

# **Online Appendix: The Effect of Zoning on Housing Prices**

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This appendix provides additional information to accompany Research Discussion Paper No 2018-03. Section 1 provides more detail of our methods for estimating detached dwelling structure values, and some of the issues involved. Section 2 describes how we construct our dataset of detached property sales for use in our hedonic regressions, and provides more detail about the results of alternative hedonic equation specifications. Section 3 provides maps of additional results by local government area. Section 4 describes our method for constructing our dataset of apartment sales, and documents how we derive our estimates of marginal construction costs for apartments in each city.

## 1. Dwelling Structure Value Estimates

This section details our three methods for constructing estimates of detached dwelling structure value and discusses some of the issues involved. Our source data (where confidentiality permits) and details of data transformations are in the Structure\_values.xlsx spreadsheet in the supplementary information published online with this appendix.

### 1.1 Summary of Dwelling Structure Value Estimate Methods

The three different methods we use to estimate the contribution of dwelling structure values to detached property prices each have pros and cons. These are summarised in Table 1.

**Table 1: Summary of Structure Value Estimate Methods**

	State valuer general	ABS Building Activity Survey	Industry sources
Advantages	<ul style="list-style-type: none"><li>• Added value of building improvements estimated using market transactions</li><li>• Entire existing dwelling stock is assessed, allowing for better matching to property sales</li><li>• Substantial resources invested in accuracy</li><li>• Available at local government area level</li></ul>	<ul style="list-style-type: none"><li>• Derived from official statistics</li><li>• Should accurately account for the different types of dwellings built in each city</li></ul>	<ul style="list-style-type: none"><li>• Respected sources that are referred to by building industry participants in decision-making</li><li>• Detailed breakdowns are available</li><li>• Most comparable to method used by international studies</li></ul>
Disadvantages	<ul style="list-style-type: none"><li>• Structure values may be overstated if land values are biased downwards</li></ul>	<ul style="list-style-type: none"><li>• Assesses value of new dwellings, which may differ from existing dwellings</li><li>• Available for states only, costs may differ from capital cities</li></ul>	<ul style="list-style-type: none"><li>• Assesses value of new dwellings, which may differ from existing dwellings</li><li>• Equally weights different construction types – some types may be more common than others, and this may differ across cities</li></ul>

Conceptually, the three approaches use similar definitions (at least, after our adjustments). Specifically, the value of land is essentially that of a vacant lot on a developed site. This includes the provision of roads and utilities. As we discuss in the paper, these costs are largely fixed and have little effect on the marginal cost of adding an extra dwelling to an already-developed site.

### 1.2 State Valuer General Estimates

For our valuer general estimates we use raw data in slightly different forms, as available, but we believe that overall the estimates are fairly consistent for the different cities. For each city, we construct average land value and dwelling structure estimates at both the aggregate city level and at the local government area (LGA) level (for use in the analysis in Section 7 of the paper). City-level estimates of average land value and structure value based on valuer general information is presented in Table 2.

**Table 2: State Valuer General Structure Value Estimates**

2016

	Perth	Brisbane	Melbourne	Sydney
Average property value (\$'000) <sup>(a)</sup>	588	542	793	1 160
Average land value (\$'000)	399	331	545	663
Average structure value (\$'000)	189	211	247	497
Average size of existing structures (m <sup>2</sup> ) <sup>(b)</sup>	180	177	183	194
<b>Implied valuer general estimate of structure value (\$/m<sup>2</sup>)</b>	<b>1 275</b>	<b>1 194</b>	<b>1 283</b>	<b>1 544</b>

Notes: (a) Mean sale price from our CoreLogic hedonic regression sample

(b) Based on average floor area sold in 2016 in our CoreLogic hedonic regression sample for each city

Sources: Authors' calculations; CoreLogic; Department of Environment, Land, Water and Planning (Victoria); Department of Natural Resources and Mines (Queensland); State of New South Wales through the Office of the Valuer General; Western Australian Land Information Authority (Landgate)

### 1.2.1 Sydney

The NSW Valuer General website supplies bulk land valuation data on individual properties by LGA.<sup>1</sup> We use valuations as of 1 July 2016 in the file from 1 July 2017.

For almost every property sale in 2016 in our unit record data set (described in Section 2) we are able to find a corresponding land valuation. We were able to successfully match 42 829 out of 43 069 observations in our regression sample. For each of these observations we subtract land value from sale price to obtain an estimate of the structure value. We then average over the whole city (in Table 2 and elsewhere) and local government areas (in Section 7 of the paper). This gives us our estimate of \$497 000 for the average structure value in Sydney in 2016.

### 1.2.2 Melbourne

For our Melbourne estimates, we use unpublished data from the Valuer-General Victoria on the average estimated 'site value' (i.e. excluding improvements) for detached dwellings by LGA. These valuations are as of 1 January 2016. To compare to our regression sample of sales for the full calendar year of 2016, we adjust up the average site valuations by 4.3 per cent – the average of the estimated coefficients on the time dummies for property sales in the second and third quarter in our 'large' regression results reported in Appendix B of the paper. If land values rose more than total property values over this period, our land value estimates may be slightly understated (and hence structure value estimates slightly overstated).

Next, we subtract the average site value for each LGA from the average sale price in our 2016 regression sample to derive our LGA-level estimates of structure value. To calculate our city-wide structure value estimate, we first calculate an average site value for the city, weighting the LGA-level site values by the proportion of sales in 2016 in our regression sample (\$545 000). We then subtract this site value estimate from the average sale price in our unit record regression sample, giving us our estimate of \$247 000 for the average structure value in Melbourne.

1 See 'Bulk land value information' found at <[http://www.valuergeneral.nsw.gov.au/land\\_value\\_summaries/lv.php](http://www.valuergeneral.nsw.gov.au/land_value_summaries/lv.php)>. It also has documentation on the methods used to derive these estimates at <[http://www.valuergeneral.nsw.gov.au/land\\_values/valuation\\_method](http://www.valuergeneral.nsw.gov.au/land_values/valuation_method)>.

### 1.2.3 Brisbane

We use information from the Queensland Valuer-General's 'Property Market Movement Report' for 2015, 2016 and 2017.<sup>2</sup> These reports list median land values by LGA. Median land values are likely to be lower than mean land values. To account for this, we adjust up the median land values by the ratio of mean sale prices to median sale prices in each LGA in our 2016 hedonic regression sample. This adjustment adds 8 per cent to our resulting average land price. We use estimates for 'residential' land values, disregarding 'multi-unit' and 'rural' categories.

Land values were not estimated for all LGAs for 2016. The most recent valuations for Lockyer Valley and Redland were in 2015, and the most recent valuation for Scenic Rim was in 2014. For these LGAs, we assume that land values are unchanged since their last valuation, because the reason they have not been revalued is because market movement over the corresponding year has been deemed to be insufficient to warrant it.<sup>3</sup> The implied growth rates for the other LGAs in Greater Brisbane that had reported valuations for both 2016 and either 2014 or 2015 were not particularly large (16 per cent from 2014 to 2016, 7 per cent from 2015 to 2016), so our unchanged assumption is unlikely to represent a significant distortion from the actual, missing growth rates.

Next, we subtract the average land value for each LGA from the average sale price in our 2016 regression sample to derive our LGA-level estimates of structure value. We then calculate the average land value for Brisbane weighted using sales in our 2016 unit record sample (\$309 000). The estimated average structure value is then the average sale price from our unit record sample minus our estimated average land value (\$233 000).

### 1.2.4 Perth

For Perth, we use unpublished data on estimated 'unimproved land values' for residential properties from Landgate (Western Australian Land Information Authority). The valuation date for these estimates is 1 August 2016. Average land values and the number of residential properties are provided by zoning code for each LGA.

First, we calculate an average land value by LGA, weighted by the number of properties recorded for each zoning code corresponding to 'low-density' up to 'medium-high' density residential.<sup>4</sup> These average land values are then subtracted from the average sale price in our 2016 regression sample to derive our LGA-level estimates of structure value. We then calculate the average land value for Perth weighted using sales in our 2016 unit record sample (\$399 000). The estimated average structure value is then the average sale price from our unit record sample minus our estimated average land value (\$189 000).

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2 The most recent valuations are as at 1 October 2016, but the estimated coefficients on the time dummies in our baseline hedonic equation (reported in Table B3 in the paper) suggest that this date is broadly representative of average property prices for the year (as prices were relatively flat in the beginning of the year, but increased over the second half).

3 See <<https://www.qld.gov.au/environment/land/title/valuation/about>>.

4 We also include town centre zoning codes. Including rural or high-density zoned properties would result in a higher average land value (and correspondingly lower structure value).

### 1.3 Building Activity Survey Estimates

The ABS's Building Activity Survey (BAS) provides estimates of the average cost of building houses by state. These estimates are defined as the value of the residence based on market costs of jobs including site preparation, but excluding land and landscaping, and should also include GST. The ABS discuss this data in a 2009 feature article (ABS 2009).

We can construct a quarterly measure of average completed house cost by state by dividing the value of houses completed by the number of houses completed, both from the ABS's 'Building Activity' publication. We then construct the average cost per square metre by financial year by dividing the average per-house cost in that financial year by the average floor area of completed houses (which is available on a financial year basis, on request from the ABS). We convert our financial year estimate to 2016 average prices using the output producer price indices (PPIs) for house construction by state.<sup>5</sup> We also add 5 per cent for professional services. The average value per square metre for 2015/16 is shown in the third row of Table 3 below.

Cost per square metre estimates are subject to year-to-year volatility due to changes in the quality of construction and sampling error in the value and size of dwellings. To mitigate this volatility, we convert each of the estimates from each of the last ten financial years to 2016 calendar year-average prices using state house construction PPIs and take the average of these ten years to derive our BAS-based estimate.

**Table 3: Building Activity Survey-based Structure Value Estimates**

	2016			
	Perth/WA	Brisbane/Qld	Melbourne/Vic	Sydney/NSW
2015/16 value (\$'000)	277	290	287	317
2015/16 size (m <sup>2</sup> )	227	238	241	227
2015/16 value (\$/m <sup>2</sup> ) <sup>(a)</sup>	1 268	1 296	1 268	1 480
Ten-year average value (\$/m <sup>2</sup> ) <sup>(a)</sup>	1 331	1 325	1 269	1 520
<i>Adjustment for 'period houses' (%)</i>	<i>+0.5</i>	<i>+2.8</i>	<i>+6.1</i>	<i>+6.7</i>
<b>BAS-based estimate (\$/m<sup>2</sup>)</b>	<b>1 338</b>	<b>1 363</b>	<b>1 347</b>	<b>1 621</b>

Note: (a) Adjusted to 2016 calendar year-average prices using state house construction PPIs, includes 5 per cent adjustment for other costs

Sources: ABS; Authors' calculations; CoreLogic

#### 1.3.1 Adjustment for period houses

A complication with using new construction costs to estimate the value of physical dwellings is that so-called 'period houses' tend to be valued more highly than newly constructed houses. This is particularly the case for certain styles of houses built in the late 1800s and early 1900s (e.g. 'Federation-style' houses). To account for this phenomenon, we adjust our estimates from both the BAS and industry construction cost methods upwards in inner city areas where substantial portions of the housing stock were built during these periods.

<sup>5</sup> Growth rates in these state PPIs are almost identical to growth rates in the corresponding capital city CPI new dwelling purchase series. The CPI series include the effect of changes in home buyer grants and so seem less appropriate, although the differences are minimal.

Specifically, we apply this adjustment for LGAs (Sydney, Melbourne, and Perth) and ABS Statistical Area Level 3 regions (Brisbane – due to the much larger size of LGAs) where the median year of construction for houses sold from 2014–16 was 1950 or earlier. We adjust up structure value by 40 per cent, which is an admittedly rough calibration based on estimates of the value of various period houses relative to modern houses from ‘paired value’ estimates, which compare the value of properties with comparable plots of vacant land – see, for example, Southern Alliance Valuation Services Pty Ltd (2016, p 38). This adjustment adds between 1 and 7 per cent to average structure values across our cities (see Table 3 above), so our results are not likely to be very sensitive to alternative calibrations of this adjustment.

## **1.4 Industry Source Estimates**

### *1.4.1 Data sources*

Our two main sources are the Rawlinsons Construction Cost Guide (Rawlinsons Group 2017) and Rider Levett Bucknall’s (RLB) ‘Riders Digest 2017’ (Rider Levett Bucknall 2017). These are widely used references in the construction industry that provide estimates of the cost per square metre of floor area for different types of construction projects in different cities. Estimates from both sources exclude land, most types of site works, legal and professional fees, and GST.

Rawlinsons provides estimates for a number of types of houses. Estimates are reported for different quality finishes/materials and various house sizes for: 1) project houses; 2) individual houses; and 3) prefabricated houses.

RLB provides ‘low’ and ‘high’ cost estimates for only one category of detached dwelling, which is described as ‘custom-built single and double storey dwellings, of medium quality’.

### *1.4.2 Method for constructing our industry source estimate*

To construct our estimates, we create an estimate for each city from each source. For Rawlinsons, we take a simple average of the costs per square metre across all of the types of houses available, excluding the ‘prestige standard’ individual house.<sup>6</sup> For RLB, we simply take the ‘low’ estimate of costs, as this estimate is already for a relatively expensive type of housing project, and the ‘high’ estimates have considerably more variation across cities (and are almost three times as high as the low estimates for some cities), so seem unlikely to be representative of the typical dwelling.

We first convert these estimates to 2016 average prices using the PPI for house construction by state. We then take the simple average of the Rawlinsons and RLB costs to get our base estimate of construction costs in each city in 2016. As with the BAS-based estimates, we add 5 per cent to account for other costs that are not included in the industry estimates (such as professional services). Finally, we then add 10 per cent to this figure to account for GST (Table 4). We then apply the same ‘period house’ adjustment as we did to the BAS-based estimates to derive our ultimate industry-based estimates.

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<sup>6</sup> Estimates are not supplied for ‘individual house – tile roof, high standard, no air-con’ framed or brick veneer for Perth. We interpolate using the average costs for these types of construction in Brisbane, Melbourne and Sydney, adjusting by the average ratio of costs in Perth for other construction types relative to the other cities.

**Table 4: Industry-based Structure Value Estimates**\$/m<sup>2</sup>, 2016

	Perth	Brisbane	Melbourne	Sydney
Rawlinsons	1 422	1 539	1 408	1 535
Rider Levett Bucknall	1 421	1 788	1 370	1 599
Average	1 421	1 664	1 389	1 567
Adjusted for other costs/margins and GST	1 642	1 922	1 604	1 810
<i>Adjustment for 'period houses' (%)</i>	<i>+0.5</i>	<i>+2.8</i>	<i>+6.1</i>	<i>+6.7</i>
<b>Industry sources estimate</b>	<b>1 650</b>	<b>1 976</b>	<b>1 702</b>	<b>1 931</b>

Sources: ABS; Authors' calculations; CoreLogic; Rawlinsons Group (2017); Rider Levett Bucknall (2017)

### 1.4.3 Comparisons to other industry sources

As a crosscheck, we can compare our estimates from the 'Average' row in Table 4 against a third source. BMT Tax Depreciation are quantity surveyors that provide estimates of construction costs. Their website has cost estimates per square metre for different types of housing projects (e.g. weatherboard or brick, single level or two level, shelf or unique design) at a low, medium, or high quality finish for Sydney (see <https://www.bmtqs.com.au/construction-cost-table>). We take the simple average of the cost estimates for each type of house (excluding the extremely costly 'architecturally designed executive residence') at the medium quality finish, and convert to 2016 average prices using the New South Wales house construction PPI.<sup>7</sup> This method gives a construction cost estimate of \$1 672 per square metre, similar to our average estimate for Sydney.

For other cities, BMT provides only indicative ranges for costs relative to Sydney. For Brisbane this range is 95–115 per cent, for Melbourne it is 95–110 per cent, and for Perth it is 100–120 per cent. These wide ranges make this source less useful for comparing construction costs across cities. Taking the midpoints of these ranges and applying the corresponding state PPIs gives estimates of \$1 766 per square metre for Brisbane, \$1 710 per square metre for Melbourne, and \$1 864 per square metre for Perth. This estimate is similar to the average from our two main sources for Brisbane, but substantially higher for Melbourne and Perth.

## 1.5 Comparison to Foreign Estimates of Structure Value

Estimates of the interquartile range of construction costs across 100 US housing markets from Glaeser and Gyourko (2018) are US\$72–86 per square foot, which at an exchange rate of 0.77 is AU\$1 007–1 202 per square metre – substantially lower than most of our estimates. Lees (2018) reports estimated structure values of NZ\$302 000–360 000 for Auckland, Christchurch, and Wellington. At an exchange rate of 1.08, this is a range of AU\$280 000–333 000, slightly higher than our estimates for Brisbane, Melbourne, and Perth, but somewhat lower than our baseline estimate for Sydney of A\$390 000.

<sup>7</sup> Estimates were obtained from the BMT Tax Depreciation website in mid 2017, and were roughly representative of costs at the beginning of 2017.

## 1.6 Issues

There is a range of plausible assumptions that we could make about structure values, some of which matter for all three of our methods, and some of which matter only for one or two. We discuss some of these issues and justify our decisions, comparing to usage of similar data for similar purposes in Glaeser and Gyourko (2003) (hereafter GG 2003); Glaeser, Gyourko and Saks (2005) (hereafter GGS 2005); and Glaeser and Gyourko (2018) (hereafter GG 2018) where helpful.

### 1.6.1 *Quality/type of dwelling assumed for industry-based estimates*

Estimates of construction costs vary hugely by the type of house to be constructed. The most appropriate construction costs will correspond to those that most closely align with the value of physical dwellings on the properties that are sold during our sample period. Apart from period houses (discussed above), the quality of newly built homes in 2016 is likely to be higher than newly built homes in the past, suggesting that construction cost estimates for lower-quality homes are likely to be appropriate.<sup>8</sup> From categories of economy, average, custom, and luxury, GG 2003 focus on economy costs, while also referencing average costs as a comparison ('average' costs are about 20 per cent higher than 'economy' costs); GGS 2005 take the mean of economy and average costs; and GG 2018 focus on economy costs. GG 2003 also note that they average across different types of siding and building frame.

This suggests that our inclusion of individual (custom) houses in our Rawlinsons calculation, particularly those of high-standard finish, is a relatively conservative approach, and might overstate construction costs for our purposes. (Excluding the high-standard specifications from our average reduces the Rawlinsons cost by 12 per cent for Sydney.) The RLB costs, which are for a medium quality custom-built dwelling, may also overstate costs.

A limitation of our industry-based estimates (which we share with GG 2003, GGS 2005 and GG 2018) is that they do not allow for differences in the type or quality of homes typical in each city (other than adjusting for floor area differences). This is an advantage, in principle, of estimates based on the BAS or valuers general.

### 1.6.2 *Depreciation of existing homes*

In addition to the improving quality of new homes over time, existing houses are likely to depreciate significantly in value over time. As such, assuming that the value of an old dwelling structure is equal to the construction cost of a new dwelling could also lead to the overstatement of structure values. However, to the extent that older homes have been significantly renovated since they were built, or there are important consumer tastes for certain older-style houses that are difficult to replicate, overstatement of structure value due to depreciation will be mitigated. Our industry- and BAS-based estimates implicitly assume that these effects are approximately offsetting, and can be ignored.

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<sup>8</sup> For Sydney sales in 2016 in our unit record sample without missing values, the mean and median year built was 1970.

Our hedonic regressions suggest that, controlling for other characteristics, newer houses typically sell at a premium to older houses, suggesting that effect of depreciation may be larger than renovations on average. This could mean that existing dwelling values inferred from new construction costs may be overstated somewhat. On the other hand, repeat sales house price indices, such as those from Residex, which include the effects of both depreciation and renovations, have tended to grow similarly to hedonic measures (Hansen 2006, Figure 3). In calculating their 'zoning tax' estimates, GGS 2005 adjust their estimate of property values for depreciation, rather than construction costs – noting an average upward adjustment of 40 per cent.

### *1.6.3 Overhead, professional services and profit margin assumptions*

Our valuers general estimates of structures are based on the market value of improvements and so will include charges for overheads, professional services and profit margins. Both the BAS- and industry-based estimates explicitly exclude professional fees, although they should include both overheads and profit margins. The BAS-based estimates are based on the market value of the building work done and so should capture the builder's gross margin. For the industry-based estimates, Rawlinsons's estimates allow for builder's profit and overheads of approximately 5 per cent, while RLB's estimates are costs that 'could be expected should tenders be called in the respective city', and so presumably should account for margins.<sup>9</sup>

In contrast, GG 2018 assume a 17 per cent gross margin for builders which they add to their estimate of 'minimum profitable production cost', though GG 2003 and GGS 2005 do not.

### *1.6.4 Usage of cost estimates on a per square metre basis*

Industry estimates typically report that the cost per square metre to build a home is slightly smaller for larger houses, reflecting benefits to scale. For example, the per square metre Rawlinsons cost estimate for a medium standard full brick project house of 160–190 square metres is 3 per cent smaller than one of 120–140 square metres. Typically, these differences are so small that the industry ignores them and estimates costs on a square metre basis. These differences could be an issue were the industry- or BAS-based estimates applied to sub-samples with unusual house sizes. However, we only use these estimates for city-wide samples, for which the mean is sufficient.

### *1.6.5 What types of costs should be included in our construction cost estimates?*

There is a range of different costs involved in the process of bringing a house to market, and it is not always clear whether we should include these in our estimate of structure value, or let them flow through to the zoning effect estimate. As a comparison, Urbis (2011) (whose estimates are also used in Hsieh, Norman and Orsmond (2012)) include a number of costs in their estimates of the total cost of bringing new dwellings to market that we exclude.

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<sup>9</sup> In comparison, a survey of the private sector construction industry in Australia by the ABS indicated that in 2011/12, the average operating margin for firms in the 'building construction' sub-industry was 7.1 per cent (ABS 2013).

For example, because Urbis's detached dwelling estimates focus on greenfield development, they include the cost of subdivision construction. For the four cities that we study, these costs are estimated at between \$42 000 and \$50 000 (including GST) on average per dwelling in a new subdivision of 100 dwellings. However, our methodology is considering the costs of using existing residential land more densely, which should entail minimal subdivision costs. And even for new greenfield developments, the *marginal* subdivision cost of increasing the density of a development of a given land area by one dwelling is likely to be small.

A similar argument applies for infrastructure contributions, which Urbis also allow for. The nature of these charges varies across states and LGAs, but broadly speaking they are intended to cover the costs to governments in providing the additional infrastructure to service new developments. Urbis's estimates of these types of charges for greenfield developments vary widely across the different cities (from \$11 000 per dwelling in Melbourne to \$44 000 in Sydney (including Section 94 contributions)).<sup>10</sup> These variations seem unlikely to represent actual differences in the costs of infrastructure provision.<sup>11</sup> Urbis estimate that per-dwelling infrastructure charges are much lower for infill apartment projects, consistent with a smaller requirement for new infrastructure for these developments.<sup>12</sup>

Urbis also account for a range of government charges and fees (e.g. stamp duty, building approval fees, land taxes and council rates) in their cost of supplying housing. However, these are quite small. Moreover, it is arguable that these should be considered as part of the zoning effect, rather than structure value, because they are not directly associated with providing services to a development that would be unavoidable in a frictionless market.

Urbis (2011) also include interest and financing costs – which seem better captured by allowances made for profit margin because: 1) they are dependent on financing structure; and 2) to the extent that large interest costs are caused by lengthy delays in the planning process, they should be in the zoning effect rather than structure value.

To the extent that our arguments for excluding these additional costs are incorrect, we could be understating structure values. Even so, these costs are not large enough to materially alter our conclusions.

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10 These estimates are for selected areas within each city – charges also vary between different regions within each city (Hsieh *et al* 2012).

11 HSAR Working Party (2012) found that charges imposed on developers sometimes lacked consistency, transparency and predictability.

12 Although these estimates still vary considerably across cities: from \$2 000 per dwelling (Melbourne) to \$15 000 (Brisbane).

## 2. Property Sales Dataset and Hedonic Estimates

This section details our dataset of property sales and our method for cleaning the data for use in our hedonic regressions (and other calculations – e.g. average sale price) for detached houses. We also provide more detail about alternative hedonic equation specifications whose estimates of the marginal value of land we report in Table 4 in the paper.

### 2.1 Data

We use a proprietary unit record data set available for purchase from CoreLogic, containing information on 7 661 493 properties and 17 299 812 property sales across Australia from 1976 to 2016.

### 2.2 Cleaning for Use in Hedonic Regressions

We take a number of steps to clean the dataset before using it in our hedonic regressions.

#### 2.2.1 Sales data

First we make some adjustments to our sales data.

- Drop duplicate observations with identical property ID, sale date and sale price.
- Drop observations with sale price equal to zero, where there is another observation with identical property ID and sale date (although we transfer sale method information from the dropped observation to the retained if missing).
- Drop any observations with a sale price \$1 000 or lower.
- For observations with duplicate sales of the same property ID on the same date, we take the median sale price of the group of observations and drop the remaining observations.
- We are then left with about 16.7 million observations.

#### 2.2.2 Characteristics data

Our property characteristics data are based on the most recently recorded information – in most cases likely from the most recent sale. This means that for properties that are sold multiple times in our sample period, if there has been any change in the characteristics of the house between sales (e.g. rooms added), then sales prior to the most recently recorded sale will have misleading characteristics when we match attributes. Accordingly, we limit our sample to the most recent sale of each property, a restriction that is unimportant for the past few years.<sup>13</sup> After dropping earlier repeat sales of the same property, we are left with about 7.6 million observations.

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<sup>13</sup> Repeat sales indices of house prices often exclude properties resold within a short time frame, as they are considered more likely to have had substantial renovations during that time period.

We make a number of adjustments to our sample based on property characteristics.

- We drop all observations whose 'property type' is not 'house'. This drops all 'units' (apartments and townhouses), leaving us with about 5.6 million observations.
- We drop observations with a missing postcode or suburb.
- We drop observations with missing data on a few key characteristics: land area, bedrooms, bathrooms and latitude and longitude coordinates.<sup>14</sup> We then drop a handful of observations with zero or negative values for bedrooms or bathrooms, or negative values for car spaces. This leaves us with about 4.8 million observations.
- We use the latitude and longitude coordinates of each sale to allocate them to the ABS's Greater Capital City Statistical Areas and to Statistical Area 1–4 regions. We also allocate them to LGAs based on boundaries from the ABS (we use the 2011 edition of LGA boundaries for Sydney, and the 2016 edition for the other cities).<sup>15</sup>
- For observations with a floor area recorded at 10 000 square metres or higher, we set this field as 'missing'. This is an implausibly large value for a detached dwelling, so these values are likely errors. These errors may affect the estimation of coefficients on this variable in our regressions and our estimates of mean floor area of houses that we use for other calculations.
- Most properties are recorded as having one or more car spaces or garages, and almost none are recorded as having zero, so we assume properties with no record of the number of car spaces or garages have zero. Following CoreLogic (2017), if a property isn't recorded as having any car spaces, we first check if it is recorded as having garages (and use this number) before setting to zero. We then use this car space variable in our hedonic equations.

Following this, we have a dataset of around 770 000 observations for Sydney, 630 000 for Melbourne, 560 000 for Brisbane and 516 000 for Perth, with around 42 000, 56 000, 39 000 and 28 000 of these observations in 2016 respectively.

### *2.2.3 Further adjustments/considerations for running hedonic regressions*

Before running our regressions, we first trim observations with extreme values from each sample for both sale price and land area to minimise the impact of outliers or coding errors. We first trim the top and bottom 1 per cent of observations at the city level each year. We then trim the top and bottom 1 per cent of remaining observations by LGA each year. As noted in the paper, we also then exclude observations with a land area greater than 2 acres (8 094 square metres) from our regression sample, in line with GGS 2005 – when we ran the regressions including these observations, our estimates of the physical value of land were slightly lower.

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<sup>14</sup> The number of properties missing information on these characteristics is small, particularly for properties associated with sales later on in the sample period.

<sup>15</sup> For Perth, we merge sales in the Peppermint Grove LGA into the neighbouring Mosman Park LGA, as there are very few observations each year in Peppermint Grove.

Appendix B in the paper shows the variables for different characteristics of houses that we included in our regression. There were a small number of sale methods that we counted as 'missing' due to their very small frequency. Dummies for swimming pool, air conditioning, ducted heating, and scenic view represent that there is a 'flag' for these characteristics recorded in the characteristics file.

The additional control variables we include in our 'large' regression do not have full coverage, especially for earlier years, which is why we chose not to drop observations missing values for these variables but to include a dummy to account for that. (Although there was little impact on the log land area coefficient from dropping them, at least for 2016.)

### **2.3 Robustness Tests of Hedonic Equation Functional Form**

Table 4 in the paper shows estimates of the marginal value of land from some alternative specifications of our hedonic regression, compared to our baseline estimates.

Rows two and three show the results of changing the functional form of our land area variable to some more flexible alternatives, keeping the sample and other control variables the same as our baseline equation.

Row two shows the estimated marginal land value when we include a (log land area) squared term in addition to the log land area term. The estimated coefficient on this term was negative in all cities except Perth, but only statistically significant for Sydney and Brisbane. Row three shows the estimated marginal land value when we replaced the log land area term with land area, land area squared, and land area cubed terms. For all four cities, the estimated coefficients were negative for the squared term and positive for the cubed term, and statistically significant. We also experimented with a range of higher-degree polynomial functional forms. These generated similar estimates to the cubic functional form.

Rows four and five of the table show the estimated physical land values calculated by running separate hedonic regressions at a disaggregated level, and then aggregating up to the city level for comparison.

For the calculation in row four, we estimate a hedonic equation of the same form as our baseline equation for each LGA within each city, with all our controls and a log-log specification. We then calculate the marginal land value for a property with the average land area and sale price in the sample for the LGA. Finally, we aggregate these estimates up for comparison with our city-wide estimates by calculating an average weighted by the land area sold in each LGA in each sample.

For the calculation in row five, we wanted to test if a linear-linear specification would produce similar results to our baseline estimate if estimated at a disaggregated enough level such that the implicit assumption of constant land value across the sample was a fair approximation. We did this using the following procedure:

1. Group together ABS Statistical Area 2 regions into geographic clusters with a minimum of 500 sales observations (68 groups for Sydney).

2. For each cluster, separately estimate a hedonic regression of the form of our baseline equation (with all controls), but with sale price and lot size (and floor area) in levels rather than logs.

This procedure gives us estimates of the hedonic value of land across different locations in each city. The estimated hedonic land value is positive for every group, and shows the expected general pattern of declining as the distance of the cluster from the city's CBD increases. Finally, to get a comparable estimate of the marginal value of land for the city as a whole, we calculate the average weighted by the land area sold in each cluster in our sample.

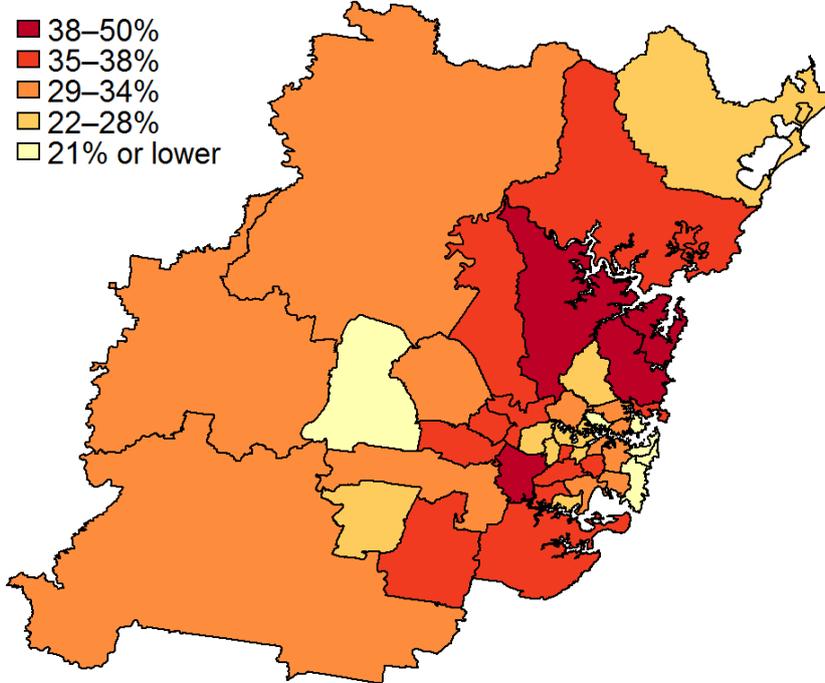
Given that our baseline physical land value estimates are very similar to those estimated using a range of different functional forms and to different levels of disaggregation, we are confident that they are at least qualitatively representative.

### 3. Maps of Additional Results by Local Government Area

Figures 1–4 are maps of our zoning effect estimates across different LGAs in each city, but as a per cent of average property value in each LGA instead of in dollar terms as in the paper.

**Figure 1: Sydney Zoning Effect Estimate by Local Government Area**

Per cent of average house sale price, 2016

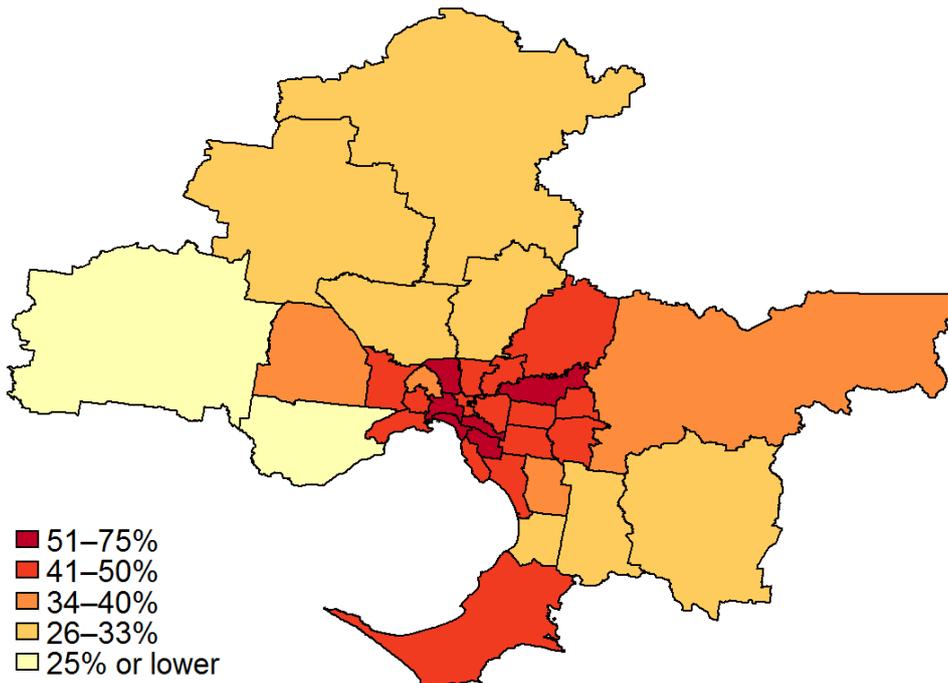


Note: The 2011 edition of the ABS’s LGA boundaries are used for Sydney

Sources: ABS; Authors’ calculations; CoreLogic

**Figure 2: Melbourne Zoning Effect Estimate by Local Government Area**

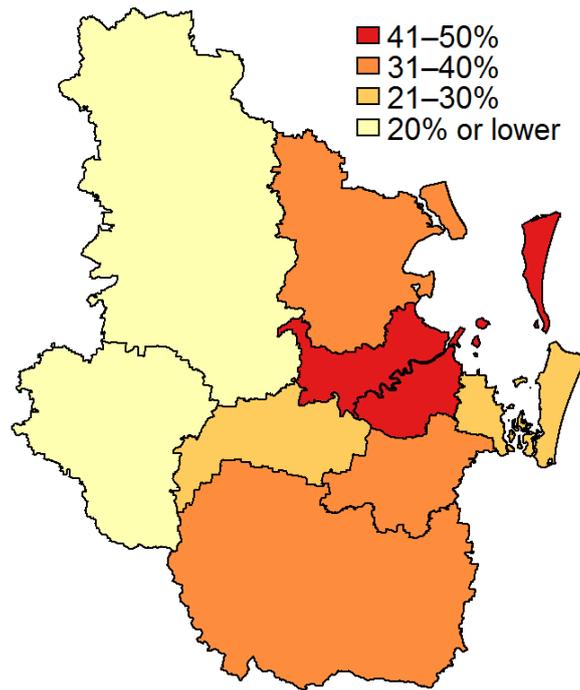
Per cent of average house sale price, 2016



Sources: ABS; Authors’ calculations; CoreLogic

**Figure 3: Brisbane Zoning Effect Estimate by Local Government Area**

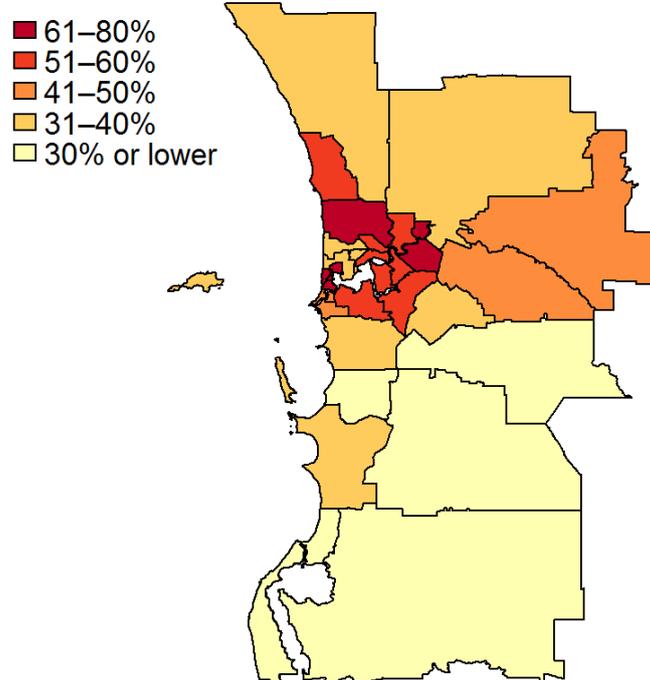
Per cent of average house sale price, 2016



Sources: ABS; Authors' calculations; CoreLogic

**Figure 4: Perth Zoning Effect Estimate by Local Government Area**

Per cent of average house sale price, 2016



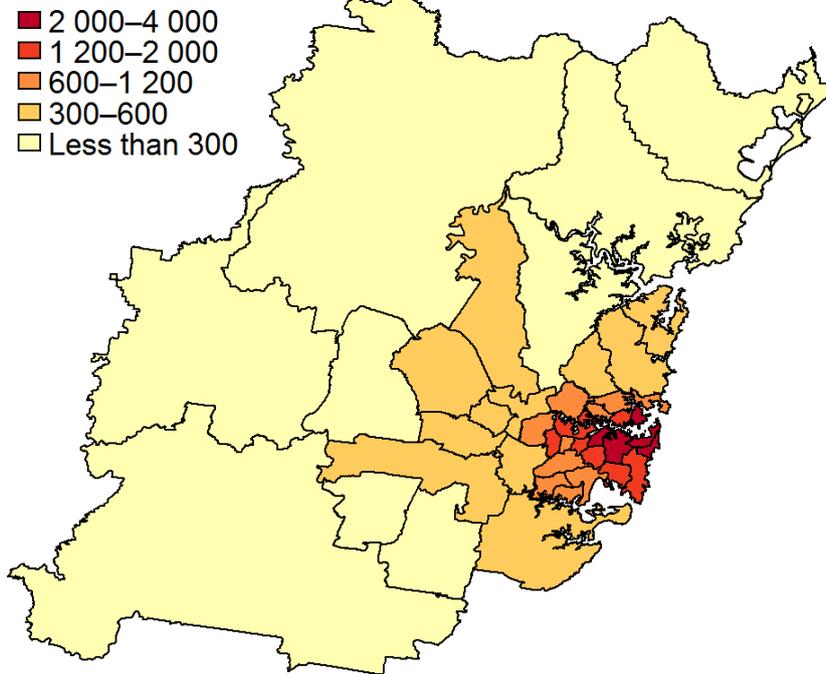
Note: Peppermint Grove LGA was combined with Mosman Park LGA for estimation purposes

Sources: ABS; Authors' calculations; CoreLogic

Figures 5–8 are maps showing our estimate of the physical value of land per square metre in each LGA estimated using our LGA-level regressions.

**Figure 5: Sydney Physical Value of Land Estimate by Local Government Area**

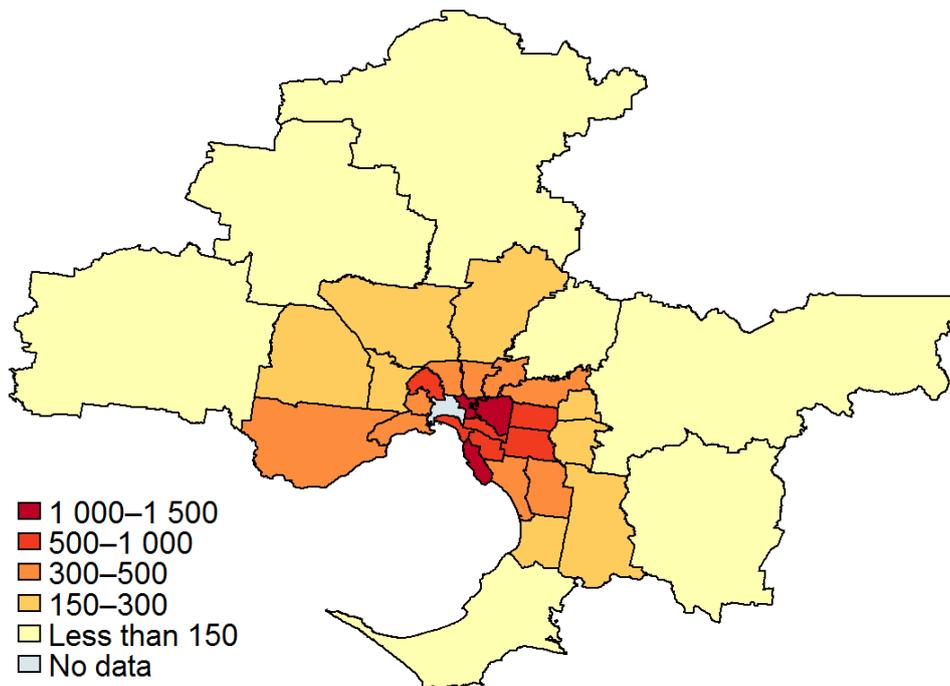
2016, \$ per square metre



Note: The 2011 edition of the ABS’s LGA boundaries are used for Sydney  
 Sources: ABS; Authors’ calculations; CoreLogic

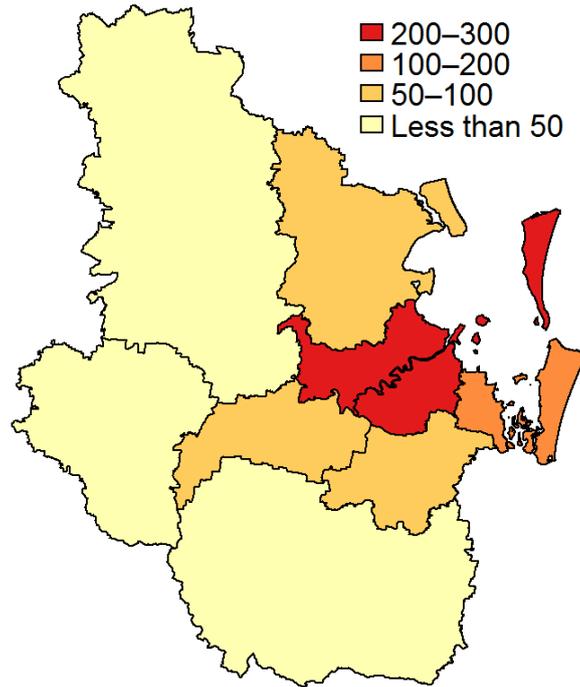
**Figure 6: Melbourne Physical Value of Land Estimate by Local Government Area**

2016, \$ per square metre



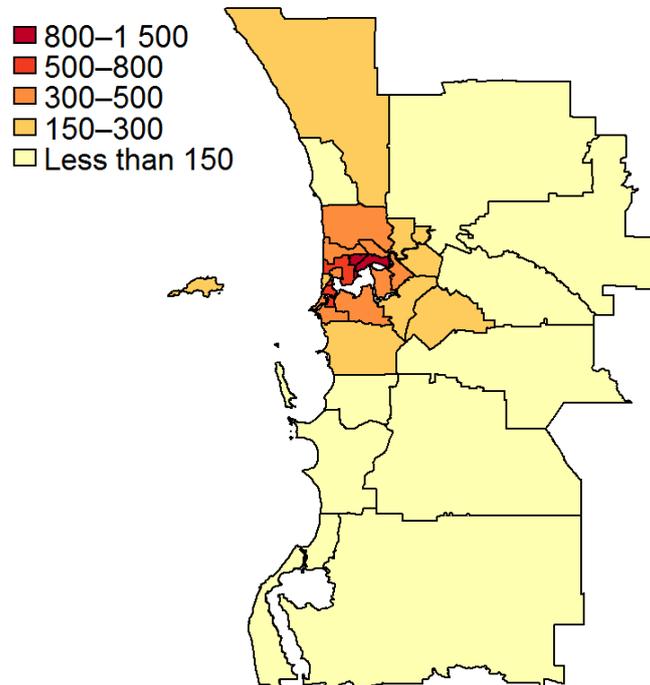
Note: City of Melbourne LGA excluded – estimate is slightly negative, perhaps reflecting small sample size and effect of outliers given the small share of detached housing in the area  
 Sources: ABS; Authors’ calculations; CoreLogic

**Figure 7: Brisbane Physical Value of Land Estimate by Local Government Area**  
 2016, \$ per square metre



Sources: ABS; Authors' calculations; CoreLogic

**Figure 8: Perth Physical Value of Land Estimate by Local Government Area**  
 2016, \$ per square metre



Note: Peppermint Grove LGA was combined with Mosman Park LGA for estimation purposes  
 Sources: ABS; Authors' calculations; CoreLogic

## 4. Apartment Sales Dataset and Construction Cost Estimates

This section details our method for constructing our dataset of apartment sales, and documents how we derive our estimates of marginal construction costs for apartments in each city.

### 4.1 Apartment Sales Data and Identification

As with detached housing, we use the unit record CoreLogic dataset to calculate average apartment sale prices in each city and each year. Because we are not conducting any hedonic regressions using this data, and individual apartments are not likely to change in floor area over time, we include all sales (i.e. including repeat sales), unlike for our detached housing analysis. Like with the detached housing data, we take a number of steps and make a number of adjustments.

- We drop all observations whose property type is 'house'. This retains all sales of 'units' (apartments and townhouses).
- We drop observations with a missing postcode or suburb.
- We drop observations with missing data on bedrooms, bathrooms and latitude and longitude coordinates.
- We use the latitude and longitude coordinates of each sale to allocate them to the ABS's Greater Capital City Statistical Areas and to Statistical Area 1–4 regions.
- We drop any observations where five or more sales occurred with the same sale price and date within the same Statistical Area 1 region, as these are likely to represent the purchase of a whole building.
- For observations with a floor area recorded at less than 10 square metres or greater than 500 square metres, we set this field as 'missing'. These seem like implausible values of floor area for an apartment, and errors in this field may affect our estimates of mean floor area of apartments that we use to compare to construction costs.

Next, we need to identify which of the observations are apartments, as the 'units' category includes other property types such as townhouses, retirement village units, etc.

To do this, we examined the unit numbers recorded for units sold at each street address.

- We first ruled out any street addresses that did not have at least two sales of (unique) units with a unit number greater than 109. This may mean that we fail to identify some apartment buildings that have certain numbering systems, but is necessary to remove a large number of non-apartment addresses from the sample.
- We then inspected remaining street addresses whose characteristics looked unlikely to represent apartment buildings, based on, for example, a large number of sequential unit numbers, location, and other property characteristics. We removed around 30 street addresses

from each city that turned out not to be apartment buildings (for the most part these were retirement villages, or sometimes blocks of townhouse developments that shared a street address).

- We then recorded any units sold at the remaining street addresses as an apartment sale.

After this process, we are left with around 2 000 street addresses identified as apartment blocks for each of Sydney and Melbourne, and around 400 for Brisbane. In 2016, these addresses are associated with around 5 000 unit sales for Sydney and Melbourne, and around 1 500 unit sales for Brisbane (the average number of sales per year is broadly similar for the past 15 years or so).

For each city and each year, we then dropped from the sample observations that were in either the top or bottom 2 per cent of values for either floor area or sale price, to mitigate the effect of outliers or coding errors. For example, the sample appeared to include as 'units' some sale observations where land was purchased (at a very high price) and then later developed into an apartment building.

We then calculated the mean sale price and floor area of apartments sold in each city and year using the remaining observations. The mean floor area is used in the subsequent analysis to scale our estimates of marginal construction cost, which are in square metre terms, to the average size of apartments that were sold in that year.

One potential issue is that not all apartments sold had information on floor area recorded. However, the coverage was relatively high – in 2016, 60 per cent of Sydney sales, 77 of Melbourne sales, and 88 per cent of Brisbane sales had floor area information (proportions were similar for earlier years of the period that we consider). So we have some confidence that the average floor areas we use are broadly representative.

## **4.2 Apartment Construction Cost Estimates**

Our main source is Rider Levett Bucknall (2017), which provides estimates of the cost per square metre of floor area for different types of construction projects in different cities. Estimates exclude land, most types of site works, legal and professional fees, and GST.

Marginal construction cost tends to increase with building height, as more expensive construction methods are required. We estimate the marginal cost of construction for apartment units by calculating the cost of adding units in the eleventh to twentieth storeys of an apartment building, relative to a building with ten storeys.

We begin by constructing average cost per square metre estimates for ten and twenty storey buildings in each city. To do this, for the 'up to 10 storeys with lift' (ten-storey) and 'over 10 and up to 20 storeys' (twenty-storey) categories reported by RLB we take the average of the four estimates provided: 'low' and 'high' estimates for units with floor area 60–70 square metres and with 90–120 square metres.

To calculate the marginal cost of the eleventh to twentieth storeys, we multiply the average cost estimate for twenty storeys by 20, to get a total cost. We then subtract the average cost estimate for ten storeys, multiplied by 10, then divide the remainder by 10.

We then allow for other costs and margins. We add 25 per cent to our initial estimate of marginal costs to allow for floor area constructed but not able to be sold in apartment buildings (e.g. common areas), consistent with 'building efficiency' of 80 per cent.<sup>16</sup> We then add 10 per cent to allow for legal fees, professional fees and marketing costs. Next, we add 15 per cent to allow for the developer's return on investment (given the usual multi-year time frame of apartment developments) and the increased difficulty financing larger-scale projects.<sup>17</sup> Finally, we add 10 per cent to account for GST, and adjust to the correct time period using the producer price index – output of other residential building construction series for each state.<sup>18</sup> This gives us our estimates of marginal construction costs per square metre for comparison with sale prices (Table 5).

**Table 5: Apartment Marginal Cost Estimates**

2016

	Brisbane	Melbourne	Sydney
Average construction cost, 10 storeys (\$/m <sup>2</sup> )	2 625	2 595	2 960
Average construction cost, 20 storeys (\$/m <sup>2</sup> )	2 775	2 936	3 230
Marginal construction cost, 11–20 storeys (\$/m <sup>2</sup> )	2 925	3 228	3 500
Marginal cost adjusted for GST, building efficiency, other costs and margins, and PPI (\$/m <sup>2</sup> )	4 953	5 731	5 985
Average floor area of apartments sold (m <sup>2</sup> )	87	68	79
<b>Marginal cost, per apartment (\$'000)</b>	<b>429</b>	<b>390</b>	<b>471</b>

Sources: ABS; Authors' calculations; CoreLogic; Rider Levett Bucknall (2017)

Finally, we multiply the cost per square metre by the average floor area of apartments sold in each city in each corresponding time period. For example, the average floor area of apartments sold in Sydney in 2016 was 79 square metres, so our estimate of the marginal cost of apartments is  $5\,985 \times 79 \approx \$471\,000$ .<sup>19</sup> Corresponding estimates for Melbourne and Brisbane are \$390 000 and \$429 000 respectively.

In comparison, the CIE (2011, Table 3.10) estimate that a typical Sydney apartment of 100 square metres, with a car space, would cost \$318 000 to build (including construction costs, finance, builder's margin and GST) in 2011, or about \$347 000 in 2016 dollars (adjusted using the same

16 RLB provide efficiency ranges (i.e. percentage of a building that can be letted) for a number of different types of office buildings. These estimates range from 68 per cent to 87 per cent. Anecdotal evidence suggests this is also broadly representative of apartment buildings.

17 Financing constraints are often highlighted by developers as an important consideration for apartment development decisions. However, the degree to which these constraints are binding (or result in projects requiring a high rate of return) likely also reflects the presence of planning regulations. The apartment zoning effect will be capitalised into development site values, a cost which has to be carried through the entire length of the project. And the time period and risk associated with receiving government permits for projects likely add further to financing costs (Hsieh *et al*/2012).

18 Cumulatively these adjustments add 58 per cent (excluding GST and PPI adjustment)/74 per cent (excluding only PPI adjustment) to the base construction costs.

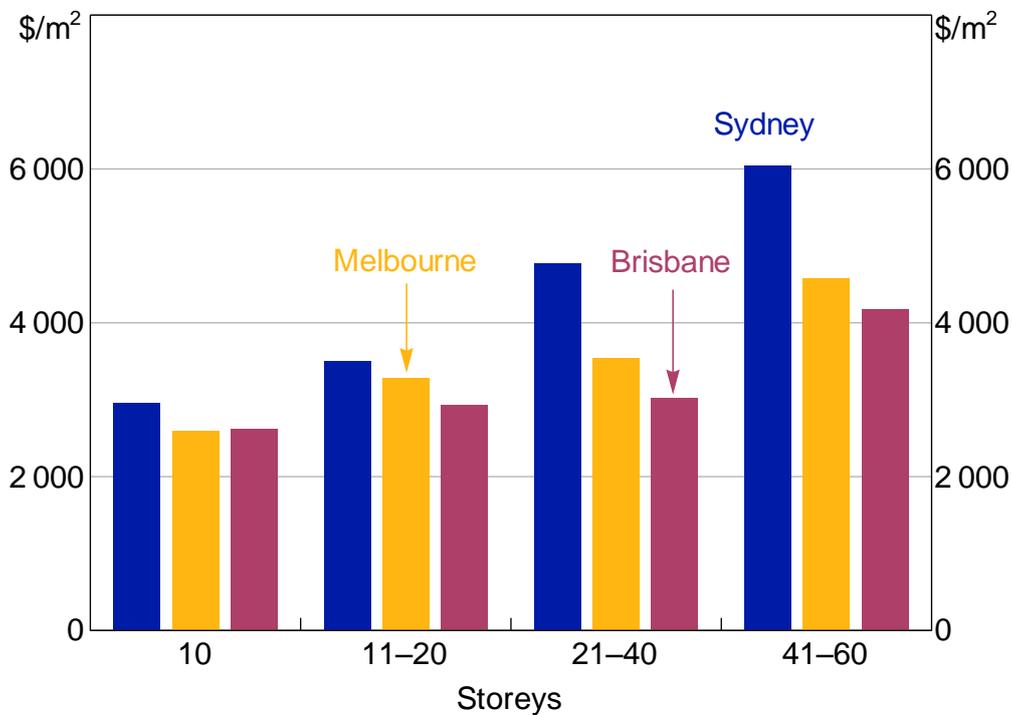
19 The average apartment size for two bedroom apartments sold in Sydney in 2016 in our sample was 89 square metres, while 55 square metres was the average for one bedroom apartments.

PPI series as above). Including estimates of development costs (management, developer's profit, marketing and sales costs, finance and GST), the CIE estimates imply total non-land costs of \$401 000 in 2011, or \$438 000 in 2016 dollars. These CIE estimates including development costs should be comparable to our estimates in row 4 in Table 5, based on RLB estimates with allowances for excluded costs. The CIE estimate for Sydney translates to \$4 380 per square metre (2016 dollars). This is lower than our estimate of \$5 985 per square metre. This partly reflects that we calculate the marginal cost, while the CIE estimates the average cost. However, even accounting for this difference, our estimates appear to be somewhat conservative (high).

AECOM (2014, p 76) also provide estimates of construction costs per square metre for apartments in Australian cities. Although these estimates are not detailed enough to calculate marginal construction costs, they can be compared to the RLB average cost estimates that we use as an input. Adjusted to 2016 dollars using the appropriate PPI, AECOM estimates for 'high-rise – medium quality' units are \$2 930 per square metre for Brisbane, \$2 697 per square metre for Melbourne and \$2 984 per square metre for Sydney – similar to the RLB estimates in rows 1 and 2 in Table 5.

Figure 9 shows the results of applying the same methodology (excluding the last stage of adjusting for building efficiency, other costs and margins, GST and PPI) to calculate the marginal costs of building apartments at different heights. Marginal construction costs increase relatively slowly with building height for Brisbane and Melbourne, but more quickly for Sydney.

**Figure 9: Apartment Height and Marginal Construction Cost**  
2016



Sources: Authors' calculations; Rider Levett Bucknall (2017)

RLB provide estimates of construction costs for some project types across a range of international cities. Table 6 compares the estimates of 'residential multi-storey construction costs' for a number of cities (taking the midpoint of their 'low' and 'high' estimates, without any further adjustments other than for exchange rates). These estimates suggest that apartment construction costs in Australian cities are broadly comparable to other countries – higher than Berlin or Chicago, but lower than in London or New York.

**Table 6: Residential Multi-storey Construction Costs**

2016, \$ per square metre

	Perth	Brisbane	Melbourne	Sydney	Berlin	London	Auckland	Chicago	New York
Exchange rate	na	na	na	na	0.67	0.57	1.08	0.77	0.77
Cost in A\$	3 030	2 600	2 908	3 510	1 789	4 204	3 241	2 377	4 019

Note: Exchange rate in terms of units of local currency per 1 Australian dollar

Sources: Authors' calculations; Rider Levett Bucknall (2017)

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