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The Welfare Effects of Character Protections on Neighbourhoods

Ryan Greenaway-McGrevy and James Allan Jones

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The Welfare Effects of Character Protections on Neighbourhoods

Ryan Greenaway-McGrevy* James Allan Jones†

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Abstract

We develop a version of the monocentric model to examine the effects of character protections on household welfare. Character protections generate amenity values for local residents by imposing floor-to-area (FAR) restrictions on urban development, thereby presenting a trade-off between welfare-increasing amenities and welfare-decreasing redevelopment restrictions. Welfare effects become negative when their attendant FAR restrictions are sufficiently binding. This is likely to be the case when character provisions are applied to neighbourhoods that have high demand due to their proximity to other (non-character) amenities or job centres. Calibrating the model to Auckland, we find character protections have negative welfare effects equivalent to an income decrease for the representative household of between \$330 and \$1,368 per year.

Keywords: Character Protections, Land Use Regulations, Redevelopment.

JEL Classification Codes: R14, R31, R52

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

†University of Auckland. Email: james.jones@auckland.ac.nz. Jones thanks the Kelliher Trust for their support.

1.0 Introduction

Many cities around the world restrict redevelopment within certain areas to preserve the character of historic neighbourhoods.[1] These policies attract praise from historic preservation groups that consider character neighbourhoods to be inherently valuable or aesthetically desirable, and criticism from proponents of urban intensification when these character neighbourhoods occupy areas where housing demand is high, such as inner suburbs that are proximate to business districts.

Character controls are justified on the basis that owners of the affected buildings are not adequately compensated for the amenity value of preservation: A substantive proportion of the amenity benefits are public, while the costs of preservation are private. Restrictions on redevelopment therefore preserve positive externalities by preventing individual property owners from removing their own built character and free-riding on the character amenities of their neighbours (Coulson and Lahr, 2005; Holman and Ahlfeldt, 2015).[2] However, such restrictions can also impede city growth by limiting the supply of housing in protected areas, thereby encouraging urban sprawl (Been *et al.*, 2016). In the worst case, redevelopment restrictions are imposed by incumbent residents to cement a low density urban form in spite of high demand, using a system of local governance that apportions no weight to the welfare of potential residents excluded by the restrictions (Manville and Monkkonen, 2021).

This paper develops a framework for assessing the welfare effects of character preservation on city residents. Our analysis incorporates two features inherent to character restrictions. First, they generate positive amenity externalities for local residents of the protected neighbourhood (Holman and Ahlfeldt, 2015). Second, they potentially reduce the supply of dwellings in protected areas through restrictions on redevelopment (Been *et al.*, 2016). The net effect of character protections on the welfare of residents is ambiguous because they generate amenity value by restricting the redevelopment potential of protected parcels. By definition, amenities increase welfare of affected individuals. But restrictions on housing (re)development reduce welfare because they result in

[1]For example, Berlin, Chicago, London, New York and Rotterdam have restrictions on redevelopment in order to preserve historic character. SeeAhlfeldt and Maennig (2010), Noonan and Krupka (2011), Koster *et al.* (2012), Ahlfeldt *et al.* (2015), and Been *et al.* (2016).

[2]There is ample empirical evidence of public amenity benefits of character. Proximity to heritage buildings generally raises surrounding property values (Coulson and Leichenko, 2001; Noonan, 2007; Moro *et al.*, 2013;Lazrak *et al.*, 2014; Nunns *et al.*, 2015; Franco and Macdonald, 2018; Andersson *et al.*, 2019; Bade *et al.*, 2020), even if the heritage building itself does not command a price premium (Ahlfeldt and Maennig, 2010). Empty lots in protected character areas command premiums even in relative new cities such as Brisbane (Warren *et al.*, 2017).

smaller, more expensive dwellings, and longer commutes (Bertaud and Brueckner, 2005). Policy-makers therefore require a framework for understanding and comparing the trade-offs of character protections on the welfare of city inhabitants.

The trade-off between amenities and redevelopment is consistent with ambiguous price effects of character protections documented in empirical studies. A substantial amount of research documents a positive price premium for properties located within controlled areas.[3] However, protections are endogenous and consequently generate an upward bias on premium estimates if unaccounted for (Noonan and Krupka (2011); Heintzelman and Altieri (2013)). Estimates become attenuated and, in some cases, negative once this endogeneity is accounted for.[4] Negative premiums have also been documented, particularly when measured relative to comparable parcels that can be redeveloped (Been *et al.*, 2016; Bade *et al.*, 2020).

We study the impact of character restrictions on urban development and welfare using a monocentric model of urban development in the tradition of Alonso (1964), Mills (1967) and Muth (1969). Our model incorporates both amenities and restrictions on housing development as location-specific features that can vary across the disk of the city. Amenities directly increase the utility of residents in locations where the protections apply. Housing development is restricted by lower bounds on the amount of land used in the production of housing floorspace. These bounds mimic floor-to-(land)-area (FAR) restrictions and are equivalent to the height restrictions used in Bertaud and Brueckner (2005), and they are permitted to vary according to different zones in the disk of the city. Character areas are modelled as as zones that have both FAR restrictions and locational amenities. Our modelling assumptions ensure that the model is amenable to calibration using observable data in order to quantify welfare effects.

FAR restrictions mimic the restrictions on redevelopment encountered in character areas in practice. Generally these restrictions result in less redevelopment in special character areas because the form and fabric of the existing heritage buildings must be preserved. However, some intensification may occur though 'building back', or development of backyards into a separate dwelling, provided it does not adversely impact the character of an area. In addition, several smaller dwellings can

[3]See Leichenko *et al.* (2001), Coulson and Lahr (2005),Noonan (2007), Thompson *et al.* (2011), Zahirovic-Herbert and Chatterjee (2012), Lazrak *et al.* (2014), Holman and Ahlfeldt, 2015, Warren *et al.*, 2017, Franco and Macdonald (2018), and Bade *et al.* (2020).

[4]See Ahlfeldt and Maennig (2010), Noonan and Krupka (2011), Koster *et al.* (2012), Heintzelman and Altieri (2013) and Been *et al.* (2016).

be created by partitioning a character property into apartments or flats. It is also worth noting that special character controls cannot prevent several households from cohabitating within the same dwelling, as frequently occurs among young adults, which is equivalent to an increase in dwelling density from a modelling perspective.

Development is characterised as being restricted, but not prohibited, within the character areas. Modelling development restrictions as an upper bound on the capital intensity of development, and not the number of dwellings per area unit of land, appears concordant with these set of regulations, as it would prohibit, for example, building three storey buildings in character areas, but not the splitting of houses into several units, or building a second dwelling behind existing dwellings. As we discuss below in more detail, restricted redevelopment is critical to understanding the ongoing welfare impacts of character protections, because it does not place an upper bound on dwelling density within affected areas.

We assess the impact of character protections under various static equilibria that correspond to different regulatory regimes. Character protections are unambiguously welfare enhancing when their attendant development restrictions are non-binding. Because utility is equal at all locations under spatial equilibrium, locational amenities that improve local resident's welfare are offset by higher house prices and smaller dwellings in high amenity locations. Smaller dwellings generate a more compact city and thus a higher level of utility for all households. These welfare gains are reduced if frictions restrict the ability of floorspaces to adjust downwards in high amenity suburbs. In the extreme case where there is a binding minimum lot size per household, there are no ongoing welfare gains.

The negative welfare impacts of character protections become manifest in situations where the FAR restrictions are binding, meaning that developers would choose to exceed the FAR restriction if permitted. Locations with protections continue to have smaller dwellings and higher dwelling prices. But the net effect of the protections on welfare can be negative because the binding FAR restrictions increase house prices and reduce dwelling sizes across the whole city. This expands the city and reduces the utility of the representative household.

The net effect of character provisions on welfare is therefore highly context dependent. In particular, it will depend on the distance of the protected areas in relation to locations of high housing demand, the aggregate housing demand to live in the city to access the wages and other available amenities, and the stringency of the redevelopment restrictions in the affected areas. In practice, model calibration may be required to assess these trade-offs. We calibrate the model to Auckland, New Zealand, to assess the welfare impacts of character protections, finding that the restrictions reduce representative household welfare by an amount that is equivalent to 1.32% to 0.32% of average household income, or between $330 and $1,368 per year.

Monocentricity is a prominent assumption of AMM models that affects potential welfare losses from redevelopment restrictions, particularly when restrictions are imposed in locations of high demand, such as those close to the CBD. Conventional descriptions of the AMM model locate all jobs in the CBD, necessitating workers to commute into the centre of the city for employment. This is an assumption that often bears little resemblance to empirical patterns. However, as outlined in Glaeser (2008), the monocentric model is observationally equivalent to a set of models in which employment is dispersed across the city and wages decrease linearly as the distance between the place of work and the CBD increases. Thus, the AMM model is monocentric in the sense that workers commute *towards* the CBD, but not necessarily all the way to the CBD. To assess the appropriateness of this condition in Auckland, we examine average wages by location-of-work, showing that wages decrease with distance to downtown. Imposing the linear relationship required by the form of observational equivalence proposed by Glaeser (2008) yields a healthy R-squared between 50 and 65%. Data on commuting patterns further buttress evidence of this monocentricity by showing that workers generally commute towards the CBD, with approximately 56% of all commutes headed towards a location within 30 degrees displacement of the CBD, and only 19% of commuters headed on a bearing that takes them away from the CBD.

Our paper builds on several strands of the extant literature. Like Bertaud and Brueckner (2005) and Kulish *et al.* (2012), we incorporate restrictions on the capital intensity of housing production into the Alonso-Muth-Mills (AMM) framework to model LURs. However, we use the version of the AMM used in Greenaway-McGrevy (2022) that allows these restrictions on housing development to vary in different areas of the city, thereby mimicking different residential zones. Like Cho (2001), amenities are permitted to vary across the city disk within our framework. These amenity flows vary according to zone in our model.

The remainder of the paper is organized as follows. Section two presents the model. Section three presents some descriptive data analysis on Auckland to support the fundamental premises of the model, namely that workers commute towards the CBD, and that the decrease in wages from the CBD is sufficiently close to being linear. Section four presents the empirical application. Section five concludes.

2.0 Model

The model is based on the conventional absentee landlord monocentric AMM model. We first present the model with a simple formulation of location-specific amenities that is amenable to calibration exercises. We then introduce FAR restrictions following Bertaud and Brueckner (2005). This approach is then extended to examine different zoning in different areas of the city based on the approach in Greenaway-McGrevy (2022).

The city lies on a flat plane and is comprised of a central business district (CBD) surrounded by suburbs that house workers. The land around the CBD suitable for housing development spans θ radians. Workers reside in the suburbs and commute to the CBD to earn wages. Their preferences over housing floorspace H and a consumption numeraire C are described by a utility function $U(H, C)$ that is increasing in both arguments and strictly quasi-concave. Households living at distance $x \in [0, \infty)$ from the CBD incur a commuting cost tx to earn the wage W.[5] Under these assumptions, both the rent of housing floorspace $P(x)$ (hereafter "dwelling prices") and floorspace $H(x)$ are decreasing in x and convex (Duranton and Puga, 2015).

Because we are interested in how regulations affect the intensity of housing development, we employ a version of the model that admits substitution between land and capital in the production of floorspace. We impose standard assumptions on the production of housing floorspace. Developers produce floorspace $H(x)$ using capital K and land L. $H(x)$ is increasing in K and L, exhibits constant returns to scale, and is strictly quasi-concave. The rental price of capital is assumed constant and is set to unity. The rental price of land (hereafter "land prices") is denoted $R(x)$. Developers are perfectly competitive. We define $h(x) = H(x)/L(x)$ as the FAR ratio that developers build to at x. Under constant returns to scale, $h(x)$ can be expressed as a function of the capital to land ratio $k(x) = K(x)/L(x)$.

The model is closed by: setting land rents at the edge of the city, $\bar{x}$, equal to exogenous agri-

[5] Travel elasticities can be incorporated via the method used in Duranton and Puga (2019). Under this approach, households located distance x from the CBD must commute towards the CBD for x^{γ} km to earn the wage W, where the parameter $\gamma \in (0, 1]$.

cultural rents, i.e., $R(\bar{x}) = \bar{R}$; the conventional population constraint

$$\int_0^{\bar{x}} \frac{h(x)}{H(x)} \theta x dx = N;$$

and the within city iso-utility condition (utility is equal at all locations), i.e. $U = \bar{U}$.

2.1 Utility and Character Amenities

Household utility is also increasing in an amenity $b(x)$ that is location specific. Following Ahlfeldt *et al.* (2015), we model amenities multiplicatively in the utility function. We assume utility is Cobb Douglas, such that $U = U(H, C, x) = b(x)H^{\alpha}C^{1-\alpha}$.

Rearranging this to be in terms of $P(x)$

$$P(x) = (W - tx)^{\frac{1}{\alpha}} (1-\alpha)^{\frac{1-\alpha}{\alpha}} \alpha \left(\frac{U}{b}\right)^{-\frac{1}{\alpha}} = \frac{b(x)^{\frac{1}{\alpha}} (W - tx)^{\frac{1}{\alpha}} (1-\alpha)^{\frac{1-\alpha}{\alpha}} \alpha}{U^{\frac{1}{\alpha}}} \tag{1}$$

and thus indirect demand for floorspace is

$$H(x) = (W - tx)^{-\frac{1-\alpha}{\alpha}} (1-\alpha)^{-\frac{1-\alpha}{\alpha}} U^{\frac{1}{\alpha}} = \frac{U^{\frac{1}{\alpha}}}{b(x)^{\frac{1}{\alpha}} (W - tx)^{\frac{1-\alpha}{\alpha}} (1-\alpha)^{\frac{1-\alpha}{\alpha}}} \tag{2}$$

The impact of amenities are to increase prices and reduce floorspace per dwelling.

In the absence of FAR restrictions, it can be shown that dwelling density is

$$\frac{h(x)}{H(x)} = \frac{\bar{R}}{\alpha(1-\gamma)} \frac{(W - tx)^{\frac{1-\alpha(1-\gamma)}{\alpha(1-\gamma)}}}{(W - t\bar{x})^{\frac{1}{\alpha(1-\gamma)}}} \frac{b(x)^{\frac{1}{\alpha(1-\gamma)}}}{b(\bar{x})^{\frac{1}{\alpha(1-\gamma)}}} \tag{3}$$

Note that this implies that where $b(x)/b(\bar{x}) > 1$,dwelling density increases.

2.2 FAR Restrictions and Zones

Because we are interested in how regulations affect the intensity of housing development, we employ regulations that restrict developers to a maximum floor to land area ratio on $h(x)$. We therefore refer to it as a FAR restriction. It is equivalent to the height restrictions employed by Arnott and MacKinnon (1977), Bertaud and Brueckner (2005) and Kulish *et al.* (2012). Under constant returns to scale this FAR restriction is equivalent to a restriction on the maximum capital-to-land ratio used in production of floorspace.

Bertaud and Brueckner (2005) and Kulish *et al.* (2012) model LURs as constraints on height. For example, $h(x) < \hat{h}$ for some $\hat{h} > 0$ that is selected by a policymaker. Under constant returns to scale, this is equivalent to a constraint on the capital intensity of the property, $k(x)$. In the framework of Arnott and MacKinnon (1977), Bertaud and Brueckner (2005) and Kulish *et al.* (2012), the FAR restriction $\hat{h}$ applies uniformly across the city. The constraint is binding on locations sufficiently close to the CBD, i.e. where $x < \hat{x}$. At such locations, dwelling density is given by $\frac{\hat{h}}{H(x)}$. Incorporating Cobb-Douglas utility and amenities $b(x)$ we can solve for this as

$$\frac{\hat{h}}{H(x)} = \hat{h}\frac{b(x)^{\frac{1}{\alpha}}}{b(\bar{x})^{\frac{1}{\alpha}}}\frac{\bar{R}^{1-\gamma}p_K^{\gamma}(W-tx)^{\frac{1-\alpha}{\alpha}}}{(1-\gamma)^{(1-\gamma)}\alpha\gamma^{\gamma}A(W-t\bar{x})^{\frac{1}{\alpha}}} \tag{4}$$

Density is therefore greater for locations x such that $b(x)/b(\bar{x}) > 1$. Note, however, that since $\gamma < 1$, the effect of amenities on density is less than under cases where the FAR restrictions do not apply – see (3) above.

The model is solved via the population constraint (c.f. (9) in Bertaud and Brueckner, 2005):

$$\int_0^{\hat{x}} \tfrac{\hat{h}}{H(x)}\theta x dx + \int_{\hat{x}}^{\bar{x}} \tfrac{h(x)}{H(x)}\theta x dx = N$$

and the condition that $\hat{x}$ satisfies $h(\hat{x}) = \hat{h}$, such that $\hat{x}$ denotes the distance at which $\hat{h}$ becomes binding. $\bar{x}$ denotes the radius of the city, while N is the number of dwellings in the city.

In practice, however, regulations that affect housing construction typically vary between different zones of a city. To bring the model closer to urban planning in practice, we extend the general framework by permitting different zones across the city disk. Each zone has a different restriction on $h(x)$. Let $\omega_j(x) \in (0,1)$ denote a continuous function in x that describes the proportion of land at distance x that is assigned to residential zone j. Let $\hat{h}_j$ denote the FAR restriction that applies in zone j, such that $h(x) \leq \hat{h_j}$. The population condition becomes

$$\theta\sum_{j=1}^{m_z}\left(\int_0^{\hat{x}_j} \tfrac{\hat{h}_j}{H(x)}\omega_j(x)\, x dx + \int_{\hat{x}_j}^{\bar{x}} \tfrac{h(x)}{H(x)}\omega_j(x)\, x dx\right) = N \tag{5}$$

where $\hat{x}_j$ satisfies $h(\hat{x}_j) = \hat{h}_j$, such that $\hat{x}_j$ denotes the distance at which $\hat{h}_j$ becomes binding.[6] The

[6]Note that this condition does not preclude $\hat{x}_j > \bar{x}$, which indicates that the FAR restriction is binding out to the boundary in zone j.

remaining conditions for solving the model are the same as in the standard AMM model.

For the case of Cobb Douglas utility, $\frac{\hat{h}_j}{H(x)}$ are given by (4) noting that the FAR restriction $\hat{h}$ now varies by zone.

A simple example of the framework is given by $\omega_j(x) = \omega_j \in (0,1)$ for all $j = 1, \ldots, m$. In this case, the city disk spanning θ radians is decomposed into circular sectors, with each sector corresponding to a zone. Such a model may be appropriate for transit-oriented zoning, whereby residential areas close to rapid transit and highway corridors are zoned for greater density.[7] Figure 1 below provides an example where $\omega_j(x) = \omega_j \in (0,1)$ for all $j = 1, \ldots, m$. However, in practice, planners often locate high density zones closer to downtown. In such cases we might expect $\omega_j(x)$ to be monotonically decreasing in x for zones that permit high levels of capital intensity in housing, and increasing for zones that permit low levels of capital intensity.

2.21 Discretization into Annulus Sectors

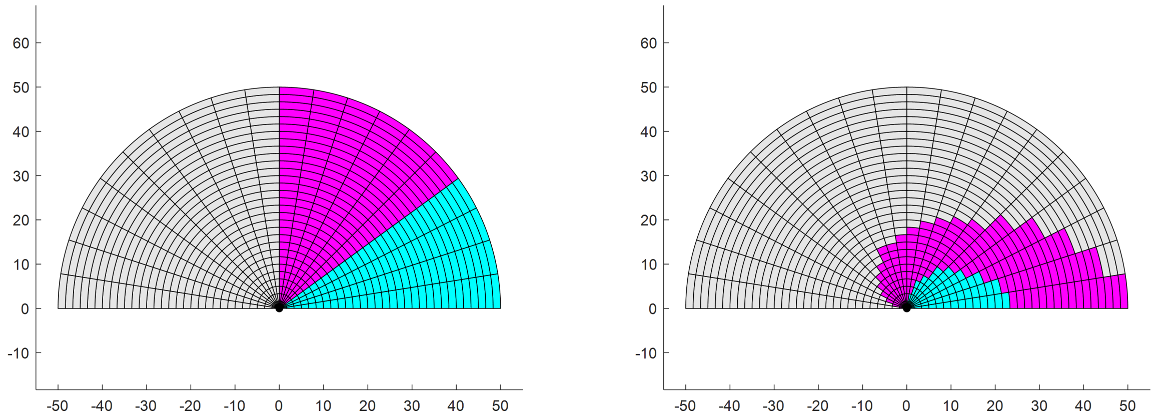
The model can also be solved via numerical integration when the functions $\{\omega_j(x)\}_{j=1}^{m_z}$ are discretized via a step function over x. Discretization may be desirable to match the zoning topography of the model to the practical implementation of zoning in urban planning.

Discretization involves decomposing the disk into a grid of annulus sectors and assigning a zone to each sector. We assign m_s circular sectors, each of angle θ/m_s. Each annulus has an annulus radius of length l. Let (a, s) index the annulus and sector, such that $s = 1, \ldots, m_s$ indexes the sectors and $a = 1, 2, \ldots$ indexes the countably infinite annuli. We define $\omega_{j,a} \in [0,1]$ to be the proportion of sectors within the ath annulus that are assigned to zone j.

Figure 1 exhibits four examples of the annulus sectors framework for a case where there are three different zones. Each annulus sector within the disk is assigned a zone and signified by a different colour (magenta, cyan or grey). In the example on the left of Figure 1, we have the case where the proportion of land assigned to each zone is constant for all distances x. In the example on the right, the cyan zone is more prevalent close to the CBD, while the grey zone becomes more prevalent towards the outskirts of the city. Because distance to the CBD determines outcomes in the monocentric AMM model, the ordering of the zones within the ath annulus is inconsequential in the disks presented in Figure 1.

[7] Transit corridors that afford faster commute times do however warp the topology of the city disk. See Baum-Snow (2007).

Figure 1: Example of Annulus Sector Zones in the Alonso-Muth-Mills model



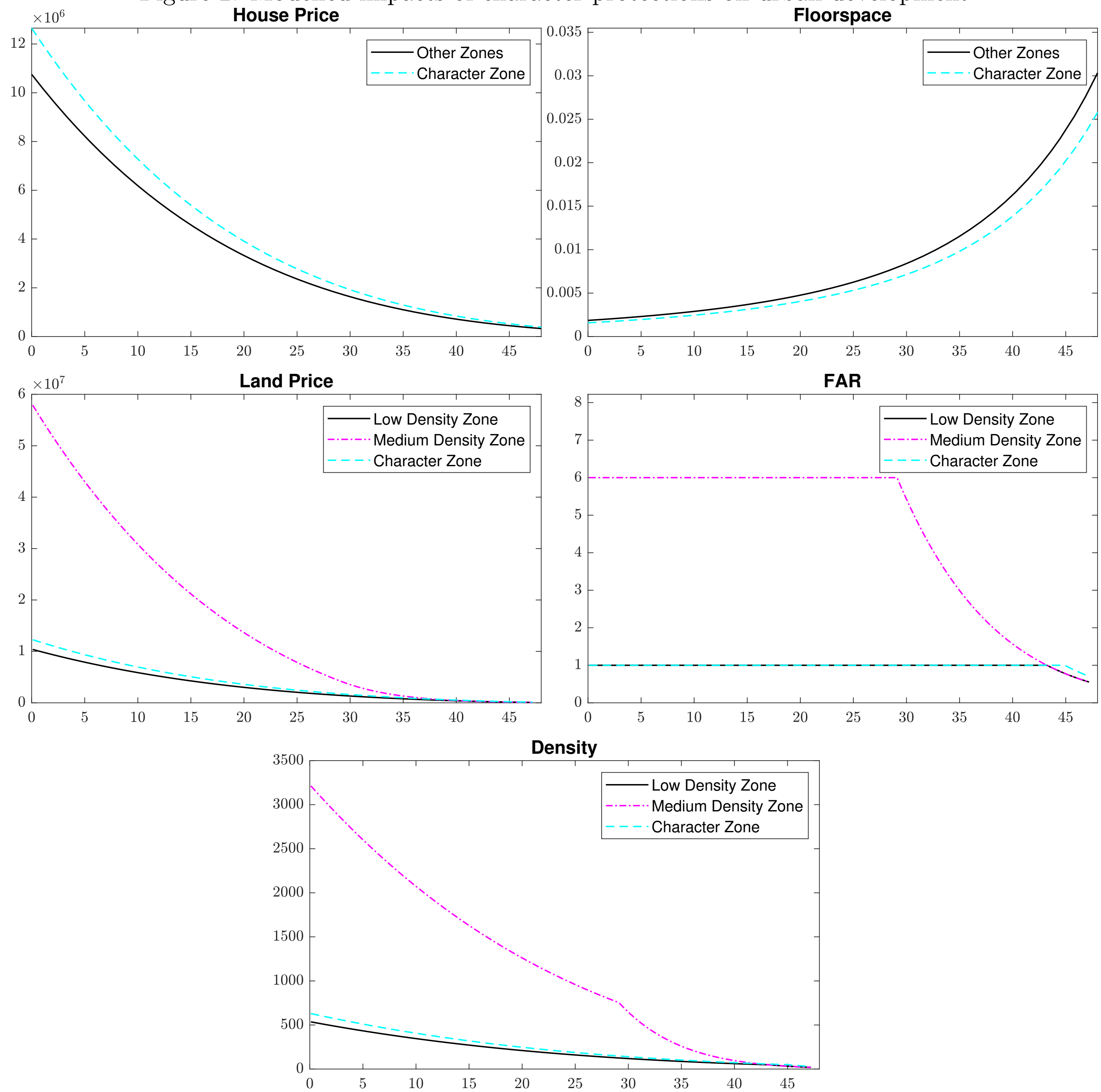
Notes: Disk decomposed into annulus sectors, $\theta = \pi$. Colours represent different zones. In the example on the left, the proportion of sectors in each annuli assigned to each zone is constant. In the example on the right, the proportion of annuli assigned to each zone is dependent on the distance of the annuli to the CBD.

Under the discretization into annulus sectors, the population condition (5) becomes more complicated. We use x_a^* to denote a discrete measure of distance to the CBD. Specifically, x_a^* is the distance of the outer edge of the ath annulus to the CBD, such that $x_a^* \in \{x_0^*, x_1^*, x_2^*, x_3^*, \ldots\} = \{0, l, 2l, 3l, \ldots\}$. Then (5) becomes

$$\theta \sum_{j=1}^{m_z} \left(\begin{array}{c} \sum_{a=1}^{a_j} \int_{x_{a-1}^*}^{x_a^*} \omega_{j,a} \frac{\hat{h}_j}{H(x)} x dx + \int_{x_{a_j}^*}^{\hat{x}_j} \omega_{j,a+1} \frac{\hat{h}_j}{H(x)} x dx + \omega_{j,a_j+1} \int_{\hat{x}_j}^{x_{a+1}^*} \frac{h(x)}{H(x)} x dx + \\ \sum_{a=a_j+2}^{\bar{a}} \omega_{j,a} \int_{x_{a-1}^*}^{x_a^*} \frac{h(x)}{H(x)} x dx + \omega_{j,\bar{a}+1} \int_{x_{\bar{a}}^*}^{\bar{x}} \frac{h(x)}{H(x)} x dx \end{array} \right) = N$$

where $a_j = \lfloor \frac{\hat{x}_j}{l} \rfloor$ and $\bar{a} = \lfloor \frac{\bar{x}}{l} \rfloor$, and where $\lfloor \cdot \rfloor$ denotes the largest integer less than or equal to the argument. Thus the FAR restriction for zone j becomes non-binding in the $(a_j + 1)$th annulus, and the radius of the city lies within the $(\bar{a} + 1)$th annulus.

Figure 2: Modelled impacts of character protections on urban development



Simulated equilibrium outcomes using the annulus sectors depicted in the lower right panel of Figure 1. Cyan denotes the character zone (FAR restriction = 1); magenta denotes the medium density zone (FAR restriction = 6), while black denotes the low density zone without character protections (FAR restriction = 1). Utility is Cobb Douglas with a housing share of 0.2, while floorspace production is Cobb-Douglas with a capital share of 0.6 and TFP of $5e^{-4}$. These parameters are adopted from (Kulish *et al.*, 2012). The remaining parameters are $W = \$100,000$, $t = \$1,046, \bar{R} = \$80,000$, $N = 1,000,000$ and $\theta = \pi$.

2.22 Numerical Simulation

We present an example of urban development outcomes when spatial equilibrium holds under the annulus sectors disk depicted on the bottom right panel of Figure 1. For the purposes of this instructive exercise, we impose a FAR restriction of 6 on the magenta annulus sectors in Figure 1. We refer to this as the 'medium density zone'. The cyan areas have a FAR restriction of 1, but is also subject to character amenities, while the grey areas have a FAR restriction of 1 and no amenity benefit. We refer to the latter as the 'low density zone'.

We normalize locational amenities as follows. We assume that $b(x) = 1$ in all areas except the character zone, where $b(x) = 1 + \kappa$ for some $\kappa > 0$. This implies that in (3) and (4) above we have

$$\frac{b_j(x)}{b_j(\bar{x})} = \begin{cases} 1 + \kappa, & j = 1 \\ 1, & j \geq 2 \end{cases}$$

where we assume that $j = 1$ corresponds to the character zone. In practice, we will select κ such that the reduction in floorspace per dwellings in character zones matches the data. For this exercise, we set $\kappa = 0.03305$, which results in a 15% reduction in floorspace in character zones.

Other parameters of the model are described in the notes to Figure 2. Further details on the model are discussed above.

Figure 2 depicts outcome variables of interest under spatial equilibrium. It depicts dwelling rents $P(x)$ and floorspaces $H(x)$, which, in the absence of amenities, depend only on x and $\bar{x}$. However, the presence of amenities in the character zone are reflected in the price and quantity of floorspace. Because utility is constant across all locations, but residents of the character zone benefit from amenities, at each distance x the price of housing is higher, and floorspace lower, in the character zone compared to non-character zones. Specifically, from (8) we have

$$P_1(x) = P(x)\, b(x)^{\frac{1}{\alpha}} \tag{6}$$

where $P_1(x)$ denotes house prices in zone $j = 1$, and $P(x)$ denotes prices in zones $j = 2, 3, \ldots$. Similarly we have

$$H(x) = H(x)\, b(x)^{-\frac{1}{\alpha}} \tag{7}$$

Figure 2 also depicts land rents $R(x)$, FARs $h(x)$, and densities $h(x)/H(x)$, all of which vary according to zone. character amenities also effect these variables in the character zone, since prices are higher and floorspace lower. Density is higher in the character zone, since there is greater demand from households to live there. Land prices are also higher, since land is an input to production of housing in these locations of higher demand.

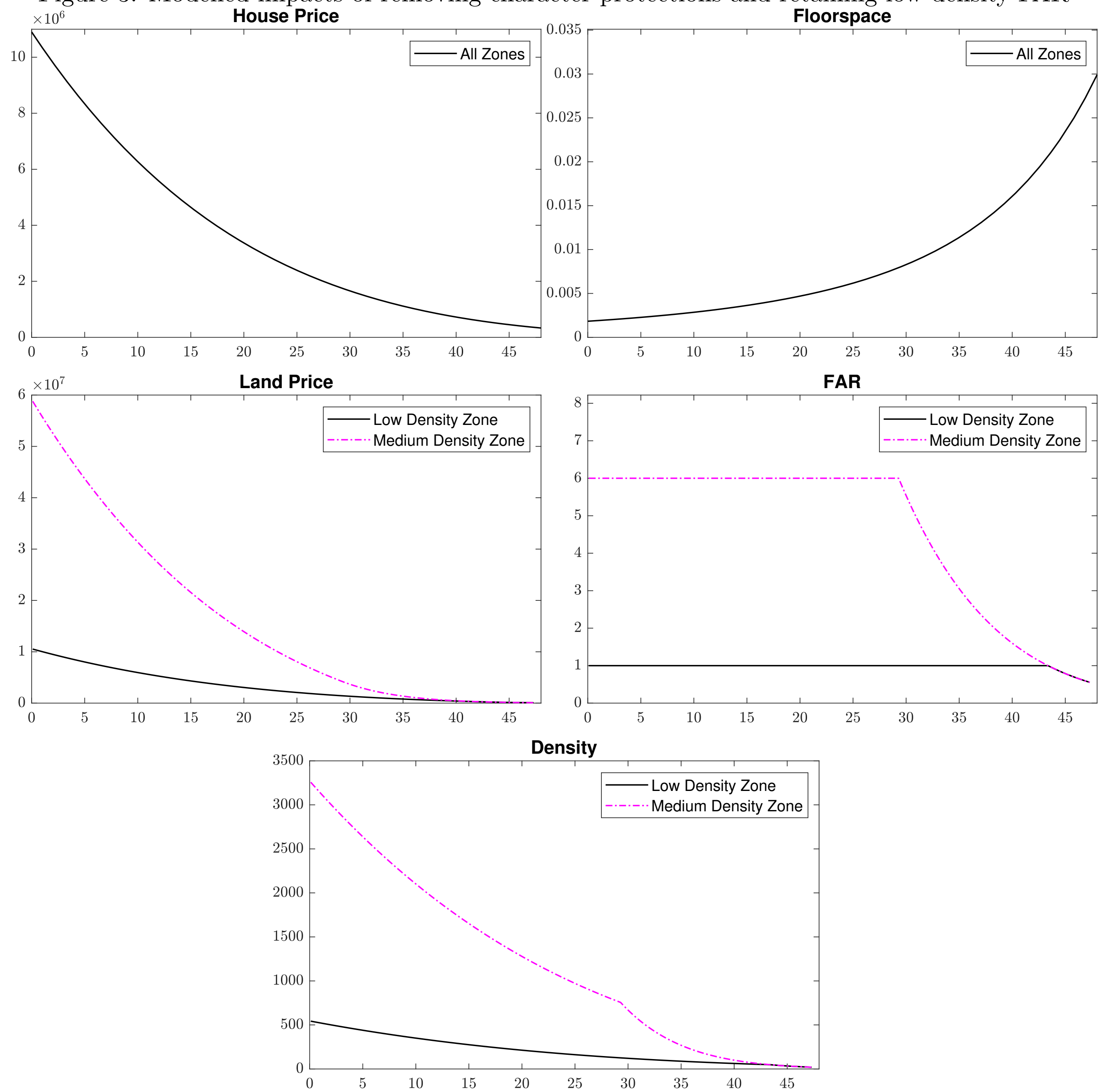
The plot of FARs illustrates the distance form the CBD at which the FAR restrictions become non-binding. The restriction in the medium density zone is non-binding at about 31 km, while that of the low density zone is binding at 44 km from the CBD. The restriction on the character zone is further out (at about 46 km), despite having the same FAR restriction of 1 as the low density zone. This reflects greater demand to live in the character zone due to amenity effects. The radius of the city is about 48.3km.

Next we consider what happens when character protections are removed but the FAR restriction remains the same in the character areas. This is achieved by setting the local amenity flows to zero. The city expands from 48.3 km to 49.1 km. This entails a welfare loss for local residents of 0.11% (since utility is proportional to $W - t\bar{x}$ under Cobb-Douglas utility). In this example, there is no welfare gain from removing the character protections because the FAR restriction has not been removed. As illustrated in Bertaud and Brueckner (2005), the welfare cost (gain) is equal to the reduction in radii, multiplied by the travel cost per km. Figure 3 exhibits the other outcomes of the model.

Finally we consider the welfare effects from relaxing the special character provision and increasing the FAR restriction to that of the medium density zone. The city shrinks from 48.3 km to 47.8km. This entails a welfare gain for local residents of 1.17%, since utility is proportional to $W - t\bar{x}$ under Cobb-Douglas utility. In this example, the welfare gain from the amenities generated by the character protections are outweighed by the welfare losses from the restrictions on development. Figure **??** exhibits the other outcomes of the model.

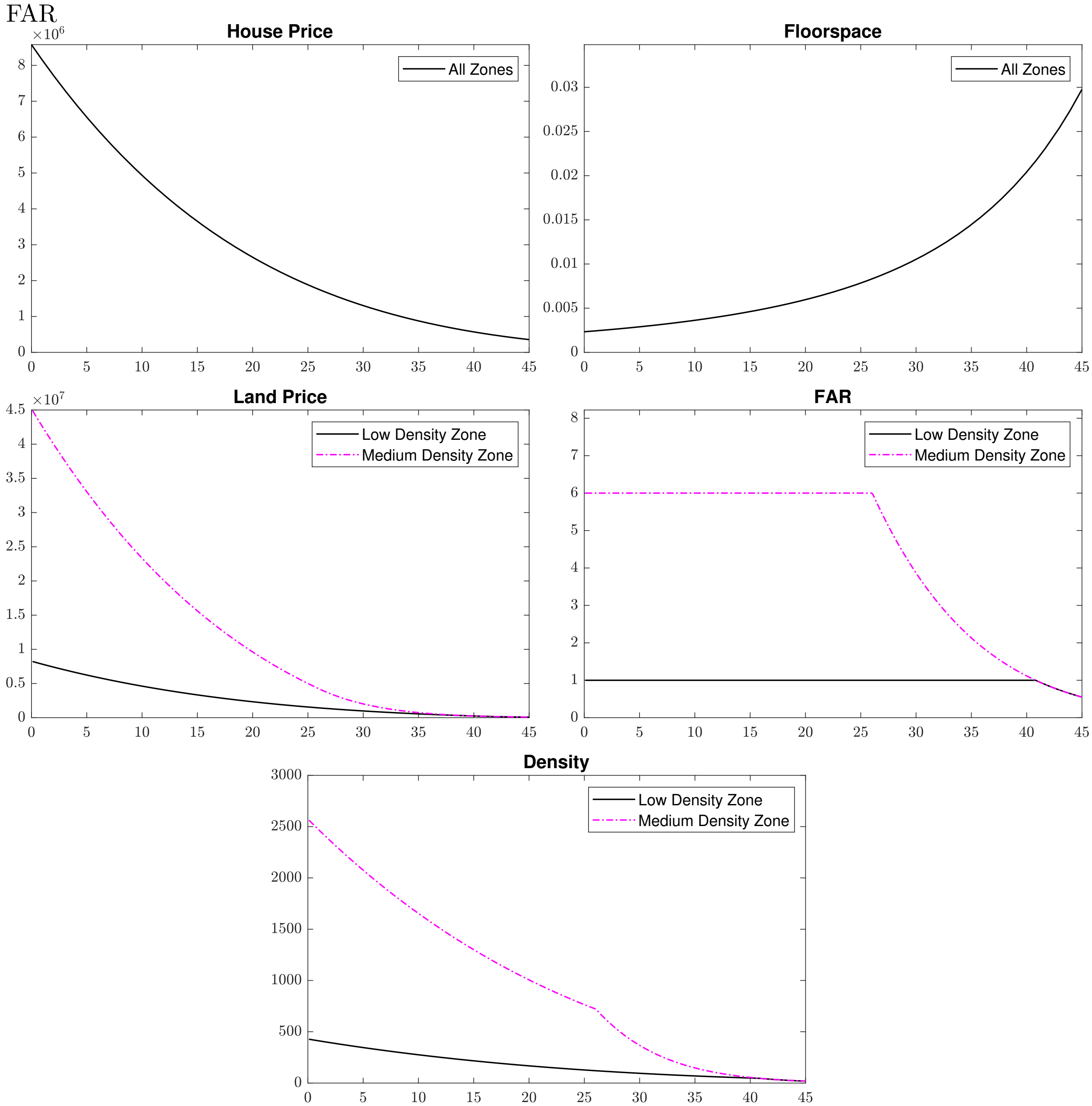
The examples pursued herein have FAR restrictions that have a significant impact on city development – generating a significant amount of sprawl. In such situations, character protections are likely to be welfare decreasing unless the alternative is restricted to a comparatively small increase in floorspace. In less populous cities, or in cities where the FARs are set at higher levels, such that FAR constraints are not at sharply binding, there can be welfare gains.

Figure 3: Modelled impacts of removing character protections and retaining low density FAR



Simulated equilibrium outcomes using the annulus sectors depicted in the lower right panel of Figure 1. Magenta denotes the medium density zone (FAR restriction = 6), while black denotes the low density zone without character protections (FAR restriction = 1). Utility is Cobb Douglas with a housing share of 0.2, while floorspace production is Cobb-Douglas with a capital share of 0.6 and TFP of $5e^{-4}$. These parameters are adopted from (Kulish *et al.*, 2012). The remaining parameters are $W = \$100,000$, $t = \$1,046$, $\bar{R} = \$80,000$, $N = 1,000,000$ and $\theta = \pi$.

Figure 4: Modelled impacts of removing character protections and upzoning to medium density FAR



Simulated equilibrium outcomes using the annulus sectors depicted in the lower right panel of Figure 1. Magenta denotes the medium density zone (FAR restriction = 6), while black denotes the low density zone without character protections (FAR restriction = 1). Utility is Cobb Douglas with a housing share of 0.2, while floorspace production is Cobb-Douglas with a capital share of 0.6 and TFP of $5e^{-4}$. These parameters are adopted from Kulish *et al.* (2012). The remaining parameters are $W = \$100,000$,$t = \$1,046$, $\bar{R} = \$80,000$, $N = 1,000,000$ and $\theta = \pi$.

3.0 Illustrative Example of the Welfare Implications of Character Protections

The previous section provides a simulation in order to gain insight into the trade off in household welfare when cities enact character protection provisions. In this section we calibrate the model to a real-world city where such restrictions are in place. AMM models are frequently employed for such tasks in real world applications (Bertaud and Brueckner, 2005; Kulish *et al.*, 2012; Larson *et al.*, 2012; Larson and Yezer, 2015; Larson and Zhao, 2017). We follow the approach laid out in Bertaud and Brueckner (2005), carefully choosing the parameters of the model so that the simulated city with character provisions matches data from the existing city. Then, in order to measure the welfare gain or loss from the character provisions, the spatial equilibrium in the absence of both the FAR restriction and amenities is computed, holding all else constant. The change in the welfare of the representative household can then be computed, either directly, or indirectly based on the change in the radius of the city.

We calibrate the model to Auckland, New Zealand, to assess the net welfare effects of character preservations currently in place in the city. Auckland is the largest city in New Zealand with a population of approximately 1.57 million within the greater metropolitan region (as of 2018 census). It is centred on an isthmus between two harbours and extends over 4,894 km^2 of land area, including several large inhabited islands. Since 2010, the entire metropolitan area, as well as several towns and a large amount of the rural land beyond the fringes of its outermost suburbs, has been under the jurisdiction of a single local government, the Auckland Council.

3.1 Institutional Background

In November 2016, the Auckland Council released the Auckland Unitary Plan (AUP) which relaxed land use regulation (LURs) in most of the city in order to enable residential intensification and greater population density, including allowing multi-family housing such as terraced housing and apartments. However, many areas of single detached family homes in the centre of the city were preserved. Many, but not all, of the single house zones within 5km of the CBD were retained and were also subject to a character area overlay (SCO). In 2021, the government announced the Medium Density Residential Standard (MDRS), which requires Auckland and other large cities to have a medium density default for residential zoning. Specifically, it requires the allowance of up to three dwellings and three storeys as of right, much like the existing Mixed Housing Urban (MHU) zone in the AUP. The MDRS allows character provisions to be retained, although it makes the conditions for retaining these more stringent. Auckland Council's proposed re-zoning in accordance with the MDRS retained approximately 71% of the houses covered by the AUP SCOs.[8]

Table 1 exhibits the LURs that apply in each of the zones retained under the proposed Auckland Unitary Plan that is compliant with the MDRS. SCOs apply to properties that are almost exclusively located in the single house zone. Thus the single house zone lists the LURs that apply to areas under an SCO.

[8] See Auckland Council Planning Committee Meeting 4 August 2022 Addendum, paragraph 21, p.8. Available from: https://infocouncil.aucklandcouncil.govt.nz/Open/2022/08/PLA_20220804_ATT_10162_PLANS.PDF, accessed 20 October 2022.

Table 1: Summary of Land Use Regulation by Residential Zone under the Unitary Plan

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

Notes: Tabulated restrictions are 'as of right' and can be exceeded through resource consent notification. Height in relation to boundary restrictions apply to side and rear boundaries. Less restrictive height in relation to boundary rules than those tabulated apply to side and rear boundaries within 20m of site frontage. Maximum dwellings per site are the number permitted as of right in the Unitary Plan. Minimum lot sizes do not apply to extant residential parcels.

*Planners have discretion in setting height in relation to boundary and setbacks in the large lot zone. The regulations "[r]require development to be of a height and bulk and have sufficient setbacks and open space to maintain and be in keeping with the spacious landscape character of the area".

SCOsimpose additional controls to those given in the single house zone. Restoring a building in a special character area to it's original form is a permitted activity 'as of right'. This means any required planning permission must be granted, provided building work meets the relevant building codes. However, additional planning consents must be sought in order to: demolish or change more than 30% of the building's area, make any minor exterior alterations that are not at the rear of a property, or construct a new building or ancillary unit. Theses activities are 'restricted discretionary', meaning consent may be granted or denied at the discretion of Auckland Council.

Factors that are considered in the decision include: whether all practical steps have been taken to retain and restore the original fabric and facade of the building; whether construction materials, styles, and building proportions are in keeping with the original building; and how the proposed development fits with the existing area, in terms of character, style, and scale of other buildings. This means that redevelopment can occur in SCAs, but typically it occurs at the back of the parcel, where it is less apparent from the road.

For ease of exposition, we will refer to Single House zoned areas that are also subject to an SCO as 'Special Character Areas' (SCAs).

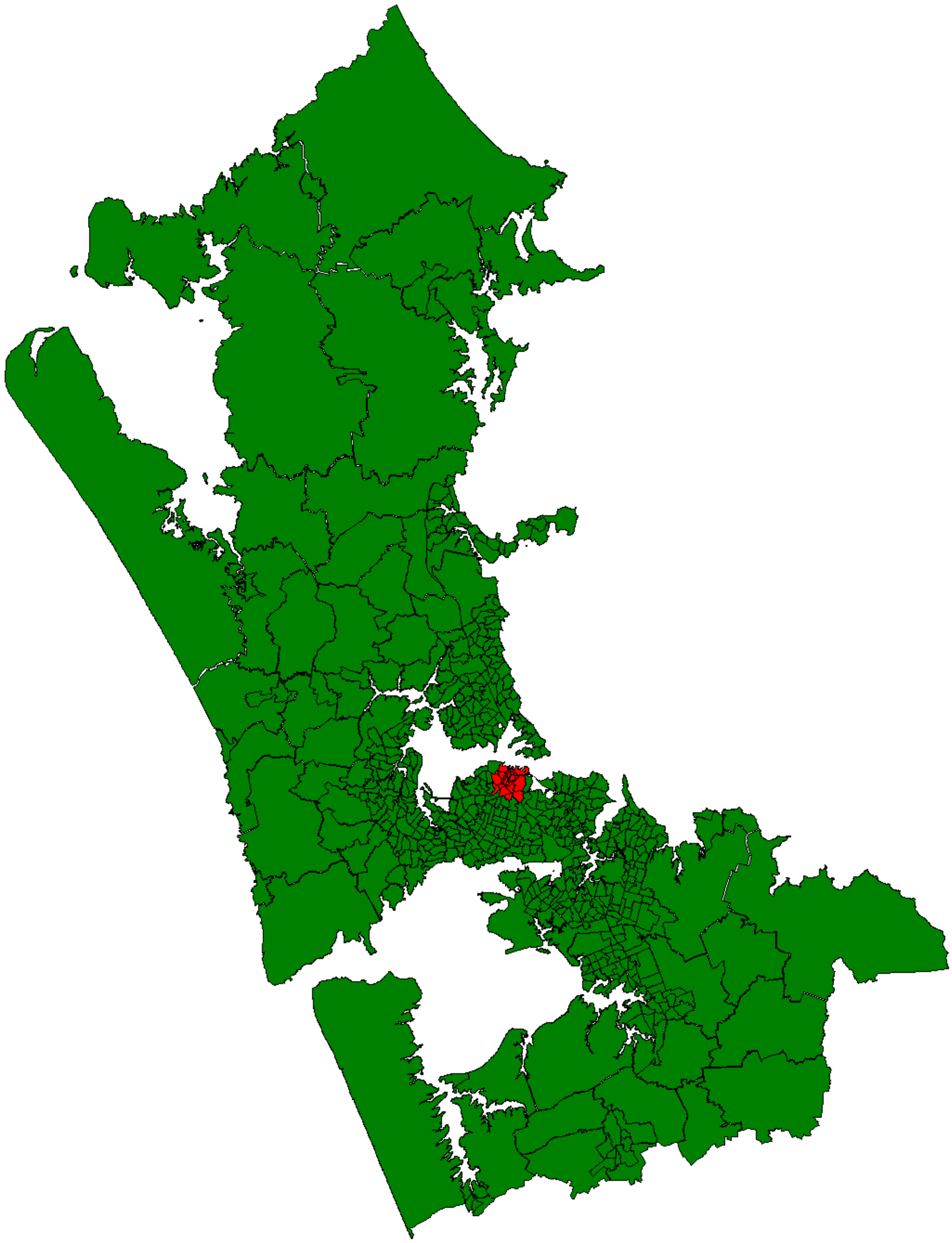
3.2 Monocentricity in Auckland

In this subsection we provide evidence of monocentricity in Auckland, in the sense that (a) workers generally commute towards the CBD, rather than away from it, and (b) wages by place of work generally decrease with distance to the CBD, so that, holding household location fixed, commuters are compensated for longer commutes with higher wages. For the purposes of these tasks, we define the CBD as the set of Statistical Areas (SAs) that lie within and adjacent to a ring of highways around the centre of the CBD.[9] [10] Figure 5 exhibits the CBD within the greater Auckland region.

[9] We use 2018 Statistical Area 2 units, which are refered to as 'SAs', throughout the paper. SAs contain 2000–4000 residents in cities such as Auckland.

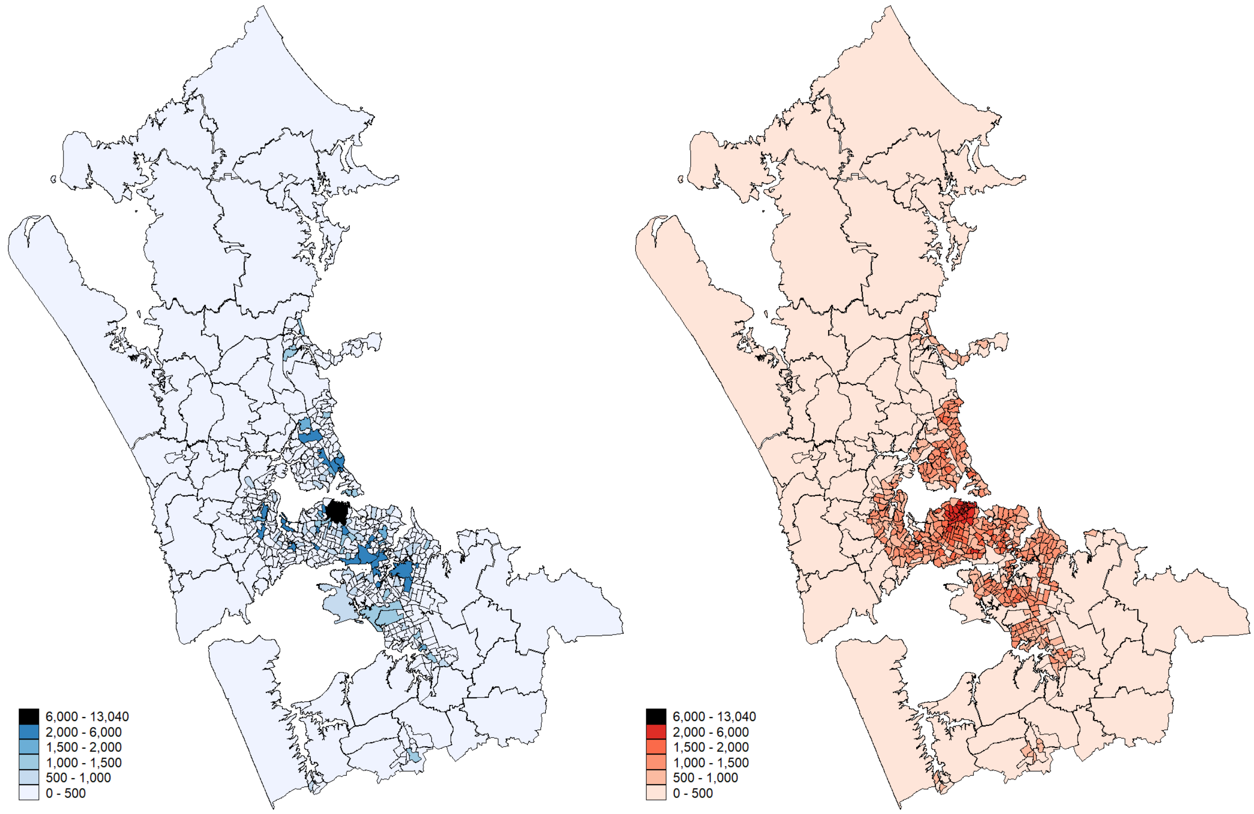
[10] This definition of the Auckland CBD is similar to that used in Maré (2008).

Figure 5: Auckland Region and CBD



Notes: CBD (red) and other areas of the Auckland region (green). Islands are excluded from the latter. The CBD is comprised of the following SAs: Anzac Avenue, Auckland-University, Eden Terrace, Freemans Bay, Grafton, Grey Lynn East, Hobson Ridge Central, Hobson Ridge North, Hobson Ridge South, Karangahape, Mount Eden North East, Newmarket, Parnell West, Quay Street-Customs Street, Queen Street, Queen Street South West, Shortland Street, Symonds Street East, Symonds Street North West, Symonds Street West, The Strand, Victoria Park, and Wynyard-Viaduct.

Figure 6: Population density by location of work and location of residence



Notes: This shows the total number of full and part time employed individuals per square kilometre by workplace location on the left and by worker home location on the right. Note that the colour scales used in each figure are identical. The scales are not linear.

3.21 Commuting Direction

Having defined the CBD, our first task is to determine commuting direction patterns to see whether workers generally commute towards the CBD. As a first pass, we examine the degree to which jobs and homes are concentrated in various regions of Auckland. Figure 6 exhibits the population density of employees by place of work and by place of residence. The left hand panel exhibits job density. Jobs are heavily concentrated in the CBD. Around the CBD there are several locations with moderate density.[11] The right hand panel exhibits employee population density by location of residence. Worker home locations are substantially more diffuse. Since the vast majority of employment is concentrated in and around the CBD, and workers live in a wide surrounding area, it makes sense that the majority of commuters commute towards the CBD.

[11] For readers familiar with Auckland geography, these are located in the suburbs of Penrose, Mt Wellington, East Tamaki, Takapuna, Albany, Wairau Park, Te Atutu, New Lynn and Henderson.

To test whether this is the case, we calculate the number of workers commuting towards the CBD using census data on commuter flows between SAs. For each SA i, we calculate the number of workers who commute towards the CBD as follows. First, the bearing is calculated between the centroid of SA i and the centroid of every SA j. For each bearing, we calculate the absolute angle of displacement between this bearing and the bearing of a commute to the CBD. The CBD bearing is taken from the centroid of i and the centroid of the Hobson Ridge North SA, which is the CBD region containing the 'Sky Tower', a central Auckland landmark and major piece of communications infrastructure. If j is a CBD SA, then we define the displacement angle to be 0 by default. Second, we assign the calculated displacement angle to all the commuters travelling between i and j.

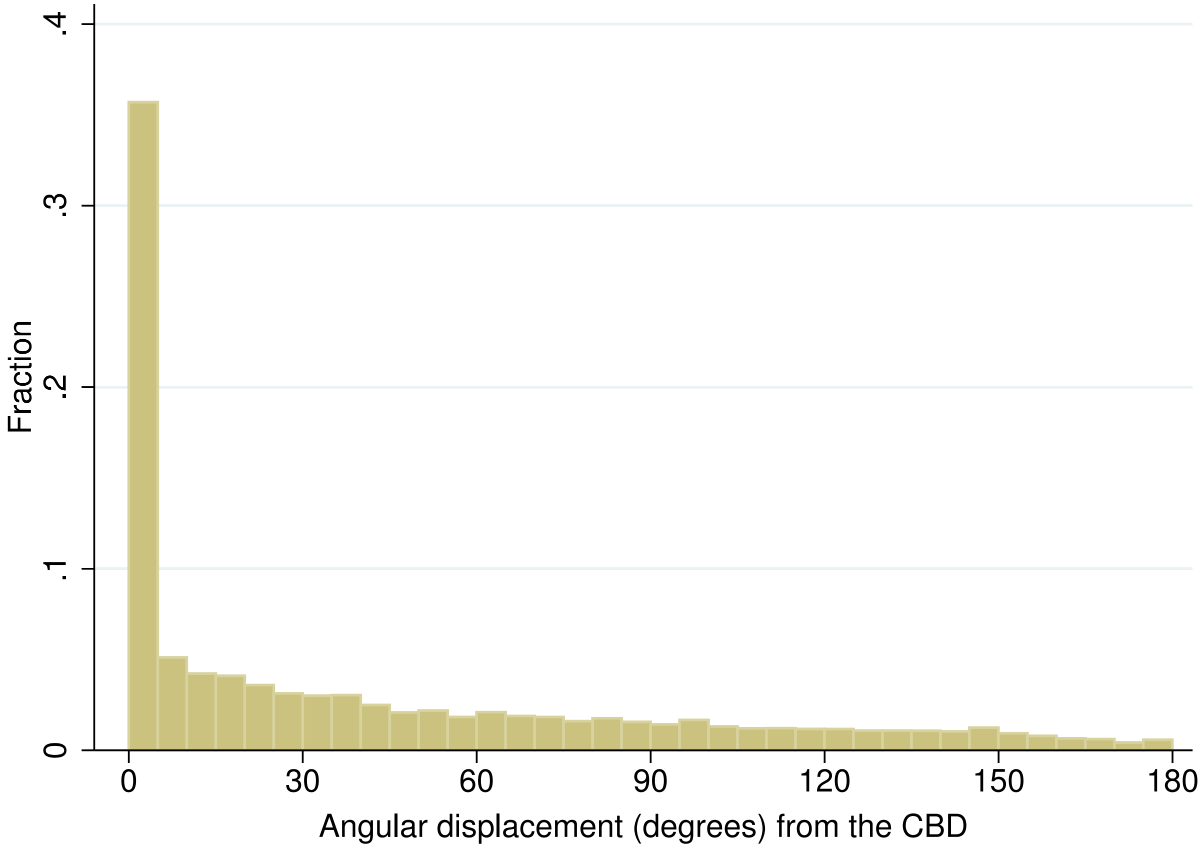
Table 2 and figure 7 display the results. The majority of commuters travel towards the CBD. Over 35% of commuters have a displacement angle between the direction of their commute and the direction of the CBD of less than 5 degrees. 56% of commuters have a displacement angle of less than 30 degrees, and only 19% have a displacement angle of greater than 90 degrees, indicating that they travel away from the CBD. These patterns provide strong evidence of monocentricity in Auckland.

Table 2: Proportion of Commuters travelling towards the CBD

Angular displacement from CBD (degrees)	Proportion of commuters	Cumulative Proportion
0 - 30	0.56	0.56
31 - 60	0.14	0.70
61 - 90	0.11	0.81
91 - 120	0.08	0.89
121 - 150	0.07	0.96
151 - 180	0.04	1.00

Notes: A displacement angle of 0 means the commute is directly towards the CBD, an angle of 180 is directly away from the CBD.

Figure 7: Commuting directions in Auckland



Notes: Histogram of the angular displacement between (i) the direction from place of residence to place of work and (ii) the direction between place of residence and the CBD. Each bin spans 5 degrees. People that work in the CBD are allocated a bearing differential of 0 degrees.

3.22 Wage Gradient

Our next task is to examine whether wages fall with distance between place of work and the CBD. The underlying intuition behind this posited relationship is that employers must compensate employees for longer commutes (Glaeser, 2008).

To do this, we calculate average wages by location, and plot this as a function of a measure of distance to the CBD. We refer to this function as the 'wage gradient'.

For average wages by location, we use median income for employees by SA. We use the median to reduce the impact of large outliers on the measure of average wages. These data are obtained from the 2018 census.

We use an estimate of commuting time between the centroid of the SA and the CBD as our measure of distance. We use commuting time for two reasons. First, transportation corridors, such as highways, have a significant impact of commuting times and housing development (Baum-Snow, 2007). Second, commuting times take into account of traffic congestion. As we show below, commuting times offer a much better model fit than physical distances. Both factors can dramatically affect the effective distance of a region from the CBD. Travel time is derived from google direction requests for the estimated travel time in traffic by private vehicle between the centroid of the SA region and the centroid of Hobson Ridge North.[12] Direction requests are made for a midweek commute in to the CBD, arriving at 9:00am, and a commute out on the same day, departing at 5:00pm. The travel time between a SA region and the CBD is given by the average duration of the two journeys.[13]

We calculate the wage gradient by regressing the median wage for workplaces located in an SA region on the time taken to drive between that region and the CBD. In order to account for the significant discrepancies in employment density between difference SAs, the regression function is weighted by the number of jobs in the SA. This means that the regression function is weighted towards observations that correspond to SAs with more jobs.

Figure 8 plots median wages against travel time in minutes from the CBD. The size of the markers corresponds to the relative number of people employed in each region. The wage gradient shows that wages decrease on average as the location of a workplace increases in distance from the CBD.

The largest circle in the top left of the figure corresponds to the CBD. Because the CBD comprises several SAs, we aggregate the contiguous SAs in the CBD into one observation.

Table 3 displays the regression analysis. Column (1) shows the regression with travel time as the explanatory variable. For completeness, we also include an alternative specification in column (2) which uses distance by road in kilometres instead of travel time[14]. The second specification displays poorer model fit, as shown by a substantially lower R-squared. This is likely because distance does

[12] Note that travel times via public transport are not considered for three reasons. First, and most importantly, for many SA regions there is no public transport option for travel to the CBD. Second, the majority of commutes in Auckland are in private motor vehicle. Third, the travel times by private vehicle are typically faster than public transport for most commuting routes.

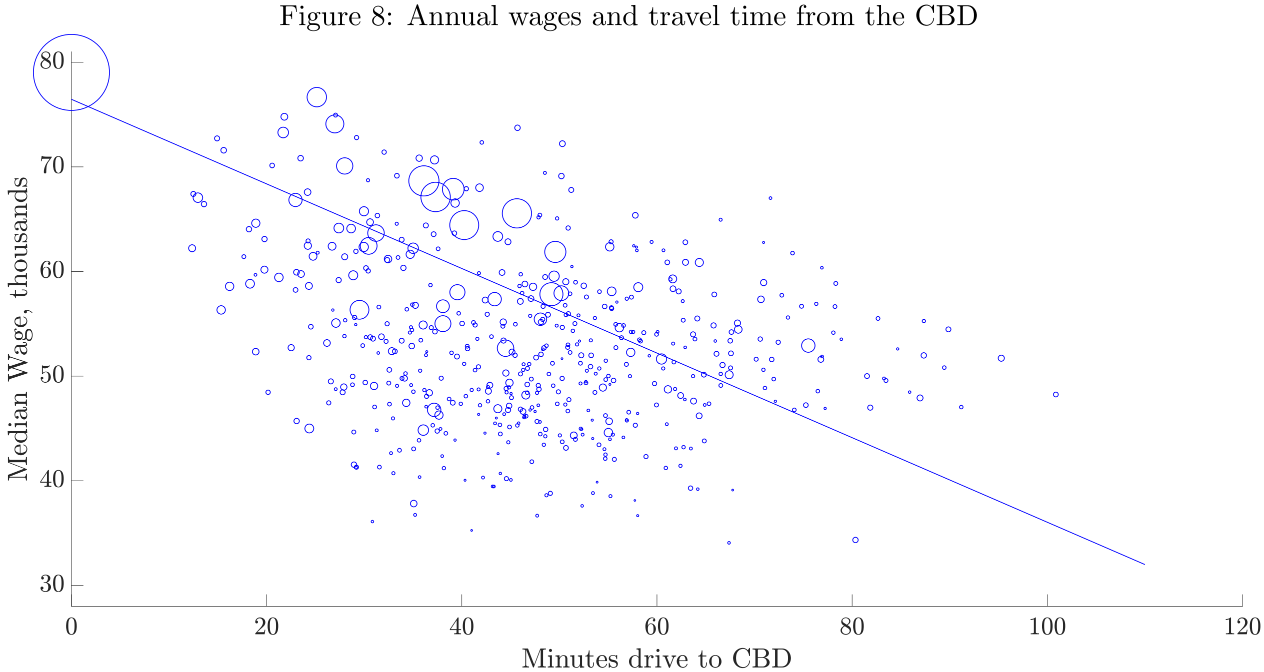
[13] Direction request are made using automated Google API calls for travel on 04/08/2021.

[14] Distance by road is also collected by the Google direction requests along with the time in traffic

not take account of variation in travel speeds to the CBD between locations that are equidistant form the CBD.

For use in the calibrated model, we convert the \$/minute coefficient from column (1) into a \$/km figure. This is achieved using the estimated average peak-hour road commute speed of 25km/h, which is derived from our commuting data. The estimated reduction in wages paid in workplaces located an additional kilometre away from the CBD is calculate in the final row of the table. This is substantially larger in magnitude than the figure estimated by the regression of road distance on median wage, suggesting that relying on measures of distance that ignore commute times will significantly understate the costs associated with commuting travel.

Figure 8: Annual wages and travel time from the CBD



Notes: The size of the circular markers corresponds to the number of people employed in each SA. Line of best fit is given by weighted OLS. Coefficients are tabulated in Table 3. Drive time is time in rush hour traffic.

Table 3: Regression analysis of median wages against drive time from the CBD

Variable	Median Wage (1)	Median Wage (2)
Constant	76,457***	70,831***
	(1,979)	(4,184)
Minutes drive from the CBD	-404.2***	
	(43.02)	
Distance by road from the CBD (km)		-492.9***
		(152.9)
Observations	521	521
R-squared	0.592	0.360
Implied change in $/km with road distance from the CBD	-$970.08	

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. The regressions are weighted by total employment in each SA. The average CBD wage is given by the constant in columns (1) and (2). The final row shows a conversion of the $/minute coefficient on minutes drive from the CBD from column (1) into a $/km figure using an estimate average commute speed of 25km/h.

3.3 Calibration

In this subsection, we calibrate the model to Auckland in order to quantify the welfares affects of the character provisions. We begin by discussing how we select modelparameters..

3.31 Parameters

We take a data-driven approach to selecting θ, the radians of the city disk. Auckland lies on an isthmus between two harbours. Consequently much of the area surrounding its downtown is not available for development. We estimate θ by calculating the land area within a carefully defined radius of the CBD. First, we aggregate the land area of all Statistical Area (SA) units with a centroid within 55km of the CBD.[15] This radius is selected as it extends to the South Eastern edge of the Auckland jurisdiction. Second, we remove the proportion of land devoted to roads, transportation and infrastructure corridors. The proportion of land relative to the area of a circle of 55km radius then yields our estimate of θ. This yields an estimate of 2.25 radians.

We perform a sensitivity analysis across a range of values for the parameters α (housing share in utility) and γ (capital share in housing production). The ranges adopted are informed by the related literature. Lees (2014) uses $\alpha = 0.175$ based on the average share of income spent on housing

[15]SA geographic units are designed for the purpose of collecting household information through the census and have populations of 2000-4000 residents in metropolitan areas.

services in New Zealand. In order to guard against the possibility that this share is low, we also consider $\alpha = 0.25$ and $\alpha = 0.325$, which correspond to one-quarter and almost one-third of income. Bertaud and Brueckner (2005), Kulish *et al.* (2012) and Lees (2014) use $\gamma = 0.6$. However, Combes *et al.* (2019) estimate $\gamma = 0.8$ for housing construction in France. We therefore consider values of $\gamma = 0.4, 0.6, 0.8$. Finally, following Kulish *et al.* (2012) we set $A = 0.0005$ (total factor productivity in housing production).

Amenity Parameter. We next consider the amenity parameter κ. A key outcome of the model is that there is a one-to-one mapping of floorspace differentials between dwellings in character protected areas and non-protected areas, and the magnitude of the amenity effect of the character provisions. This observation enables us to use a hedonic regression to obtain an estimate of κ,because a direct implication of the model is that homeowners are willing to accept a smaller house to live in a character neighbourhood. Hedonic methods that accurately price elasticities of special character areas and floorspace can be used to calculate the 'floor area equivalent' of the amenity value of living in a special character area as follows:

$$F_{SC} = \frac{E_{SC}}{E_F \left(1 - E_{SC}\right)}$$

where F_{SC} is the floor area equivalent (in percentage terms), E_{SC} and E_F are the price elasticities with respect to character protections and floor space respectively.[16] We then set $\kappa = (1 + F_{SC})^{\alpha} - 1$ so that the amenity value in character areas results in a F_{SC} percent reduction in floorspace in character areas under (7).

In order to estimate E_{SC} and E_F we fit a linear hedonic regression to a sample of individual log house prices using an array of individual attributes as explanatory variables. House prices are obtained from the June 2021 Auckland Council ratings valuations (RVs). These are used to calculate property taxes and are estimated every three years based on property characteristics and local sales information. RVs also contain additional information on housing attributes that are used as explanatory variables in the regression. Our set of explanatory variables include: an indicator for whether the property is in a special character area; the (log) floorspace of the dwelling; an

[16] Nunns *et al.* (2015) uses a similar hedonic approach to estimate the relative trade-off between preserving a character building and allowing redevelopment.

indicator for whether the individual property is subject to additional heritage-listing development restrictions; and the log of the total land area. In order to distinguish between the SCA and whether there is a premium or discount associated with owning a house from the early 20th century, in some specifications we include an indicator for whether the house was built prior to 1940.[17] We also consider a larger set of regressions that also include: an indicator for if the property has a deck; the combined number of off-street and garaged parking spaces; an indicator for whether the walls and roof are in 'good' condition as opposed to 'average', 'poor' or 'mixed'; an indicator for whether the land parcel is 'level' as opposed to having a 'medium' or a 'steep' gradient; an indicator for whether the property has an appreciable view; and the total number of secondary school zones covering the property. We follow Ahlfeldt and Maennig (2010), Heintzelman and Altieri (2013), and Bade *et al.* (2020) and control for any unobserved locational or neighbourhood using local area fixed effects (based on SAs). We also account for spatial dependence in house prices by adopting Conley (1999) standard errors

SCAs almost exclusively cover areas zoned for single housing. Our sample is comprised exclusively of houses located in the single house zone in order to ensure that the estimated coefficient on the SCA indicator is based on a comparison of houses in SCA areas to houses that otherwise share equivalent development rights. Housing in higher density zones – such as MHS, MHU or THAB – are a less plausible counterfactual because properties in these zones have substantially enhanced development rights. We also exclude any property with zero land area recorded from the sample. These properties generally refer to cross-lease properties or unit titles, such as apartments, which do not have exclusive land rights. We also exclude vacant land, any property not recorded as being used for residential purposes, and any property valued at greater than $10M. The latter generally represents residential institutions such as nursing homes or communal housing. We exclude properties that have missing explanatory variables. Many are missing the decade of construction.[18] Refer to the Appendix for the regression results.

We find that the SCA elasticity E_{SC} ranges from between 0.037 and 0.006, and depends, in particular, on how the model controls for the epoch of the house.

Excluding the pre-1940 indicator, the SCA premium is 0.037 in the smaller model and 0.033

[17] Nunns *et al.* (2015) uses a similar indicator to identity properties with heritage amenity.

[18] This represents ~13,000 property records out of ~80,000 properties that meet all the other criterial listed

in a larger model. This means that, holding all else constant, a house located in an SCA sells for approximately 3.3 to 3.7% more, on average, to an identical house not located in an SCA. These estimated premia are similar in magnitude to those found by Fernandez and Martin (2020) and Bade *et al.* (2020). Together with an elasticity on floorspace between between 0.418 and 0.397, these premiums imply $F_{SC} = 0.09$ (2 d.p.). A typical property owner in a special character area with 140m^2 of floorspace would be willing to forgo their special character protection if it allows them to gain at least 12.6m^2 of additional floor area.

However, once the pre-1940 indicator is included in the regression, the SCA elasticity falls to 0.022 in the smaller model and 0.017 in the larger model – while the coefficient on the pre-1940 indicator is 0.058 and 0.065 in the small and large model, respectively. The latter coefficients are highly significant, while the SCA coefficients lose significance. Thus it appears that houses built before 1940 command a premium.[19] Since many houses in SCA areas were built prior to 1940, it is critical to control for the epoch of construction.

Finally, we also include the interaction of the pre-1940 and SCA indicators, which further reduces the SCA premiums to 0.008q in the small model and 0.006 in the large model, while the coefficient on the interactions is significant and 0.027 in the small model and 0.021 in the large model. This suggests that the premia on a pre1940s property is higher when it is located in an SCA. In these specifications, we sum the coefficients on the SCA indicator and the interacted SCA indicator (yielding 0.035 and 0.027 for the small and large models) when constructing F_{SC}. Thus we are comparing a pre-1940s house in an SCA to a pre-1940s house not in an-SCA that are otherwise identical when calculating the amount of floorspace a home owner is willing to forgo to live in a character area. Together with the floor area elasticities, this yields $F_{SC} = 0.09$ or 0.07 (2 d.p.) for the small and large model . If we instead compared a house built after 1940 located in an SCA to a house built after 1940 in a non-SCA, we obtain $F_{SC} = 0.02$ for both the small and large models.

We therefore use a range of values for F_{SC} between 0.02 and 0.09 in our calibration exercise.

3.32 Data

We obtain household income for commuters that work in the CBD from the wage regressions presented above in subsection 3.2. The intercept tells us the average income in the CBD. We use

[19] These estimates are are similar in magnitude to premia on pre1940s properties estimated by Nunns *et al.* (2015) based on earlier property data for Auckland.

$76,500 for this figure. We multiply this by 1.35, which is the average number of workers per household in Auckland (Lees, 2014).

We obtain a figure from the rental price of agricultural land using REINZ data on farm sales between January 2011 to December 2016. We take the average sales price per hectare over this period from the two regions surrounding Auckland – Northland and Waikato. This yields an average price per hectare of $20,000. This equates to a rental price of $80,000 per km^2 under a capitalization rate of 4%.

We obtain a per km commuting costs based on the wage regressions presented above in subsection 3.2. The slope coefficient tells us the decrease in wages when a worker shortens their commute time by one minute. This reduction in wage is equal to their commuting cost under the observational equivalence argument put forward by Glaeser (2008). We covert the travel cost per minute into a travel costs per km using the average commuting speed in Auckland. Commuting speeds to the CBD are estimated using weighted averages of private vehicle speed to the CBD, derived from automated google direction requests for time in traffic for peak-hour travel, with weights determined by the commuting patterns in the 2018 census.

The 2018 census includes the commuting mode, home location (SA), and workplace location (SA) of employed individuals aged 15 years or older (including full-time, part-time, and self-employed individuals). From this dataset we identify the number of workers in each SA in the Auckland region that commute to a CBD SA using private vehicles. This yields the proportion of to-CBD commuters in each SA in the Auckland region.[20] For each SA-to-CBD-SA commute, we assign a commute speed using estimated private vehicle speeds from google direction requests. Automated Google Directions API calls are made for route-finding between the GPS coordinates of the centroids of pairs of SA regions. We set the AM commute to arrive before 9am and the PM commute to leave after 5pm.[21] This yields an average speed in traffic of 25km/h. Combining this with the regression coefficient from subsection 3.2 above yields a commuting cost t=$950/km.

[20] We exclude car commuters than live in the CBD and commute to the CBD when calculating these proportions.

[21] Note that, while Google travel time estimates are not available for past dates, the contemporary travel estimates are based on historical travel times. Direction request are made for travel on 04/08/2021.

3.33 FARs and Annulus Sectors

Finally, we also require a method to assign annulus sectors to different zones. We then assign FAR restrictions to each zone as implied by the LURs in 1.

To assign annulus sectors to different zones, we calculate the proportion of residential land assigned to each zone at distances from the CBD spanning 0 to 70km. We then fit a smoothed function to these proportions that serves as the basis for assigning zones to annulus sectors.

We use 2018 SAs as the geographic unit of analysis for calculating these proportions. For each SA we calculate total area of land assigned to each zone, and the Manhattan distance from the centroid of the SA to the CBD. We then calculate the proportion of land assigned to each zone within 5km of the CBD, 5-10km of the CBD, 10-15km of the CBD, and so forth.[22] We then fit a smoothing spline to the proportions, with the smoothing parameter set to the commonly used value of $1/(1 + (5^3)/6)$, using the mid points of the 5km bins as the explanatory variable.

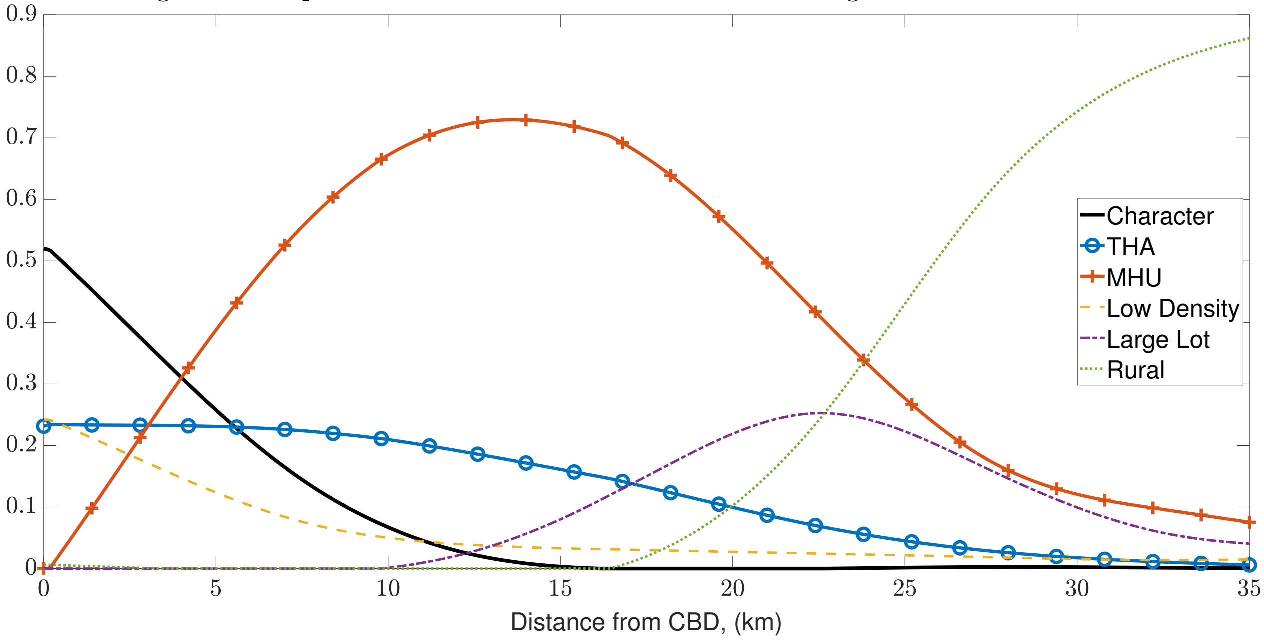
We expand the set of zones from the three zones discussed thus far to include two additional zones: *Large Lot* and *Rural*. Large Lot (LL) is a residential zone used at suburban fringes of the city. Its LURs are also tabulated in Table 1, and demonstrate that it is a very low density residential zone. For the purposes of this exercise, we include rural zones within residential land because commuters can live in dwellings on rural land, albeit in dwellings with significantly lower capital intensities than those built in residential areas due to even more restrictive LURs. Allowing residents to commute in from rural zones is important because urban growth boundaries have been found to constrain urban growth in Auckland (Grimes and Liang, 2009). Excluding these zones from the analysis would significantly bias the increase in floorspace capacity upwards.[23]

The results shown in figure 9 demonstrate how a large proportion of Auckland's real-estate falls under special character protections. According to the smoothed function, over 50% of land very near the CBD falls under a SCO. In contrast, less than 25% of the area is zoned for maximum intensity as terrace houses and apartments (THA). The remaining land is zoned mixed housing urban, which permits greater density than SCO following the MDRS. The proportion of SCO decreases with

[22] These calculations are based on GIS databases of the 2016 Unitary Plan but with the 'Mixed Housing Suburban' areas re-assigned to be MHU in order to model the effects of the MDRS. Although Auckland Council has released maps of re-zoning to meet the MDRS (under 'plan change 78'), GIS databases were not available at the time of writing. Although there was a reduction in SCAs under plan change 78 to the Unitary Plan, approximately 71% of houses retained the SCO.

[23] We include the Unitary Plan "Future Urban" zone in Rural and the "Hauraki Gulf Islands" zone in Large Lot.

Figure 9: Proportion of Residential and Rural Land assigned to different Zones



Notes: Smoothed proportions of each zone by Manhattan Distance from the CBD. 'THA' is a high density urban zone (FAR = 2.5) and 'MHU' is a medium density zone (FAR = 1.35). 'Low Density' refers to zones designed for detached simgle family dwellings (FAR = 0.7). 'Large Lot' is a peri-urban zone with very low density.

distance to the CBD while the MHU category increases to almost 70% of all land at 10km from the CBD. THA remains at a relative constant proportion of all land. level From 10km+, the proportion of rural and large lot zones begins to increase, and the MHU proportion decreases, along with THA.

Using these functions we can assign each annulus sector in a gridded disc to a zone. We use 100 sectors and set increments in the annuli to 100 metres.

FAR restrictions in each zone are taken as the site coverage ratio multiplied by the number of storeys permitted under the maximum height provision. We assume that two storeys are permitted under Single House Character Zones, three under MHU, and 5 in THA. Taken with the site coverage ratios tabulated in Table 1 above, this means that $\hat{h}_j$ is 0.7 in character areas, 1.35 in MHU, and 2.5 in THA. The Large Lot and Rural zones lack binding site coverage ratios, so we cannot use this approach to model FARs in these zones. We instead use the empirical FARs given in Greenaway-McGrevy (2022), which yields an $\hat{h}_j$ of 0.2 in LL and 0.02 in rural.

3.4 Results

In this section we present results from the calibration exercise. Following Bertaud and Brueckner (2005) our primary measure of representative household welfare is the change in income for a household that is located at the edge of the city. Their change in income is straightforwardly given by the change in city radius multiplied by t (travel cost per km). For each urban resident, the welfare cost of the FAR restriction equals the increase in commuting cost for this edge resident (Bertaud and Brueckner, 2005). We express this change in income as a percentage of average household income. Table exhibits the results across a range of values of α, γ and F_{SC}.

The welfare effects from removing character restrictions and upzoning are positive across all parametrizations considered. However, there is substantial variation around the size of the positive effect, ranging from 1.32% down to 0.32%. Given the (average) household wage of \$103,275 = \$76,500 $\times$ 1.35 for workers in the CBD, this equates to between \$330 and \$1368 per year.

Welfare gains are increasing in α since representative household welfare depends more on the quantity of housing services as α grows larger. Welfare is also decreasing in F_{SC}, since larger values of F_{SC} imply greater amenity benefits from protections. Finally, note that welfare gains are increasing in γ. As γ increases, the land becomes more productive (in terms of floorspace capacity), and thus restraints on productivity entail larger welfare losses.

Table 4: Welfare Impacts of Removing Character Protections and Upzoning to Medium Density

	$F_{SC} = 0.02$			$F_{SC} = 0.055$			$F_{SC} = 0.09$		
γ	α			α			α		
	0.175	0.25	0.325	0.175	0.25	0.325	0.175	0.25	0.325
0.4	0.4238	0.5869	0.7209	0.3796	0.5436	0.6795	0.3197	0.4849	0.6235
0.6	0.8223	0.9898	1.1286	0.8058	0.9735	1.1129	0.7838	0.9518	1.0919
0.8	1.0587	1.2242	1.3248	1.0482	1.2155	1.3179	1.0344	1.2040	1.3087

Notes: Table entries are percent increases in average household income for households living at the boundary of the city. α denotes housing share in utility. γ denotes capital share in housing production. F_{SC} denotes floorspace elasticity with respect to character area. Amenities from living in character areas are increasing in F_{SC}.

4.0 Discussion

This paper presents a version of the monocentric AMM model to study the welfare impacts of character protections. Within our framework, character protections present a trade-off between welfare-increasing amenities and welfare-decreasing redevelopment restrictions. The overall effect of protections is therefore ambiguous. Welfare effects become negative when their attendant FAR restrictions are sufficiently binding. This is likely to be the case when character provisions are applied to neighbourhoods that have high demand due to their proximity to other (non-character) amenities or job centres.

The trade-off makes it difficult to accurately assess the welfare effects of character protections in practice.In order to get some idea of the direction of these welfare effects in the case of Auckland, we calibrate the model using a plausible range of parameter values, finding that character protections have negative welfare effects that are equivalent to a reduction in average household income of between $330 and $1,1,368 per year.

The absentee landlord AMM model measures welfare based on income flows, so that localised amenities affect representative household utility via an increase in population density in the affected suburbs. If increases in density are prevented via regulation, then there are no positive ongoing welfare effects from locational amenities: Although the residents gain utility from living in suburbs with amenities, in equilibrium this is exactly offset by a utility loss from higher housing rents, and the amenity benefits are captured exclusively by the landlord. By the same token, landlords also bear some of the costs of development restrictions via lower land rents.

In practice many residents own the property they occupy. The model could also be used to make predictions about the welfare effects of locational amenities for landowners by focussing on wealth rather than income. Under the plausible assumption that housing rents are capitalised into house prices, policies that generate positive local amenities will be reflected in higher house prices. Thus it is resident property owners *at the time the policy is announced or implemented* that experience an increase in wealth via a capital gain. Residents that purchased their property after the amenity was created are made no better off by the policy because the value of the amenities are capitalised into house prices. In the case of character protections, a reduction in the wealth of incumbent households due to lower land prices under redevelopment restrictions would also have to be considered when assessing the total wealth effects of the policy.

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A Appendix

1.1 Alonso-Muth-Mills Model

Our smodel follows Bertaud and Brueckner (2005). Households have preferences described by

$$U\left(C,H\right)=C^{1-\alpha}H^{\alpha},\ \alpha\in\left(0,1\right)$$

where C is the consumption numeraire (price set to unity) and H is housing floorspace. Their budget constraint is

$$C=W-tx-P\left(x\right)H$$

where x denotes the distance of their house to the CBD, t is the per distance cost of commuting, and $P\left(x\right)$ is dwelling rent at distance x. Travel costs t are comprised of a pecuniary cost g and an opportunity cost of time $\upsilon\times W$ for some $\upsilon\in(0,1]$, such that $t=g+\upsilon Ws^{-1}$, where s is the speed of commute.

Housing floorspace H is produced using capital K and land L as

$$H\left(K,L\right)=AK^{\gamma}L^{1-\gamma},\ \gamma\in\left(0,1\right)$$

where L is land and K is capital K. Because production is constant returns to scale, we can define housing per unit of land as

$$h=\frac{H}{L}=A\left(\frac{K}{L}\right)^{\gamma}=Ak^{\gamma}$$

where $k=K/L$ is the capital to land ratio. Developer profits per unit of land are then

$$P\left(x\right)h\left(k\right)-p_{K}k-R\left(x\right)$$

where $R\left(x\right)$ is per unit land rent at x. Developers profit-maximise and earn zero profits. Under these assumptions, h, H and k depend on distance to the city centre x, and are henceforth denoted as $h\left(x\right)$, $H\left(x\right)$ and $k\left(x\right)$.

Three equilibrium conditions solve the standard model without restrictions on $h\left(x\right)$. First, utility is equalized at all locations x. Second, land rent at the edge of the city $\bar{x}$ is equal to exogenous agricultural rents $\bar{R}$, $R(\bar{x}) = \bar{R}$. Finally, the city population N fits into the area of the city, $\int_0^{\bar{x}} \theta h(x) / H(x) x dx = N$, where we normalize one worker per dwelling.

In equilibrium, utility, dwelling prices and floorspace depend only on $\bar{x}$. Equilibrium utility $\bar{U}$ is given by

$$\bar{U} = \frac{\alpha^{\alpha}\gamma^{\alpha\gamma}A^{\alpha}(1-\gamma)^{\alpha(1-\gamma)}(W-t\bar{x})(1-\alpha)^{(1-\alpha)}}{\bar{R}^{\alpha(1-\gamma)}p_K^{\alpha\gamma}}$$

Then by solving for the Hicksian demand functions we have

$$P(x) = \frac{(W-tx)^{\frac{1}{\alpha}}(1-\alpha)^{\frac{1-\alpha}{\alpha}}\alpha}{\bar{U}^{\frac{1}{\alpha}}} \tag{8}$$

and

$$H(x) = \frac{\bar{U}^{\frac{1}{\alpha}}}{(W-tx)^{\frac{1-\alpha}{\alpha}}(1-\alpha)^{\frac{1-\alpha}{\alpha}}} \tag{9}$$

$h(x)$ and $R(x)$ can then be solved for in each zone $k = 1, \ldots, m_z$ using the zero profit condition and the restriction on $h(x)$ that applies in each zone.

1.2 Hedonic Regression

Table 5: Hedonic Regression

Variable	(1)	(2)	(3)	(4)	(5)	(6)
SCA (=1)	0.037	0.022	0.008	0.033	0.017	0.006
	[0.006]	[0.006]	[0.007]	[0.006]	[0.006]	[0.007]
	(0.024)	(0.022)	(0.024)	(0.024)	(0.022)	(0.023)
Pre-1940 (=1)		0.058	0.038		0.065	0.050
		[0.003]	[0.005]		[0.003]	[0.005]
		(0.007)	(0.011)		(0.006)	(0.010)
SCA×Pre-1940 (=1)			0.027			0.021
			[0.006]			[0.006]
			(0.014)			(0.013)
HHE (=1)	0.113	0.103	0.104	0.107	0.096	0.097
	[0.007]	[0.007]	[0.007]	[0.007]	[0.007]	[0.007]
	(0.030)	(0.031)	(0.030)	(0.029)	(0.030)	(0.029)
log(Floor Area)	0.418	0.422	0.422	0.397	0.398	0.398
	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]
	(0.010)	(0.010)	(0.010)	(0.011)	(0.011)	(0.011)
log(Land Area)	0.218	0.215	0.216	0.224	0.221	0.221
	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]
	(0.012)	(0.011)	(0.011)	(0.012)	(0.012)	(0.012)
Appreciable view (=1)				0.037	0.037	0.037
				[0.002]	[0.002]	[0.002]
				(0.007)	(0.007)	(0.007)
Deck (=1)				0.010	0.009	0.009
				[0.002]	[0.002]	[0.002]
				(0.002)	(0.002)	(0.002)
Walls and roof in good condition (=1)				0.039	0.043	0.043
				[0.002]	[0.002]	[0.002]
				(0.004)	(0.004)	(0.004)
Level site (=1)				0.049	0.048	0.048
				[0.002]	[0.002]	[0.002]
				(0.008)	(0.008)	(0.008)
Off-street and garage parking spaces				0.005	0.007	0.007
				[0.001]	[0.001]	[0.001]
				(0.002)	(0.002)	(0.002)
Number of school zones				0.041	0.042	0.042
				[0.004]	[0.004]	[0.004]
				(0.019)	(0.020)	(0.020)
Observations	66,663	66,663	66,663	66,663	66,663	66,663
R-squared / Adj. R-squared	0.88 / 0.88	0.88 / 0.88	0.88 / 0.88	0.89 / 0.89	0.89 / 0.89	0.89 / 0.89
AIC	-47,744	-48,122	-48,138	-49,644	-50,135	-50,144
BIC	-45,631	-46,000	-46,007	-47,476	-47,958	-47,958

Notes: All specifications include SA fixed effects. SCA, Pre-1940 and HHE are indicators for: houses located in special character areas; houses built prior to 1940; and houses that are protected by heritage restrictions on demolitions and alterations, respectively. The reference group is a house not in an SCA built in 1940 or later. The dependent variable is log of the council valuation of house price. Classical standard errors are in [] brackets. Conley (1999) HAC robust standard errors are in () parentheses. Our preferred specification based on AIC and BIC is shown in column (6).