

1. As the price of land increases, builders can choose to build taller buildings to reduce the size of the dwellings land footprint to reduce total construction costs.

2. As the price of land increases, a household can choose to buy a smaller garden and a smaller house.

3. As the price of construction increases, a household can choose to buy a smaller house and spend the rest on more land or other goods and services.

The model finds that when the above can occur frictionlessly, the PCR should not alter significantly with changes in land value. In theory, this makes reliable measurement of the ratio between price and cost of dwellings over time an accurate indicator of restrictions on the supply of land for construction.

Key features of the model

Supply

A property consists of a house plus additional land.

For single story houses, there is a constant "up-front" cost P_f per square metre to construct a house with floorspace size *f*.

For multiple story houses, the price per square metre is increased by a factor *g(h)* where *h* is the number of levels. For the purpose of this exercise, each story comprises a separate dwelling. Thus if $h = 2$ and $f = 100$ it means two 100m^2 houses, not one 200m^2 house.

The house also needs land, whose cost is shared amongst the h levels. A house with floorspace *f* needs an additional *Θ(h)* amount of land to allow construction. The cost per dwelling of an *h* story house with *f* m^2 floorspace is thus

$$P_h(h, f) = \left(\frac{1+\theta(h)}{h} P_L + g(h)P_f\right) f \qquad (2)$$

where P_L is the price per square metre of land and P_f is the construction cost per square metre.

The property also has additional space *L* for a garden. In the modelling, this is calculated independently of the height of the building, and can be considered a person's allotment of private space. The total cost of a dwelling is thus:

$$P_D(h, f, L) = P_L L + \left(\frac{1+\theta(h)}{h} P_L + g(h)P_f\right) f \qquad (3)$$

The budget constraint: user costs versus up-front dollar costs.

A household demands (i) goods and services *C* that cost *P* and are consumed in a home; (ii) amenities *A* (such as schools, views, parks, and services that are produced on site) that cost P_A and are consumed away from the home; and (iii) a dwelling *D* that comprises a house with floorspace *f* and an accompanying amount of additional land *L*.[6]

The budget constraint for a household should be expressed in "user cost" terms since houses and land are durable. In the following somewhat simplified derivation, it is assumed that the household buys a property at the beginning of a multi-year period, and pays the property off in equal instalments over the year period. In contrast, consumption goods and amenities are purchased each year. If these prices are constant (and inflation is zero), the budget constraint is

6 The price of amenities PA depends on the location of the home (e.g. the suburb in which someone lives), and while this aspect of the model is important in general equilibrium, it is not emphasised in this note.

$$P\left(\sum_{i=0}^{n-1}\frac{C_{t+i}}{(1+r)^i}\right)+P_A\left(\sum_{i=0}^{n-1}\frac{A_{t+i}}{(1+r)^i}\right)+(P_L L+P_h f)r^*\left(\sum_{i=0}^{n-1}\frac{1}{(1+r)^i}\right)=P\left(\sum_{i=0}^{n-1}\frac{Y_{t+i}}{(1+r)^i}\right) \quad (4)$$

where r* is the annual repayment rate on the mortgage each year of a n-year mortgage (see the derivation in the appendix.) If consumption, amenities and income are constant each period and equal to $\bar{C}$ and $\bar{A}$ and $\bar{Y}$. equation (4) becomes:

$$P\bar{C}+P_A\bar{A}+r^*P_L L+r^*P_h f=P\bar{Y} \quad (5)$$

This is the "user cost" form of the budget constraint. The "up-front" price of land and housing has to be multiplied by the amortisation rate r* to make it comparable to the costs of ordinary goods and services. For example, if n = 30 years and r = 5 percent, the amortisation rate is r* = 6.5 percent and so if it cost \$3000/m^2 up front to purchase a square metre of land, the user cost is \$195/m^2 per year.

The difference between the up-front costs and the user costs can be important for calculating demand if P_f and P_L respond differently to the interest rate. (Note, however, that the PCR is the same whether it is calculated using the user costs or the up-front dollar values). If, as evidence suggests, land prices are more responsive to interest rates than building construction costs, then there are likely to be different responses in the demand for land and structures as interest rate changes. In the following analysis two cases are considered. In section 2, the effect of exogenous changes in P_f and P_L on the PCR are examined. Accordingly, in this section it is assumed that P_f and P_L are independent of the interest rate (this encompasses the case that interest rates are constant.) In section 3 it is assumed that up-front building costs are independent of interest rates, but that the user costs of land is constant – i.e. that land prices are inversely proportional to the amortization rate:

$$P_f(r^*)=P_f^*$$

$$P_L(r^*)=P_L^*\times(r^*)^{-1}$$

This assumption means that if interest rates fall households will bid up the price of land in a manner that keeps the amortization cost for land constant. In contrast, a decline in interest rate is assumed to have no effect on up-front building costs, which means the amortised cost of building declines when interest rates decline. Thus the increase in land prices is associated with an increase in the user price of land but no change in the user price of structures in section 2, but with no change in the user cost of land and a decline in the user cost of structures in section 3. These differences lead to different demand patterns for land and structures, but (as we shall see) little difference in the PCR when households are free to alter the size of the properties they demand in response to price movements.

Demand

Suppose a household's utility function has a constant elasticity of substitution between C, A and D. This could take one of several forms, of which one is a two-tier utility function: the first tier is defined over consumption, amenities, and the dwelling; and the second defines the dwelling in terms of housing and land, with a potentially different elasticity of substitution. The general form is

$$U(C,A,L,f) = (\alpha_C C^{\rho} + \alpha_A A^{\rho} + \alpha_D D^{\rho})^{1/\rho} \quad (4)$$

$$D(L,f) = \left(\alpha_L L^{\rho d} + \alpha_f f^{\rho d}\right)^{1/\rho d} \quad (5)$$

where $\alpha_C + \alpha_A + \alpha_D = 1$ and $\alpha_L + \alpha_f = 1$ and $\rho, p_d < 1$.[7]

In most cases it can be expected that and $\rho, p_d > 0$. In the limit case that $\rho, p_d = 0$, the production function is Cobb-Douglas. The elasticity of substitution is $\sigma = \frac{1}{\rho-1}$.

With this type of utility function, a household will substitute between land and floorspace as prices of land and floorspace change, and also substitute between housing and consumption goods (and amenities) as the total price of housing changes. In the Cobb Douglas case, a constant amount is spent on land and floorspace irrespective of their prices. This means that if the price of floorspace doubles, the amount of floorspace halves, irrespective of other prices. Note that in the Cobb Douglas case that if the price floorspace increases but there is no change in the price of land, the main effect is to reduce the size of floorspace with no effect of the demand for land. The inclusion of amenities in the demand function means a household will pay more for land located near nice amenities, as this reduces the price of obtaining amenities.

The utility function leads (with a lot of algebra) to the following demand functions:

$$C = \frac{\alpha_C^{-\sigma} P_C^{\sigma}}{\bar{P}} Y \quad (6)$$

where Y is income,

$$\bar{P} = (\alpha_C^{-\sigma} P_C^{\sigma+1} + \alpha_A^{-\sigma} P_A^{\sigma+1} + \alpha_D^{-\sigma} P_D^{\sigma+1}) \quad (7)$$

$$P_D = \left(\alpha_L^{-\sigma d} P_L^{\sigma d+1} + \alpha_f^{-\sigma d} P_h^{\sigma d+1}\right)^{1/(\sigma d+1)} \quad (8)$$

$$D = \frac{\alpha_C^{-\sigma} P_D^{\sigma}}{\bar{P}} Y \quad (9)$$

$$L = \frac{\alpha_L^{-\sigma d} P_L^{\sigma d}}{(P_D)^{\sigma d+1}} (P_D D) \quad (10)$$

$$f = \frac{\alpha_f^{-\sigma d} P_h^{\sigma d}}{(P_D)^{\sigma d+1}} (P_D D) \quad (11)$$

and all prices are the equivalent of annual user cost prices. Given land prices and construction costs, equations 1, 2, 3, and 10 and 11 can be used to calculate the equilibrium PCR in

7 Note that the literature is often uses a related form of the CES function with negative coefficients:
$U(C,A,L,f) = (\alpha_C C^{-\rho} + \alpha_A A^{-\rho} + \alpha_D D^{-\rho})^{-1/\rho} \qquad \rho, p_d > -1 \qquad (4)$

circumstances that construction firms and households can change supply and demand in response to price signals. There are three important adjustment mechanisms.

1. As the (user-cost) price of land increases, a builder can substitute height for land to reduce construction costs. Their ability to do this depends on how quickly the cost of construction increases as height increases: if it is very expensive to build up instead of out, builders will prefer to build out.
2. As the (user-cost) price of construction P_f increases, a household can substitute towards buying a smaller house, spending the rest on more land or other goods and services.
3. As the (user-cost) price of land increases, the household (i) will substitute away from land, and so buy a smaller garden; and (ii) will substitute away from a more expensive house (because the price of land is a component of the house's footprint) and buy a smaller house.

In the limit Cobb Douglas case, an increase in the (user cost) price of land or construction does not change the total amount spent on either component, as there is a one-for-one reduction in the size of the land or the house, or both. This means the user-cost PCR does not change as prices change.

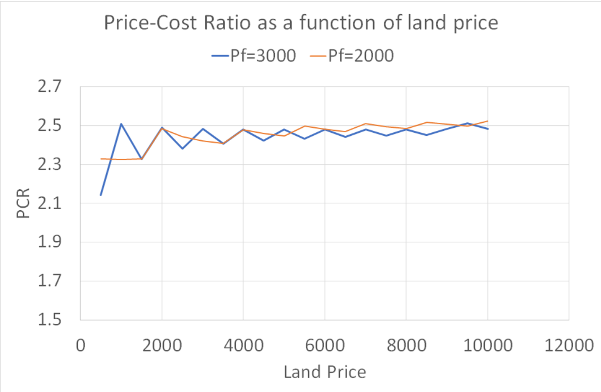
The Cobb-Douglas result is very strong. However, simulations show it is approximately true even for other substitution parameters.

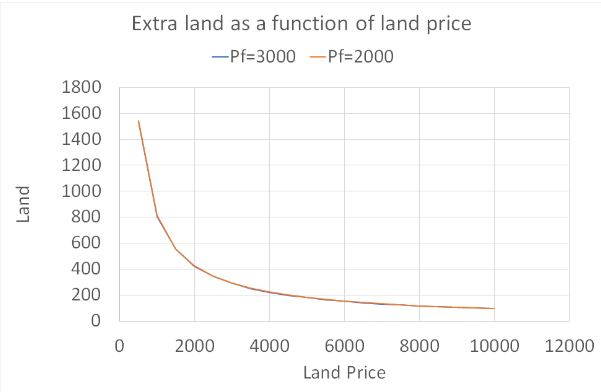
Simulations with constant interest rates

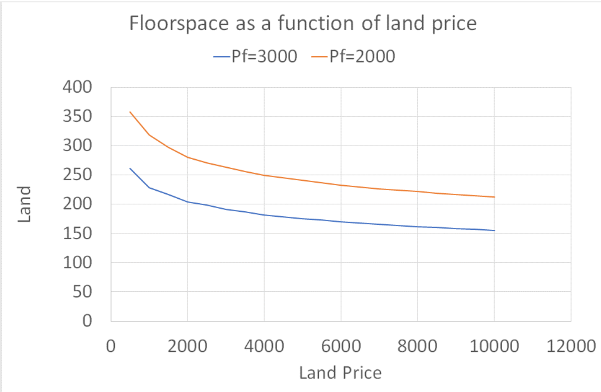
The following graphs show how the equilibrium PCR, building height, extra land, floorspace, and utility change as the land price increases, taking into account the changing demand for land and housing. In the base line scenario the price of construction is $3000/m^2, height is optimised under the assumptions that $\theta(h) = 0$ and $g(h) = h^{0.2}$, and the elasticity of substitutions are close to 1 (ρ=-0.1, which is close to the Cobb-Douglas case.) The interest rate is constant. Each of these parameters is then changed. Note the denominator of the PCR excludes the land component of housing construction costs.

1. **Scenario 1**: the cost of construction falls from the baseline of $3000/m^2 to $2000/m^2, holding other parameters equal.
2. **Scenario 2**: A maximum building height of 4 stories is imposed.
3. **Scenario 3**: The elasticity of substitution is changed so that ρ_d = -0.5 (land and houses are greater complements).
4. **Scenario 4**: The elasticity of substitution is changed so that ρ_d = -0.1 (land and houses are substitutes).

Scenario 1: Construction costs fall; Pf = $3000 or $Pf = $2000







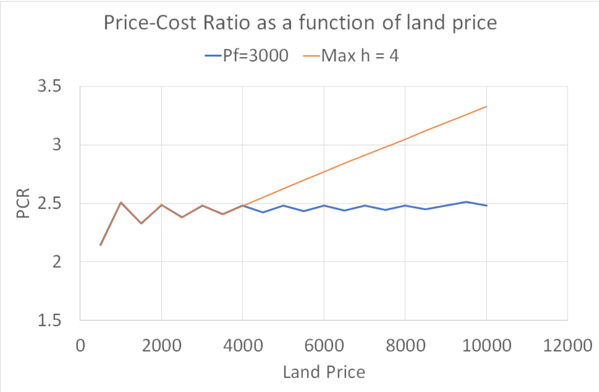
Points to note

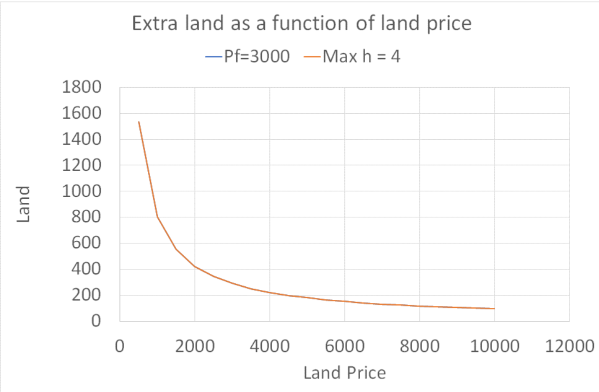
1. The PCR increases as the land price increases; but it only increases by about 10-20 percent despite a ten-fold increase in land prices. The PCR decreases whenever building height increases (this is the reason for the spiky line), but it does not depend much on the level of construction costs. This is because houses are larger when construction costs are lower, so the total amount spent on a dwelling is approximately the same.

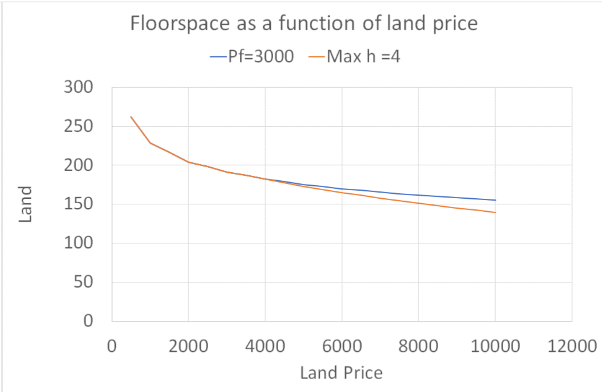
2. As the land price increases, there is a rapid decrease in the quantity of additional land demanded, and a rapid increase in building height (which reduces the demand for land for construction purposes.) The decrease ensures total expenditure on land reduces slowly as the land price increases, which ensures the PCR only increases slowly.

3. A fall in the construction cost increases floorspace, but there is no substitution towards land.

Scenario 2: A maximum building height of 4 stories is imposed



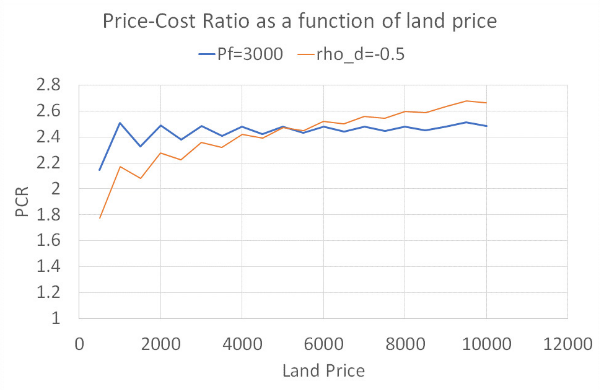


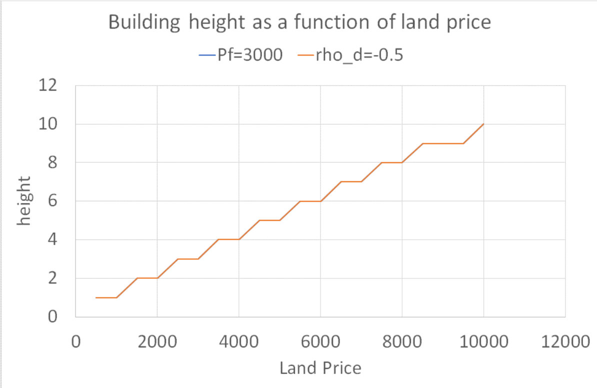


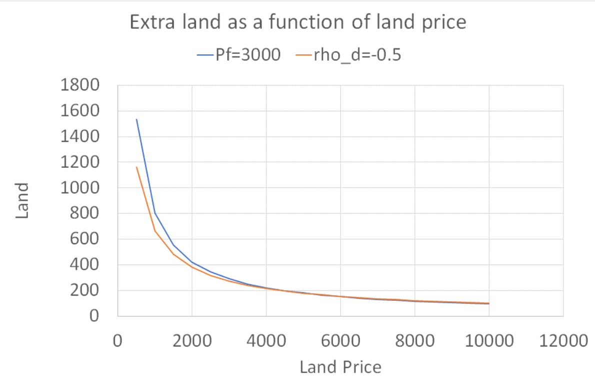
Points to note

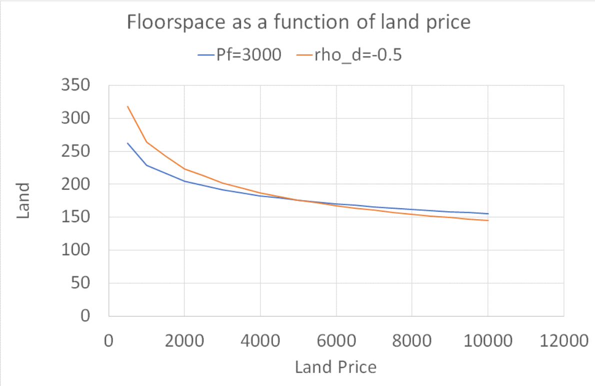
1. When the height restriction is imposed households cannot economise on land if they want a large house. The PCR increases and house sizes shrink as land prices increase, increasing the price-cost price ratio relative to optimal height buildings.
2. The height restriction does not affect the amount of extra land (garden) demanded, although it does increase the amount of land used in construction.
3. The height restriction reduces utility by little, even though floorspace and the consumption of other goods and services reduce when the restriction is imposed. In the model, an increase in the land price from \$4000/m2 to \$10000/m2 only increases the height-restricted building costs by 12 percent and reduces apartment sizes by 11 percent. This reduces utility by approximately 5 percent.

Scenario 3: Change in the elasticity of substitution so land and houses become more complementary (ρ_d = -0.5)





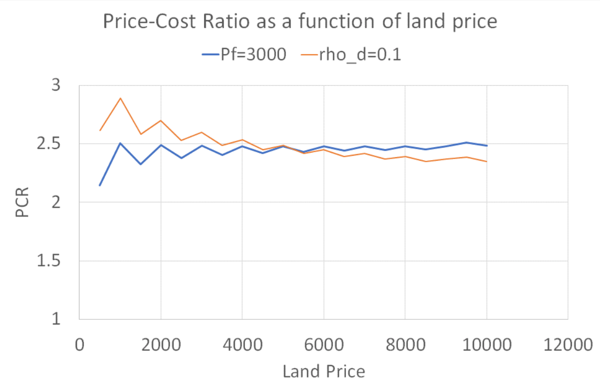


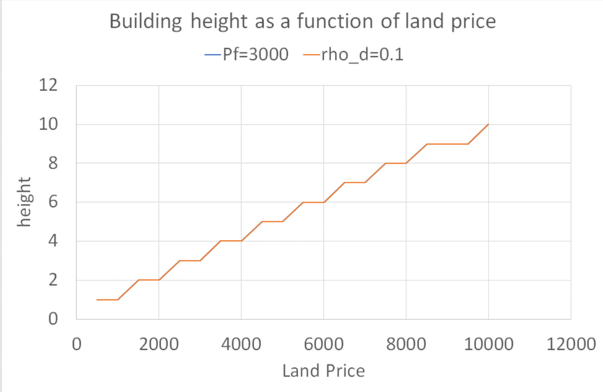


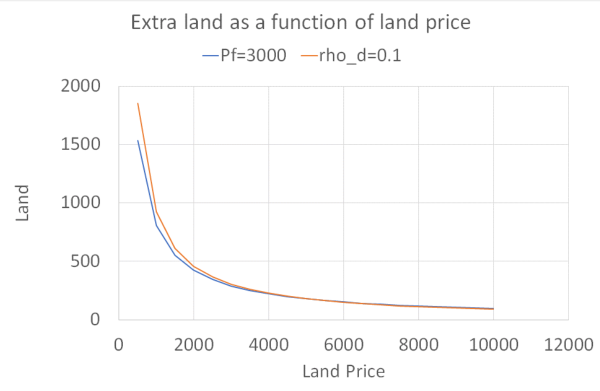
Points to note

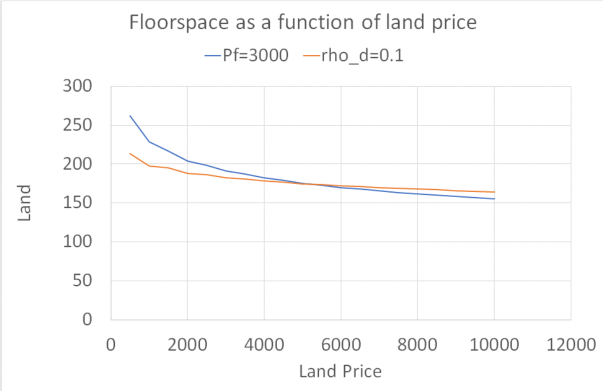
1. If land (gardens) and houses are complements, the PCR becomes more responsive to changes in the land price than previously. The PCR increases more rapidly as the price of land increases, as there is a more rapid decline in floorspace and thus a more rapid decline in the amount of land demanded for floorspace as the land price increases. (There is also a slower decrease in the amount of land demanded for gardens than when ρ = -0.1.)
2. The substitution parameter has no effect on building height.
3. As land is a complement to houses, when the land price is low the house size is larger than in the baseline comparison.

Scenario 4: Change in the elasticity of substitution so land and houses become substitutes (ρ_d =0.1)









Points to note

1. When land and houses become substitutes, the PCR decreases not increases as the land price increases. This is because households rapidly substitute away from land to floorspace. In this case floorspace still decreases, as the land price increases, but not as rapidly as previously. There is a faster decrease in the amount of land demanded for gardens than when ρ = -0.1.
2. The substitution parameter has no effect on building height, as this is a technical supply side parameter.
3. As land is a substitute to houses, when the land price is low the house size is lower than in the baseline comparison.

Discussion

These simulations indicate that if markets for land and new construction were frictionless, changes in either the price of land or the price of construction should have only minimal effects on the PCR. This is because people demanding houses should rapidly change the size of their houses and gardens as the price of land and construction change. This result appears to hold for a range of demand substitution parameters. If land and houses are substitutes, the PCR should actually fall as the land price increases, because households rapidly substitute from gardens to houses.

In the simulations, the main occasion when the PCR changes as land prices increase is when there are significant limits on building heights. In this case it is far more difficult for households to reduce their land use, for even though they can reduce the size of their gardens they cannot reduce the footprint required for construction. Building height restrictions also lead to smaller houses. A similar increase in the PCR will occur if there are minimum lot sizes. This restriction means households cannot substitute away from gardens as land prices reduce, and will lead to a large increase the minimum cost of land that is necessary to purchase to dwell in a house.

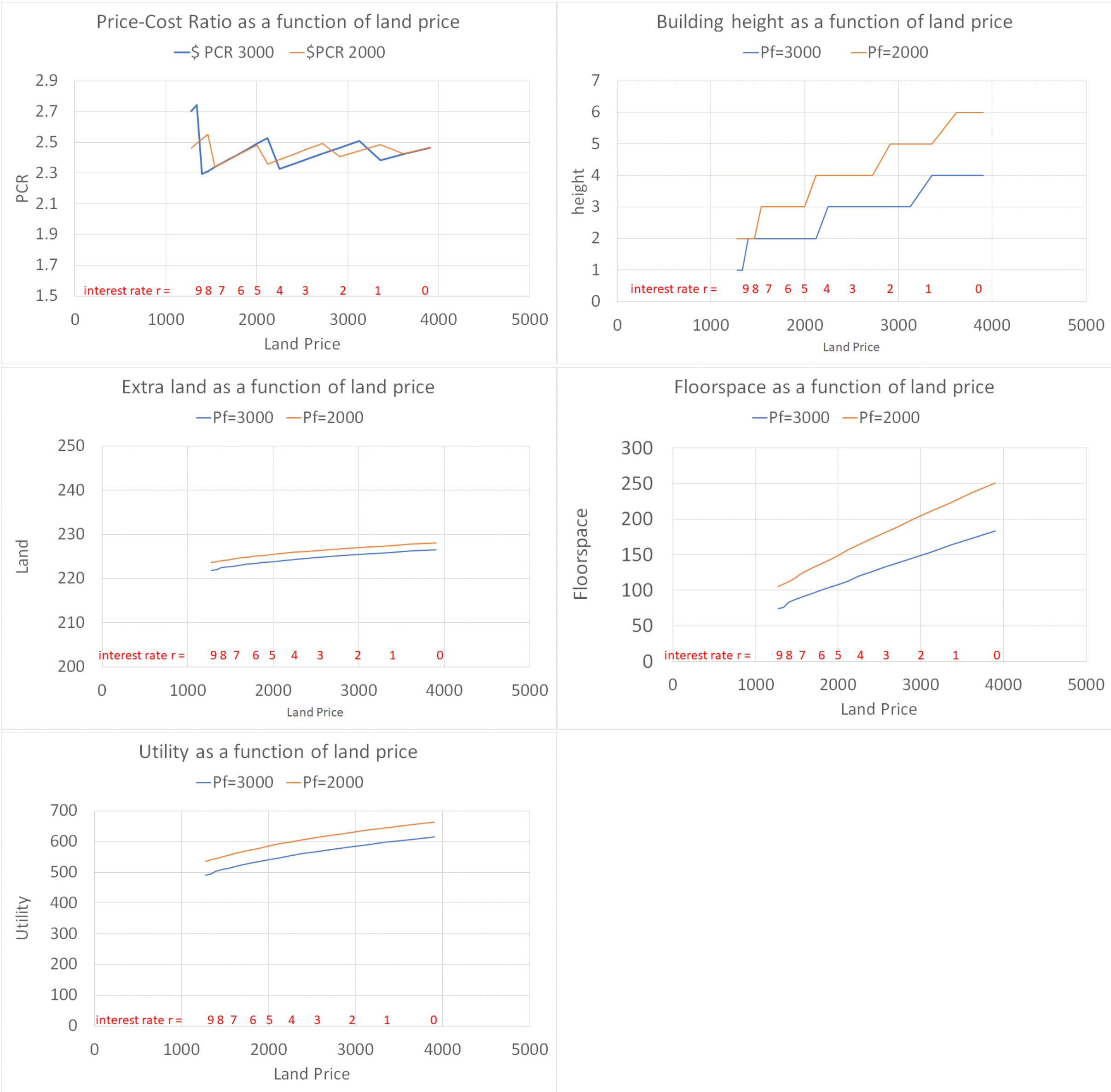
This note has not attempted to calculate the equilibrium price of land. The equilibrium price of land will depend on the height of building, for this partly determines how much land each household requires. When height is not restricted, not only will the PCR be lower because there are more houses on a section, but the price of the section is also likely to be lower due to the reduced demand for land.

Simulations with interest rates changes

In this section the PCR is calculated under the assumptions that (i) building costs are independent of interest rates (so the user cost of building declines when interest rates decline) and (ii) land prices are inversely proportional to amortisation rates (so the user cost of land is constant when interest rates decline). This means that the price of land relative to building costs increases when interest rates fall. However, in contrast to the situation in section 2, there is almost no change in land demanded but an increase in the size of the houses that are demanded, since the decline in interest rates results in no change in the user costs of land but a decline in the user cost of building.

The following diagrams show the effect of falling interest rates on the PCR, user costs of land and building, building height, land size, floorspace, and utility as the interest rate changes from 0 to 9.5 percent and the land price increases. The PCR is the same whether calculated in user-cost terms or up-front dollar terms. Note the horizontal axis records both the interest rate and the associated land price.

Scenario 5: Price cost ratio when the interest rate changes

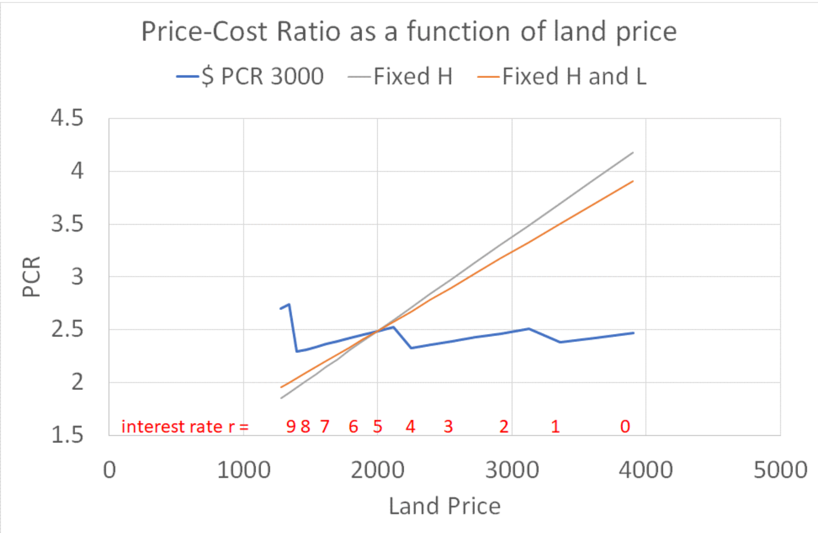


The top left graph shows PCRs are nearly constant as interest rates decline whether the up-front building cost is $3000 or $2000. The PCR graph is thus quite similar to the first graph in section 2. This suggests that declining interest rates should not be a reason for a change in the PCR, if the desired size of land and structures can change endogenously as interest rates fall. In user-cost terms the PCRs are nearly identical whether the up-front building cost is $2000 or $3000. This is because when the up-front building cost is lower, households demand larger houses, and there is little change in the total amount spent on structures. The remaining graphs show there is only a very small increase in size of extra land (garden) when the interest rate declines, for the user cost is constant; in contrast there is a large increase in the size of structures as interest rates decline and the user cost of construction declines. Note that the height of buildings also increases as interest rates falls, as it becomes relatively cheaper to build up than out. Furthermore, falling interest rates lead to an increase in utility in this model despite the up-front increase in land costs, as the budget position of borrowers is enhanced.[8]

The key reason why the PCR is constant is the endogenous changes in land and structure size as prices change. The importance of this adjustment mechanism can be seen by calculating the PCR when either the structure size or both the structure size and land size are fixed. Scenario 6 shows the PCR when the interest rate changes for three different cases:

1. Land and structure size adjust fully in response to a change in interest rates (same as scenario 5);
2. Structure size is fixed at the value pertaining to interest rates = 5 percent, but land size can change ("Fixed H");
3. Both structure size and land size are fixed at the values pertaining to an interest rate= 5 percent ("Fixed H and L").

Scenario 6: Price-cost ratio when structure sizes are fixed



The graphs show that the PCR steeply increase when interest rates decline if either house structure or land size are fixed. The increase in the PCR occurs because when interest rates fall the user cost of building falls, but the user cost of land is unchanged; since agents demand at least as much land as previously, (for its price has not changed but households have a positive income effect), the numerator of the PCR increases while the denominator falls due to the decrease in the user cost of structures. The PCR increases by slightly less when both land size and structure size are fixed, as agents no longer increase the size of the land they want when the user cost of structures declines.

At a microeconomic level, there is no obvious reason why households are prevented from buying larger houses or more land. This is not true at the macroeconomic level, however. The essential problem is the capacity constraints in the construction sector. If interest rates decline and the user cost of structures declines, a large number of households will simultaneously desire an increase in

8 The loss of interest income accruing to lenders is not considered.

the size of the housing structures they want. Because houses are long lasting, however, the construction industry typically only has capacity to build or renovate about 2 percent of the housing stock each year. The capacity constraints mean the stock of better quality houses cannot increase fast enough to satisfy demand at existing prices, and as a result the quality desired at the lower user costs will not rapidly increase even if there are no regulatory restrictions on the building industry.[9] Consequently, an increase in the *average* PCR can occur when there is a decline in interest rates because the price of land is liable to increase much faster than the supply of the larger houses. In theory, the increase in the PCR should be temporary, but it could be long lasting if the increase in the supply of new high-quality houses takes a very long time. This is plausibly the case in the New Zealand after 2002, where large inward migration and the Christchurch earthquake occurred at the same time that interest rates declined significantly, placing pressure on construction capacity and plausibly delaying the time it takes to transform the quality profile of the housing stock.

Discussion

When quantities in the land and structures market can easily be adjusted, a decline in interest rates that leads to an increase in land prices should not lead to an increase in the PCR. Rather, it should lead to an increase in the size of houses. At the margin, the buyers of new houses can increase the size of the houses that they buy, so that at the margin the PCR may not change. The overall quality profile of the building stock cannot change quickly, however. Since the up-front prices people pay for well-located property can increase quickly in response to interest rate declines, the average PCR may increase when interest rates fall even if the marginal PCR does not. For this reason, it is important to distinguish between changes in the marginal and average PCRs.

Conclusion from simulations

This note has analysed circumstances when the PCR is likely to change little in response to land price changes, and circumstances when it may change substantially. In general, if households can freely change the size of the properties and structures they purchase when land prices change, and builders can vary their inputs, the PCR should vary little with land prices. This is true whether the land price change is in response to interest rate changes or due to other factors.

There are at least two exceptions to this rule. First, if there are regulatory restrictions that prevent changes in the size of land or structures that people can purchase, the PCR is liable to increase when land prices increase, because agents cannot economise on expensive inputs. Building height restrictions or minimum land size restrictions are examples of regulations that could generate artificially high PCRs. Secondly, if the construction sector is limited in its ability to rapidly change the quality profile of the housing stock, the average PCR may increase when interest rates fall and the increase in demand for better quality property cannot be quickly satisfied. This may explain some of the increase in the average PCR in New Zealand, for the decline in interest rates since 1990 is associated with an increase in the demand for large new houses, and a substantial albeit gradual increase in the supply of these houses. If this is the case, an adequate distinction between marginal and average PCRs is likely to be important to adequately distinguish between regulatory

9 Regulatory restrictions can delay building, however, extending the time it takes for the demand for larger buildings to be satisfied.

and non-regulatory factors the prevent or slow down the response to changes in land prices and building costs.

The model suggests that when households can readily adjust the size of their properties and builders can adjust the inputs they use, PCRs are relatively insensitive to land or construction price changes, as households can substitute land for houses, and builders can substitute height for horizontal expansion.

On the other hand, the model suggests PCRs are sensitive to building height restrictions, minimum lot sizes, and interest rate changes, which affect the ability to freely substitute land for building and the building sector's ability to adjust the housing stock via the following mechanisms:

- Building height restrictions prevent builders from reducing the land footprint associated with each dwelling when land price rise, and lead to higher PCRs.
- Minimum lot sizes prevent households from reducing the size of their sections as land prices rise, leading to higher PCRs.
- There are capacity constraints in the building sector that restrict how quickly builders and developers can transform the quality composition (the number of differently sized houses) of the housing stock. This can be important when interest rates decline if (i) 'up-front' building costs remain the same but building user costs decline and (ii) land user costs remain the same, but land prices increase. In these circumstances, average PCRs can be expected to increase at the economy -wide level because land prices respond more quickly to the change in interest rates than the quantity of new building. In contrast, the PCR will change little if the construction sector can transform house sizes at the same rate that land prices increase.

In summary, the modelled scenarios highlight PCR as an indicator that is relatively unaffected by land or construction price changes while it adjusts when there are restrictions to substitution flexibility between inputs, such as building height restrictions, minimum lot sizes and interest rate changes. Its practical application relies on the accuracy with which it can be measured as discussed in chapter 1.

Appendix 1: Multiperiod budget constraint models for price-cost ratio model

(1) Assume there is an n-year mortgage. The annual payment flow that pays of the mortgage over n years are

$$r^* = \begin{cases} \frac{1}{n} & r = 0 \\ \frac{r(1+r)^n}{(1+r)^n - 1} & r > 0 \end{cases} \tag{A1}$$

(2) Assume a person purchases an L sized piece of land costing P_L per m^2 and an f sized house costing P_f per m^2 at the beginning of the period, and pays this off at a rate r* per year over n years. The n year budget constraint (including payments on consumption goods and amenities) is

$$P\left(\sum_{i=0}^{n-1} \frac{C_{t+i}}{(1+r)^i}\right) + P_A\left(\sum_{i=0}^{n-1} \frac{A_{t+i}}{(1+r)^i}\right) + \left(P_L L + P_f f\right) r^* \left(\sum_{i=0}^{n-1} \frac{1}{(1+r)^i}\right) = P\left(\sum_{i=0}^{n-1} \frac{Y_{t+i}}{(1+r)^i}\right) \tag{A2}$$

Note that $r^* \sum_{i=0}^{n-1} \frac{1}{(1+r)^i} = r^* \frac{(1+r)^n - 1}{r(1+r)^{n-1}} = (1+r)$ (A3)

(3) Suppose that consumption, amenities and income are both constant and equal to $\bar{C}$ and $\bar{A}$ and $\bar{Y}$. Then equation (A2) becomes:

$$(P\bar{C} + P_A\bar{A})\left(\sum_{i=0}^{n-1} \frac{1}{(1+r)^i}\right) + \left(P_L L + P_f f\right) r^* \left(\sum_{i=0}^{n-1} \frac{1}{(1+r)^i}\right) = P\bar{Y}\left(\sum_{i=0}^{n-1} \frac{Y_{t+i}}{(1+r)^i}\right) \tag{A.4}$$

$$\Longrightarrow P\bar{C} + P_A\bar{A} + \left(P_L L + P_f f\right) r^* = P\bar{Y} \tag{A.5}$$

(5)Equation 5 is applied by assuming that (i) P_f is independent of interest rates and

(ii) P_L is a function of the mortgage rate.

In particular, for some constant P_L^*

$$r^* P_L(r^*) = P_L^* \times (r^*)^\gamma \Rightarrow P_L(r^*) = P_L^* \times (r^*)^{\gamma - 1} \tag{A.6}$$

When γ=1, the dollar price of land is independent of interest rates and is assumed to equal some constant. This is the limit case that would prevail if all land had the same quality and the supply of land was perfectly elastic. (This case is not realistic when the quality of amenities vary across space and transport costs are positive.)

When γ=0 the user cost is constant i.e. the annual user costs (mortgage payment) to purchase a square metre of land is constant. In this case the price of land is inversely related to the annual mortgage rate payment.

Appendix 2: Methodology overview of improved New Zealand Land Value Model

Methodology changes from previous versions of the LVM

The LVM was substantively rewritten by HUD in 2023.

Property clusters

The base unit of analysis is now the "property cluster". A cluster represents a group of DVR records and parcels which are associated with each other.

For example, if DVR "A" is associated with Parcels "X" & "Y", and DVR "B" is also associated with Parcel "Y", then {A, B, X, Y} are all considered as a single cluster. For the purposes of calculating land value and adjusting by land attributes, the values of {A, B} are combined and considered against the spatial extents defined by {X, Y}.

Clustering can capture multi-parcel properties (one DVR, many parcels), properties with shared parcels (many DVRs, one parcel), or complex arrangements with both (many DVRs, many parcels). Multi-parcel properties are of particular significance, as this is a very common in large rural properties, and account for 75 percent of total parcels by land area.

In previous versions, only properties with one-to-one DVR-parcel relationships were included. The new methodology has resulted in a greatly improved coverage rate.

All valuations and spatial attributes (distance to boundary, distance to water, etc) are calculated at a cluster level.

Historical snapshots

Whereas previous versions used the latest valuations, the new methodology creates snapshots at each valuation period in each TA, using the zoning, valuations and property attributes in that period. Every time the model is re-run, all historical snapshots are recalculated using the latest methodology. This means that snapshots for the same TA are comparable within the same run, and snapshots can be compared across runs to assess the impact of methodology changes.

The use of valuation dates to create "snapshots" means that SPAR-based valuation adjustments (to infer the valuations of properties some time after the valuation date) are no longer applied. Caution should be used when comparing between different TAs as the snapshot for different TAs are taken at different times.

For Auckland, valuation dates are aligned across its various TAs. For other cities that cross multiple TAs, some have valuations periods that are misaligned by more than a year. This should be considered when using results from a new centre that crosses multiple TAs.

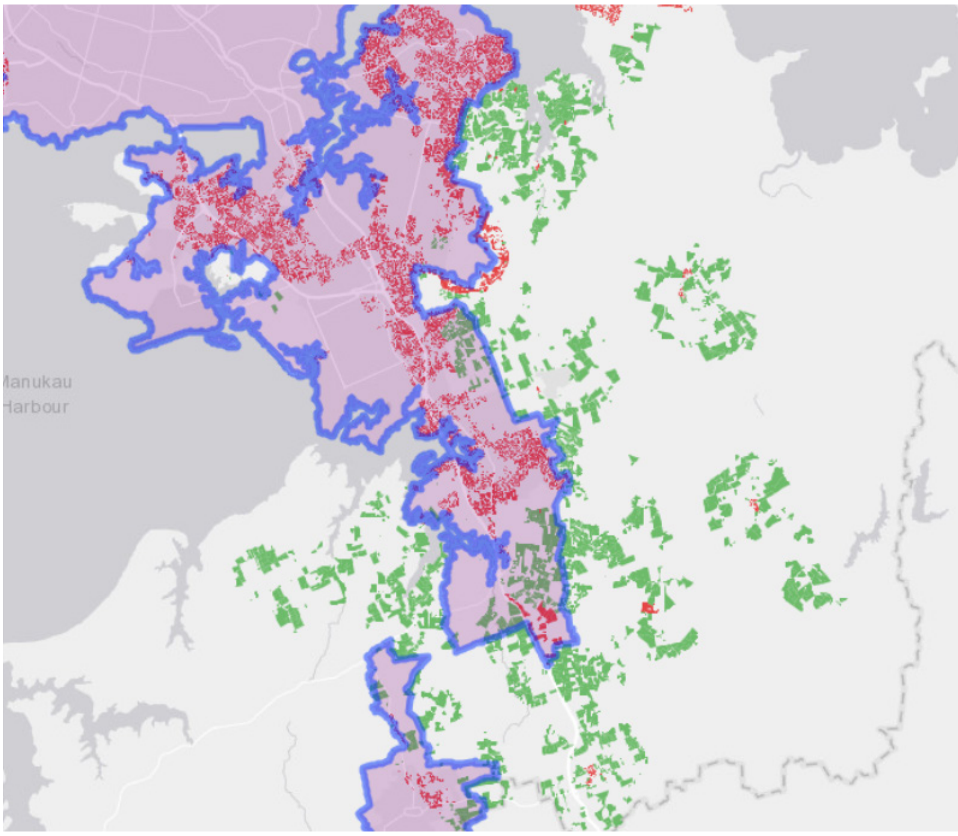
Distance to water

The previous method for water bodies determination has been replaced with a more direct method using the LINZ coastlines/river/lakes datasets. Only lakes over 50,000 square metres are considered.

Rural Urban Boundaries

The previous method of inferring a rural urban boundary using DVR land-zoning code has been completely replaced by a new DVR land-zoning code inference method. This method combines adjacent and near-adjacent urban clusters, and fills enclosed or near-enclosed gaps between them to create contiguous rural-urban boundaries, and removes small, isolated urban areas.

This process is crucial as isolated urban areas can create an "island effect", capturing every rural cluster within a 2km radius around them.



Map of the 2020 version of the Land Value Model in South Auckland. Red areas are urban parcels within 2km of the inferred rural-urban boundary, and green areas are rural parcels within 2km of the inferred rural-urban boundary. Blue outline is the Auckland Council's 2016 Rural-Urban Boundary. Note the island effect of small red dots (likely to be small townships or rural shops) creating a much larger circle of green around them (deep rural areas misidentified as near-urban rural areas).

Where available, administrative boundaries are used in addition to the inferred rural-urban boundaries:

- Auckland: 2010 Metropolitan Urban Limit

- Auckland: 2013 Metropolitan Urban Limit
- Auckland: 2016 Rural-Urban Boundary
- Christchurch: 2023 District Plan (with additional cleaning)
- Hamilton: 2021 Urban Footprint

Manual ad-hoc adjustments from previous versions have been discarded completely.

Hazards

These have been discarded as they cannot be consistently applied to other regions.

Filtering

Clusters are filtered based on the following set of rules:

- Must have an area greater than 1/50th of the area of its bounding box (A perfect north-south aligned rectangle would have an area equal to its bounding box. The more irregularly shaped or non-contiguous an area, the lower this ratio would be.)
- Must be less than 1000 km2 (i.e. Excludes national parks/Chatham Island)
- Must have fewer than 10 QPIDs (i.e. Exclude apartment blocks)
- Must have a minimum size of 50m2
- Must have valid combined LV
- Must have LV per sqm <$20,000/sqm
- Must have land use of rural, lifestyle, industrial, commercial, residential (land zoning codes 1/2/7/8/9)