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**Article:**

Costello, G., Leishman, C., Rowley, S. et al. (1 more author) (2019) Drivers of spatial change in urban housing submarkets. *Geographical Journal*. ISSN 0016-7398

<https://doi.org/10.1111/geoj.12303>

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# Drivers of spatial change in urban housing submarkets

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Spatial urban housing submarkets are now widely used constructs. Recent housing market modelling strategies have emphasised the need for flexibility in modelling approaches in order to best accommodate submarkets which account for spatial variations in hedonic prices. But this raises important unanswered questions concerning the stability of submarket structures over time, and the role of housing market dynamics in breaking down or shifting submarket boundaries. The influence of new supply, in particular, may have a stabilising or destabilising effect on differences in hedonic prices, depending on the wider housing market context. In this paper we examine the temporal influence of new supply, intra-urban migration and socio-economic change as a means of understanding the impact of key drivers of submarket boundary change. Using the Greater Perth region of Western Australia as a case study, we estimate income elasticities of demand for housing services that vary spatially within the urban area. We find evidence that higher income elasticities, new development, socio-economic change and intra-urban migration are associated with changes in the spatial structure of housing prices within the metropolitan housing market.

## KEYWORDS

housing stock, spatial change, stability of housing markets, urban housing submarkets

## 1 | THE NATURE OF INTRA-URBAN HOUSING MARKET SPATIAL SUBMARKET CHANGE

The notion that many urban housing markets are spatially and/or structurally segmented has now been empirically tested so thoroughly that it is no longer contested. It has become a working assumption for many housing economists, market analysts, and policy-makers (Kyriakidis, 2017; Rae & Sener, 2016). Submarkets arise where spatial clustering of close substitute housing units within an otherwise heterogeneous housing market combines with inelastic demand for specific housing attributes that are not ubiquitous within the urban area (Grigsby, 1963; Leishman, 2009; Maclennan & Tu, 1996; Watkins, 2001). Land use policies have an important impact on the supply, price, and the price elasticity of housing units and their underlying locational and amenity attributes (Locke et al., 2017; Poudyal et al., 2009). In one of the first empirical studies of housing submarkets, Schnare and Struyk (1976) used the example of inelastic household demand for location within the catchment area of a good school. Maclennan and Tu (1996) suggested that other housing attributes, such as historic stone-built construction methods or large private gardens in central urban housing neighbourhoods, are so difficult to replicate in contemporary housing markets that demand for these may become relatively price inelastic. The combination of spatially clustered heterogeneous housing attributes and segmented, price inelastic demand

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for the attributes, can give rise to spatial discontinuities in housing attribute prices (implicit or hedonic prices) across the urban area.

As mentioned, these arguments are now familiar and generally accepted in the housing economics literature. The circumstances surrounding the creation of spatial housing submarket boundaries are well understood (see Watkins, 2012), and the literature is also advancing in its understanding of determinants of the volatility of housing systems over time (see Costello, 2014; Holmes et al., 2019). However, we know much less about the circumstances leading to the breaking down, redefinition, and reconfiguration of the boundaries of spatial housing submarkets over time which have important implications for market analysis (see Meen, 2016, for a very full overview of the state of the art in spatial housing economics).

The focus of this paper is on exploring change to the spatial housing submarket structure over time and, in particular, the question of what drives these changes? Although statistical approaches to identifying spatial housing submarket structures have become more sophisticated, this has arguably come at the expense of deepening our understanding of the drivers of change in the urban housing system's structure (Watkins, 2012). Why might the boundaries of spatial urban housing submarkets change, and why might this matter from the viewpoint of housing policy-makers? Grigsby (1963) argued that spatial urban housing submarkets are likely to be in a constant state of flux, the underlying rationale being that variations in the hedonic prices of housing attributes within the urban area cannot persist in the long run. Jones et al. (2003, 2004) argued that differential levels of new supply and internal migration within cities should ensure that differences in hedonic prices between neighbourhoods (submarkets) do not persist in the long run. They found some evidence that intra-urban migration breaks down spatial submarket boundaries, but in the case of new supply they found that the supply of development opportunities, that is, development land, was generally higher in the lower-priced submarkets of their Glasgow case study. They concluded that new supply can reinforce, rather than break down, spatial submarket boundaries. However, in the absence of a larger evidence base exploring a range of spatial economic and institutional contexts, it is not clear whether this finding is generalisable or merely a product of the long history of deindustrialisation, and the subsequent significant urban renewal response led by the public sector, in that specific study area. It is entirely possible that the role of new supply in mediating price differentials between submarkets may differ in other urban contexts. Thus, there are still remaining questions unanswered in the applied literature.

In addition to intra-urban migration, or “spatial arbitrage,” and differential new housing supply, submarket boundaries may break down or shift over time as a consequence of other factors such as changes in tastes and preferences, or the relative desirability of different housing and neighbourhood attributes. This might arise from significant socio-economic or demographic change in urban neighbourhoods that are located on or near the boundaries of areas previously found to be urban housing submarkets. This may also be a product of urban policy interventions that serve over time to recast the role played by neighbourhoods in the housing system (Bates, 2006; Kauko, 2018; Leishman & Watkins, 2017). Another potential source of spatial change within urban housing markets relates to the relationships between cities and their hinterlands. This is presently of particular policy interest in an Australian context, where this case study is set, and where many of Australia's capital cities are increasingly being seen as unaffordable to workers in low-paid jobs. The Australian government has questioned whether spatial mismatch between low-income housing and low-income employment opportunities could have a knock-on impact to economic productivity (Productivity Commission, 2015). This has led to the Australian government questioning whether satellite cities might play a more important role in providing affordable housing to low-income capital city workers (van den Nouweland et al., 2016). If low-income capital city employees are increasingly relocating and commuting to their workplace, this raises questions about the impacts on both the extent of the market and the internal spatial structure of urban housing markets and submarkets.

This paper, thus, seeks to explore the drivers of submarket change. It draws on evidence from Australia that is significant in its own right but is also intended to allow comparison with findings from other international market contexts and to add to the international evidence base on submarket dynamics. The paper has four further sections. In the next section, we seek to review the existing applied literature on submarket dynamics and the drivers of submarket change. The review highlights variations in findings and in methods applied. We note that there is little explicit discussion within the literature of the underlying conceptual framework for these analyses. We set out the multiple equilibrium model used here and, in that context, set out the likely drivers of submarket change. This informs the research design discussed in the third section. Here, we explain the analytical framework employed, discuss the methods used, and describe our data sources. In the fourth section, we present the key finding and discuss their implications. The final section offers some brief conclusions and reflects on the wider conceptual and policy implications of the analysis.

## 2 | ANALYSING SUBMARKET CHANGE

Although the literature on submarket change is far less voluminous than that which offers static analysis of submarket boundaries, as we note in the introduction there has been a long recognised need to take account of submarket dynamics in market and policy analysis (Galster, 1996; Grigsby, 1963). In recent years, we have seen a modest increase in the number of empirical studies of submarket dynamics. These studies have different motivations, use varied methods, and offer varying conclusions.

Jones et al. (2003), for example, questioned whether a combination of household moves within the urban area, plus differential new housing supply between submarkets, might act to break down submarket boundaries over time. They hypothesised that price differentials between submarkets would be eroded through a process of spatial arbitrage. They allowed for the possibility that the arbitrage process would be enacted individually or in combination by households relocating to take advantage of lower prices for housing service, and/or developers increasing supply in high-price (and high-profit) submarkets. They concluded that the system of spatial submarkets they examined (in Glasgow, UK) was remarkably stable over time. There was little evidence of arbitrage processes impacting on spatial price structures. They pointed out that opportunities for developers to purchase land and develop housing were much more abundant in the city's cheaper spatial submarkets. By contrast, the more expensive city centre and west end submarkets were associated with much lower levels of housing development activity. The spatial pattern of housing development opportunities therefore acted to reinforce historic price differences and segmentation between neighbourhoods or submarkets within the city.

In a subsequent and related piece of work, Jones et al. (2004) explored the number and direction of household moves between a system of six spatial submarkets in Glasgow during a single year between the mid-points of 1991 and 1992. Their hedonic analysis, and well-rehearsed application of Chow and weighted standard error tests, suggested that only four spatial areas could be considered as having passed these standard tests for spatial submarkets. One of these four areas was formed by amalgamating three neighbourhoods previously found to be independent spatial submarkets in the initial statistical test, but no longer able to pass the independence test in the new study. Interestingly, the analysis of migration data revealed a high degree of self-containment within the three constituent parts of this “collapsed” submarket. The authors concluded that the standard tests for spatial submarkets may, at times, be misleading and that care was required in interpreting evidence of cleavages in the price surface in static models.

Since the early 2000s, empirical studies of housing submarkets have sought to improve the rather crude statistical methods used historically to define and test for submarkets. Goodman and Thibodeau (1998) were among the first to suggest a more disaggregated and bottom-up approach to defining submarkets. They suggested beginning with small core neighbourhoods that are very likely to be submarkets, then building up these areas by adding small spatial units to each based on the behaviour of hedonic coefficients. Leishman (2009) reviews a number of similar studies involving attempts to impose more flexible spatial structures to hedonic models of urban housing prices. This includes the use of  $x$ ,  $y$  coordinates interacting with housing attributes (Fik et al., 2003; Pavlov, 2000) and his own use of the multi-level modelling, again applied to Glasgow. The latter approach, he argues, can be used to reveal the changing spatial structure of the submarket system by allowing hedonic estimates to vary (estimated as random effects) at a finely grained spatial scale within submarkets and the housing market overall (see also Keskin & Watkins, 2017; Keskin et al., 2017 for an application to Istanbul).

In this context, Leishman et al. (2013) focused specifically on the predictive accuracy of several alternative approaches to accommodating the spatial submarket structure in hedonic analysis based on an analysis of Perth, Western Australia. They found that the Hedonic Multi-Level Model (HMLM) had the lowest mean prediction error compared with the standard city-wide ordinary least squares (OLS) hedonic model, and a segmented model based on real estate agents' definitions of submarkets. However, this finding held only when the multi-level model was defined with the smallest spatial unit available (postcodes, rather than the much larger real estate agents' spatial areas). The authors also noted in their conclusions that the flexible hedonic modelling strategies put forward by Pavlov (2000) and Fik et al. (2003) remain untested with respect to standard and spatially segmented hedonic models, or to the multi-level model.

In addition to their headline findings, the empirical analysis put forward by Leishman et al. (2013) is of interest simply by virtue of being based on a relatively young and rapidly expanding Australian city. The behaviour of the hedonic models and submarket structure appear quite unlike those demonstrated in earlier studies of British housing markets (mainly Glasgow) where their economic history leaves a clear imprint on the operation of markets (Meen et al., 2016). In particular, the explanatory power of even the simple city-wide OLS hedonic models was very high after accounting for distance from the Central Business District (CBD) and neighbourhood dummies. The analysis also revealed significant differential rates of price change between neighbourhoods/submarkets, suggesting much more fluid submarket structures than found in earlier

studies of Glasgow, perhaps hinting at either more mobile households or significant spatial variation in the population and household growth rates.

We would contend that another of the weaknesses of the existing applied literature is that there has been a lack of specificity about the underlying theoretical basis for submarket existence and, by extension, a lack of clarity about the variables that are likely to drive dynamic change. As Watkins (2012) explains, those who employ submarkets as a key analytical construct in their analyses of the housing system tend to offer a rationale that is explicitly or implicitly based on one of three broad theoretical frames. First, there is a general equilibrium approach (Ball & Kirwan, 1977; Fletcher et al., 2000). In this framework, the analyst recognises that there are spatial variations in constant quality prices. They include submarket dummies to capture these but do not allow for variation in other attribute prices as these are viewed to have been set at the market-wide or general equilibrium level. Spatial differences that are not captured by the variables that seek to explain differences in neighbourhood or locational attributes are seen as transitory and will be eroded over time by spatial arbitrage. As discussed above, this is the conceptual model that Jones et al. (2004) sought to test. Second, there is the general disequilibrium approach (Maclennan, 1982). This theoretical stance is based on the assumption that long-run equilibrium is elusive. Submarkets arise as a result of the interaction between segmented market demand, where households have extremely heterogeneous preferences, and a highly fragmented housing stock, characterised by a wide variety of product types. The complexity of the market, information asymmetries, and spatial rigidities on the supply and demand sides of the market mean that there is a pervasive mismatch between the consumer demand and supply of different product types and this gives rise to a highly spatially differentiated price surface. The underlying assumptions about rationality, common in mainstream equilibrium theories, mean that this model cannot be operationalised using conventional econometric methods. Typically, analysts have sought to use institutional modes of analysis to explore market dynamics where disequilibria are thought to be pervasive (see Watkins, 2008 for an overview). Third, there is a multiple equilibrium model (Goodman & Thibodeau, 1998). This perspective suggests that the housing system is made up of a set of quasi-independent submarkets, each of which will tend towards equilibrium. The submarket-specific equilibria condition allows for the possibility that attributes might achieve different equilibrium prices in different parts of the market (for example, the value of parking space might differ between central and suburban market segments). Significantly, the multiple equilibrium framework allows for the possibility that submarket prices might adapt to new equilibrium positions over time and, importantly, that this change can be explained and modelled using probabilistic econometric analytical techniques.

In the empirical part of this paper, we assume that the housing system is characterised by multiple equilibria. Consequently, we recognise that new equilibrium positions will be established at different points in time. In line with the evidence summarised above, these positions will be established as the system adapts to changes in tastes and preferences, demographics and the economy, and also as the stock is modified, through new build, redevelopment, and as a result of ageing and depreciation. As these adaptations take place, it is possible that the number and configuration of submarkets might change. Thus, our analysis seeks to explore the drivers of submarket change and to understand the impact that these have in reshaping submarkets as the system transitions between different multiple equilibrium solutions.

### 3 | RESEARCH QUESTIONS, METHODOLOGICAL APPROACH, STUDY AREA AND DATA

In this paper, we address a gap in knowledge about housing submarket dynamics in several steps. We start by exploring whether spatial urban housing submarket boundaries shift over time. The second stage seeks to assess the role of several drivers of such change: new housing supply, intra-urban migration, and differential rates of socio-economic change within the urban area. We also propose an additional innovation by asking whether the income elasticity of demand for housing services varies geographically within cities, and whether this might explain shifts in spatial housing submarket boundaries.

#### 3.1 | Modelling approach

Many previous studies of spatial housing submarkets have used a priori boundaries as a starting point for the analysis – boundaries of market areas as defined by real estate agents, for example (Watkins, 2001). More recently, the literature has emphasised methods that either deal with spatial variation in prices directly within the modelling framework (Fik et al., 2003; Leishman et al., 2013; Pavlov, 2000), or by beginning with no pre-conceived notion of the spatial structure of the housing market (Leishman, 2009). In this paper we opt for the latter, and do this by operationalising the HMLM used by Leishman (2009), allowing a selection of the most statistically important hedonic parameters to vary spatially:



$$P_{ij} = \alpha + \sum_k \beta_k X_i + \sum_j \mu_{0j} + \sum_j \sum_k \mu_{kj} X_i + \varepsilon_i \quad (1)$$

where  $P_{ij}$  is the log of transaction price of the  $i$ th dwelling in the  $j$ th spatial area (suburb);  $\mu_{0j}$  is the random intercept for the  $j$ th suburb; and  $\mu_{kj}$  represents the random slope parameters for the  $k$  attributes, specific to the  $j$ th suburb.

We use as our case study the Greater Perth region of Western Australia (Perth). This allows a comparison of the results with an earlier study by Leishman et al. (2013), but the main advantage in using data for an Australian city is that we are better able to explore the role of socio-economic change and new-build housing supply in the dynamics of housing submarket boundaries than in previous studies based on British cities. This is because Perth has a relatively modern dwelling stock, with little variation in building methods or materials (traditionally single-storey, double-brick construction). The region is very low density, even by Australian standards, with around 75% of total stock being defined as stand-alone (detached) housing (Australian Bureau of Statistics, 2016). The remaining stock is split between apartments and semi-detached/terrace/townhouse products. Much of the limited housing diversity exists within inner urban areas in close proximity to the CBD, with outer areas consisting almost exclusively of detached dwellings. The region is therefore fairly free from issues such as the spatial clustering of historical, non-replicable housing attributes that affect most British cities. The planning system is also much more permissive than in the UK, with substantial stock change possible through demolition and redevelopment, or “knock-down and rebuild” processes (see Pinnegar et al., 2010; Wiesel et al., 2013). It is common for a standard size lot from the 1980s of around 700 m<sup>2</sup> containing a detached dwelling to be subdivided into two dwellings. The change is usually from one single-storey dwelling to two double-storey detached houses. The rate of demolition is around 10%–12% of new housing supply in a given year (Housing Industry Forecasting Group, 2017), with much of that demolition concentrated within inner areas. The region underwent significant economic growth between 2006 and 2013, the result of a rapidly expanding resources sector, particularly exports of iron ore. This resulted in very high rates of employment, population and income growth, at least for those involved in the resources sector, and new housing development.

The choice of case study allows us to explore whether the findings from previous analyses of European cities, where the evidence suggests that the imprint of their economic histories and prominent urban renewal activities are generalisable to other global contexts. Perth is a city which extends around 150 km north to south but heavy industry is clustered into a small number of defined locations. Therefore, the region does not have significant tracts of post-industrial land or a history of urban renewal policy interventions. Given the concentrations of industrial land, most suburbs are simply a mix of residential dwellings with neighbourhood retail centres, outside those contained in the few dedicated sub-regional retail centres. Some suburbs have a light industrial component but these are few and far between, located around the key road networks, the two airports, and ports. The context of new housing supply is therefore very different, being characterised largely by consumers purchasing land and then engaging a project home builder to deliver a dwelling. Large national developers concentrate on land subdivision, apartment development, and commercial projects. Perth provides an alternative test of the role of new supply in shifting housing submarket boundaries.

For the reasons just outlined, a logical prior expectation would be that the Perth housing market might have a more fluid set of spatial submarket boundaries than those found in the British cities that have been explored extensively in the existing literature. Greater household mobility, very strong population growth, a more flexible planning system, a development industry dominated by land subdivision rather than built-form product, high levels of new supply by international standards (Rowley et al., 2017), and continuing urban expansion should lead us to expect that spatial arbitrage may play a much stronger role in market dynamics, shifting submarket boundaries over time. The analysis therefore concentrates on identifying spatial submarket boundaries in two cross-sections, and then identifying possible change to those boundaries between those cross-sections. We then examine whether areas of significant submarket boundary movement relate to migration within the urban area, change in spatial patterns of socio-economic and demographic variables, and differential rates of new housing supply. To accomplish this, we proceed as follows.

First, we establish whether the boundaries of spatial submarkets in the Greater Perth region are likely to have changed over time, and since the study described by Leishman et al. (2013). This is facilitated by deploying the multi-level hedonic model shown earlier. This is estimated for two time periods, 2011 and 2016 – these being chosen to allow the examination of related five-yearly census data in one strand of the analysis. We then assess the stability of hedonic prices at small area level (suburbs) between the two time periods. By carrying out the analysis for the two time periods chosen, we are able to identify suburbs that appear to have moved from one spatial submarket to another.

Second, we examine the wider housing market context of those suburbs that have experienced significant change in hedonic prices between census years. Specifically, we examine the scale of change to the housing stock between census

years, change in the Index of Relative Socio-economic Advantage and Disadvantage (IRSAD), and the degree of migratory self-containment between censuses.

The third step introduces an innovation to the housing submarkets literature. Following the methodology proposed by Rosen (1974) and refined by Zabel (2004), we use the outputs of our hedonic model (1) to estimate the price of a constant-quality bundle of housing services. By virtue of the suburb level price premia derived from the HMLM, our estimates of the price of housing services varies within the metropolitan housing market area. This permits us to model the demand for housing services as shown in Equation 3. The derivation of the price of housing services at suburb level is shown as Equation 2. This involves the prediction of the market price of a fixed bundle of hedonic attributes, including the suburb-specific constant or fixed effect, and expressing as an index.

$$p_j = \frac{\exp(\alpha_{0j} + \alpha_{1j} \ln \bar{X}_1 + \alpha_{2j} \ln \bar{X}_2 + \dots + \alpha_{kj} \ln \bar{X}_k)}{\exp(\alpha_{01} + \alpha_{11} \ln \bar{X}_1 + \alpha_{21} \ln \bar{X}_2 + \dots + \alpha_{k1} \ln \bar{X}_k)} \quad (2)$$

$$\ln H_i = \beta_0 + \beta_1 \ln p + \beta_2 \ln y_i + \beta_3 \ln z_i + \varepsilon_i \quad (3)$$

where  $p_j$  is the index of the price of housing services in the  $j$ th suburb;  $\alpha_{0j}$  is a constant (fixed effect) for the  $j$ th suburb;  $\alpha_{1j}$  is a coefficient (implied attribute price) for the first (etc.) hedonic attribute in the  $j$ th suburb;  $\bar{X}_k$  is the population mean or modal value of the  $k$ th hedonic attribute;  $H_i$  is the quantity of housing services consumed by the  $i$ th household;  $p$  is the price of housing services;  $y$  is the income of the  $i$ th household;  $z$  is the vector of personal and household attributes driving consumption of non-housing services.

The data used to estimate Equation 1 are provided by Landgate (the Western Australia Land Information Authority). This dataset includes all residential transactions in the state for 2011 and 2016. The geocoded data include sale price, transaction date, and a range of property attributes including floor area, land area, rooms, property type, and several others. Descriptive statistics for the two annual samples are provided in the next section.

Following the empirical estimation of (Equation 1), the hedonic index is created by multiplying out the hedonic coefficients, as described by Zabel (2004). This creates a constant-quality predicted property value for each suburb in each of the two time periods. The specification of the hypothetical dwelling is set as the mean or modal values of each of the attribute variables for 2006 and are assumed to be unchanged in 2011.

Finally, Equation 3 is estimated using Australian census data which have been generated using the Australian Bureau of Statistics TableBuilderPro. Naturally, census data cannot be used to reveal information about individuals, but it is possible to generate finely grained information about household composition, expenditure on housing costs, and household income for very small cells (the average cell size in this instance is 5.7 households). There are 25 weekly income ranges beginning at \$1–150 through \$8,000 and above, and 18 monthly mortgage repayment cost ranges beginning at \$1–149 through \$5,000 and over. Together with simple information on household composition (single adult, single parent, couple with children, couple without children), and a geographic identifier (suburb) the information was used to build a simple dataset of 32,260 observations. Using the suburb variable, the constant quality hedonic index for 2016 was then added. Finally, the index of consumption of housing services was imputed by capitalising the monthly mortgage cost variable, assuming a 30-year mortgage at the prevailing 4% mortgage rate, then dividing by the hedonic index. This generates a measure of consumption of housing services which can then be regressed on the remaining, explanatory, variables. Counts of households in each cell range from 3 to 117, with a mean of 5.7, and are used as frequency weights in the regression.

## 4 | EMPIRICAL RESULTS

Table 1 sets out descriptive statistics for each of the variables defined in Equations 1–3. The first estimations follow the specification shown in Equation 1. The HMLM is estimated city-wide and includes the familiar physical attribute variables used commonly in the literature (see Malpezzi, 2003). Land area and internal floor area are measured separately for strata and non-strata<sup>1</sup> properties. The squared values of land area, house area, rooms, and age are also entered to account for non-linearity, and these quadratic terms are all statistically significant. The specification also includes the ratio of bathrooms to bedrooms – a variable known to be a powerful predictor based on previous work. In fact, the common term used for a detached house in Perth is the  $4 \times 2$ , that is, four bedrooms and two bathrooms. The coefficients of these variables are estimated as fixed effects, and can be interpreted as hedonic prices that hold across the market.

**TABLE 1** Descriptive statistics for key estimation variables

|  | Mean     | Standard deviation | Mean    | Standard deviation |
|--|----------|--------------------|---------|--------------------|
| <b>Hedonic model</b>                     |          |                    |         |                    |
| Log sale price (\$AU)                    | 13.146   | 0.414              | 13.231  | 0.438              |
| Land area (m <sup>2</sup> ; not strata)  | 684.312  | 179.920            | 667.445 | 190.071            |
| Land area (m <sup>2</sup> ; strata)      | 282.122  | 79.765             | 282.193 | 79.062             |
| House area (m <sup>2</sup> ; not strata) | 163.573  | 55.107             | 171.977 | 55.602             |
| House area (m <sup>2</sup> ; strata)     | 120.414  | 21.295             | 122.280 | 24.865             |
| Rooms                                    | 8.917    | 2.343              | 9.039   | 2.268              |
| Age (years)                              | 24.775   | 20.940             | 26.843  | 22.025             |
| Cars                                     | 1.473    | 0.741              | 1.551   | 0.736              |
| Ratio baths/beds                         | 0.498    | 0.175              | 0.520   | 0.188              |
| Distance – CBD                           | 14.335   | 12.957             | 14.572  | 13.087             |
| <i>N</i>                                 | 25,669   |                    | 25,391  |                    |
| <b>Housing services demand</b>           |          |                    |         |                    |
| Monthly income (\$AU)                    | 2,641.19 | 1,323.02           |         |                    |
| Monthly mortgage costs (\$AU)            | 2,263.99 | 982.90             |         |                    |
| Children                                 | 0.447    | 0.497              |         |                    |
| Single                                   | 0.255    | 0.436              |         |                    |
| Single parent                            | 0.020    | 0.141              |         |                    |
| Housing services index                   | 2.29     | 0.958              |         |                    |
| <i>N</i>                                 | 32,260   |                    |         |                    |

Four variables are chosen as random effects – an intercept, house area (measured separately for strata and non-strata properties), squared house area, and number of rooms. Apart from the intercept term, these variables were chosen because they are the most important predictors in the city-wide model. By including them as random effects, the model allows the parameters of these attributes to vary across the city or, more precisely, between suburbs.

The top portion of Table 2 (from “constant” through to “Quarter 4”) summarises the hedonic coefficients for the 2011 and 2016 data. The multi-level model is estimated using Stata's `xtmixed` command, with the hedonic parameters being treated as fixed effects – analogous to hedonic coefficients obtained from an OLS estimation. The next seven lines (each row beginning with “sd” ...) provide a summary of the variance within the random effects estimates. The coefficients themselves are not shown in the table, but are produced within the dataset as fitted values after estimation. For this reason, it is not possible to carry out a meaningful comparison between the random effects parameters in the two time periods as shown in Table 2. However, it is clear from the inter-suburb mean values of the random effect estimates that there is considerable spatial variation within the hedonic prices of the chosen attributes. These should be interpreted in conjunction with the city-wide hedonic coefficients but, in general, the results are confirmatory of prior expectations and contain few surprises. For example, housing prices rise with respect to floor area, land area, the number of bedrooms, and the ratio of bathrooms to bedrooms. Most of the quadratic effects are significant and negative, suggesting that prices rise at a decreasing rate with respect to the presence of these attributes – floor area, land area, and the ratio of bathrooms to bedrooms. The number of bedrooms has a negative coefficient, and its quadratic is positive. This suggests that the price of dwellings rises at an increasing rate with the addition of more bedrooms. With regards to locational variables, we can see that distance from the CBD has a significant and negative relationship with housing prices. This is interesting given that location is, to an extent, controlled through the multi-level random effects variables which account for suburb-level price premia and differences in the chosen set of hedonic coefficients.

The results shown in Table 2 provide a clear suggestion that hedonic prices vary spatially within the Greater Perth housing market. In a similar analysis of the Glasgow housing market, Leishman (2009) combined small area hedonic coefficients with *x*, *y* co-ordinates in cluster analysis in order to construct spatial clusters that might be thought of as submarkets in the sense that they were spatially concentrated, though not necessarily contiguous, and areas of homogeneity in hedonic



**TABLE 2** Results of the city-wide HMLM estimations

| LN_SALE        | 2011 coefficient |           | 2016 coefficient |           |
|----------------|------------------|-----------|------------------|-----------|
| Constant       | 11.76929         | **        | 11.84344         | **        |
| f_strata       | -0.3482823       | **        | -0.3730561       | **        |
| LandNS         | 0.0001685        | **        | 0.0001539        | **        |
| LandNS sq      | -1.45E-08        |           | -8.97E-09        |           |
| LandS          | 0.0003614        | **        | 0.0003356        | **        |
| LandS sq       | -2.56E-07        | **        | -2.63E-07        | **        |
| AreaNS         | 0.0054036        | **        | 0.0061909        | **        |
| AreaNS sq      | -3.37E-06        | **        | -5.39E-06        | **        |
| AreaS          | 0.0087995        | **        | 0.0086137        | **        |
| AreaS sq       | -0.0000127       | **        | -0.0000113       | **        |
| Age            | -0.0042422       | **        | -0.0046316       | **        |
| Age sq         | 0.0000669        | **        | 0.0000653        | **        |
| Rooms          | -0.0421292       | **        | -0.0586469       | **        |
| Rooms sq       | 0.000402         | **        | 0.0011264        | **        |
| BthBedRatio    | 0.1703863        | **        | 0.189198         | **        |
| BthBedRatio sq | -0.0376048       | **        | -0.0622417       | **        |
| Car spaces     | -0.0072821       | **        | -0.0108297       | **        |
| Car spaces sq  | 0.003131         | **        | 0.004149         | **        |
| Swimming pool  | 0.0364483        | **        | 0.0415291        | **        |
| DistanceCBD    | -0.001579        | **        | -0.0012873       | **        |
| DistanceCBD_2  | -0.0000517       | **        | -0.000022        | *         |
| Quarter 2      | -0.009575        | **        | -0.013031        | **        |
| Quarter 3      | -0.0209333       | **        | -0.0173641       | **        |
| Quarter 4      | -0.0185838       | **        | -0.0233471       | **        |
| sd(constant)   | 0.1793753        | 0.0114099 | 0.1853068        | 0.0115211 |
| sd(RoomsN)     | 0.0130557        | 0.0011234 | 0.0128955        | 0.017638  |
| sd(RoomsN_2)   | 0.0003654        | 0.0001057 | 0.0003238        | 0.0007148 |
| sd(AreaS)      | 0.0012054        | 0.0000823 | 0.0008477        | 0.0011369 |
| sd(AreaNS)     | 0.0008003        | 0.0000453 | 0.0007757        | 0.0009662 |
| sd(LandS)      | 0.0002481        | 0.0000206 | 0.0002656        | 0.0003698 |
| sd(LandNS)     | 0.0001251        | 8.76E-06  | 0.0001184        | 0.0001548 |
| LR test        | 29,678.77        | **        | 26,127.64        | **        |
| Wald $\chi^2$  | 32,244.65        | **        | 31,534.31        | **        |
| N              | 25,669           |           | 25,391           |           |

\*\*Significant at 1%. \*Significant at 5%.

attribute prices. The structure of Perth's spatial submarkets is already well researched using Real Estate Industry of Western Australia (REIWA data) (Costello, 2000; Costello & Watkins, 2002). More recently, Leishman et al. (2013) further demonstrated that sub-regions defined by REIWA are a good proxy for spatial housing submarkets. The HMLM provides sufficiently finely grained empirical detail that it is possible to observe change in hedonic prices at small spatial scales without the need to construct competing combinations of possible spatial submarkets and laboriously test these. Figures 1 and 2 summarise the spatial patterns of the first multi-level hedonic attribute – the suburb level price premium – in 2011 and 2016. The white areas on the map reflect insufficient data due to a lack of residential transactions within the suburb (the suburb might be dominated by a geographical feature such as a river, a water catchment area, or an alternative land use such as an airport).

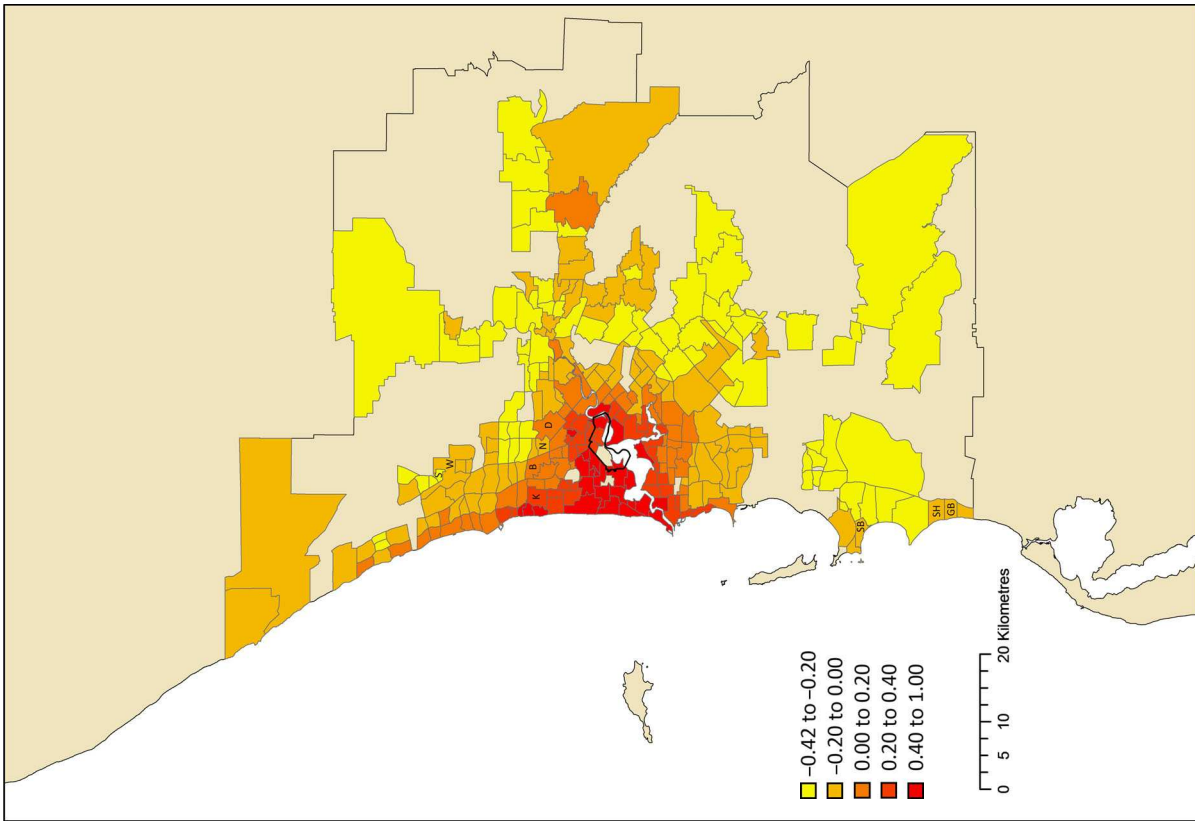


FIGURE 1 Spatial pattern of suburb clusters in 2011.

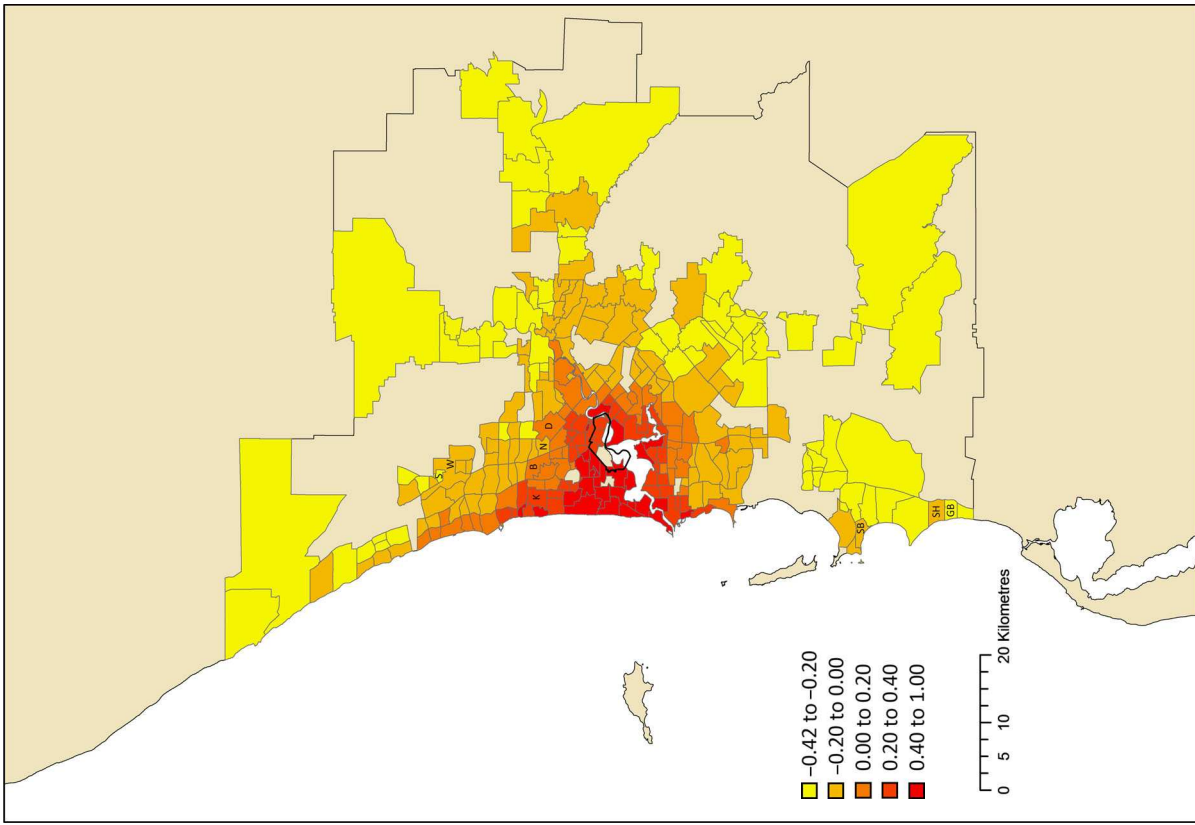


FIGURE 2 Spatial pattern of suburb clusters in 2016.

A visual inspection of the maps reveals that a number of suburbs in a ring around the city centre appear to have reduced in price relative to elsewhere in the city (shown as orange in Figure 1, and yellow in Figure 2). These include Balcatta, Nollamara, Dianella, Karrinyup just to the north of the CBD, and Sinagra and Wanneroo towards the northern periphery of the region (denoted B, N, D, K, S, and W on the maps). There are fewer suburbs with a reduction in hedonic price to the south of the CBD, and those that are affected tend to be around the city of Rockingham, 45 km away. These include Safety Bay, Golden Bay, and Secret Harbour, areas that have seen rapid supply expansion in recent years (denoted SB, GB, and SH on the maps).

The location and spatial pattern of suburbs with a significant hedonic price change relative to elsewhere in the region are, of course, not particularly easy to detect from a visual inspection of maps, but they provide useful context. Table 3 sets out some additional descriptive statistics, focusing on migration, housing stock change, and change in socio-economic profile of suburbs between census years. Of course, it is important to note that some of the variables chosen are necessarily reductionist – particularly the IRSAD which, as a measure of deprivation, will almost certainly mask other important changes such as in neighbourhood amenity, crime rates, school quality, to mention just a few. Statistics are provided for three groups of suburb: those in which hedonic prices were stable between the two estimations, those that show some evidence of change (defined as between 5% and 10% change in constant quality price), and those with 10% or greater price change. Although these definitions of price (in)stability are arbitrary, the descriptive statistics yield some interesting patterns. Migration-based self-containment is perhaps the least interesting in that it shows only marginal differences between the three categories of suburb, although the proportion of migrants coming from overseas is notably lower in the suburbs that witnessed the greatest price change. Unlike the other statistics shown in Table 3, self-containment based on migration activity is only available at the local government area (LGA) spatial scale, which is a higher unit of geography than the suburb definitions used.

What is more striking is that suburbs associated with greater (i.e., positive or negative) relative price change also had significant change in the housing stock between census years. Suburbs in which prices were stable saw an average stock change of 232 dwellings, while those associated with high levels of price change experienced a change in housing stock of 384–398 dwellings. The suburbs with a 10% or higher change in average price levels stand out clearly as areas in which new development is adding considerably to a housing stock that was relatively small in the 2011 census; that is, these areas are rapidly expanding in size and amenity. Finally, the data on income and the index of relative socio-economic advantage and disadvantage (IRSAD) also reveal interesting spatial patterns. Suburbs with significant (i.e., over 10%) price change between census years are also associated with a reduction in average household income, and an average shift downward of nearly one decile in terms of the socio-economic advantage measure. This pattern of results seems to suggest that households migrating to suburbs with newly developed housing opportunities, which were largely concentrated in the outer areas of Greater Perth and generally more affordable than inner regions, have lower incomes and are less advantaged than those already resident in such locations.

The final step in the analysis is the estimation of the constant-quality housing services demand function. The multi-level hedonic estimates summarised in Table 2 are used to construct a constant-quality hedonic price index which varies at suburb level (there are 348 suburbs in the Greater Perth region). As discussed earlier, the Australian census for 2016 was used to produce a nested table in which median income and median mortgage costs were derived for each combination of household type (single, single family, childless couple, couple with children) and suburb. By capitalising mortgage costs using the median mortgage rate assuming 30-year terms, and expressing these relative to the

**TABLE 3** Potential drivers of absolute price change

|                            | Hedonic price change |         |       |
|----------------------------|----------------------|---------|-------|
|                            | <5%                  | 5%–<10% | ≤10%  |
| Migratory self-containment | 62.3%                | 61.4%   | 63.7% |
| Overseas migrants          | 5.1%                 | 5.4%    | 3.4%  |
| Average stock change       | 232.4 dwellings      | 397.6   | 383.5 |
| Average % stock change     | 13.5%                | 18.1%   | 67.8% |
| Average income change      | –2.1%                | 2.5%    | –7.5% |
| Average IRSAD change       | –0.19 deciles        | –0.14   | –0.82 |
| Number of suburbs          | 178                  | 57      | 11    |

**TABLE 4** Housing services demand estimation results

| Variable      | Coefficient |           |
|---------------|-------------|-----------|
| Constant      | 1.042357    | **        |
| LN(Income)    | 0.3702974   | **        |
| Single        | 0.0318029   | **        |
| Single parent | -0.0174041  | *         |
| Children      | 0.1209408   | **        |
| sd(_cons)     | 0.6505722   | 0.0298771 |
| sd(l_income)  | 0.0802260   | 0.0037829 |
| sd(residual)  | 0.4244944   | 0.0006742 |
| LR test       | 14,112.79   | **        |

\*\*Significant at 1%. \*Significant at 5%.

suburb level hedonic index, a measure of housing services consumption was derived. This was then regressed on income and household characteristics. Our approach is similar to that followed by Ermisch et al. (1996) who estimated income elasticities of demand for six British cities (see also Goodman, 1988; Zabel, 2004). The equation might be enriched by including permanent, in addition to transitory, income, and a wider range of household characteristics, but expanding the table structure further than described was not permitted under the Australian Bureau of Statistics data license. The results of the multi-level housing services demand estimation are shown in Table 4, and the mapped results in Figures 3 and 4.

The estimation results suggest a city-wide income elasticity of demand for housing services of 0.37. However, there is considerable variation between suburbs, according to the first random effect. When the multi-level model is used to predict income elasticity for each suburb, the estimates range from  $-0.21$  to  $0.82$ , with a mean of  $0.33$  and median of  $0.34$ . Figure 3 shows the spatial pattern of income elasticities. It also indicates the location of suburbs in which hedonic prices changed by  $\pm 5\%$  or more between census years (these suburbs are identified by the appearance of a dot at their centroids). Figure 4 reveals the location of suburbs whose prices changed by  $10\%$  or more (also shown by suburb centroid dots). The thematic mapping itself, that is the shading of state suburbs, refers to income elasticity of demand.

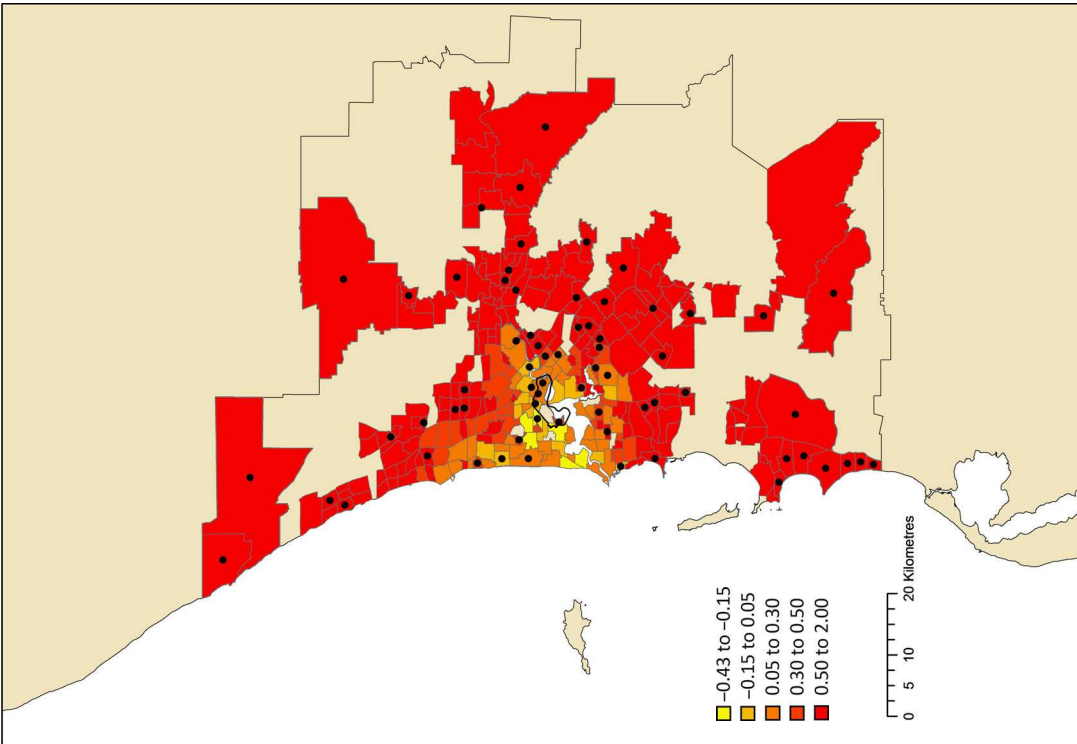
The dominant spatial pattern revealed by the maps is of low-income elasticities in the CBD and central suburbs, but with rising elasticities broadly following concentric rings through the inner, then outer, suburbs. Income elasticities are highest in the suburbs furthest from the CBD. This accords well with the predictions of the standard access-space model used widely as a conceptual construct in urban housing economic analysis (Alonso, 1964; Muth, 1969). Given the high housing prices in central locations, we would predict that a rise in income for an individual or household would not have a proportionate rise in housing consumption, assuming the individual or household chooses to remain.

While the spatial distribution of suburbs with moderate price change, shown in Figure 3, is suggestive that these areas are also the ones with moderate to high-income elasticities, this is not conclusive. In particular, a handful of centrally located suburbs with low-income elasticities witnessed moderate (negative) price change. Figure 4 is more conclusive. Without exception, suburbs that experienced relatively high price change between census years are distant from the CBD, and have the highest income elasticities of demand. As noted earlier, these are also areas of significant stock growth and of falling incomes and socio-economic advantage.

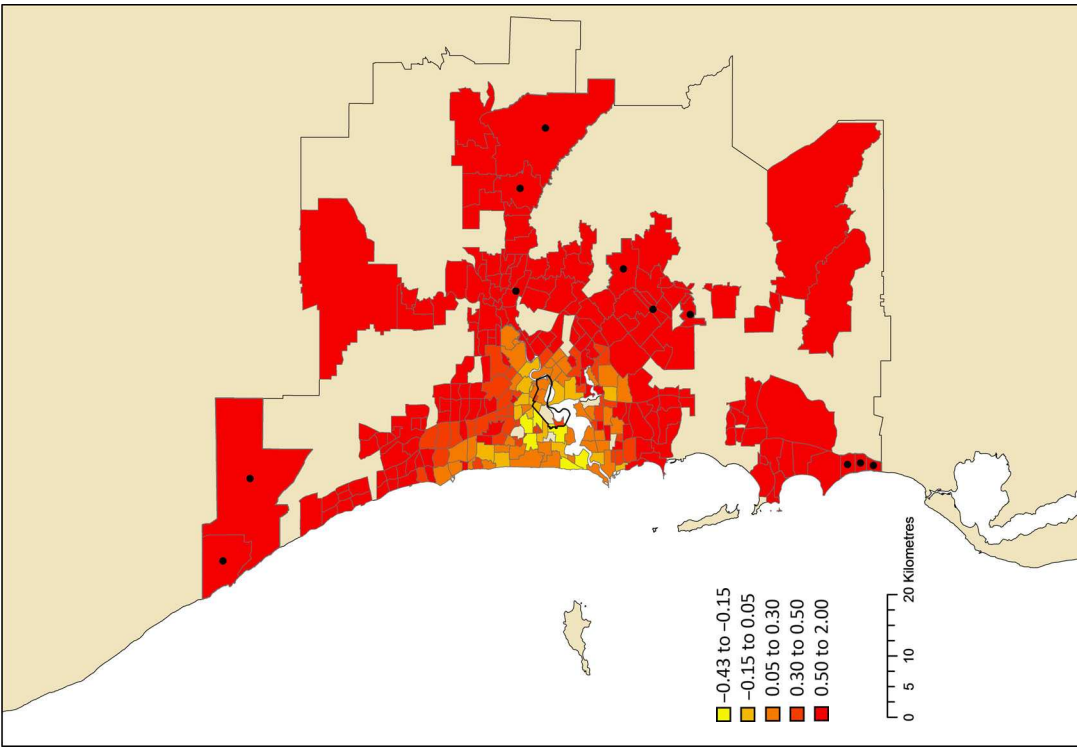
## 5 | DISCUSSION AND CONCLUSION

While urban housing submarkets as a construct are of theoretical interest in scholarly research, questions about their existence, stability, and change over time are of practical importance to housing and planning policy and practice. For example, understanding submarket structures and dynamics can help determine whether the spatial location of new housing supply within a metropolitan housing market will suppress further price growth uniformly within the market, or simply affect prices and market conditions in the locality or neighbourhood in which that new supply takes place.

Recent advances in conceptualising and testing for spatial urban housing submarkets have emphasised new modelling approaches that are more flexible and powerful, steering analysts away from the need to begin with prior notions of where



**FIGURE 3** Moderate price change and income elasticity of demand for housing. Shading/thematic mapping refers to income elasticities, and bold dots indicate areas of moderate/high price change.



**FIGURE 4** Significant price change and income elasticity of demand for housing. Shading/thematic mapping refers to income elasticities, and bold dots indicate areas of moderate/high price change.



submarket boundaries may lie. In this article, and in several other recent contributions to the literature, HMLMs have been used to fit single, city-wide hedonic models that nevertheless contain useable detail on spatial variation in constant quality housing prices within cities. Recent champions of this approach have examined the predictive accuracy of these methods and have found them to be generally superior to conventional regression methods. They have also been shown to have greater functionality, for example, in modelling dynamic change. The focus of this article has been to return to some largely untested propositions in housing economics about the nature and extent of dynamic change within housing market structures rather than to offer further methodological refinement of the hedonic multi-level approach.

We began by asking whether, as theory suggests, spatial change within urban housing markets might be caused by three socio-economic processes: new housing supply, intra-urban migration, and differential rates of socio-economic change within the urban area. We also provided an estimation of spatially varying income elasticities of demand within the urban area – an innovation which, to our knowledge, is new to the housing economics literature. This allowed us to seek to understand the changes in spatial market structures within a housing system conceptualised as comprising quasi-independent submarkets in states of multiple equilibrium.

The results of our analysis have both broad theoretical and methodological significance and specific implications for the study area. On this latter point, it is important to note the economic context of Greater Perth, Western Australia, during our study period. Western Australia experienced a pronounced and well documented economic boom, centred on mining industry exports, with an inter-linked housing boom. Our study period was chosen so as to miss the mining boom, and the period of housing market adjustment that followed it. Our choice of 2011 and 2016 was guided by our interest in examining how a metropolitan housing market adjusts, and how spatial change in housing prices occurs, in a period of relative stability. Both periods reflected a relatively calm market following population and construction booms of 2005–2008 and 2012–2015. Nevertheless, the fact remains that five years is not a long time period, and we might therefore expect the scope for spatial submarket change to be relatively limited as a result.

In fact, our analysis of migration data drawn from the census is generally not supportive of the idea that intra-urban migration is a driver of differential price change within cities. However, this may reflect the unavailability of migration data at sufficiently finely grained spatial scales. Our analysis of change in the size of the residential dwelling stock indicates that new development can, indeed, act as a driver of price change. This is particularly the case in areas that are expanding rapidly and/or from a relatively small initial housing stock. Given the latter, it is evident that migration plays a role in shifting prices within cities, even though this does not show up in the LGA-level migration data. We also found evidence that the nexus of new supply and intra-urban migration is associated with falling mean incomes and socio-economic advantage. It is impossible to shed light on the reasons without undertaking further qualitative work, but it seems likely that this finding points to lower-income households being priced out of central locations, and migrating to outer suburbs with more affordable new housing supply opportunities. For a household seeking to purchase, it is cheaper to buy a four-bedroom house on the urban periphery than a two-bedroom apartment within an established urban area.

More generally, however, the approach we use offers an effective and novel approach to revealing the differences in demand elasticities between housing submarkets. These estimated elasticities can be used to anticipate the likely effects of demographic change or changing income levels on demand and to reveal alterations in the tastes and preferences that shape market structures and spatial house price patterns. When set alongside our analysis of the impacts of new supply on localised, submarket prices, the approach developed here provides an analytical apparatus from which to understand the likely effects of new homes on affordability within the housing system. This framework outlined here represents a significant extension to that used in previous studies of submarket dynamics and, in our view, offers a potentially fruitful platform from which to explore market change and the market impacts of policy interventions in different international contexts.

## ACKNOWLEDGEMENTS

This research was made possible through the provision of a visiting research fellowship granted by Curtin University, Western Australia, and through access to data by LandGate, WA. We thank the reviewers for their helpful suggestions which have certainly improved the paper. Remaining errors remain the responsibility of the authors.

## ENDNOTE

<sup>1</sup> Strata refers to multiple properties on a single lot as opposed to a single dwelling on a single lot.

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**How to cite this article:** Costello G, Leishman C, Rowley S, Watkins C. Drivers of spatial change in urban housing submarkets. *Geogr J.* 2019;00:1–15. <https://doi.org/10.1111/geoj.12303>