Working paper

The value of land, floorspace, and amenities: A hedonic price analysis of Auckland property sales

New Zealand Association of Economists Annual Conference 2015

Peter Nunns
MRCagney Pty Ltd

16 June 2015

MRCagney

Document Information

Project Name	**The value of land, floorspace, and amenities: A hedonic price analysis of Auckland property sales**
Document Name	Working Paper
Client	New Zealand Association of Economists Conference 2015
Job Number	N/A
Prepared by	Peter Nunns MRCagney Pty Ltd, Auckland With gratitude for comments and advice from Karl Baker, Stu Donovan, Chris Parker, Hadyn Hitchins, Kyle Balderston, and Eilya Torshizian. All errors and omissions are the responsibility of the author.

Quality Assurance Register

Issue	Description	Prepared by	Reviewed by	Authorised by	Date
1	First Draft Issue	PN	KB/SD	PN	150616

Abstract

What makes a house – or a city – an attractive place to live? Why do people pay higher prices to live in some places than in others? And what can urban planning do to improve the attractiveness of a city or neighbourhood? This paper investigates these questions using spatial hedonic price modelling of recent Auckland residential property sales. It considers the effect of a range of dwelling and neighbourhood characteristics, including land, floorspace, car parking, proximity to amenities such as the coast and city centre, and pre-1940 buildings. Even after controlling for spatial dependence, it finds evidence that some neighbourhood-level amenities are positively associated with residential sale prices, as are a range of other dwelling attributes such as building size, lot size, and proximity to the city centre and coast.

After identifying the hedonic structure of residential property values in Auckland, this paper discusses some implications for analysis of urban planning policies. It argues that planning regulations can have both negative and positive effects on wellbeing. On the one hand, they can constrain the supply of building floorspace in areas of high demand, and on the other hand, they can provide or preserve access to public amenities and manage positive and negative externalities related to development. It identifies several approaches that economists have used to evaluate the costs and benefits of planning regulations using the results of hedonic analysis. Finally, it presents some examples of how these approaches could be used to study the impacts of New Zealand's planning policies.

Contents

1 Introduction and context

What makes a house – or a city – an attractive place to live? Why do people pay higher prices to live in some places than in others?

These are not idle questions. Developers ask them when choosing where and how to construct new dwellings. Individuals and families ask them when choosing which city to live in, and where to live within cities. Urban planners ask them when attempting to establish rules that govern how and where new dwellings can be developed. And, of course, economists ask them when attempting to understand the decisions made by households, developers, and planners.

1.1 Planning for amenity

The above questions are particularly important when developing and evaluating urban planning policies. The aim of planning, at a very high level, is to provide for population and economic growth while managing the positive and negative externalities associated with growth. For example, an urban plan may include:

- Requirements for public and private open spaces, which can improve amenity in surrounding areas
- Rules around the size and design of buildings and their position on sites, which can have localised negative or positive externalities such as building overshadowing
- Requirements to preserve buildings in areas with heritage value or "special character", which can have positive external benefits.

In short, planning rules often aim to provide or preserve things that make cities attractive places to live[1]. But: how much amenity is enough? How can we tell whether the benefits of providing amenities through the planning system exceed the costs?

This paper sets out an approach to address this question empirically. It uses a hedonic price model of recent Auckland residential property sales to identify people's "willingness to pay" for different types of amenities, including living space, proximity to the city centre and to coasts, and proximity to heritage buildings. It employs these results to implement a simple cost-benefit test to consider the trade-off between alternative planning approaches.

1.2 Auckland: growing demand and constrained geography

Auckland, New Zealand's largest city, faces some particular challenges in urban planning. In a country where economic performance suffers from small market size and long distances from major markets, Auckland is best placed to emerge as a productive and innovative city with good international connections (McCann, 2009).

According to Grimes et al (2014) and Donovan (2011), Auckland's potential for agglomeration economies – the advantages of city size and density for producers and consumers – has been a fundamental driver of the city's growth. In addition, the city benefits from good natural amenities, such as its climate and relatively high sunshine hours. As a result, locating in Auckland offers advantages for households, who can access a larger labour market and more consumer amenities, and for businesses, who have better access to skilled labour, inputs, and markets for their products – the foundations of the "Auckland productivity premium" (Maré, 2008).

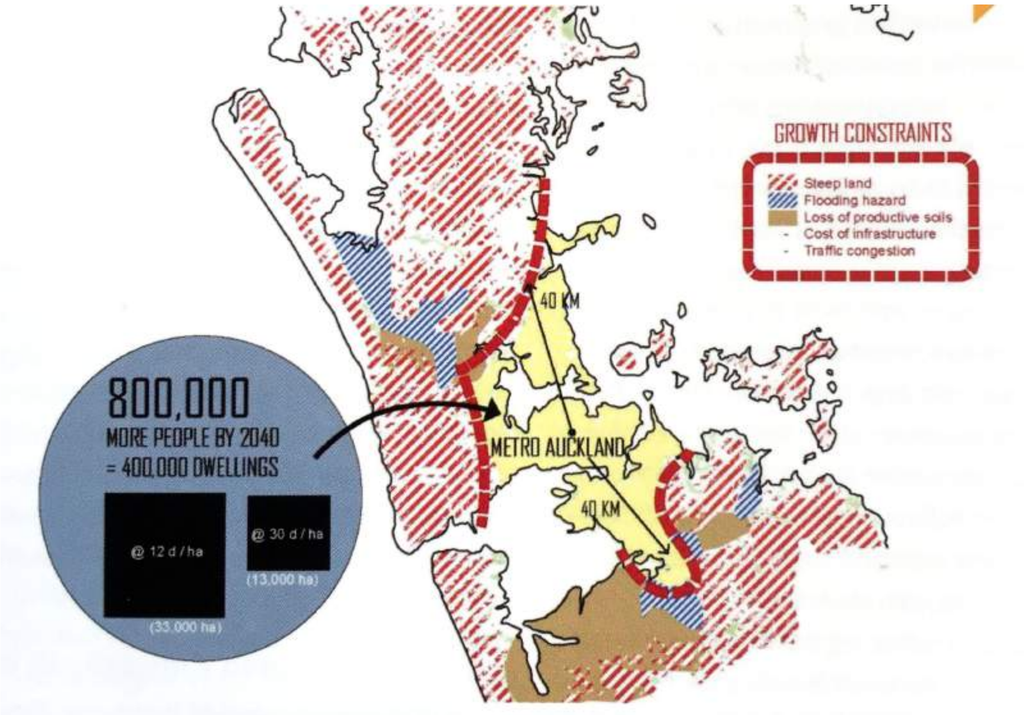
[1] Which is not to say that they cannot have unintended negative consequences. For example, rules such as boundary setbacks, minimum lot sizes, and building height limits, which are aimed at preserving suburban amenity values such as spaciousness and daylight access, are also a key barrier to the development of high-amenity medium-density mixed-use neighbourhoods seen in European cities.

Auckland's geographic advantages within New Zealand and its comparatively high productivity mean that it is likely to continue growing rapidly. According to Statistics New Zealand's latest (2015) subnational population projections[2], the city is expected to grow at an average annual rate of 1.3% per annum from 2013 to 2043, compared with projected growth of 0.8% for New Zealand as a whole. Overall, Auckland is expected to accommodate over 60% of national population growth in upcoming decades.

However, fitting in population and economic growth is challenging due to geographical barriers. Figure 1 presents a stylised view on the constraints on Auckland's outward growth, which include two harbours, and a significant amount of flood-prone or otherwise challenging terrain on the fringes of the city[3]. In a similar vein, Lees (2014) observes that Auckland's harbours mean that it has significantly less land for development than comparably sized Australian cities. He estimates only 32% of the area within 30 kilometres of the city centre is made up of developable land, compared with 48% of the area around the six major Australian cities, and concludes that:

> *"the impact of Auckland's narrow geography is equivalent to adding about 900,000 residents or moving the city up to 2,200,000 residents – about the size of Brisbane."*

Figure 1: A stylised view of Auckland's geographical constraints (Source: Falconer, 2015)



The combination of growing demand and geographical constraints means that Auckland is likely to develop more intensively in the future. This process is already underway. Nunns (2014) finds that the city's population-weighted density – roughly speaking, the density of the neighbourhood in which the average Aucklander lives – increased by one third from 2001 to 2013. Data published by MBIE (2013) suggests that this has been the result of both infill development in established suburbs and a boom in large-scale apartment construction.

If this is to continue, Auckland's planning framework must enable more intensive development in areas that are accessible to employment, education, and other amenities. In many cases, this will mean redeveloping sites in existing neighbourhoods at a higher density. While this will enable people to have more of what they want –

---

[2] http://www.stats.govt.nz/browse_for_stats/population/estimates_and_projections/SubnationalPopulationProjections_HOTP2013base.aspx

[3] Of course, this map does not show which parts of the existing urbanised area are flood-prone or built on steep land. It is likely that similar geographical constraints have been overcome in the past, albeit at a cost.

housing in the right location – there may be trade-offs with other amenities, such as public and private open space and heritage preservation.

1.3 Structure of this paper

This paper is structured as follows:

- Section 2 reviews several approaches to quantifying the costs and benefits of planning regulations using results from hedonic analysis of property sales
- Section 3 develops a hedonic price model of recent Auckland residential property sales that accounts for the impact of a range of amenity features
- Section 4 employs the results of this analysis to implement a simple cost-benefit test of the trade-off between planning policies that enable intensification or preserve build heritage
- Section 5 offers some concluding remarks and identifies some areas for further empirical research.

2 Some approaches to evaluating planning regulations

In this section, I discuss several approaches to evaluating the planning regulations using hedonic analysis of property sales. Hedonic price models can be used to estimate the implicit prices that people are willing to pay for attributes that are "bundled" together (see Rosen, 1974). They have played an important role in economists' attempts to assess the costs and benefits of planning rules. According to Sheppard (1999):

> *"A primary reason for undertaking hedonic analysis of housing markets is to understand the structure of demand for housing attributes and environmental amenities. Such understanding is essential for predicting the response to changes in the housing market and for providing welfare estimates of the costs and benefits associated with such changes."*

In other words, hedonic analysis can enable us to identify the value of both:

- Things that are potentially made scarce by planning rules, such as floorspace and appropriately zoned land
- Public amenities that are provided or preserved by planning rules, such as parks, heritage buildings, and attractive neighbourhood features.

There are three broad approaches to evaluating planning regulations using the outputs from hedonic price models:

- Formal models of household housing demand and welfare that are estimated using the outputs from hedonic analysis
- Analysis of "boundary discontinuities" at between adjacent zones (e.g. industrial and commercial zones) or at Metropolitan Urban Limits (MULs)
- Implementation of "cost-benefit tests" to understand whether the amenities provided by planning rules are more or less valuable than the building floorspace foregone in the process.

2.1 Costs and benefits of planning regulations

When evaluating planning regulations, it is necessary to consider how they can impose costs on households – and how they can generate benefits for households and society that would not have otherwise occurred.

On the one hand, planning regulations can impose two broad types of costs on individual property owners or households:

- Compliance costs: Planning policies and processes may impose a range of financial costs on individuals seeking to build (or buy) new housing. These range from costs associated with preparing and processing resource consent applications, paying development contributions for infrastructure costs, or complying with planning rules or consent conditions. These can also be described as added "resource costs" – i.e. they require people to expend additional resources, such as their time or construction costs, to obtain their desired outcomes.
- Deadweight costs: Planning regulations can also limit the amount of housing that people can built on sites, or reduce the likelihood that new housing is developed. This can result in a loss for both developers, who aren't able to build their preferred projects, and households, who may not be able to find housing in the places they would prefer to live. Deadweight costs may arise as a result of rules that limit the amount of housing that can be developed in desirable areas, or that increase the cost and uncertainty of applying for

resource consents (Grimes and Mitchell, 2015). They can also be described as "opportunity costs" – i.e. they prevent people from realising opportunities in the housing market.

In addition, there may also be some indirect costs in imperfectly functioning markets (Boardman et al, 2011). As planning rules affect the choices that people make about where and how to live, they may also result in some broader impacts such as added congestion arising from increased travel distances on congested roads, public health costs due to poor dwelling quality, or low productivity due to poor access to jobs[4]. While these costs are generally disregarded in the economic literature, they may be significant.

On the other hand, planning regulations can raise wellbeing by correcting for market failures that would have otherwise led to a poor outcome for society[5]. Anas, Arnott, and Small (1998) observe that "cities are awash in very localized externalities, from the smells from a fish shop to the blockage of ocean views by neighbors' houses [sic]." For example, development may be associated with:

- Negative externalities associated with the colocation of incompatible activities (e.g. industrial activities in residential areas) or negative spillovers to neighbours (e.g. building overshadowing, localised traffic impacts)
- Positive externalities resulting from agglomeration economies or the provision of features such as parks and attractive building frontages that have positive spillovers for neighbours.

Externalities may arise at a range of geographical scales – think of the regional or national importance of having good labour market accessibility or the global impact of greenhouse gas emissions from household energy use. However, externalities that arise at the neighbourhood scale tend to be most important to planning processes. Issues such as building overshadowing, noise, or demand for on-street parking are a frequent source of residents' opposition to new developments.

In the absence of well-designed planning regulations, individuals may externalise some of the costs of their activities on society or the environment or under-provide public goods, such as parks, because they are unable to recover costs from people who enjoy them.

2.2 Modelling household welfare based on hedonic analysis

Cheshire and Sheppard (2002) develop an approach to formally modelling the costs and benefits of planning regulations using a household demand function estimated using the implicit prices from a hedonic analysis of house prices, plus survey data on household income and composition. They employ this approach to analyse the welfare impacts of greenbelt and MUL policies in Reading (UK), which "faces some of the most restrictive land use planning in Britain". They model the amenity that households derive from private living space and yards (which may be constrained by planning regulations) and public and private open spaces within and around the urban area (which are protected by planning regulations).

First, the authors look at the gross benefit of three "planning amenities". Their results, which are summarised in Table 1, suggest that the average household derives substantial gross benefits from Reading's planning regulations, although the effects vary significantly between households (as demonstrated by the large standard deviations). As one would expect, the value of accessible open space (e.g. public parks) is greater than the value of inaccessible open space (e.g. farmland), as it offers better recreational opportunities.

[4] Glaeser et al (2005) argue that "the social costs of binding development restrictions lie in the misallocation of consumers, and having them live in less productive, less attractive places."

[5] They may also correct for government failures, which arise as a result of the perverse consequences of other policy interventions.

Table 1: Gross value of benefits from planning amenities (Source: Cheshire and Sheppard, 2002)

Amenity	Amount available in the absence of planning	Average annual value per household (£)	Standard deviation (£)
Accessible open space	Zero accessible open space in urban area	2424.45	1745.05
Inaccessible open space	Zero inaccessible open space in urban area	1029.65	1223.90
Industrial land use	47% of land in every part of the city is in industrial use	1092.00	600.96

Second, the authors calculate the net costs associated with planning amenities. In order to do so, they model three scenarios in which Reading's greenbelt and MUL policies are relaxed, leading to lower housing costs (or increased housing consumption) as well as a reduction in the amenity value of open space. Their results, which are summarised in Table 2, suggest that relaxing planning regulations would improve wellbeing for the average household (i.e. reduce net costs to welfare) even after accounting for the loss of amenity from reduced open space. As above, these effects vary significantly between households, as demonstrated by the large standard deviations.

However, it is instructive to compare the *magnitude* of Cheshire and Sheppard (2002)'s estimates of the net costs of planning regulations with their estimate of the gross benefits of those regulations. Their estimated net costs are significantly smaller than gross benefits – in the range of £45-407 per household per year compared with £1000-2400. This suggests that analyses that disregard amenities produced or preserved by planning regulations may over-state the true costs of those regulations.

Table 2: Net costs of planning amenities compared to several scenarios for relaxing rules (Source: Cheshire and Sheppard, 2002)

Scenario for relaxing rules	Description of scenario	Average annual net cost per household (£)	Standard deviation (£)
Reduced internal open space	17.23% reduction in open space within Reading's MUL – i.e. enabling development on some greenbelt sites	45.55	61.20
Modest relaxation of MUL and greenbelt policies	46.9% increase in urbanised land area as a result of a 17.23% reduction in internal open space and a relaxation of the MUL	210.94	376.68
Significant relaxation of MUL and greenbelt policies	70.7% increase in urbanised land area as a result of a 17.23% reduction in internal open space and a more significant relaxation of the MUL	407.44	335.40

Finally, Cheshire and Sheppard (2002) consider the distributional impact of changes to planning rules. They conclude that:

> *"Provision of open space that is generally accessible to the public generates benefits that are significant and tend to reduce inequality. Provision of open space that is inaccessible to the public (largely located at the urban periphery) generates benefits that are very unequally distributed, and tend to increase inequality.*
>
> *Overall, the benefits produced by the planning system appear to be distributed in a way that favors those who are already favoured with high incomes."*

Cheshire and Sheppard's approach has a number of advantages. As it formally models household demand functions and welfare, it avoids some of the estimation issues discussed by Sheppard (1999)[6]. Furthermore, unlike some other approaches, it allows for an explicit quantification and comparison of both costs and benefits.

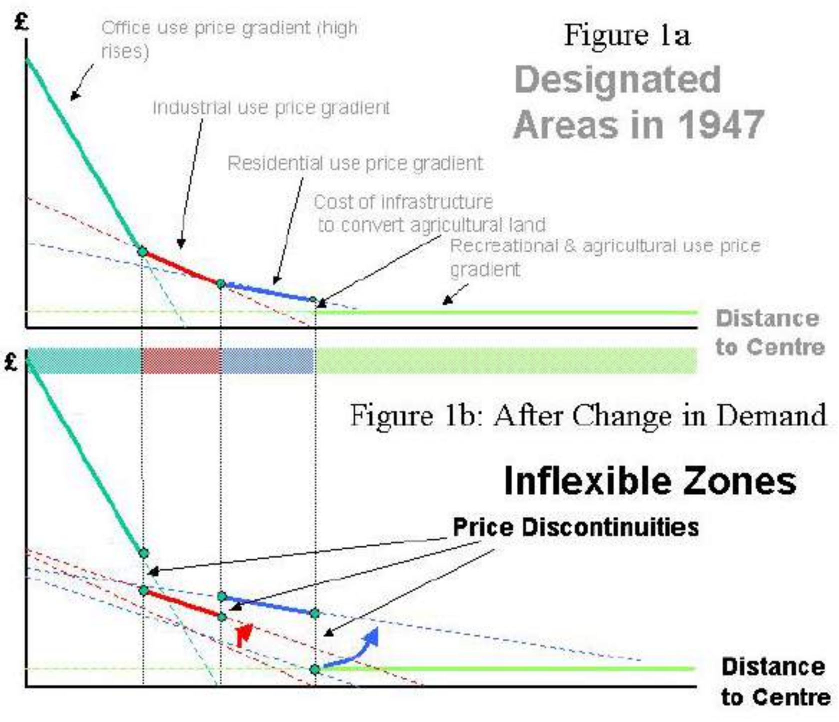
However, this approach has not been widely employed in the literature, due to its complexity and high data requirements[7]. In particular, the requirement for survey data on household income and composition aligned to property sale data means that it is difficult to apply on a regular basis.

2.3 Identifying boundary discontinuities using hedonic analysis

Cheshire and Sheppard (2005) present another approach that is commonly used to analyse constraints imposed by planning regulations. They argue that observed discontinuities in land values should be seen as a "market signal" that land should be rezoned to a higher-value use. Figure 2 depicts how a combination of fixed zoning and changing urban land values can result in differences in land prices between adjacent areas.

While discontinuities in land prices are most commonly observed at the urban fringe, where MULs may pose barriers to urban growth, they can *also* arise within the urban area if zoning varies significantly between adjacent areas. For example, Kulish et al (2012) present some modelling results that indicate that if planning regulations limit the density of development within cities, large "windfall gains" in land prices will arise if density controls are relaxed for some sites but not others.

Figure 2: The emergence of land price discontinuities under fixed zoning (Source: Cheshire and Sheppard, 2005)



Several papers have used hedonic analysis to search for boundary discontinuities around Auckland's MUL. Grimes and Liang (2009) use a hedonic price model to study determinants of land prices in Auckland,

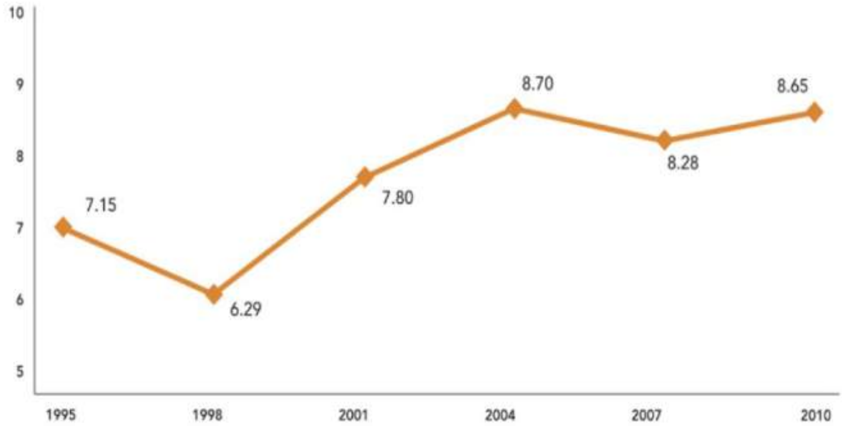
[6] In particular, Sheppard (1999) argues that estimating attribute demand using linearised household budget functions derived from a HPM can over-state the welfare losses associated with planning regulations that restrict the supply of desired attributes, due to the convexity of budget constraints and endogeneity in the price of dwelling/neighbourhood attributes. The modelling approach employed in Cheshire and Sheppard (2002) corrects for this.

[7] Brinkman (2013) employs a somewhat similar approach to model the net welfare impacts of congestion pricing in the presence of a negative congestion externality and a positive agglomeration externality.

concluding that land just inside the MUL boundary is around 12 times more expensive per hectare than is land situated just outside the MUL.

In a similar vein, Zheng (2013) employs a quantile regression approach to identify the magnitude of the boundary discontinuity. His estimates are summarised in Figure 3. Zheng (2013) also notes that “the impact of the MUL on housing affordability is most pronounced for those at the lower end of the housing market. One reason for this is that lower priced land is more often found further out on the fringes of cities.”

Figure 3: Estimated boundary discontinuity in land prices near the Auckland MUL (Source: Zheng, 2013)



Source: Housing affordability report from New Zealand Productivity Commission
Note: The price multiple of land 2km within the MUL to land 2km outside the MUL

However, this discontinuity cannot necessarily be attributed solely to the MUL. First, other planning regulations may limit the supply of dwellings in areas that are more accessible to employment and urban amenities. Economic modelling suggests that this can artificially inflate demand for land at the urban fringe and thus push up the size of the discontinuity (see Kulish et al, 2012; Lees, 2015).

Second, planning regulation is not the only factor that can result in land price discontinuities. In some cases, low-value land is simply ill-suited for development for reasons that have nothing to do with its zoning. For example, a low-lying area next to an existing residential subdivision may be flood-prone and hence difficult to develop. In this case, the flood-prone land may be kept in rural zoning – a case of zoning following the underlying value of the land rather than distorting its value.

Third, as McCann (2001) notes, zoning may result in localised amenities that push up house prices on one side of the zoning boundary: “If environmental amenities are relatively localized and it is perceived that the greenbelt policy will be maintained in the long term, this implies that the persons who are resident on the urban fringes will always enjoy superior environmental amenities in comparison to those who are resident closer to the city centre.” Failing to explicitly account for these effects, as Cheshire and Sheppard (2002) do, may result in too high an estimate of the cost of the boundary discontinuity[8].

Notwithstanding these challenges, hedonic analysis of boundary discontinuities in land prices is a valuable tool for understanding the costs of planning regulations. In Section 5, I discuss some ways in which it could be adapted to analyse other planning regulations, such as minimum section size rules and mixed-use versus single-use zoning.

[8] It is worth noting, however, that Grimes and Liang (2009) do not find strong evidence of this effect in Auckland. In their analysis of Auckland’s MUL, they conclude that “distance variables are capturing the values of land just inside the MUL boundary, implying that there is no extra amenity value placed on this land. Second, even if there were such higher amenity value, it is likely that higher income (and less deprived) households will move into the sought-after area. Our extended model controls for these household characteristics and hence indirectly controls for such amenity values.”

2.4 Cost-benefit tests based on hedonic analysis

Rouwendal and van der Straaten (2015) present a third approach to comparing the costs and benefits of planning regulations using the outputs from a hedonic price model. Following Cheshire and Sheppard (2002), they observe that providing public parks and gardens results in positive amenity spillovers for nearby properties, while also constraining the supply of private living space and yards. Consequently, they propose the following cost-benefit test:

> *"Open space should be provided until the sum of the marginal willingness to pay of all the inhabitants in of a neighbourhood is equal to the market value of residential land in the neighbourhood."*

Rouwendal and van der Straaten use house sales data to estimate the value of public and private space to households in the Netherlands' three largest cities. They use the outputs from a hedonic price model to calculate the marginal price of open space and the marginal price of floor area in each city – i.e. the amount of money that a new household could be expected to pay for each amenity. By dividing the marginal price of floor area into the marginal price of open space, they obtain an estimate of the population densities that would be required to obtain an optimal balance of public parks and housing.

Table 3 summarises the results of their analysis. They interpret these results as results as follows:

- Amsterdam is over-supplied with open space –actual population densities of 72 households per hectare are considerably lower than the optimal density of 201 households per hectare implied by the cost-benefit test
- The Hague is under-supplied with open space – actual population densities of 59 households per hectare are considerably higher than the estimated optimal density of 42 households per hectare
- Rotterdam is about right – actual population densities of 42 households per hectare are similar to the estimated optimal density of 43 households per hectare.

Table 3: Willingness to pay for open space and housing in three Dutch cities (Source: Rouwendal and van der Straaten, 2015)

City	Marginal price of open space (€ / m2 / hectare / household)	Marginal price of floor area (€ / m2 / household)	Optimal number of households per hectare	Actual number of households per hectare
Amsterdam	4.01 (1.38)[9]	806 (42)	201	72
The Hague	14.55 (1.04)	606 (38)	42	59
Rotterdam	9.87 (1.79)	429 (47)	43	42

MRCagney (2013) employ a similar cost-benefit test in their analysis of minimum parking requirements (MPRs) in Auckland. As their name implies, MPRs define the minimum amount of parking that developers are allowed to supply with commercial and residential buildings. In many cases, the ratios applied are significantly in excess of actual parking demand (see Donovan, 2015 for a discussion of the lack of scientific rigour in parking policies).

MRCagney (2013) suggest that MPRs have resulted in an oversupply of parking if the following cost-benefit test holds true:

> *"An additional square metre of floor area is worth more than an additional square metre of parking."*

[9] Standard errors are given in parentheses to provide an indication of the potential uncertainty in these estimates. All coefficients are highly statistically significant.

In order to implement this test, they use a hedonic analysis of 219 commercial property sales in three Auckland retail centres (Takapuna, Dominion Road, and Onehunga). Table 4 summarises the results of this analysis, which shows that:

- The elasticity of price with respect to commercial floorspace [i.e. the coefficient on ln(F)] is positive and statistically significant at the 1% level
- The elasticity of price with respect to surface parking area [i.e. the coefficient on ln(P)] is negative, albeit statistically insignificant.

In other words, additional floorspace is associated with higher property values, while additional parking spaces have no positive effect on property values. This can be interpreted as evidence that MPRs have required businesses to over-supply car parking[10]. Further analysis by MRCagney (2013) suggests that the regulated oversupply of parking imposes large economic costs in return for few benefits.

Table 4: The value of commercial floorspace and parking in three Auckland retail centres (Source: MRCagney, 2013)

Variable		Coefficient	t-stat	P-value	95% confidence interval	
					Low	High
$ln(L)$	β_1	0.452	4.16	0.000	0.239	0.664
$ln(F)$	β_2	0.403	4.98	0.000	0.245	0.562
$ln(P)$	β_3	-0.068	-1.44	0.149	-0.165	0.025
$ln(D)$	β_4	-0.285	-4.18	0.000	-0.419	-0.151
$Year$	β_5	0.004	2.61	0.009	0.001	0.007
$Sale$	β_6	0.066	7.48	0.000	0.049	0.084
T	β_7	-0.547	-2.55	0.011	-0.968	-0.127
O	β_8	-1.183	-6.81	0.000	-1.522	-0.842
Com	β_9	-0.260	-3.74	0.000	-0.397	-0.124
c		-129.8	-6.81	0.000	-166.8	-92.8

The model has an overall R-squared of 82% and an F-statistic of 116.15,

There are both advantages and disadvantages to employing hedonic analysis to implement cost-benefit tests for planning regulations. As these examples show, this approach can be applied flexibly to assess various different types of planning regulations. Depending upon the specification of the model and the availability of data on building and neighbourhood attributes affected by planning rules, it can be generalised to address a range of issues. In Section 4, for example, I propose a simple cost-benefit test for heritage preservation policies.

In common with the "boundary discontinuity" method, this approach does not explicitly estimate and monetise the costs of planning regulations[11]. Rather, it can be used to identify cases in which planning regulations have resulted in the over-supply of building or neighbourhood characteristics. (Or, conversely, where these characteristics may be undersupplied due to an absence of regulations.) It is therefore a useful tool for identifying the *direction* in which planning regulations should change, but other information is needed in order to understand the *degree* to which this will result in improvements to welfare.

[10] These results are supported by a number of studies that employ different approaches to identify parking oversupply, including comparison of parking supply outcomes before and after the removal of MPRs (Guo and Ren, 2013) and analysis of actual parking demand in commercial centres (Hulme-Moir, 2010; Weinberger and Karlin-Resnick, 2015).

[11] In addition, this approach does not necessarily address the estimation issues identified by Sheppard (1999).

3 A hedonic price model of recent Auckland residential property sales

In this section, I briefly discuss the specification and estimation of a hedonic price model of recent (2011-2014) Auckland residential property sales, and highlight some key results. The material in this section is drawn from recent empirical work published as an Auckland Council technical report. See Nunns et al (2015) for a fuller discussion of this analysis.

3.1 Previous hedonic analysis of the Auckland housing market

This analysis follows on a number of previous studies that have used data from the 1990s and early 2000s. These studies have revealed several "stylised facts" about property prices in Auckland. I used these findings to inform the identification of a preferred hedonic price model. However, I also test the impact of additional variables, including pre-1940 buildings within the neighbourhood:

- Larger lots and larger buildings are associated with higher sale prices – i.e. buyers value having more space. Interestingly, prices seem to be more responsive to building size (floorspace) than they are to land area (Bourassa, et al., 2003; Samarasinghe and Sharpe, 2010; MRCagney, 2013)
- Building quality features are associated with sale prices – including the age of buildings, exterior construction materials, and features such as decks or garages (Rehm, Filippova and Stone, 2006; Bourassa, et al., 2003; Rehm, 2009; Samarasinghe and Sharpe, 2010; MRCagney, 2013)
- Proximity to the city centre is associated with higher sale prices, as is proximity to the coast and school zoning (Grimes and Liang, 2009; Rohani, 2012)
- The Metropolitan Urban Limit is associated with a "boundary discontinuity" in sale prices (Grimes and Liang, 2009, Zheng, 2013)
- Neighbourhood-level amenities, such as landscaping and views of water, are associated with higher property values (Bourassa, et al., 2003; Samarasinghe and Sharp, 2010; Rohani, 2012; Filippova, 2009). School zoning also influences property values (Rohani, 2012; Rehm and Filippova, 2008).

The relationship between these attributes and property prices tend to be relatively consistent between studies, with coefficients generally exhibiting the same sign and statistical significance. Some studies have found spatial variation in coefficients on land and floorspace variables (Donovan, 2011) and water views indicators (Filippova, 2009). Moreover, several studies find evidence that the magnitude of some coefficients has changed over time, which may be attributable to changes to the property market structure and prices over the last decade[12]. Similarly, Bourassa et al. (2003) find that the hedonic value of aesthetic externalities (e.g. "attractive immediate surroundings" and "good landscaping") increased more rapidly than house prices from 1986 to 1996.

3.2 Are there externalities associated with built heritage?

Most of the hedonic literature on built heritage has focused on the question of whether people are willing to pay more for old or historic buildings. Nijkamp (2012) reviews a large number of overseas studies on this topic. In most cases, these studies have found evidence of a price premium for properties that are scheduled as historic or regulated to maintain aspects of historic character. Previous New Zealand-specific work has found that buildings constructed prior to the 1940s or 1930s tend to sell for higher prices than comparable buildings

[12] Interestingly, they find that between 1992 and 1998 close proximity to the city centre changed from being a disamenity (i.e. associated with lower land values) to an amenity (i.e. associated with higher land values).

constructed in later decades (see e.g. Rehm, Filippova and Stone, 2006). Researchers have interpreted these findings as evidence that people value some aspects of old or historic buildings.

However, there has been less research into the external value of built heritage at a neighbourhood or regional level. Do we expect built heritage to have positive spillovers for neighbours or visitors?

Some recent overseas research has attempted to address this question. Lazrak, et al. (2014) apply hedonic analysis to property sales in Zaanstad, the Netherlands. After geolocating property sales and scheduled heritage properties, they find that each additional scheduled property within a 50-metre radius is associated with a price increase of 0.24-0.28 percent. They interpret this as evidence that heritage is a public amenity, albeit a highly localised one.

3.3 Data and methodology

This analysis is based on the following three data sources:

- An extract from the Auckland Council (2015) *District Valuation Roll* (DVR) database, which includes detailed information on all property sales recorded in the region compiled according to guidelines published by LINZ (2010). The data used covered the 2011-2014 period.
- Geographic information system (GIS) analysis to identify the location of properties, their proximity to amenities such as the city centre (CBD) and the coast, and their proximity to other property sales
- Data from the 2013 Census to identify key socioeconomic characteristics of meshblocks, including median household income and population density (Statistics NZ, 2014).

As all of this data is inherently spatial, it was possible to relate property sales records to data organised by meshblocks. After cleaning and filtering the data to exclude sales records with incomplete or implausible values (see Appendix B), I obtained a dataset of 72,855 residential property sales.

3.3.1 OLS regression

I began by testing ordinary least squares (OLS) models by testing several alternative models that followed the form given in Equation 1. The preferred model specification was informed by the previous empirical work summarised in Sections 3.1 and 3.2 and by analysis of alternative model specifications[13].

Equation 1: A generic OLS regression model

$$y_i = \alpha + \beta x_i + \varepsilon_i$$

Where NETPRICE is the dependent variable (y_i, an nx1 vector), α is a constant term to be estimated, x_i is a nxk vector of k explanatory variables (including variables of interest such as LAND, DCBD, and PRE1940, control variables such as HHINCOME and DENSITY, and time dummies), β is a 1xk vector of coefficients to be estimated, ε_i is an nx1 vector of error terms, and $i=1,2,\ldots,n$ are index values for property sales records.

I then tested the preferred OLS model for heteroskedasticity (using the Breusch-Pagan test) and spatial dependence (using Moran's I), finding that (a) the OLS model exhibited heteroskedasticity and (b) model residuals exhibited spatial dependence. As a result, I then tested alternative models to control for spatial dependence.

[13] E.G. through the removal of variables exhibiting excessive multicollinearity. See Nunns et al (2015) for a fuller discussion.

3.3.2 Approaches to spatial regression

There are two main approaches to spatial regression that treat the spatial processes underlying the data in slightly different ways:

- Some types of models treat spatial processes as a "nuisance" to be eliminated or controlled. This is the approach underpinning a spatial error model.
- Other types of models treat spatial processes as a substantive effect of interest. They build spatial relationships into the model as parameters to be estimated. This approach underpins a spatial lag model (as well as other types of models such as geographically weighted regressions).

I tested both types of models on two alternative definitions of "neighbouring" properties:

- Sale records located within a one-kilometre radius (K1KM)
- Sale records located within the same meshblock (KMB).

Previous research into the relationship between dwelling and neighbourhood features and residential satisfaction in Auckland has identified these as the most relevant definitions of a residential neighbourhood. In particular, Torshizian and Grimes (2014b) find that a "dynamic" definition of a neighbourhood, which uses road network analysis to identify properties located within a 15-minute walking distance, performs best.

Here, a one-kilometre radius was used to approximate 15-minute walking distance from residential properties. I have assumed that people walk, on average, one kilometre every twelve minutes, and that the structure of street networks will tend to mean that people cannot simply walk in a straight line. As illustrated in Figure 4, a one-kilometre radius may overestimate walking catchments in some areas and underestimate them in others.

Figure 4: Walking catchments vary depending upon street networks and natural barriers (Source: Wieckowski, 2010)

IMAGES AND MAPPING COURTESY OF URBAN DESIGN 4 HEALTH

Finally, as spatial regression imposes significant computational requirements, I found that it was not feasible to estimate spatial regression models on the full Auckland property sales dataset, which included 72,855 points. As a result, spatial regression analysis was conducted on a randomly selected subset of 10,000 data points from the full dataset[14].

[14] We ran the preferred OLS regression model on the subset, finding that the results closely matched the OLS analysis of the full dataset.

3.3.3 Spatial error models

Spatial error models decompose the error into two parts: a spatially autocorrelated component and a remaining uncorrelated component. They take on the following form:

Equation 2: A generic spatial error regression model

$$y_i = \alpha + \beta x_i + \varepsilon_i$$

Where NETPRICE is the dependent variable (y_i), α is a constant term to be estimated, β is a vector of coefficients to be estimated, x_i is a vector of explanatory variables (including variables of interest such as LAND, DCBD, and PRE1940, control variables such as HHINCOME and DENSITY, and time dummies), ε_i is an error term, and $i=1,2,\ldots,n$ are index values for property sales records.

The error term is in turn decomposed into two parts as follows:

Equation 3: Decomposition of the error term in a spatial error model

$$\varepsilon_i = \lambda W_{ij}\varepsilon_j + \xi_i$$

Where ε_j is a vector of error terms for $j{\neq}i$, weighted using spatial weights matrix W_{ij} (based on either K1KM or KMB), λ is the spatial error coefficient, ξ_i is a vector of uncorrelated error terms, and $j=1,2,\ldots,n,\ j{\neq}i$ are index values for property sales records.

3.3.4 Spatial lag models

By contrast, a spatial lag model treats spatial dependence as a process of interest that the model seeks to explain. It attempts to explain the value of a data point partly in terms of the characteristics of neighbouring data points. For example, this may mean modelling the sale price of a single house as a function of the sale price of neighbouring properties. (Or, equally, of other characteristics of neighbouring properties, such as building size or condition.)

In order to do so, spatial lag models incorporate a "spatially lagged" variable on the right hand side of the regression equation. They take on the following form:

Equation 4: A generic spatial lag regression model

$$y_i = \alpha + \beta x_i + \rho W_{ij} y_j + \varepsilon_i$$

Where NETPRICE is the dependent variable (y_i), α is a constant term to be estimated, β is a vector of coefficients to be estimated, x_i is a vector of explanatory variables (including variables of interest such as LAND, DCBD, and PRE1940, control variables such as HHINCOME and DENSITY, and time dummies), y_j are dependent variables for $j{\neq}i$, weighted using spatial weights matrix W_{ij}, ρ is the spatial coefficient, ε_i is an error term, and $i=1,2,\ldots,n$, $j=1,2,\ldots,n,\ j{\neq}i$ are index values for property sales records.

3.3.5 Regression outputs

Table 5 presents a comparison of the preferred OLS model with the four spatial regression models that were tested. All models are estimated on the same randomly selected subset of 10,000 property sales – results from OLS models estimated on the full dataset are available in Appendix B.

Based on the models' Akaike Information Criterion (AIC) scores, which measure the combination of goodness of fit and degrees of freedom (df) offered by each model, I found that the spatial error model with a 1-km radius neighbourhood (highlighted in yellow) was the preferred model. This finding is consistent with earlier research on the Auckland housing market (Grimes and Liang, 2009, which employed a spatial error model to analyse property values) and residential satisfaction in Auckland (Torshizian and Grimes, 2014a, which identified a 15 minute walking catchment as the preferred definition of a neighbourhood).

Table 5: OLS and spatial regression results for a randomly-selected subset of 10,000 residential sales

Auckland residential property sales 2011-2014, OLS and spatial regression models

	Dependent variable:				
	log(sale_price_net)				
		Spatial error models		Spatial lag models	
	OLS model	1km radius neighbourhood	Meshblock neighbourhood	1km radius neighbourhood	Meshblock neighbourhood
log(LAND)	0.120***	0.209***	0.145***	0.139***	0.123***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
log(FLOORSPACE)	0.609***	0.479***	0.570***	0.586***	0.607***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
log(DCBD)	-0.284***	-0.340***	-0.289***	-0.278***	-0.285***
	(0.006)	(0.018)	(0.007)	(0.006)	(0.006)
log(DCOAST)	-0.014***	-0.028***	-0.014***	-0.010***	-0.014***
	(0.003)	(0.005)	(0.003)	(0.003)	(0.003)
PRE1940	0.121***	0.098***	0.120***	0.119***	0.123***
	(0.011)	(0.01)	(0.011)	(0.011)	(0.011)
CARPARKS	0.001	0.0003	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
VIEW:OTHER (1)	0.006	-0.017**	0.0004	0.003	0.006
	(0.008)	(0.007)	(0.008)	(0.008)	(0.008)
VIEW:WATER (1)	0.164***	0.083***	0.141***	0.151***	0.164***
	(0.011)	(0.01)	(0.011)	(0.01)	(0.011)
COND_WALL:FAIR (2)	-0.022	-0.018	-0.042**	-0.022	-0.023
	(0.022)	(0.019)	(0.021)	(0.022)	(0.022)
COND_WALL:GOOD (2)	0.066***	0.064***	0.065***	0.068***	0.066***
	(0.008)	(0.007)	(0.008)	(0.008)	(0.008)
COND_WALL:POOR (2)	-0.168***	-0.086**	-0.164***	-0.161***	-0.168***
	(0.041)	(0.036)	(0.04)	(0.041)	(0.041)
COND_WALL:MIXED (2)	-0.006	-0.019	-0.006	0.009	-0.003
	(0.053)	(0.045)	(0.049)	(0.052)	(0.053)
MBHERITAGE	0.004***	0.003***	0.004***	0.004***	0.004***
	(0.0005)	(0.001)	(0.001)	(0.0005)	(0.0005)
log(HHINCOME)	0.194***	0.083***	0.208***	0.180***	0.191***
	(0.01)	(0.01)	(0.011)	(0.01)	(0.01)
log(DENSITY)	-0.034***	-0.011**	-0.027***	-0.053***	-0.033***
	(0.004)	(0.005)	(0.005)	(0.004)	(0.004)
SALEYEAR:2012 (3)	0.068***	0.101***	0.076***	0.070***	0.068***
	(0.01)	(0.009)	(0.01)	(0.01)	(0.01)
SALEYEAR:2013 (3)	0.197***	0.229***	0.205***	0.198***	0.197***
	(0.01)	(0.009)	(0.01)	(0.01)	(0.01)
SALEYEAR:2014 (3)	0.300***	0.327***	0.311***	0.302***	0.300***
	(0.011)	(0.01)	(0.01)	(0.011)	(0.011)
Constant	11.093***	13.756***	11.216***	10.661***	11.136***
	(0.144)	(0.225)	(0.161)	(0.145)	(0.144)
Observations	10,000	10,000	10,000	10,000	10,000
Adjusted R2	0.625				
F Statistic	927.097*** (df = 18; 9981)				
Log Likelihood		-1,540.51	-2,354.63	-2,585.20	-2,720.93
sigma^2		0.077	0.091	0.098	0.101
Akaike Inf. Crit.	5,492.39	3,123.01	4,751.25	5,212.39	5,483.86
Wald Test (df = 1)		5,108.288***	854.388***	281.183***	10.550***
LR Test (df = 1)		2,371.383***	743.139***	281.998***	10.532***

Notes: *p<0.1; **p<0.05; ***p<0.01

(1) VIEW is a categorical (dummy) variable. The base level is "no view".

(2) COND_WALL is a categorical (dummy) variable. The base level is "average" condition.

(3) SALEYEAR is a categorical (dummy) variable. The base level is 2011.

3.4 Key findings from hedonic analysis of Auckland residential property sales

I identify six key conclusions from a hedonic analysis of recent Auckland property sales.

The first, most important finding is that buyers exhibit a strong preference for more floorspace. Based on the results from the preferred spatial error model, properties with more floorspace or more land command higher prices. The coefficient on the floorspace variable is considerably higher than the coefficient on the land variable in both the baseline OLS model and the preferred spatial error model estimated on a subset of property sales. While this does not provide a sufficient basis for firm conclusions, it is consistent with the results of earlier research (Bourassa, et al, 2003; Donovan, 2011). It also strengthens the intuition – drawn from a casual observation of recent housing development outcomes – that Auckland's underlying challenge is not necessarily a scarcity of developable land, but a scarcity of floorspace.

A second important finding is that sale prices are influenced by location within the city. People are not indifferent between different locations – all else being equal, they show a distinct preference to be closer to the city centre and a weaker, but still significant, preference to be close to the coast. Increasing distance from the city centre is associated with lower property values, as is increasing distance from the coast.

Third, other characteristics of dwellings are associated with higher (or lower) sales prices. Even after controlling for some neighbourhood and location characteristics, people place a higher value on older (pre-1940) buildings. And, unsurprisingly, people prefer dwellings that are in good condition – houses with walls that are in good condition tend to sell for higher prices than houses with walls in average condition, while houses with walls in poor condition are worth less.

However, carparking does not appear to have a strong impact on sales prices. While the coefficient on the carparking variable was positive and statistically significant in the baseline OLS model, it is not statistically significant in the spatial error model estimated on a subset of property sales. In other words, the value of carparking may be quite marginal, and potentially lower than the cost to construct a single parking space, which ranges from $1,900-$2,200 for surface parking to $40,600-$46,100 for underground parking (Rawlinsons, 2013). This strengthens the findings of previous Auckland-specific research that has shown that minimum carparking requirements impose an opportunity cost on property owners (MRCagney 2013).

Fourth, these findings support the view that property markets are influenced by "highly localised externalities" related to neighbouring land uses. While it was not possible to measure all potential neighbourhood effects, I did find evidence that proximity to pre-1940 buildings was associated with higher sales prices (in line with Lazrak et al, 2014). Likewise, dwellings with a view of water commanded higher prices than comparable properties with no views.

Lastly, there is evidence of spatial dependence in Auckland's housing market. The OLS regression models that we tested could not fully explain these localised correlations, possibly due to omitted variables that we were not able to observe. I tested several spatial regression models, finding that a spatial error model (which treats spatial dependence as a "nuisance" to control) performed better than a spatial lag model (which treats spatial dependence as a process of interest to explain). This suggests that there are some unexplained spatial processes that influence property prices. However, the differences between the preferred spatial error model and an OLS model were not "economically" significant, as the sign and statistical significance of most coefficients remains the same.

4 A simple cost-benefit test for heritage preservation policy

In this section, I employ the empirical findings from Section 3 to analyse some of the costs and benefits of heritage preservation policy. I identify a simple cost-benefit test that can be used to understand the trade-offs between planning to preserve built heritage and planning to enable intensification and apply it to Auckland.

4.1 What is heritage preservation policy?

Heritage preservation policies aim to prevent (or manage) the demolition of buildings with significant aesthetic or historical value. They can accomplish this in a number of ways, including but not limited to:

- Blanket rules controlling demolitions and alterations throughout entire heritage-y neighbourhoods
- Heritage listings that identify and control the demolition of notable buildings or streets
- Providing information on built heritage to buyers and owners
- "Letting the market sort it out" – trusting that people will be reluctant to demolish old buildings that have particular values.

Preservation of built heritage has been an important – and in many respects contentious – issue for urban planning in Auckland. A number of inner-city suburbs, such as Ponsonby, Grey Lynn, Mount Eden, and Devonport, feature relatively well-preserved neighbourhoods that were all built in the early days of Auckland's development[15]. Other, similar suburbs, such as Newton and Freemans Bay, were demolished in the 1960s and 1970s to make way for motorways or new housing and offices.

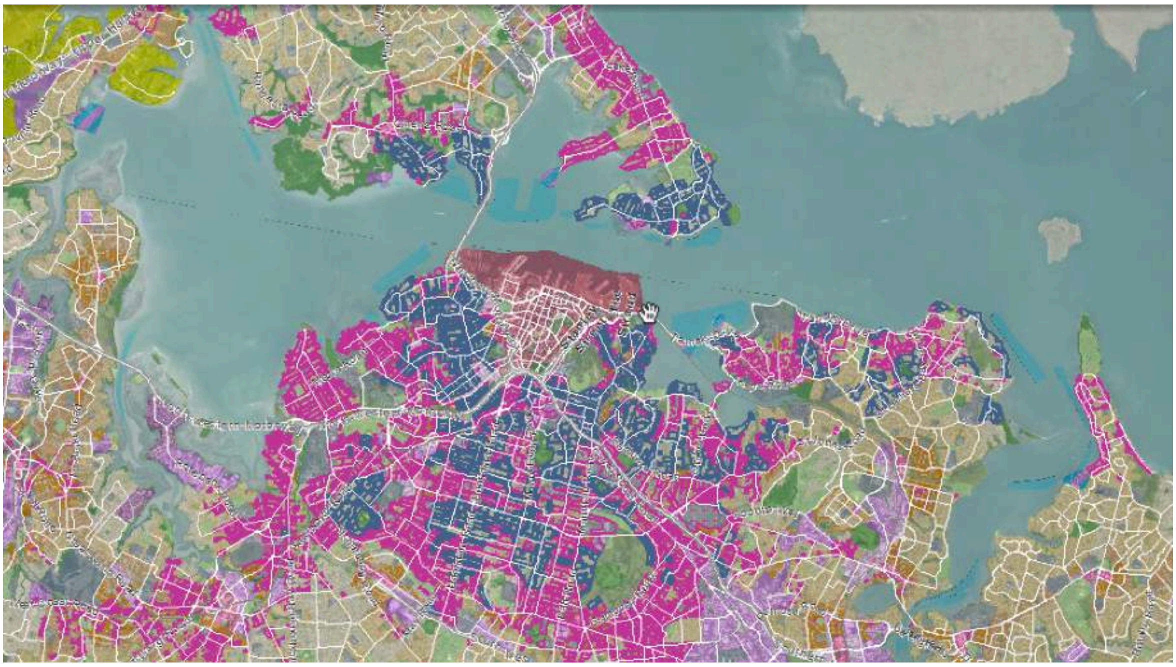
The planning approach taken by the former Auckland City Council, and carried over into the notified version of Auckland Council's Unitary Plan, has been to control demolition and alteration of buildings within entire heritage suburbs. Figure 1 displays the overlays that were proposed in the notified version of the Unitary Plan – dark blue areas are "special character" overlays that have largely been carried over from previous urban plans, while bright pink areas show new "pre-1944 building demolition control" overlays[16].

This approach serves to preserve heritage values, but there is a trade-off, as heritage preservation policies make it more difficult to develop new buildings in some of Auckland's most desirable areas. This can result in opportunity costs as a result of foregone opportunities to develop sites more intensively. And, as this map indicates, overlays may also result in costs for owners of non-heritage properties that fall within the overlays.

[15] Ponsonby and Grey Lynn illustrate an important fact, which is that built heritage is often preserved by low property values and urban neglect. In the mid-20th century, these suburbs were considered considered to be "slums". As they gentrified in the 1990s and 2000s, new residents discovered that Ponsonby and Grey Lynn contained many run-down but sound heritage properties and began buying them up for renovation.

[16] Based on conversations with Auckland Council planning teams, pre-1944 overlays have been applied on a precautionary basis to enable heritage assessments to be carried out prior to any significant level of demolitions. Consequently, they may not be applied in perpetuity.

Figure 5: Areas covered by special character overlays (dark blue) and pre-1944 overlays (bright pink) (Source: Auckland Council, 2013)



4.2 Measuring the trade-offs associated with heritage preservation

How should we resolve the trade-offs associated with heritage preservation? Would it be better to protect built heritage or enable intensification in heritage suburbs?

As discussed in Section 2, the results of hedonic analysis of Auckland residential property sales can be used to obtain an empirical understanding of this trade-off. The analysis reported in Table 5 suggests that people place a value on:

- Larger buildings – all else equal, people are willing to pay more for dwellings with more floorspace
- Old buildings – all else equal, people are willing to pay more to live in dwellings constructed prior to 1940
- Proximity to old buildings – all else equal, people are willing to pay more to live in neighbourhoods with more pre-1940 buildings, even if their dwelling was constructed more recently.

I use the coefficients from the preferred hedonic regression model – a spatial error model using a 1-km radius neighbourhood – as price elasticities and semi-elasticities for these values. (However, as this model was estimated on a random subset of the house sales dataset, these results should be treated with caution. They may not provide a good estimate of the true values.) Key values used in this analysis are summarised in Table 6.

Table 6: Price elasticities or semi-elasticities for use in a cost-benefit test of heritage preservation policies

Variable	Formula	Value (Standard error)
E_F: Elasticity of price with respect to floorspace	$\frac{\partial P}{\partial F} * \frac{F}{P}$	0.479 (0.009)
E_H: Semi-elasticity of price with respect to pre-1940 status	$\frac{\partial \mathrm{P}}{\partial \mathrm{H}} * \frac{1}{\mathrm{P}}$	0.098 (0.01)
E_{NH}: Semi-elasticity of price with respect to pre-1940 buildings in the neighbourhood	$\frac{\partial \mathrm{P}}{\partial \mathrm{NH}} * \frac{1}{\mathrm{P}}$	0.003 (0.001)

Based on these values, I implement two simple cost-benefit tests:

- First, I consider costs and benefits for individual owners of heritage properties: under what conditions would they prefer to intensify their sites rather than maintaining the value premium associated with old buildings?
- Second, I consider costs and benefits for neighbours of heritage properties: under what conditions would they prefer the opportunity to intensify their sites rather than maintaining the value premium associated with proximity to old buildings?

These cost-benefit tests do not provide a definitive analysis of the economics of heritage preservation. Importantly, they exclude a range of potential costs and benefits, including the costs to obtain resource consents for demolition or alteration in protected areas, the cost of physically building new dwellings (which is offset against the value of new floorspace), and any benefits of heritage that are not captured within neighbourhoods. Nonetheless, they provide a useful illustration of the trade-offs that heritage preservation policy (or the lack thereof) creates for individuals and society.

4.3 The building owner's choice: demolish or preserve?

The costs of heritage preservation tend to fall upon the owners of heritage properties. Because these policies entail restrictions on owners' ability to alter their buildings or demolish them to make way for new developments, they can impose opportunity costs[17]. However, owners may not necessarily seek to demolish or substantially alter their buildings – as this may entail sacrificing the "heritage premium" associated with old buildings.

If the value of the heritage premium exceeds the value of having more floorspace, then the costs of heritage overlays for owners of individual heritage buildings may not be large. But if the value of added floorspace is large relative to the heritage premium, then heritage preservation rules may impose significant opportunity costs.

Consequently, I propose the following cost-benefit test for owners of heritage properties:

> *"How much additional floorspace would be required to compensate owners of heritage properties for the loss of the heritage premium?"*

It is possible to estimate this figure using the selected results from the model of Auckland residential property sales summarised in Table 6. Equation 5 describes how we can calculate it using the estimated elasticity of price with respect to floorspace (**E_F**) and semi-elasticity of price with respect to heritage status (**E_H**). The numerator of this equation reflects the heritage premium, while the denominator reflects the value of additional floorspace in an equivalent non-heritage building.

I estimate that the heritage premium is equivalent in value to a 22.7% increase in a dwelling's living area, holding other factors constant.

Equation 5: A cost-benefit test for owners of individual heritage properties

$$\frac{E_H}{E_F*(1\text{-}E_H)} = \frac{0.098}{0.479*(1\text{-}0.098)} = 22.7\%$$

As the average size of dwellings constructed before 1940 in the property sales dataset is approximately 140 m^2, this implies that owners of heritage properties would be willing to demolish or substantially alter their dwellings – and bear the loss of their "heritage premium" – if it allowed them to obtain a minimum of 32 m^2 of additional

[17] Of course, one would expect constraints imposed by heritage preservation rules to be factored into sale prices, meaning that people who purchased heritage buildings after the rules were put in place would not necessarily bear any additional costs. This does not, however, mean that there are no social opportunity costs – there may be people who would enjoy the opportunity to live in protected areas but who cannot find an affordable dwelling there.

living area. Of course, the true figure is likely to be larger, as property owners must also factor in construction costs when choosing to expand or rebuild their dwellings.

Nonetheless, this simple analysis does suggest that heritage preservation policies will tend to impose costs on the owners of heritage properties. Because the amount of floorspace required to offset the loss of the heritage premium is relatively small, limiting the redevelopment of heritage buildings is likely to impose an opportunity cost for individual properties.

4.4 Not in my backyard: what might the neighbours prefer?

Decisions about how to trade off *internalised* heritage premiums against the value of larger buildings are, ultimately, made by individual property owners. There is little case for policy intervention to require people to choose one value over another.

However, hedonic analysis suggests that there may also be some *external* benefits of heritage buildings that accrue to neighbouring properties. There may be a case to regulate to preserve the public amenity elements of built heritage. Doing so comes with a trade-off, needless to say, as heritage preservation policies often make it more difficult for *any* redevelopment or demolitions to occur in areas with heritage buildings.

We must therefore ask: would the neighbours of heritage properties prefer to have opportunities for intensification (which would allow them to expand the size of their buildings) or would they prefer to have the certainty that the public amenity of neighbouring heritage properties will be preserved?

I propose the following cost-benefit test for the external ("neighbourhood") benefits of preserving heritage buildings:

> *"How much additional floorspace would be required to compensate neighbours for losing the external benefits of heritage buildings?"*

It is possible to estimate this figure using the hedonic price estimates summarised in Table 6. Equation 6 describes how we can calculate it using the estimated elasticity of price with respect to floorspace (**E_F**) and semi-elasticity of price with respect to heritage status (**E_{NH}**), plus an estimate of the number of pre-1940 buildings in each neighbourhood (**Q_H**)[18]. The numerator of this equation reflects the estimated total value of neighbourhood heritage within an individual meshblock, while the denominator reflects the value of additional floorspace in an equivalent neighbourhood with no heritage buildings.

Equation 6: A cost-benefit test for neighbours of heritage properties

$$\frac{E_{NH}*Q_H}{E_F*(1-E_{NH}*Q_H)}=\frac{0.003*Q_H}{0.479*(1-0.003*Q_H)}$$

For example, in a neighbourhood with 25 heritage buildings, this equation would suggest that the owner of a non-heritage property would be indifferent between maintaining the external benefits of heritage and having a dwelling with 16.9% more living space. (Holding all else constant, of course.) As discussed above, this figure is likely to be a low estimate, as property owners must also factor in construction costs when choosing to expand or rebuild their dwellings.

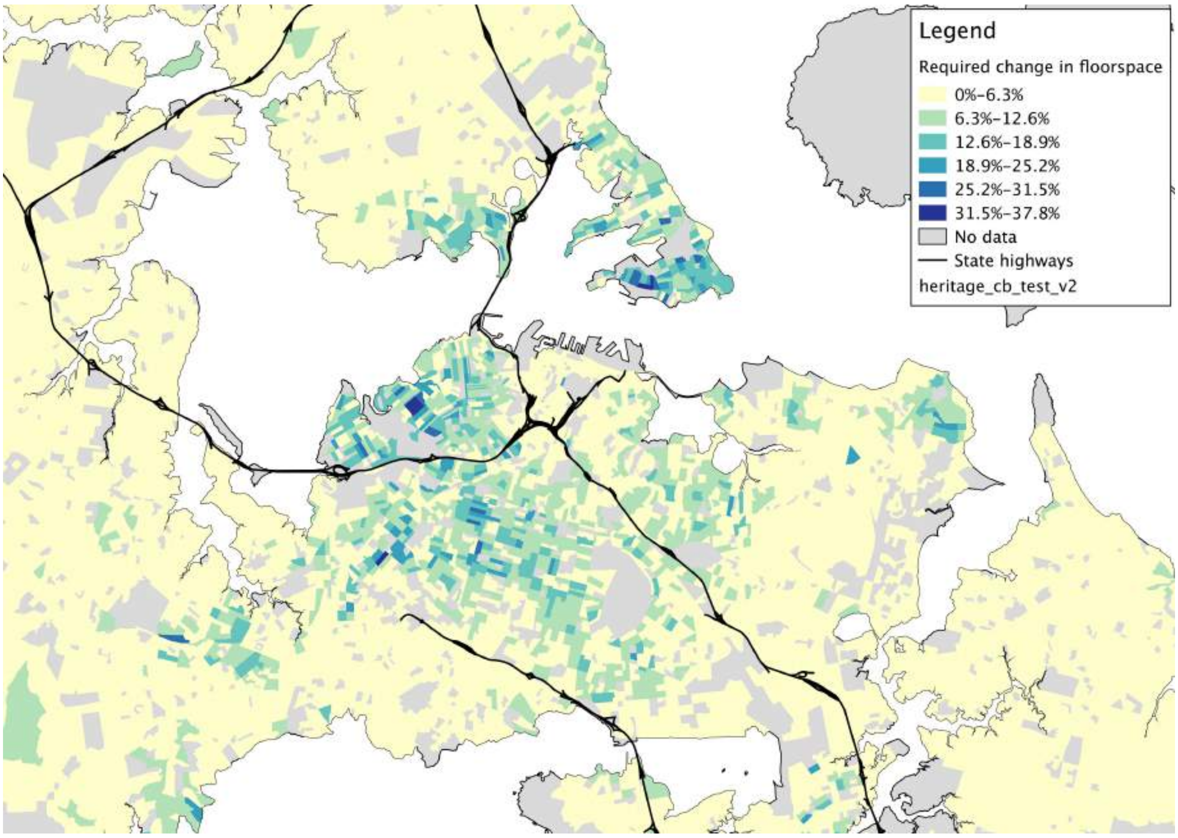
I use this formula, plus data on the number of pre-1940 buildings within individual Census meshblocks in Auckland, to estimate the minimum percentage change that would be required in order to compensate neighbours for the loss of the external benefits of built heritage that may occur in the absence of heritage

[18] The number of pre-1940 buildings in each neighbourhood (i.e. Census meshblock) has been estimated using ratings valuation and property sale data. It was used as input into hedonic analysis. However, we note that there may be measurement error in this dataset.

preservation rules. These results, which are summarised in Figure 6, suggest that the relationship between the external benefits of heritage and the costs of preserving it vary significantly within Auckland. Reassuringly, the areas with higher values generally align with the heritage overlays in Figure 5.

However, we note that the magnitude of estimates suggests that heritage preservation policies may in some cases generate more costs than benefits for neighbours. The amount of additional floorspace required to offset the loss of the neighbourhood benefits of heritage ranges from around 12% to around 38% in areas covered by heritage overlays. Because this range is not especially large, making it more difficult to redevelop non-heritage buildings within heritage overlays may in some cases result in net costs.

Figure 6: Minimum percentage increase in floorspace required to "compensate" neighbours for forgoing the external benefits of heritage



5 Discussion and conclusions

Finally, I consider some implications and future directions for policymakers and researchers. In my view, there are opportunities to employ hedonic analysis and cost-benefit tests to inform the design of urban planning regulations. However, successfully implementing this approach will require the planning and economic disciplines, as well as local and central government decision-makers, to raise their game:

- Planning regulations are often based on a nuanced and detailed knowledge of urban spaces and interactions between different land uses. Economic analysis sometimes plays an important role in the regulatory process, but it is not consistently applied to evaluate new or existing regulations.
- Economic concepts and empirical methodologies to develop a robust intervention logic for planning regulations and to identify the trade-offs between alternative regulatory approaches. However, they do not always consider planning regulations in a sufficiently detailed fashion to inform policymaking. Furthermore, economists' use of technical jargon can make their findings inaccessible to non-economists.
- Local and central government decision-makers are ultimately responsible for choosing planning regulations. While they draw upon expert advice from planners and economists, they must also take into account the interests – or perceived interests – of their constituents. In doing so, they must be aware of the trade-offs created by planning.

5.1 Implications for policymakers

This paper presents some new evidence on the determinants of residential property prices in Auckland, with a focus on the value that buyers and neighbours place on built heritage. Based on a review of previous research, it discusses how these results can be used to implement a simple cost-benefit test to assess the welfare implications of heritage preservation policies.

My analysis has several implications for policymakers.

First, hedonic analysis of recent Auckland property sales identifies some key factors that have a strong influence on willingness to pay for housing. In particular, additional living space and increased proximity to the city centre have a strongly positive impact on house prices, while additional land has a positive but smaller positive impact on house prices.

One possible interpretation of this finding is that people value private living space, especially in areas that have good access to employment opportunities and amenities, more than they value private open space. If this is the case, then planning policies that enable an increase in the quantity of buildings and dwellings ("intensification") on sites may improve welfare.

Second, planning regulations often impose trade-offs. They can impose costs on individual property owners or households in order to provide or preserve public amenities or manage negative externalities associated with development patterns. A robust intervention logic for planning regulations should identify, and if possible quantify, these trade-offs. In doing so, it is necessary to distinguish between cases where most costs and benefits are purely private, and hence best assessed by individuals, and cases where there are externalities or spillover effects that may require regulation to manage.

Third, economic analysis can be used to understand and quantify planning trade-offs. I discuss three approaches to analysing the costs and benefits of planning regulations using the results of hedonic analysis of property prices, including formal modelling of household welfare, identification of boundary discontinuities in land prices, and development of cost-benefit tests to weigh up the trade-offs between building floorspace and public amenities.

I demonstrate how the third approach can be used to assess the relative costs and benefits of heritage preservation policies in Auckland. I compare the magnitude of the price premiums for individual heritage buildings (i.e. the internalised heritage premium) and for neighbouring buildings (i.e. the external benefit of built heritage) with the value of floorspace. This analysis identifies the average amount of additional living space that people would require in order to be willing to forego the internalised and external value of built heritage.

This analysis is not a full cost-benefit analysis, as it does not account for important factors such as the cost to construct additional floorspace or any external benefits of built heritage that are not localised within neighbourhoods. However, it does show that:

- Heritage preservation rules that make it difficult to demolish or alter old buildings are likely to impose net costs on the owners of individual heritage properties, as the amount of additional floorspace required to offset the loss of the heritage premium is relatively modest
- If blanket heritage overlays are applied to control demolitions and alterations in “heritage-y” neighbourhoods, it is desirable to focus them carefully in order to target the areas where the external benefits of built heritage are largest relative to the value of additional floorspace.

5.2 Opportunities for further research

There are a number of opportunities for economists to undertake further research into the costs and benefits of planning regulations. My key recommendation is that researchers should familiarise themselves with the details of urban plans and work with planners to understand the intended and unintended consequences of rules. While some planning policies, such as Auckland’s Metropolitan Urban Limit, are easy to identify, others can fly below the radar in spite of their large impact on development outcomes.

For example, residential zones in New Zealand cities typically set a maximum limit on building coverage. Building coverage ratios do not necessarily vary between low-density and higher-density residential zones, although they can have a significant impact on built form and the efficiency of land use. In the proposed Auckland Unitary Plan, both the Mixed Housing Suburban zone and the Terraced Housing and Apartment Building zone had a maximum building coverage ratio of 40% (Auckland Council, 2013)[19]. However, this has attracted much less attention than building height limits, even though both rules have a similar impact on the amount of floorspace that can be built on sites.

With that in mind, here are a few topics that could be addressed using the methods discussed in this paper.

5.2.1 Geographical disaggregation

There is no reason to expect the value of floorspace and amenities to be constant throughout the city. While most hedonic analysis of the Auckland property market has been done at a citywide level, some studies have found evidence of geographical variation in the hedonic value of land and floorspace (Donovan, 2011) and amenities such as views of water (Filippova, 2009). As a result, it is possible that the costs and benefits of planning regulations vary between different locations. For example, some areas may be over-supplied with public open space, meaning that it may be possible to improve wellbeing by developing new housing on open spaces, while other areas may be under-supplied with public open space, meaning that there may be a case for government to purchase properties to create them.

[19] One reason for this requirement is to ensure that there is sufficient permeable surface to enable stormwater to drain from sites. This can be seen as a case of local governments requiring residents to internalise some of the costs of infrastructure provision.

Consequently, when undertaking hedonic analysis to inform an assessment of planning regulations whose impacts may vary across space, it may be appropriate to interact key variables of interest with categorical variables for suburbs or local boards.

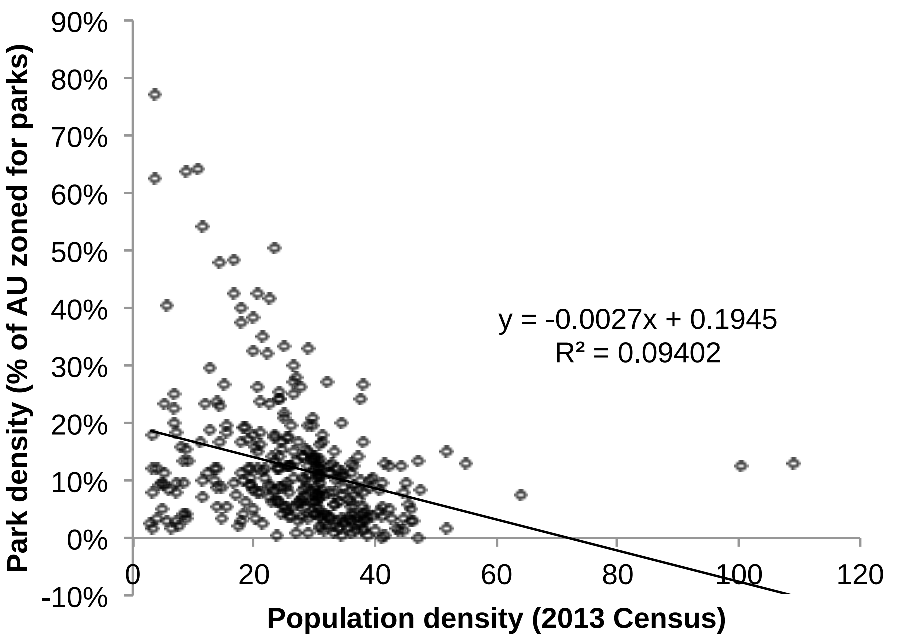
5.2.2 Applying cost-benefit tests to other topics

There are a number of opportunities to implement cost-benefit tests to assess a number of other regulations.

Local and central government are currently asking whether they should release publicly owned land for housing development. This includes land held as reserves, acquired for the development of schools and other social facilities, and land in transport corridors. Cost-benefit tests based on hedonic analysis can play an important role in deciding where and when to release this land for other uses.

For example, the cost-benefit test implemented by Rouwendal and van der Straaten (2015) to study the optimal supply of public open space in three Dutch cities could be applied to Auckland. Geographically disaggregated variables could be used to identify areas of over- and under-supply within the city. A casual analysis of land zoned for public open spaces (see Figure 7) suggests that park provision varies significantly throughout Auckland, which may indicate opportunities to release land in some areas.

Figure 7: Population density and park density in Auckland area units (Source: Auckland Council, 2013; Statistics New Zealand, 2014; author's analysis)



Another important example is given by land used for transport infrastructure, particularly roads. Roads consume a large amount of land in Auckland – according to UN-Habitat (2013), 14.1% of the city's urbanised land area is used for roads. Donovan (2015) argues that common road design practices "give little consideration to economic value" and frequently result in the over-allocation of valuable land to road corridors and wide intersections.

Vickrey (1963) proposes the following cost-benefit test to determine whether land should be used for roads or released for development:

> *"A cost benefit analysis can justify devoting land to transportation only when the savings in transportation costs yield a return considerably greater than the gross rentals, including taxes, that private businesses would be willing to pay for the space. This in turn means that an even greater preference should be given to space economizing modes of transport than would be indicated by rent and tax levels."*

Finally, previous analysis, including a cost benefit analysis conducted by MRCagney (2013), has identified large opportunity costs arising from minimum parking requirements. As MPRs are relaxed or removed, it may be possible to redevelop a significant amount of land used for surface carparking – especially if it is in public ownership.

In addition, the hedonic analysis of recent Auckland property sales reported in this paper suggests that the value of residential carparks is relatively small when compared with alternative uses for that space. While the value of residential parking is likely to be higher in some areas, such as heritage areas where off-street carparks are not common, it is likely that garages could in many cases be put to more valuable uses.

5.2.3 The search for boundary discontinuities

Similarly, hedonic analysis can be used to identify various boundary discontinuities in land prices. While previous research has focused on discontinuities around Auckland's MUL, they can also occur *within* the urbanised area.

Land prices may differ significantly on either side of zoning boundaries. This is particularly likely to happen at boundaries between low-density and higher-density residential zones, or between residential zones and commercial or industrial zones. If systematic differences in land prices can be observed at zoning boundaries, it may indicate that too much land has been zoned for one use, and too little for another. In such a case, there may be a case to re-zone some land in order to provide for activities that are in higher demand.

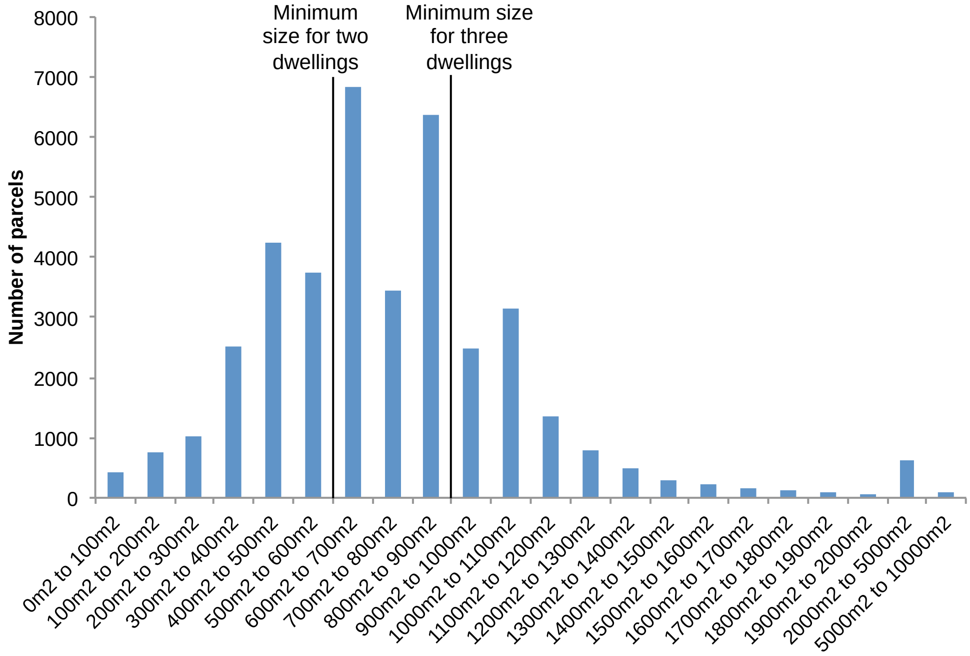
However, boundary discontinuities do not necessarily need to be spatial in nature, as planning regulations can impose various types of barriers to development. Consider the example of minimum lot sizes and dwelling density controls, which require each new house to have a specified minimum amount of land. While these rules can serve useful purposes – for example, to manage the demands placed upon water and stormwater networks – they can also have economic and social costs. Anas, Arnott and Small (1998) describe large minimum lot sizes as a case of "exclusionary zoning" aimed at keeping out "undesired socioeconomic, racial, or ethnic groups" that lack the money to afford large quantities of land.

Figure 8 presents a histogram of the distribution of lot sizes in the proposed Auckland Unitary Plan's Mixed Housing Urban zone, which is zoned for low- to medium-density development. The proposed zoning rules require each dwelling to have a minimum of 300 m^2 of land, with exceptions for large sites and sites with large frontages and setbacks[20]. The black lines on the chart show the minimum amount of land required in order to build two or three dwellings on a site.

As this suggests, minimum lot sizes can potentially result in discontinuities in land values. For example, it may be the case that a lot in the Mixed Housing Urban zone with 601 m^2 of land is worth significantly more than a lot with 599 m^2 of land, as it has potential to be subdivided. If so, it may indicate that there is pent-up demand for subdivision and infill development that could be enabled by a change in zoning rules.

[20] In practice, it is likely that many dwellings will be able to provide a minimum of 250 m^2 of land as they are likely to meet the minimum frontage rules. I have used the figure of 300 m^2 for indicative purposes, even though some sites may have a lower limit.

Figure 8: Distribution of lot sizes in Auckland's proposed Mixed Housing Urban zone (Source: Auckland Council, 2013, author's analysis)



5.3 The political economy of planning

Lastly, it is important to recognise that urban planning does not happen in a vacuum. Public input, especially from existing homeowners, can have a large impact on the design of planning rules and the application of zones. For example, residents of established neighbourhoods may oppose planning rules that may result in increased development in their neighbourhoods, fearing that it may lead to increased traffic and noise, overshadowing from new buildings, or other localised effects.

In my view, it is not possible to conclude that the net impact of externalities associated with new developments is negative. Discussions of intensification typically neglect the positive effects of density, such as the increased potential for agglomeration economies in production, consumption, and the provision of infrastructure and public services (for a full discussion of these effects, see Fujita, Krugman and Venables, 2001; Glaeser et al, 2001; and Glaeser, 2008). For example, larger or denser places tend to offer a better variety of services and consumer goods, which can enhance choice for both existing and new residents.

Notwithstanding the completeness and validity of some of the claims made in public debates about urban planning, this is the context in which planning policies are made. In order to understand and improve urban policies, it is necessary to take into account of two different "markets":

- Economic markets, which are driven by the demands of the marginal buyer; and
- Political markets, which are driven by the demands of the median voter.

In the long term, a city's success or failure depends upon its ability to attract (or retain) the next resident and the next business. Urban policy must therefore be attentive to the needs and demands of these "marginal buyers". But, at the same time, local and central governments must respond the needs and demands of their median voters if they are to be re-elected. In some situations, this means pursuing policies that limit harmful types of growth in order to preserve public amenities for existing residents.

This is, perhaps, a tension that economists can recognise but not resolve in isolation.

APPENDIX A References

Anas, A., Arnott, R., & Small, K. A. (1998). Urban spatial structure. *Journal of economic literature*, 1426-1464.

Auckland Council. (2013). *Proposed Auckland Unitary Plan GIS Viewer (notified 30 September 2013)*. Available online at http://acmaps.aucklandcouncil.govt.nz/unitaryplan/FlexViewer/index.html.

Auckland Council. (2015). *Auckland property sales audit file*. Some information available online at http://www.aucklandcouncil.govt.nz/EN/ratesbuildingproperty/propertyinformation/Pages/PropertyFilesReportshome.aspx.

Boardman, A., Greenberg, D., Vining, A., & Weimer, D. (2011). *Cost-Benefit Analysis: Concepts and Practice, Fourth Edition*. Boston: Pearson Education.

Bourassa, S., Hoesli, M., & Sun, J. (2003). The price of aesthetic externalities. *Geneva: FAME research paper no. 98*.

Brinkman, J. (2013). Congestion, agglomeration, and the structure of cities. *Federal Reserve Bank of Philadelphia working paper 13/25*.

Cheshire, P., & Sheppard, S. (2002). The welfare economics of land use planning. *Journal of Urban economics*, *52*(2), 242-269.

Cheshire, P., & Sheppard, S. (2005). The introduction of price signals into land use planning decision-making: a proposal. *Urban studies*, *42*(4), 647-663.

Donovan, S. (2011). Space matters: Agglomeration economies and spatial competition in New Zealand. *Unpublished master's thesis). VU University, Amsterdam, the Netherlands*.

Donovan, S. (2015). Do our aspirations match our abilities? Systematic challenges facing the traffic and transport profession. Paper presented at the 2015 Institute of Professional Engineers New Zealand – Transportation Group conference.

Falconer, Garth. (2015). *Living in Paradox: A History of Urban Design Across Kainga, Towns and Cities in New Zealand*, Auckland: Blue Acres Press.

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

Fujita, M., Krugman, P., & Venables, A. (2001). *The Spatial Economy: Cities, Regions, and International Trade*. Boston: MIT Press.

Glaeser, E. (2008). *Cities, Agglomeration, and Spatial Equilibrium: The Lindahl Lectures*. Oxford, Oxford University Press.

Glaeser, L. E., Gyourko, J., & RE, S. (2005). Why is Manhattan So Expensive? Regulation and the Rise in Housing Prices. *Journal of Law and Economics*, *48*.

Glaeser, E. L., Kolko, J., & Saiz, A. (2001). Consumer city. *Journal of economic geography*, *1*(1), 27-50.

Grimes, A., Apatov, E., Lutchman, L., & Robinson, A. (2014). Infrastructure's Long-Lived Impact on Urban Development: Theory and Empirics. *Motu Working Paper 14/11*.

Grimes, A., & Liang, Y. (2009). Spatial Determinants of Land Prices: Does Auckland's Metropolitan Urban Limit Have an Effect?. *Applied Spatial Analysis and Policy*, *2*(1), 23-45.

Grimes, A., & Mitchell, I. (2015). Impacts of Planning Rules, Regulations, Uncertainty and Delay on Residential Property Development. *Motu Working Paper 2015/02*.

Lees, K. (2014). Big city life? Challenges and trade-offs for Auckland city. *New Zealand Institute of Economic Research working paper 2014/2*.

Lees, K. (2015). Moving on up: Relaxing land use restrictions can lift Auckland city. *New Zealand Institute of Economic Research working paper 2015/1*.

Kulish, M., Richards, A., & Gillitzer, C. (2012). Urban Structure and Housing Prices: Some Evidence from Australian Cities. *Economic Record*, *88*(282), 303-322.

Lazrak, F., Nijkamp, P., Rietveld, P., & Rouwendal, J. (2014). The market value of cultural heritage in urban areas: an application of spatial hedonic pricing. *Journal of Geographical Systems*, *16*(1), 89-114.

Maré, D. C. (2008). Labour Productivity in Auckland Firms. *Motu Working Paper 08/12*.

McCann, P. (2001). *Urban and regional economics*. Oxford: Oxford University Press

McCann, P. (2009). Economic geography, globalisation and New Zealand's productivity paradox. *New Zealand Economic Paper*, *43*(3), 279-314.

Ministry of Business, Innovation and Employment. (2013). *Residential Land Supply in Auckland*. Available online at http://building.govt.nz/UserFiles/File/Publications/Sector/pdf/residential-land-available-in-auckland-report.pdf.

MRCagney. (2013). The Economic Impacts of Parking Requirements in Auckland. A report for Auckland Council.

Nijkamp, P. (2012). Economic valuation of cultural heritage. *The Economics of Uniqueness*, 75-106.

Nunns, P. (2014). Population-weighted densities in New Zealand and Australian cities: A new comparative dataset. *MRCagney working paper 2014/2*.

Nunns, P., Hitchins, H., & Balderston, K. (2015). The value of land, floorspace, and amenities: A hedonic price analysis of property sales in Auckland 2011-2014. *Auckland Council technical report TR15/012*.

Rawlinsons New Zealand. (2013). *Rawlinsons New Zealand Construction Cost Handbook 2013/14*, 28th Edition. Auckland: Rawlinsons Publications.

Rehm, M. (2009). Judging a house by its cover: Leaky building stigma and house prices in New Zealand. *International Journal of Housing Markets and Analysis*, 2(1).

Rehm, M., Filippova, O., & Stone, J. (2006). The influence of vintage on house value. *Pacific Rim Property Research Journal* 12(3).

Rehm, M. and Filippova, O. (2008). The impact of geographically defined school zones on house prices in New Zealand. *International Journal of Housing Markets and Analysis* 1(4).

Rohani, M. (2012). Impact of Hauraki Gulf amenity on the land price of neighbourhood properties. An empirical Hedonic Pricing Method case study, North Shore, Auckland. *Auckland Council Working Paper 2012/001*.

Rosen, S. (1974). Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition. *Journal of Political Economy*, 82(1), 34-55.

Rouwendal, J., & van der Straaten, J. W. (2015). The Costs and Benefits of Providing Open Space in Cities. *Journal of Labor Economics*, *33*(2), 269-296.

Samarasinghe, O., & Sharpe, B. (2010). Flood prone risk and amenity values: a spatial hedonic analysis. *The Australian Journal of Agricultural and Resource Economics*, 54(1), pp. 457-475.

Sheppard, S. (1999). Hedonic analysis of housing markets. *Handbook of regional and urban economics*, *3*, 1595-1635.

Statistics New Zealand. (2014). *2013 Census meshblock dataset*. Available online at http://www.stats.govt.nz/Census/2013-census/data-tables/meshblock-dataset.aspx.

Statistics New Zealand (2015). *Subnational Population Projections: 2013 (base) - 2043*. Available online at http://www.stats.govt.nz/browse_for_stats/population/estimates_and_projections/SubnationalPopulationProjections_HOTP2013base.aspx.

Torshizian, E., & Grimes, A. (2014a). Residential Satisfaction, Crowding and Density: Evidence over Different Geographic Scales in Auckland. Paper presented at the 2014 New Zealand Association of Economists Conference.

Torshizian, E., & Grimes, A. (2014b). Negative Envy or Positive Amenity Effects? A Neighbourhood Study of Aucklanders' Residential Satisfaction. Paper presented at the 2014 Regional Studies Association Winter Conference.

UN-Habitat. (2013). Streets as Public Spaces and Drivers of Urban Prosperity. *Nairobi, Kenya: United Nations Human Settlements Programme*.

Vickrey, W. S. (1963). Pricing in urban and suburban transport. *The American Economic Review*, 452-465.

Wieckowski, A. (2010). Back to the City. *Harvard Business Review* May 2010 issue.

Zheng, G. (2013). The effect of Auckland's Metropolitan Urban Limit on land prices. *Productivity Commission Research Note*.

APPENDIX B Overview of data

B.1 Overview of sales audit file

We obtained an extract from the DVR database maintained by Auckland Council (2015) that covers the years 2011 to 2014[21]. This database is maintained by the Council as an input into ratings valuations that are conducted every three years and compiled in accordance with ratings valuation rules published by Land Information New Zealand (2010). As a result, it contains data on the following attributes of properties (key model variables in parentheses):

- The location of the property – defined by both the corresponding Auckland Council rates valuation reference and the property's street address
- The date when the property was sold (SALEYEAR)
- The gross sale price including chattels (e.g. furniture and appliances) and the net sale price (NETPRICE)
- Land use data, including zoning, actual property use (e.g. type of residential or commercial property), number of units, and number of off-street carparks (CARPARKS)
- Data on the estimated decade of construction (used to identify PRE1940 status[22]) and condition of the primary buildings on the property (COND_WALL, COND_ROOF)
- Land area (LAND), building size (gross floor area) and site coverage
- Mass appraisal data, including the total living area (FLOORSPACE), presence of decks, workshops, garages, and the view from the building (VIEW).
- Other details of the sale, such as whether the property is sold freehold, leasehold, or in some other way.

In order to enable spatial analysis of this dataset, we associated each sales record with the longitude and latitude coordinates[23] of the relevant rating unit (as at 18 February 2015). Because data on rating units is continuously updated, with titles regularly being created and destroyed, it was not possible to match a small number of sales.

B.2 Additional variables joined to sales audit file

After geocoding the data, it was possible to join it to spatial data from other datasets, including meshblock-level from the Census and from other Auckland Council datasets.

We used GIS analysis to identify the 2013 Census meshblock associated with each sale record. Meshblocks were used for two reasons. First, this is the most fine-grained level at which Statistics New Zealand makes Census demographic data available. Second, meshblocks are likely to provide a reasonable representation of the "neighbourhood" around each property as they generally include around 20-80 residences that are bounded by roads, parks, or natural barriers (Torshizian and Grimes, 2014a).

We joined the following meshblock-level variables to each sale record:

- Straight-line distance from the meshblock centroid to the city centre (DCBD)[24] and to the coast (DCOAST)[25]

[21] Because this dataset was obtained in December 2014, it excludes some sales from the end of the 2014 calendar year.

[22] 1940 was used as the cutoff for heritage status for two reasons. First, it aligns with Auckland Council's built heritage policies, which aim to control the demolition of pre-1944 buildings. Second, previous research into the influence of vintage on Auckland property values has found evidence of a price premium for buildings constructed prior to the 1940s, but not after (Rehm, Filippova and Stone, 2006).

[23] The coordinate reference system for these points is the New Zealand Transverse Mercator 2000 projection (EPSG:2193). This is standard practice for the majority of data published by New Zealand governments or about New Zealand.

[24] One alternative would be to use road network distance to the city centre, as travel distances are affected by Auckland's geography and infrastructure. This would result in a more realistic estimate of distances for some places but not for others. For example, although the road network distance from

- Number of pre-1940 buildings within each meshblock (MBHERITAGE) – this variable was created using GIS analysis of Auckland Council's DVR database. This represents the best available estimate of the number of properties with potential heritage significance in Auckland.
- Median household income within the meshblock, from the 2013 Census (HHINCOME). We did not adjust this value to account for wage inflation between 2011-2014. Due to the fact that the annual change in Statistics New Zealand's (2015) *Labour Cost Index* was consistently below 2% during this period, we did not expect the differences from 2013 incomes to be significant.
- Population density (usually resident population per hectare) within the meshblock, from the 2013 Census (DENSITY).

Other meshblock-level variables were also available from previous RIMU analysis, including data on nearby transport infrastructure and other amenities such as public parks. In addition, it would also be possible to incorporate information on nearby schools – e.g. school decile ratings. Although these variables were not included in this model as they were not directly relevant to the aims of the study, it would be possible to incorporate them into a future study.

B.3 Filters applied to data

It was necessary to filter the data to exclude property sales that had missing variables or unsuitable variable values. For example, we excluded properties sold with no land or floorspace, as including those values would not enable us to use a logarithmic model specification[26].

We applied the following filters to the data:

- Exclude all sales records with missing or non-complying data in the variables tested for inclusion in the regression model[27]
- Exclude all sale records which had a zero value for the following variables: LAND, DCBD, DCOAST, HHINCOME, DENSITY[28]
- Exclude all non-residential property sales (i.e. only include sales with an actual property use value between 90 and 99)[29].
- Exclude all sale records with: FLOORSPACE less than 20 square metres and NETPRICE less than $10,000[30]

After applying these filters, we were left with a total of 72,855 usable sales records, out of a total of 142,449 sales records in Auckland Council's sales audit file.

Devonport, a harbourside suburb on the North Shore, to the city centre is approximately 14 kilometres, actual travel distances are much smaller due to the presence of a frequent ferry service.

[25] Meshblock-level data was used here to reduce computational requirements. However, it is worth noting that this will tend to introduce some small spatial correlations between sales in the same meshblock. Torshizian (2014) presents a new package for the Stata statistical analysis programme that attempts to overcome these computational limits.

[26] As discussed in the following section, we employed a logarithmic model specification to control for heteroskedasticity in the data. This is a common tactic in hedonic price studies.

[27] This resulted in the removal of approximately 21,300 sales.

[28] Zero values make it impossible to take the logarithm of these values. The exclusion of properties sold with no land resulted in the removal of 42,200 sales, while other filters had a relatively minor effect. Some properties sold with no land represent sales of apartments or leasehold properties, while others may be data entry errors. In principle, GIS analysis could be used to correct for data entry errors.

[29] This resulted in the removal of approximately 5,400 data points.

[30] The aim of this is to prevent the inclusion of sales of outbuildings or garages mistakenly classified as residential sales. After applying the previous filters, this resulted in the removal of less than 300 sales.

B.4 Summary statistics of final dataset of residential property sales

After joining datasets and filtering out unsuitable values, we obtained a final dataset of 72,855 residential property sales. Descriptive statistics about key variables are summarised in Table 7.

Table 7: Summary statistics of residential sales dataset, 2011-2014 (n=72,855)

Statistic	Unit	Mean	Std Dev	Min	Max
X coordinates	NZTM2000 (metres)	1,758,899	9,886	1,711,391	1,824,563
Y coordinates	NZTM2000 (metres)	5,917,523	15,328	5,874,246	5,996,054
NETPRICE	Current NZD	$715,080	$653,689	$10,000	$95,630,000
LAND	Hectares	0.15	12.76	0.001	3131.00
FLOORSPACE	Square metres	145	67	20	3,987
DCBD	Metres	15,009	10,845	147	101,187
DCOAST	Metres	1,290	1,404	2	9,983
PRE1940	Dummy	15.3%	Not applicable		
CARPARKS	Number	1.6	3.0	0	302
VIEW:NO VIEW	Dummy	61.3%	Not applicable		
VIEW:OTHER	Dummy	25.5%			
VIEW:WATER	Dummy	13.2%			
COND_ROOF:AVERAGE	Dummy	31.5%			
COND_ROOF:FAIR	Dummy	1.9%			
COND_ROOF:GOOD	Dummy	65.9%			
COND_ROOF:POOR	Dummy	0.5%			
COND_ROOF:MIXED	Dummy	0.3%			
COND_WALL:AVERAGE	Dummy	30.4%			
COND_WALL:FAIR	Dummy	1.8%			
COND_WALL:GOOD	Dummy	66.9%			
COND_WALL:POOR	Dummy	0.6%			
COND_WALL:MIXED	Dummy	0.3%			
MBHERITAGE	Number	4.6	7.8	0	70
HHINCOME	Current NZD	$86,507	$29,381	$2,500	$150,000
DENSITY	Residents / hectare	32.9	18.0	0.01	806.3
SALEYEAR:2011	Dummy	14.1%	Not applicable		
SALEYEAR:2012 (3)	Dummy	31.8%			
SALEYEAR:2013 (3)	Dummy	32.4%			
SALEYEAR:2014 (3)	Dummy	21.7%			

B.5 Comparison of OLS regression results on full dataset and random subset

Spatial regression imposes significant computational requirements due to the fact that it is necessary to analyse the relationships between a large number of points. In this case, we found that it was not feasible to estimate spatial regression models on the full Auckland property sales dataset, which included 72,855 points.

We addressed this by randomly selecting a subset of 10,000 points from the full dataset[31]. We ran the preferred OLS regression model on the subset, finding that the results closely matched OLS analysis of the full dataset. A comparison of the two models is presented in Table 8.

[31] For the sake of replicability, we provided an arbitrarily chosen seed number to R's random number generator. Seed number and other code is available on request.

Table 8: Comparison of OLS models on full dataset and randomly selected subset of 10,000 sales

Auckland residential property sales 2011-2014, OLS models		
	Dependent variable:	
	log(sale_price_net)	
	Full dataset	Subset
log(LAND)	0.121***	0.120***
	(0.002)	(0.007)
log(FLOORSPACE)	0.611***	0.609***
	(0.003)	(0.009)
log(DCBD)	-0.283***	-0.284***
	(0.002)	(0.006)
log(DCOAST)	-0.011***	-0.014***
	(0.001)	(0.003)
PRE1940	0.118***	0.121***
	(0.004)	(0.011)
CARPARKS	0.001***	0.001
	(0.0004)	(0.001)
VIEW:OTHER (1)	0.006**	0.006
	(0.003)	(0.008)
VIEW:WATER (1)	0.172***	0.164***
	(0.004)	(0.011)
COND_WALL:FAIR (2)	0.001	-0.022
	(0.009)	(0.022)
COND_WALL:GOOD (2)	0.072***	0.066***
	(0.003)	(0.008)
COND_WALL:POOR (2)	-0.141***	-0.168***
	(0.015)	(0.041)
COND_WALL:MIXED (2)	0.006	-0.006
	(0.021)	(0.053)
MBHERITAGE	0.004***	0.004***
	(0.0002)	(0.0005)
log(HHINCOME)	0.201***	0.194***
	(0.004)	(0.01)
log(DENSITY)	-0.038***	-0.034***
	(0.001)	(0.004)
SALEYEAR:2012 (3)	0.052***	0.068***
	(0.004)	(0.01)
SALEYEAR:2013 (3)	0.186***	0.197***
	(0.004)	(0.01)
SALEYEAR:2014 (3)	0.267***	0.300***
	(0.004)	(0.011)
Constant	11.008***	11.093***
	(0.053)	(0.144)
Observations	72,855	10,000
Adjusted R^2	0.640	0.625
F Statistic	7,197.600*** (df = 18; 72836)	927.097*** (df = 18; 9981)
Notes:	*p<0.1; **p<0.05; ***p<0.01	

(1) VIEW is a categorical (dummy) variable. The base level is "no view".
(2) COND_WALL is a categorical (dummy) variable. The base level is "average" condition.
(3) SALEYEAR is a categorical (dummy) variable. The base level is 2011.