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The Apartment Shortage

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Abstract

This paper measures the excess demand for apartments in Australia's largest cities. We estimate that home buyers will pay an average of $873,000 for a new apartment in Sydney though it only costs $519,000 to supply, a gap of $355,000 (68 per cent of costs). There are smaller gaps of $97,000 (20 per cent of costs) in Melbourne and $10,000 (2 per cent of costs) in Brisbane. The large gaps are sustained by planning restrictions. The shortage of apartments is most severe in the inner suburbs of Sydney, where height limits prevent more construction. Elsewhere, restrictions on converting low-density housing to apartments are important. High-rise apartments are a much less costly means of supplying extra housing than the medium-density housing that some planners favour.

JEL Classification Numbers: R31, R38, R52

Keywords: housing prices, apartments, zoning, land use

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1. Introduction

Australian cities face a shortage of apartments. The severity of this shortage can be gauged by the difference between what home buyers will pay for an apartment and what it costs to supply. For example, we estimate that the average new apartment in Sydney sells for $873,000 but only costs $519,000 to supply, a difference of $355,000 or 68 per cent of costs. The wedge is 20 per cent of costs in Melbourne and 2 per cent in Brisbane. Why don't builders and developers exploit these profitable opportunities? The standard answer is that planning regulations stop them.

There are frequent media reports of people willing to pay hundreds of thousands of dollars more for the legal right to add an extra apartment to their building. For example, in 2014 a property at 661 Chapel St, South Yarra in Melbourne was sold for $20 million when it was zoned for 13 storeys. It was then rezoned for 31 storeys and sold later that year for $56 million (Lucas 2017). Loosening restrictions added $36 million in value. For more examples see Kendall and Tulip (2018, Appendix A). These anecdotes suggest that, but for planning restrictions, apartments would be readily supplied for much less than current market prices.

While observations like these are common, it is not clear how representative they are. This paper quantifies the shortage by comparing city-wide estimates of costs and prices. Kendall and Tulip (2018) conducted a similar exercise, focusing on houses, with some simple estimates for apartments. This paper takes a closer look at apartments, given that they are the focal point in planning debates. Whereas estimates of the zoning effect for houses answer the question: why is housing so expensive?; estimates for apartments are more relevant to the question: what do we do about it?

The first objective of this paper is to examine the effect of building restrictions on apartment prices in more detail, using data that Kendall and Tulip did not have. We use unpublished construction cost data from the ABS, filter CoreLogic sale price data more finely, add an extra two years of data and review other assumptions based on further consultation with the industry. This results in smaller but qualitatively similar estimates of the zoning effect in Sydney and Melbourne and significantly smaller estimates in Brisbane. A closely related objective is to examine the applicability of similar overseas research, discussed in the following section, in an Australian context. We confirm the key qualitative result of this previous research: building restrictions substantially increase the cost of housing. Consistent with this, a key contribution of this paper is to assemble and compare representative data for Australia's largest cities.

Our second objective is to examine how the shortage of apartments varies across time, location and building types. We find that, over the past decade, the excess demand for apartments has increased substantially in Sydney, fluctuated without trend in Melbourne and declined in Brisbane. In Sydney the excess demand is most severe in inner suburbs. In Melbourne and Brisbane excess demand is more dispersed. Tall buildings are a substantially less costly way of increasing supply than the 'missing middle' of medium density in middle-ring suburbs promoted by some planners.

Our paper only looks at the costs of land use restrictions. Policy decisions need to weigh these against benefits, which would be desirable to quantify. Pending that, we note that the literature surveyed by Ahlfeldt and Pietrostefani (2019) suggests that net externalities of urban density may be positive. Higher wages, more patent applications, less energy use and other benefits of density are found to more than offset traffic congestion, shadows, noise and other costs. Local studies, specifically Travers Morgan and Applied Economics (1991), Trubka, Newman and Bilsborough (2008) and CIE (2010), are less comprehensive, but do not point to overall results being very different in Australia. Glaeser, Gyourko and Saks (2005) specifically examine height restrictions and estimate their external costs to be small. Moreover, many observers have a sense of whether the benefits of lower density are 'large' or 'small' and these judgements can be compared with our estimates of costs.

Our results have obvious implications for housing policy and town planning. They also contribute to understanding the responsiveness of residential construction, a key parameter in the transmission of monetary policy. And they help to explain the determinants and sustainability of housing prices, which are important in financial stability policy.

2. Relationship to Other Research

Numerous studies have attributed the high cost of Australian housing to land use restrictions. These include: OECD (2010); Kulish, Richards and Gillitzer (2011); Productivity Commission (2011, 2017); Housing Supply and Affordability Reform Working Party (2012); RBA (2014); Senate Economics References Committee (2015); CEDA (2017); Stevens (2017); and Daley, Coates and Wiltshire (2018) among others. These papers' views on land use restrictions seem to be strongly influenced by anecdotal evidence like that mentioned in the previous section.

Clearly then, our paper cannot make any claim to originality for our main finding – planning restrictions cause large increases in apartment prices. Rather, our contribution is to quantify this effect, assess how it varies, and discuss some of the implications that follow.

Our method of measurement follows the widely cited approach of Glaeser *et al* (2005) for apartments in Manhattan. Similar studies include Lees (2019) for apartments in Auckland, Wälty (2020) for condominiums in Zurich and Geneva, and Cheshire and Hilber (2008) for commercial property in Britain and Europe. Like us, these papers find that planning restrictions have large effects on prices. Our paper differs by looking at Australian cities. Specifically, we examine Sydney, Melbourne and Brisbane, which account for 72 per cent of all apartments in Australia (according to the 2016 Census).[1]

2.1 Objections

Although reports like those cited above repeatedly argue that planning restrictions have large effects on the cost of housing, this idea is controversial in public discussions. Some objections are worth addressing.

It is sometimes argued that there is not a significant shortage of apartments because supply is growing quickly. Phillips and Joseph (2017) and Murray (2020) subtract changes in household formation from high levels of new construction and conclude there is an 'oversupply' of dwellings. This approach was earlier popularised by the National Housing Supply Council (2014), though with different results. Rowley, Gurran and Phibbs (2017) point to similar data and conclude that 'Australia

1 Throughout the paper we use city names as abbreviations for Greater Capital City Statistical Areas (GCCSA). The next largest concentration of apartments is Perth with 4 per cent of the national total.

is almost a world leader in rates of new housing production' and that 'supply seems pretty healthy'. Pawson, Milligan and Yates (2020, Section 9.6) emphasise findings like these in explaining their scepticism of the importance of planning restrictions. However, it is important to distinguish levels from changes. Rapid growth in supply, relative to changes in population or the number of households, implies the shortage is *decreasing* – it does not imply that the supply is adequate or that housing is affordable. Similarly, whether prices and rents are rising or falling does not indicate whether they are excessive. That can be judged by whether price is close to marginal cost. Looking forward, population growth is forecast to temporarily fall following the COVID-19 pandemic, reducing the demand for housing.[2] This would reduce the shortage, as we define it, but would not necessarily create an oversupply. We discuss definitions further in the following section.

A very similar argument is that housing shortages can instead be identified by market frictions, such as the rental vacancy rate, auction clearance rate or time on market. These measures are informative for some purposes. However, in contrast to the difference between price and marginal cost, they do not provide guidance on whether we need more housing.

A second objection is that high housing prices reflect high demand rather than limited supply. Factors boosting demand include interest rates, taxes, financialisation and immigration at a national level (Mulheirn 2017; Pawson *et al* 2020, Sections 3.4.1 and 9.6) and nearby amenities at a local level. High and rising demand is undoubtedly important but it does not mean that supply restrictions are unimportant. On the contrary, high demand only results in very high prices when supply is inelastic. For example, apartments in the inner suburbs of Sydney attract a 'location premium'. As we show in Section 5.1, this premium has been sustained because relatively few apartments have been built in inner Sydney recently. In contrast, central Melbourne and Brisbane, where building has been strong, do not exhibit a premium.

A third objection is that the correlation between prices and the severity of building restrictions is weak, or even positive (Michael Buxton, as quoted in Ross (2019)). For example, the most expensive housing is often found near the city centre, where the highest density is permitted. However, market-level effects cannot be inferred from neighbourhood-level variations. Housing in nearby locations is highly substitutable, so restrictions in one location increase demand and prices elsewhere. Planning regulations increase the *average* price by restricting *total* supply. To see this, suppose odd-numbered addresses were limited to four storeys and even-numbered addresses to eight storeys. Apartments in adjacent buildings would still sell for approximately the same price, despite the variation in restrictions. This argument has important implications for research design: spillovers in demand mean that the effect of local restrictions cannot be inferred just from variations in local prices. Researchers often complain about the difficulty in quantifying and standardising local planning regulations, but it is not clear how disaggregated measures could be used to gauge market-level effects on prices.

A positive correlation can also be seen in time series data: the effects of building restrictions are estimated to have increased over time despite denser development being permitted. As with cross-section comparisons, the perverse correlation arises because the restrictions are *partially* responsive to market needs. However, the wedge between cost and price we find shows restrictions

2 CoreLogic's unit price index has ceased growing following the pandemic, with little change from March to June.

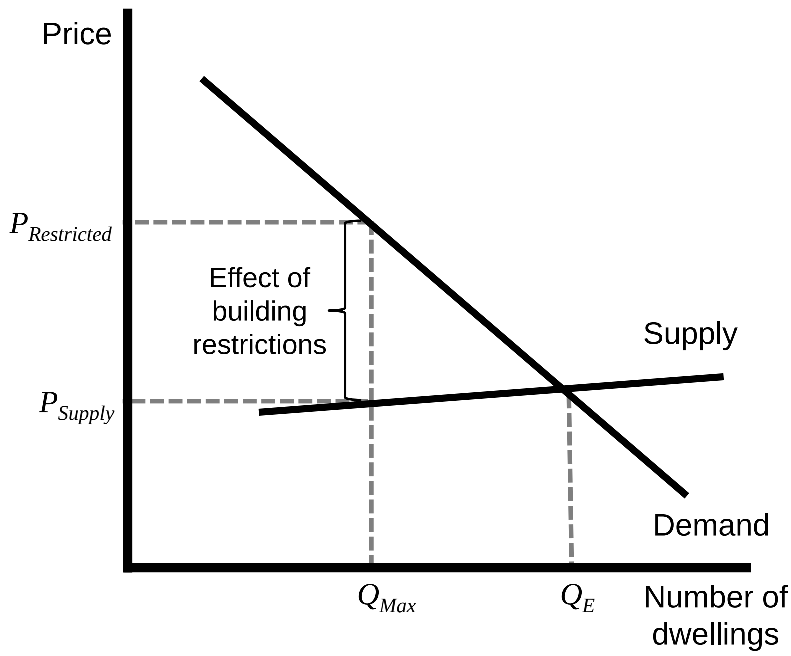
do not fully accommodate changes in demand, so they become more binding as demand rises over time.

A fourth objection is that binding supply constraints are inconsistent with the pronounced sensitivity of high-density building approvals to interest rates, sale prices and other demand conditions (Sneesby 2020). For evidence of this sensitivity, see Saunders and Tulip (2019, Figure 4). The problem with this argument is that it ignores that land prices, and hence developer's equity, depend on supply constraints in the short run. As discussed in the next section, construction is a highly competitive industry. So land prices are bid up to levels at which developments become marginal. This is often when collateral constraints start to bind. At this point, any downward revision to demand prospects can make a project unviable in the short run; for example, by reducing developer's equity. In time, lower sale prices would flow through, almost one-for-one, to lower land prices. The original developer would suffer a capital loss and be unable to proceed, at least for a while, but other developers would find the project viable. Until that process is complete, the availability of finance and construction activity will be highly responsive to demand. So planning restrictions bind in the medium run while financing (in turn, a function of planning) binds in the short run.

3. The Effect of Planning Restrictions

A 'shortage' can be defined in different ways. We do not discuss the merits of alternative definitions but we do want to be clear about what we measure. As shown in Figure 1, planning restrictions can reduce the quantity of housing and thereby raise the price. The difference between $P_{Restricted}$ and P_{Supply} provides a measure of the severity of these restrictions and the shortage they cause. The primary goal of this paper is to estimate this difference. This difference can be described as an 'effect of planning regulations', 'zoning tax', 'excess demand' or 'apartment shortage', among other terms.

Figure 1: Stylised Apartment Market with Binding Quantitative Constraint



For many purposes, it does not matter why the gap arises or is sustained. If price exceeds marginal social cost, then welfare is improved by increasing supply, regardless of the reason for the difference. That said, we agree with the literature cited in Section 2 that the gap can be attributed to planning restrictions. This approach may seem like labelling a residual. However, as discussed above, there is abundant evidence of supply being restricted by planning regulations and this having large effects on prices. In contrast, non-regulatory factors seem unlikely to be important.

The most obvious alternative explanation of the gap between price and marginal cost is imperfect competition. However, Grattan Institute analysis of IBISWorld industry reports indicates that apartment construction has low barriers to entry and low levels of concentration. The four largest firms in the 'apartment and townhouse construction' industry account for only 19 per cent of industry revenue (Minifie, Chisholm and Percival (2017), supporting data for Figure 1.3). According to ABS Cat No 8165.0 (Counts of Australian Businesses, including Entries and Exits), 24,641 firms were primarily engaged in other residential building construction in 2018/19. Of these, 822 businesses reported annual turnover in excess of $10 million. A small number of firms build the very tallest buildings and hence have market power over some specialised inputs, such as cranes or land in the CBD. However, by their nature, these account for a small fraction of the industry-wide costs that affect our estimates. More importantly, these firms sell their output in the broader market for apartments (including sales from the existing stock), for which their market power is negligible.

Other non-regulatory explanations are simpler to dismiss. The persistence of excess demand, shown in Section 5.2, makes the gap between price and cost difficult to attribute to transitory supply adjustments. The severity of height restrictions makes it difficult to attribute to a shortage of land. The size of the gap makes it difficult to attribute to momentary misperceptions, frictions or measurement error. As we argue in the previous section, difficulties in obtaining access to finance and the high cost of land should be interpreted as effects of planning restrictions, not as alternative explanations. Similarly, it is sometimes suggested that speculators are withholding properties from the market. But they would only do this if they expect higher prices in the future – that is, they expect planning constraints to bind even more tightly. We acknowledge there are important times and places where regulatory constraints are not binding. Section 5 identifies some of these and shows that they are consistent with planning restrictions having a large effect on *average* apartment prices.

Apartments can be supplied by either allowing builders to increase building heights ('building up') or by increasing the number of apartment buildings ('building out'). We provide estimates of the costs of both these margins of adjustment. We use the term 'height restrictions' to encompass various regulations, including floor space ratios (FSRs), that discourage building up, whereas a wider range of land use restrictions discourage building out. Our main estimates are shown in Table 1 and discussed in detail in following sections.

In Sydney, for example, the average new apartment sells for $873,000 but can be supplied for $519,000, a gap of 68 per cent of costs. The gap is 20 per cent in Melbourne and 2 per cent in Brisbane. We think it is fair to describe these effects as huge in Sydney, moderate in Melbourne and unimportant in Brisbane. We calculate these gaps using the less costly method of supply, building up. However, the difference in costs between building up and building out is often quite small. The differences between cities largely reflect differences in apartment prices, with variations in costs being secondary.

Table 1: Apartment Prices, Costs and the Effect of Building Restrictions
Per apartment, $'000, 2018

	Sydney	Melbourne	Brisbane
Average new sale price	873	588	470
Cost of building up	519	491	460
Cost of building out	610	505	471
Effect of building restrictions	355	97	10
Effect as per cent of price	41	16	2
Effect as per cent of cost	68	20	2

Note: Data sources and estimates are explained in Section 4 and Appendix A

Our estimates of the effect of building restrictions in Sydney and Melbourne are a bit smaller than those of Kendall and Tulip (2018). Our estimate for Brisbane is substantially smaller, being revised down from $110,000 to $10,000 per apartment. The revisions to prices reflect the use of building characteristics to filter townhouses and updating of data to 2018. Revisions to cost estimates are discussed in Appendix A.

4. The Effect of Height Restrictions

4.1 Major Data Sources

In the following paragraphs we give a brief summary of our major data sources, then turn to some of the more interesting and difficult assumptions. We discuss details of data construction in Appendix A. We view these details as important – perhaps as the main contribution of the paper – but no conceptual issues are involved and we recognise that data technicalities are primarily of interest to specialists. For both prices and costs we use the ABS definition of an apartment: a unit in a multi-dwelling structure that shares a common entrance and does not have private grounds. Contrary to some usage, an apartment need not be in a tall building.

Our estimates for apartment prices are based on transaction-level data from CoreLogic for 2016. The raw data provides prices from a very large sample of unit sales in 2016. These estimates, comparable to those widely discussed in the media, are shown in row 1 of Table 2. Conceptually, we are more interested in apartments than units (which include townhouses) and in new sales than the average price. In practice, data anomalies are of comparable, if not more, importance. We adjust the data to provide estimates of the average price of new apartment sales in 2018, shown in row 2.[3] The multiple filters and adjustments are explained in Appendix A.1. Several of the individual adjustments raise or lower prices by a few per cent, and hence affect overall conclusions for Brisbane but not Sydney or Melbourne. In net terms they tend to be offsetting. As can be seen in Table 2, our final estimates are quite similar to the original data.

3 2018 is the most recent period for which we have many disaggregated data series.

Table 2: Apartment Prices
$'000

	Sydney	Melbourne	Brisbane
Unfiltered average unit price (2016)	884	578	475
New apartment prices (2018)	873	588	470

Note: Data sources, details and estimates are explained in Appendix A

Our main data source for costs is the ABS Building Activity Survey. The ABS has published estimates of average construction costs for apartments by state in 2017/18 in ABS (2019a), reproduced in row 1 of Table 3. We use unpublished estimates for major cities, adjusted to be in 2018 prices, shown in row 2.[4] These data are somewhat volatile, in part because building height varies from year to year. As it is *expected* costs that affect building decisions, we smooth through the data as discussed in Appendix A.2 and focus on predicted average cost, shown in row 3.

Table 3: Apartment Supply Costs
$'000

	NSW/ Sydney	Victoria/ Melbourne	Queensland/ Brisbane
Average state construction cost (published, 2017/18)	342	310	312
Average capital city construction cost (2018)	323	295	285
Predicted average construction cost (2018)	340	312	287
Marginal construction cost[(a)]	364	350	316
Professional fees (3 per cent of total costs)	12	12	11
Marketing and sales (5 per cent)	20	20	18
Finance (7 per cent)	29	28	26
Developer's margin (17 per cent)[(b)]	74	71	64
Infrastructure charges[(c)]	18	10	26
Total cost of building up[(d)]	519	491	460

Notes: Sources for most entries are discussed in the accompanying text, with further details in Appendix A
(a) Explained in Section 4.2
(b) Explained in Section 4.3
(c) Includes development levies and Voluntary Planning Agreements
(d) Rows do not sum to totals due to rounding

The average cost estimates include the cost of building the primary structure, GST, the cost of constructing internal parking, foyers and other common areas, architect fees and builder's margins. They exclude costs of land acquisition and preparation, demolition and moveable furnishings. We suspect that some costs are not included by survey respondents such as legal and management fees, marketing costs and infrastructure contributions. We add these to the totals presented in Table 3, based on the estimates in Urbis (2011) and CIE (2011). These are reports by industry consultants commissioned to examine the cost of supplying housing. We have crosschecked these estimates with financial statements from developers and – with a few qualifications discussed in later sections – they line up. Two more important adjustments, the costs arising from increased

4 We are very grateful to Bill Becker and Daniel Rossi of the ABS for their assistance in providing this data and helping us with its interpretation. The ABS data we use – both published and unpublished – are available in the supplementary information published with this paper.

height and developer's margins, are discussed in the following subsections. The final row of Table 3, the total cost of building up, is also shown in Table 1.

4.2 The Role of Building Height

Extra apartments can be supplied by raising the height of future buildings. This increases average costs due to a need for stronger reinforcing, more space for lift wells and extra safety requirements. Partially offsetting these, larger construction projects benefit from economies of scale such as specialisation in labour and machinery and the sharing of utility connections, walls and other fixed costs. Some of these factors might be expected to give rise to discontinuities – for example, sprinklers are required in buildings above three storeys (FPAA 2018) – but these are not evident in our data. The relationship between height and costs is a major determinant of housing density, and the data surprise some readers, so we discuss this in some detail.

Figure 2 shows average construction cost per apartment for different building heights for our three cities from 2013 to 2018. The data are an unpublished disaggregation of the average capital city construction cost estimates in Table 3, discussed in ABS (2019b). The size of each circle reflects the number of building completions at each height. The horizontal axis is on a log scale, to focus on shorter buildings, which are more numerous. Three important relationships are clear:

1. Average construction cost does not change much with building height. So large increases in housing are possible without a substantial increase in the cost of supply.

2. Nevertheless, there is a small positive correlation. Apartments do tend to become a bit more expensive to supply as building heights increase.

3. It costs slightly more to build apartments in Sydney than in Melbourne, followed by Brisbane.

We summarise these relationships with the following rule of thumb:

$$Average\ cost\,(in\ \$/dwelling) = Base\ cost + \$2,291 \times number\ of\ storeys \tag{1}$$

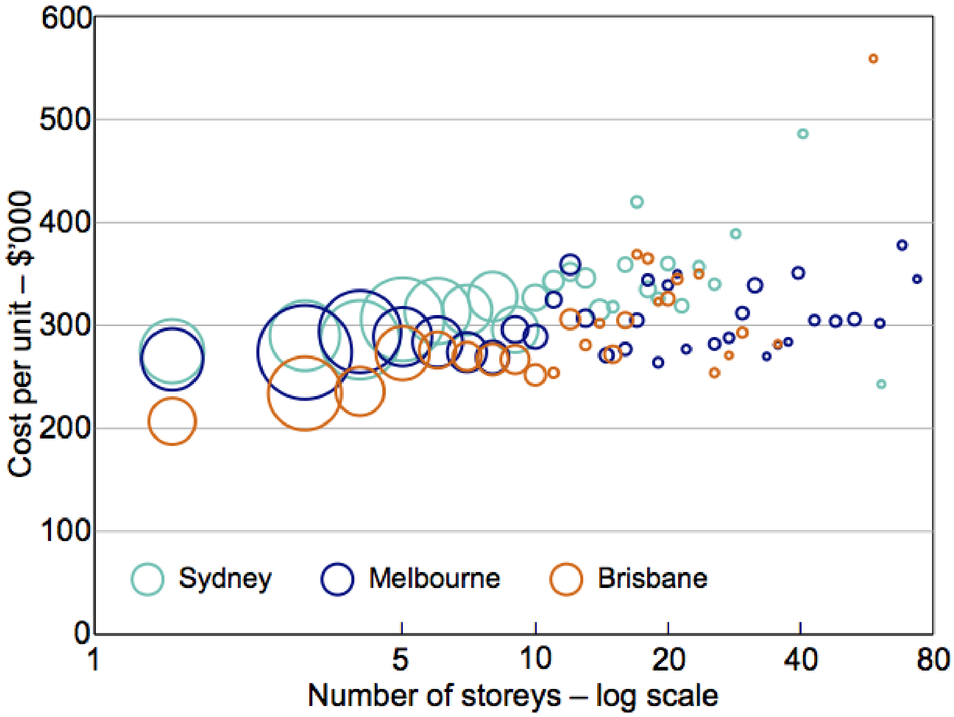
where the base cost is \$316,337 for Sydney, \$273,450 for Melbourne and \$258,470 for Brisbane. These estimates are from a regression of the 85 observations (representing 3,732 buildings) plotted in Figure 2.[5] The regression sample is 2013–18; we scale the coefficients to 2018 prices using changes in the other residential producer price index (PPI). We have relatively few tall buildings in Sydney or Brisbane. For example, in Sydney fewer than 1 per cent of apartment building completions in our sample are above 30 storeys. Accordingly, we assume that costs in Melbourne provide a guide to what tall buildings would cost in Sydney or Brisbane. Specifically, we constrain the slope coefficients to be the same, though intercepts are allowed to vary. This constraint is significantly rejected, but extrapolating unrestricted coefficients would imply large differences in costs of very tall buildings across cities which would be inconsistent with other data sources, such as Rider Levett Bucknell (2017). Moreover, similar slope coefficients would be expected given that construction techniques, architectural design and the cost of labour and materials are similar across cities. We weight the regression observations by the number of buildings, on the assumption that

5 The ABS data are generally available at an individual storey level up to 20 storeys. Beyond this height, buildings are grouped into larger categories to preserve confidentiality and we use the midpoint of the range.

each building provides an independent observation on the relationship. We show some alternative specifications in Appendix E. A regression that is unweighted or weighted by the number of apartments would have a flatter slope. Excluding the tallest buildings would increase the slope estimate slightly, but this approach seems like ignoring relevant information.

Figure 2: Average Apartment Construction Costs

Circle size represents number of buildings, 2013–18



Source: ABS (unpublished)

A more complicated model could allow for the possibility that apartment characteristics vary with building height. If these characteristics also varied with costs then our slope coefficient would be biased. Apartment size, as measured by gross floor space per apartment, is weakly correlated with building height and is not statistically significant when included in our regression (p-value = 0.99). We do not have good data on how costs might vary with location or other dimensions of quality. We expect that future research using information on building characteristics could develop a more detailed model.

Figure 3 compares our estimates with others. The thicker black line labelled ABS is an unweighted average of our estimates for Sydney, Melbourne and Brisbane. Alternative estimates come from a range of countries and are estimated with different methods. The ABS figures appear to be broadly in line with most of these other data sources. Most importantly, they are close to the estimates from

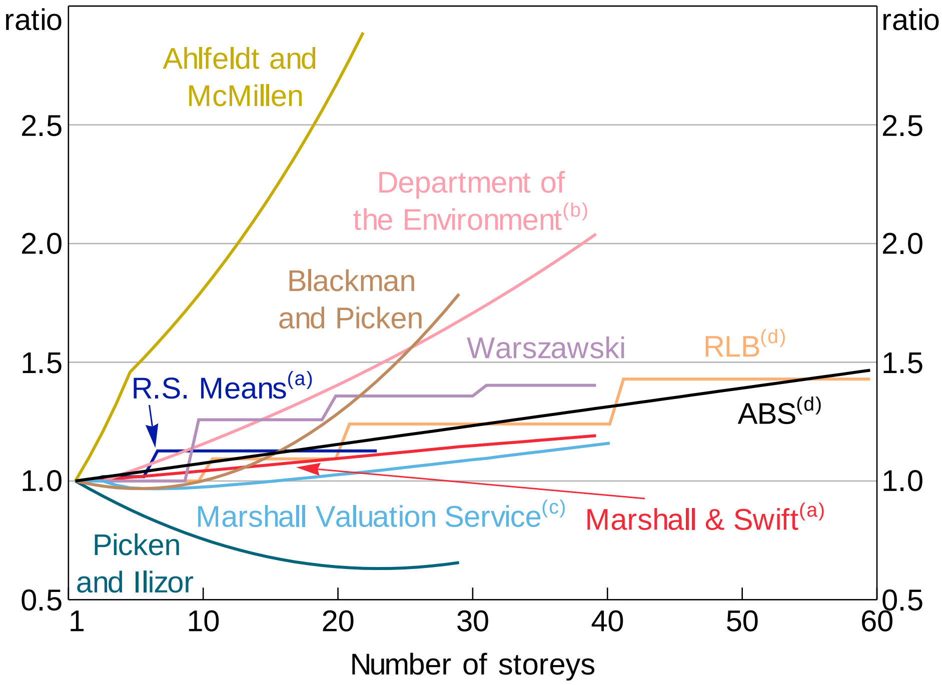
Rider Levett Bucknell (the orange line, labelled RLB), the other data source we have for Australia. The RLB estimates, like several others, hold quality constant.[6]

The flatness of the empirical cost profiles shown in Figure 3 contrasts with the steep profiles assumed in calibrated models of urban structure. For example, in an Alonso-Muth-Mills model of Australian cities, Kulish *et al* (2011) assume, following the international literature, that the elasticity of housing production with respect to the capital-to-land ratio is 0.6. Given some simple assumptions, that implies the average cost of supplying an apartment increases by 6.7 per cent with every 10 per cent increase in height, which would be steeper than any of the empirical estimates in Figure 3. These models may be attributing the flat, sprawling nature of our cities to unrealistically high costs of building up instead of to planning restrictions. (Though Kulish *et al* also find planning restrictions to have large effects).

The cost schedules in Figure 3, or marginal costs derived from them, can be interpreted as representing a relatively flat short-run supply curve for apartments in the absence of planning restrictions. We discuss this interpretation further in Section 8. In contrast, empirical estimates of the actual supply of apartments find it to be highly price inelastic. For example, Saunders and Tulip (2019, Figures 4 and 7) estimate that a sustained 10 per cent increase in price would temporarily boost construction of high-density housing by 30 per cent. However, this response is short-lived and the housing stock only increases by 0.7 per cent. So the estimated medium and long-run price elasticity of supply is only 0.07 (not a typo). Planning restrictions do not prevent all building, but they do make it much less responsive to relative prices than it would be otherwise.

6 Some other comments. Picken and Ilozor (2003) for Hong Kong and Blackman and Picken (2010) for Shanghai contain substantial literature reviews, including discussion of papers we do not show. We estimate costs increase slightly faster than estimates for Manhattan by R.S. Means and Marshall & Swift discussed in detail by Glaeser *et al* (2005). However, their estimates of marginal cost are much higher, reflecting the lower height of Australian buildings. Ahlfeldt and McMillen (2018, Table 5) is high profile and thorough, however, their focus is on super-tall skyscrapers. Their estimates for small and moderate buildings are from a large international survey that we suspect is heterogenous: taller buildings within a country are more likely to be built in relatively expensive cities. The Department of Environment (Seeley 1976) rule of thumb that costs increase by 2 per cent per floor is widely cited, but old. Warszawski's (2003) engineering-based estimates assume that buildings above 10 storeys need to provide undercover parking whereas shorter buildings do not. In contrast, our ABS estimates reflect actual expenditure on undercover parking.

Figure 3: Average Apartment Costs
By number of storeys, ratio to lowest height



Notes: (a) As cited in Glaeser *et al* (2005)
(b) As cited in Seeley (1976)
(c) As cited in Arnott and MacKinnon (1977)
(d) Simple average of Sydney, Melbourne and Brisbane construction costs

Sources: ABS; Ahlfeldt and McMillen (2018); Arnott and MacKinnon (1977); Authors' calculations; Blackman and Picken (2010); Glaeser *et al* (2005); Picken and Ilozor (2003); Rider Levett Bucknall; Seeley (1976); Warszawski (2003)

Multiplying Equation (1) by the number of apartments then differentiating gives marginal construction cost, the cost of supplying an extra apartment by adding a storey:

$$Marginal\ cost = \frac{\partial Total\ costs}{\partial number} = Base\ cost + 2 \times \$2,291 \times number\ of\ storeys \quad (2)$$

We evaluate Equation (2) at the trend building height of the average apartment.[7] In 2018 this was 10 storeys in Sydney, 17 in Melbourne and 13 in Brisbane. Evaluation at this point gives consistent comparisons with the price of the average apartment and the cost of building out in Section 6. Estimates are shown in row 4 of Table 3.

We allow construction costs to increase with height and assume that most other costs (with the exception of infrastructure charges) increase in proportion. Finance and equity costs should arguably increase more than proportionately, reflecting the longer construction time and complexity of taller buildings. Offsetting this, sale prices also increase with height. We suspect the net effect of these complications is small and we ignore them.

7 This admittedly awkward expression represents the average building height when weighted by the number of apartments. It is substantially higher than the unweighted average building height because more apartments are in taller buildings.

4.3 Financing Costs and Developer's Profit

Construction cost estimates above are for the 'tender price' and include *builder's* margins. Table 3 makes additional allowances for interest and *developer's* margins. These returns reflect compensation for the risks taken by creditors and equity holders respectively. (It is often convenient to combine returns to equity and debt because there are large variations in leverage among developers). The risks (and hence profit) are greater for spending on land than for spending on the structure. Land is often purchased when planning approval, demand conditions and so on are uncertain, so is highly speculative. In contrast, construction spending occurs after legal permission to build has been granted and apartments have been pre-sold, so is less risky. Accordingly, we assume developer's margins are greater for land and hence building out than for building up.

Following industry discussions and the estimates in Urbis (2011, pp 42–44) and CIE (2011, p 40), we assume finance costs are 8 per cent of structure costs for 'building up' while developer's margins are 17 per cent.[8] These are larger estimates than the 15 per cent (covering both finance and equity) in Kendall and Tulip (2018), 10 per cent for developer margins in Kelly, Weidmann and Walsh (2011) or 10 to 14 per cent for developer margins in Hsieh, Norman and Orsmond (2012, Table 2). Based on industry discussions, we assume finance adds 10 per cent and equity 25 per cent to the cost of land acquisition. Several industry participants use a rule of thumb of 20 or 25 per cent of total costs (both land and construction) for developer's margins, which fall between our estimates for land and structures. This rule of thumb is often used in residual land valuation, discussed in Appendix B.

Returns to finance and equity is perhaps the element of costs with the greatest uncertainty. Part of the difficulty is quantification, given the absence of broad-based evidence and the variety of industry estimates. This is especially difficult as the relevant measure for our purposes is *ex ante* or planned returns, not the *ex post* or actual returns that are often documented. The greater difficulty is conceptual. To what extent are these costs separate from the effect of planning restrictions?

Many developers argue that the risks in housing supply (and, by implication, compensation for those risks) should be attributed to the planning system. A major source of losses is rejection of development proposals after property has been purchased at prices that reflected a positive probability of approval. Profits need to be high on completed projects to compensate for these losses. CIE (2011, p 46) suggest that, based on estimates for the United States, a less risky planning environment could reduce margins by about 5 percentage points. Moreover, the delays in gaining approval substantially increase financing costs.

Glaeser *et al* (2005) assume that developer's margins should not be counted as a cost of supply. They argue that the planning system generates large rents which are dissipated in efforts to get around them. It is not clear that losses incurred on lobbying or on rejected rezoning applications represent social costs or resources requiring compensation. Rather, rent-seeking expenses represent part of the effect of planning restrictions on housing prices.

In principle, developers also require compensation for bearing the risks of variations in demand and costs. Unexpected variations in demand are typically small relative to uncertainty about planning. Most apartments are pre-sold before construction, with buyers putting down deposits of around

8 Taking unweighted averages across the three cities, Urbis estimates that finance and profit comprise 8 per cent and 17 per cent respectively of total costs, while CIE estimates 7 per cent and 17 per cent.

10 per cent. A small share of these fail to settle (RBA 2019). The cost of these failures is initially borne by buyers forfeiting their deposit. Developers make losses when prices fall by more than deposits, but this is infrequent. Likewise, cost overruns are a smaller risk than they may appear. The ABS estimates of construction costs are for actual – not planned – expenditures so include the average overrun. While uncertainty about overruns creates a risk that requires compensation, this is a primary role of the builder's margin, which is also in the ABS estimate.

In short, we consider our assumptions, especially the 17 per cent developer's margin for building up, to be generous. Some industry contacts suggest a lower margin for construction costs and a higher margin for land costs might be realistic. That would further strengthen our main conclusions, so our results may be conservative. We are also told, but are unable to quantify, that margins are substantially higher in Sydney than in Brisbane. More research and data on this topic would be useful.

5. Variations in Apartment Shortages

5.1 Where is the Shortage Most Severe?

Where new housing should be located will be determined by site-specific factors such as the price of land, alternative uses and so on. Nevertheless, the gap between price and cost at a regional level should be important in determining the broad contours of development. Figure 4 shows the effects of building restrictions at the ABS's Statistical Area 3 (SA3) level for Sydney, Melbourne and Brisbane.[9] The effect is calculated by taking the difference between the average sale price of new apartments and the cost of supply within each region. We focus on the cost of building up, which is typically lower than the cost of building out.

To reliably estimate at a local level, we average prices and costs over a longer period of time, from July 2011 to December 2016. As discussed in Section 5.2, the average effects of building restrictions were somewhat different over this period than in 2018, especially for Brisbane. Sale prices are SA3 averages from CoreLogic, with the same filters used as in Section 4.1 and Appendix A.1. To estimate marginal costs, we first calculate average cost per dwelling from the ABS Building Approvals collection for each SA3. In measuring construction costs at a local level we are allowing for apartments in expensive areas being larger and of higher quality. We then make a series of adjustments to convert these raw average construction costs to marginal costs. Specifically, we make a 5 per cent allowance for cost overruns (our estimate of the average difference in costs in the ABS Building Activity Survey and its Approvals collection) and an adjustment for the difference between marginal and average costs. The adjustment from average to marginal costs varies by region within each city, and depends on the average building height of recently constructed apartments. For instance, we scale up costs, in accordance with Equation (2), in Sydney Inner City by 9 per cent (where the building height of the average apartment is 13 storeys) and in Hornsby by 4 per cent (6 storeys).

9 We cannot disaggregate further – for example, to the suburb level – without disaggregated estimates of construction costs.

We make additional adjustments for margins, financing costs and legal and marketing fees, which collectively add another 37 per cent to our estimate of marginal cost. Finally, we make an allowance for infrastructure charges, which adds between $10,000 and $20,000 per dwelling, depending on the city. SA3s with fewer than 200 sales or apartments approved (such as Manly in Sydney or Keilor in Melbourne) are not shown.

Figure 4: Apartment Shortage by SA3

July 2011–December 2016

(*continued next page*)

Sydney

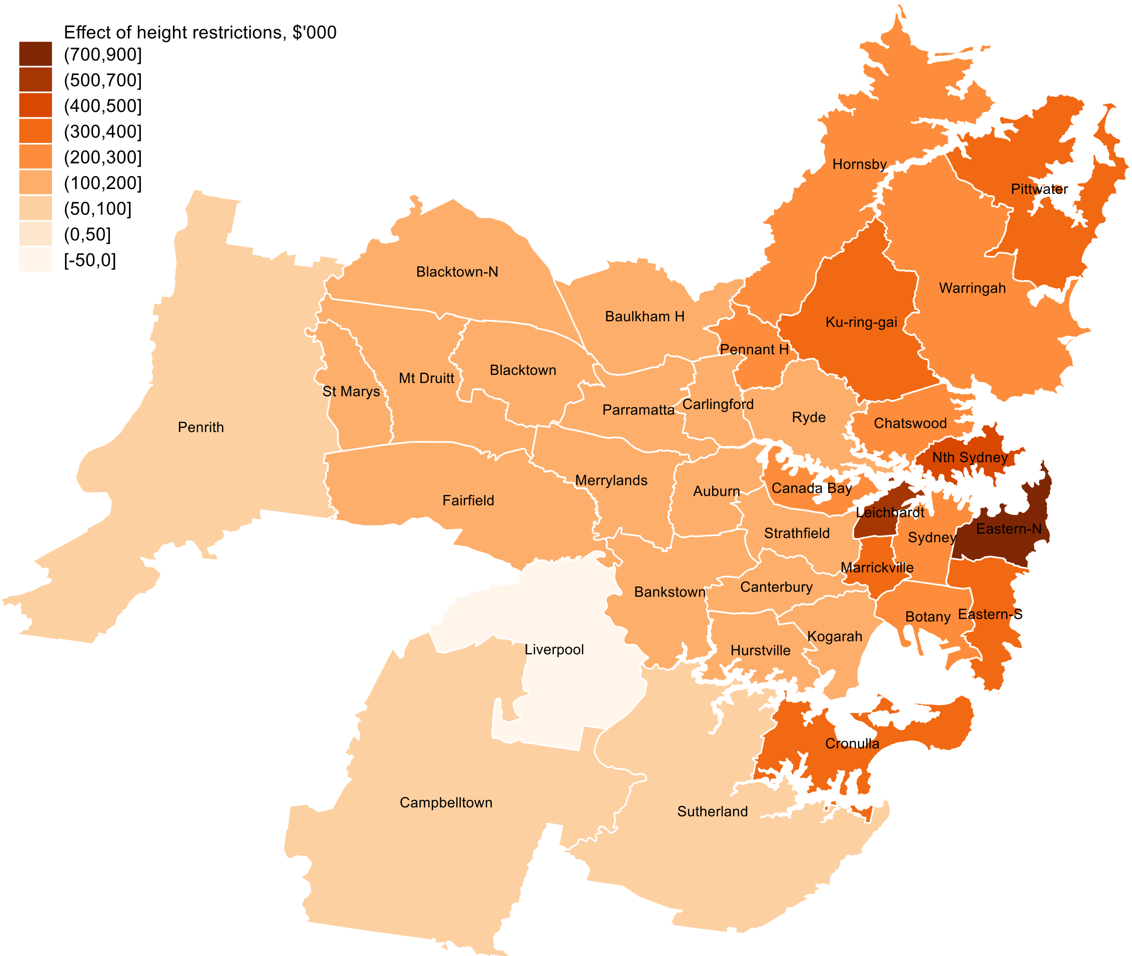
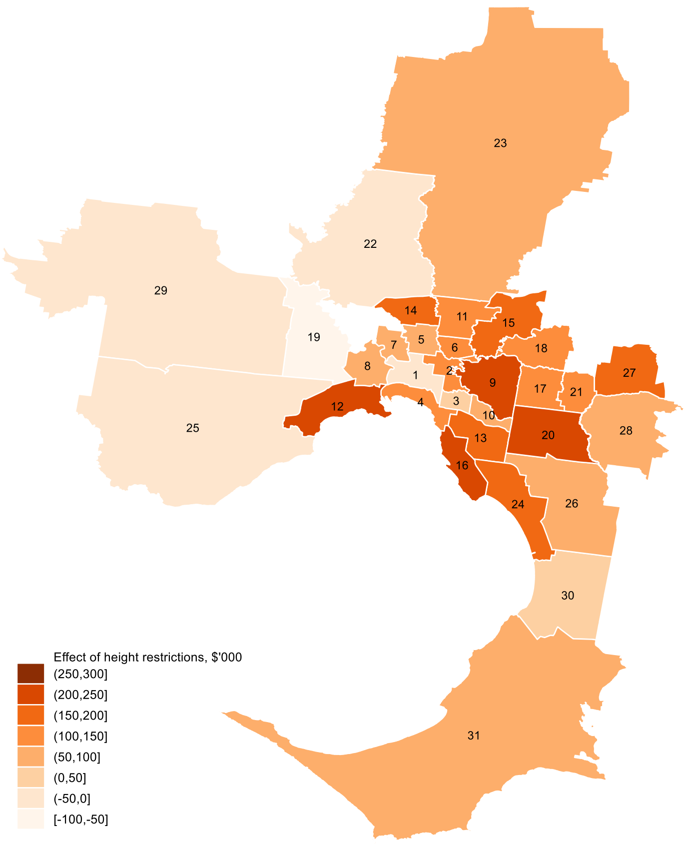


Figure 4: Apartment Shortage by SA3

July 2011–December 2016

(*continued*)

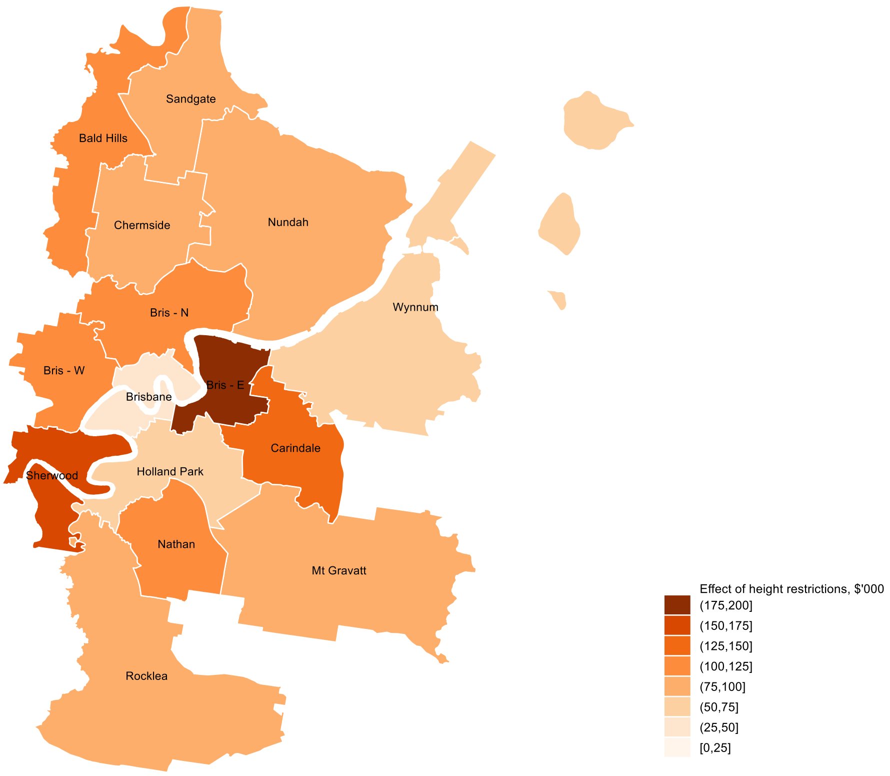
Melbourne



SA3s ranked by distance to CBD

1 Melbourne City
2 Yarra
3 Stonnington – West
4 Port Phillip
5 Brunswick–Coburg
6 Darebin – South
7 Essendon
8 Maribyrnong
9 Boroondara
10 Stonnington – East
11 Darebin – North
12 Hobsons Bay
13 Glen Eira
14 Moreland – North
15 Banyule
16 Bayside
17 Whitehorse – West
18 Manningham – West
19 Brimbank
20 Monash
21 Whitehorse – East
22 Tullamarine–Broadmeadows
23 Whittlesea–Wallan
24 Kingston
25 Wyndham
26 Dandenong
27 Maroondah
28 Knox
29 Melton–Bacchus Marsh
30 Frankston
31 Mornington Peninsula

Brisbane

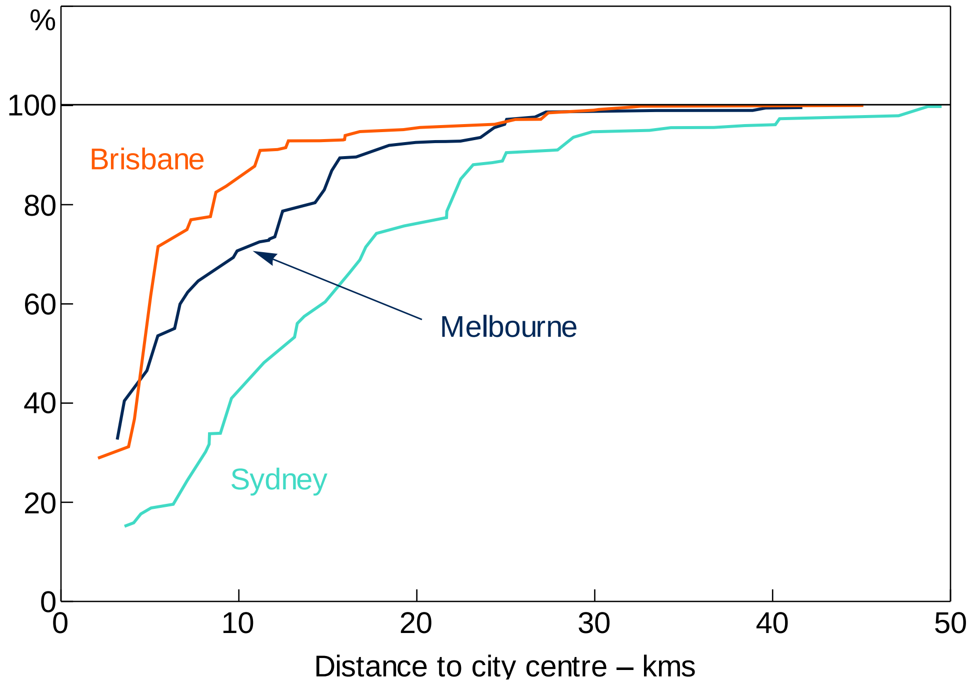


Sources: ABS; Authors' calculations; Centre for International Economics; CoreLogic data; Industry consultation; Urbis

The map of Sydney shows the effect of restrictions to be small on the outskirts, moderate in the middle ring and large near the centre. The largest gaps between demand and cost occur in inner areas of Sydney, such as the Eastern Suburbs, Leichardt and North Sydney. In contrast, prices near the centre of Melbourne and Brisbane are close to costs – even though relative travel times and amenities are comparable to inner Sydney. These differences seem to reflect differences in building patterns. As Figure 5 shows, apartment building in Brisbane and Melbourne has been concentrated in the centre, whereas most of Sydney's apartments have been built in middle-ring suburbs. As noted in the introduction, a large location premium, as in inner Sydney, can only be sustained with supply restrictions.

Figure 5: Apartment Completions by Distance to CBD

Cumulative share of city total, 2013–18



Sources: ABS (unpublished); Authors' calculations; CoreLogic data

The dispersal of apartment building in Sydney is sometimes supported on the grounds that it is less costly to build in outlying suburbs, where land is cheaper. However, home buyers place a lower value on apartments that are far from the city centre and they will readily pay the higher costs of central locations. Recent development in Melbourne and Brisbane accommodates these preferences. Housing on the outskirts is worth providing, but it is an imperfect substitute for the housing that home buyers are most willing to pay for.

Regional disparities within Sydney may get more severe. The NSW Planning Department's 'Sydney Housing Supply Forecast' projects that a ring of six local government areas some 40 to 65 kilometres from the city centre (Blacktown, Camden, Campbelltown, Liverpool, Penrith and The Hills) will account for 36 per cent of new housing built over the next five years, although these areas only account for 24 per cent of the Greater Sydney population.[10]

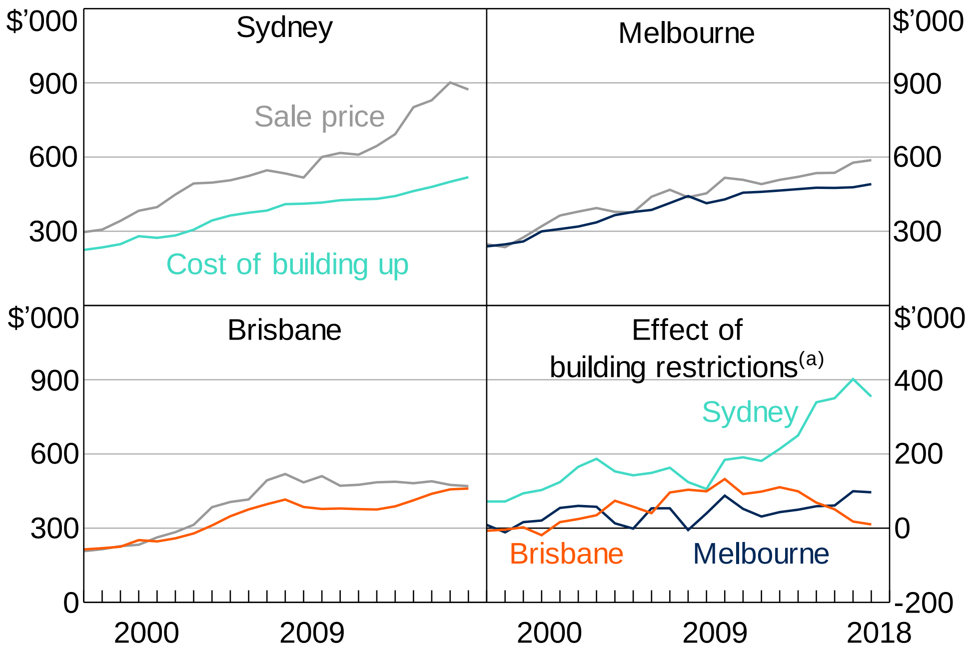
Each of the three maps shows areas in which the effect of building restrictions is small or negative. Although measurement error and other noise may be a factor, we would expect construction activity to vary due to non-regulatory factors in these areas. Perhaps more importantly, these observations show that our overall results are consistent with planning restrictions being important at the metropolitan level while not binding in some areas. Moreover, they demonstrate that there is nothing in our estimation technique that forces the effect of building restrictions to be large or positive.

5.2 Changes over Time

Figure 6 extends the estimated effect of building restrictions from Table 1 back in time.

Figure 6: Prices, Costs and Effect of Height Restrictions

Per apartment



Note: (a) The effect of building restrictions for each city is the average sale price of new apartments less the estimated cost of building up

Sources: ABS; Authors' calculations; Centre for International Economics; CoreLogic data; Rider Levett Bucknall; Urbis

We use sales data from CoreLogic from 1997 to 2016 and apply the same filters as discussed in Appendix A.1. That means the price series represents the average sale price of new apartments. We do not control for changes in characteristics. After 2016 we assume prices grow at the same rate as CoreLogic's hedonic unit price index for the relevant city.

Our marginal cost estimates, discussed in Section 4.1 and Appendix A, are calculated using building completions data from 2013–18. We extend these estimates back to 1997 (the earliest period for

10 The 2019 'Sydney Housing Supply Forecast' data can be downloaded from the NSW Department of Planning, Industry and Environment website at <https://www.planning.nsw.gov.au/Research-and-Demography/Sydney-Housing-Supply-Forecast/Forecast-data>.

which data are available) using the other residential PPI for each state. We evaluate marginal costs at the trend building height of the average apartment for each city, as discussed in Appendix A.2. We make the same proportionate adjustments for developer's margins, financing costs, marketing and legal fees.[11]

Over the past decade, we find that the effect of height restrictions has increased substantially in Sydney while remaining moderate in Melbourne. The small estimate for Brisbane in 2018 is unusual relative to previous experience – for most of the past two decades apartment prices in Brisbane have substantially exceeded costs. The differences in recent price movements seem to partly reflect differences in supply. Shoory (2016, Table 1) shows that the apartment stock has been growing relatively slowly in Sydney, moderately in Melbourne and quickly in Brisbane.

6. The Cost of Building Out

6.1 Land Purchase Costs

Whereas Sections 4 and 5 assumed that extra apartments could be supplied by increasing building height, in this section we consider increasing the number of buildings. That saves on construction costs but requires extra land on which to build the structure. Valuing land is sensitive to assumptions about where extra construction might occur. For example, land tends to be expensive near the city centre and inexpensive on the outskirts. Some illustrative data are in Table 4.

Table 4: Apartment Land Requirements and Costs
2018

	Sydney	Melbourne	Brisbane
Average number of apartments per building[(a)]	117	175	112
Average land per building (m^2)[(a)]	2,397	1,924	2,136
Average land area per apartment (m^2)[(a)]	20	11	19
Average land area of detached houses (m^2)[(b)]	625	629	803
Average price of detached houses[(c),(d)]	$1.23m	$0.90m	$0.56m
Cost of land per m^2 (unweighted)[(e)]	$1,965	$1,438	$700
Cost of land per m^2 (weighted)[(e)]	$4,033	$4,045	$1,763
Cost of land per apartment (weighted)	$82,664	$44,475	$33,581

Notes: (a) Data for these variables are only available aggregated over the 2013–18 period; for the sake of comparability with our other estimates, we assume that this period overall provides a good representation of the nature of apartment development in 2018

(b) Average detached house lot areas are for 2016, the latest year for which data are available

(c) House sale prices are trimmed at the top and bottom 1 per cent each year, first at the city level and then within each SA3; all properties with a land area greater than 2 acres (8,094 m^2) have also been excluded

(d) The CoreLogic unit record data we use extends to 2016; estimates for 2018 are made by extrapolating forward using CoreLogic's city-level hedonic unit price index

(e) Unweighted land costs are averaged over all detached house sales in a city within our CoreLogic database; weighted land costs take SA3-level detached house sale prices and weight them by each region's 2013–18 share of new apartment completions within each city

Sources: ABS (unpublished); Authors' calculations; CoreLogic data

11 We assume that the GST raised costs relative to the PPI by 10 per cent in 2000. The CoreLogic price data include GST (in principle) and do not require adjustment.

Unpublished data from the Building Activity Survey covering the 2013–18 period indicate that the average new Sydney apartment is in a building comprised of 117 apartments (row 1, Table 4) and which occupies 2,397 square metres of land (row 2). That implies the average apartment uses 20 square metres of land (row 3). For reasons discussed below we do not value this land at its market price but at its opportunity cost under an alternative policy: its value if reserved for detached houses. The average Sydney house occupies 625 square metres of land and costs $1.2 million, including structure (Kendall and Tulip (2018), updated) at an (unweighted) average cost of $1,965 per square metre (rows 4, 5 and 6). This represents a simple benchmark to which we refer later. A more realistic assumption, and one consistent with estimating effects of marginal changes, is to assume that new building occurs in similar locations to recent construction. In particular, more apartments are built on relatively expensive land closer to the city centre. If we weight by apartment completions in each SA3 from 2013 to 2018, the average price of land used for detached housing increases to $4,033 per square metre.[12] Multiplying this by the land requirement of the average apartment implies that the land for extra apartments would cost about $82,700 per apartment (final row), or $9.7 million for the representative apartment building. Similar calculations in columns 2 and 3 imply that the cost of land for replacing nearby houses with apartments of their current configuration is about $44,000 per apartment in Melbourne and $34,000 per apartment in Brisbane.

In comparison, Urbis assumes land acquisition costs of $105,000, $41,000 and $53,000 per apartment in Sydney, Melbourne and Brisbane in 2011, based on a 50-apartment building requiring 5,000 to 10,000 square metres of land and the average price of urban development land at chosen locations. In 2018 prices, this is substantially more expensive than our estimates. This partly reflects larger land area spread over fewer apartments. CIE (2011, p 36) assumes costs of $85,000, $55,000 and $72,000 in Sydney, Melbourne and Brisbane for the median apartment in 2011, but does not provide underlying details.

To value land at the average cost of detached housing would be an unrealistic description of how apartments are built under existing policy. The most likely sites for development include a large premium above other land, because their development potential is capitalised into the property value. Nevertheless, valuing land as though it were used for average detached housing is appropriate for comparing different policies. An alternative to the current policy of reserving most of our urban land for detached housing is that we build some apartments on that land. The opportunity cost of permitting more apartment buildings is the value of land when it is used for detached housing.[13]

6.2 Finance and Margins

We assume finance and developer's margins add 10 per cent and 25 per cent respectively to the cost of land, as discussed in Section 4.3. These assumptions are larger than those of Urbis and the CIE. As previously discussed, it seems appropriate to assume risks are substantially bigger at the beginning of a project than at the end.

12 For the sake of computational simplicity, this estimate ignores some small costs such as stamp duty, conveyancing and other transaction costs (about 4.5 per cent of the property value, according to Fox and Tulip (2014, Section A.5)); land tax, rates and other holding costs (about 5 per cent of property costs according to CIE (2011, p 42)) and demolition costs (about $15,000 for the average-sized house according to industry contacts and Rider Levett Bucknall (2017, p 40)).

13 This is perhaps the most important difference between our estimate of the effect of planning restrictions and the CIE's (2010) estimate of 'transformation benefits' from infill development.

6.3 The Cost of Building Out

Table 5 shows the cost of building out; that is, supplying extra apartment buildings of the current size and design in nearby locations. Average construction cost estimates are discussed in Appendix A.2. We then add land acquisition costs and higher finance and margin estimates, as discussed in the previous two subsections.

Table 5: Costs of Building Out
Per apartment, $'000, 2018

	Sydney	Melbourne	Brisbane
Average construction cost	340	312	287
Land[(a)]	83	44	34
Professional fees (3 per cent of total costs)	14	12	11
Marketing and sales (5 per cent)	24	20	18
Finance (10 per cent land, 7 per cent structure)	36	30	27
Developer's margin (25 per cent land, 17 per cent structure)	94	76	68
Infrastructure charges	18	10	26
Total average cost[(b)]	610	505	471

Notes: Sources for most entries are the same as for Table 3 or discussed in the accompanying text
(a) From Table 4
(b) Rows do not sum to total due to rounding

Total average cost estimates, the final row, are also presented in Table 1, which shows that the cost of building out is similar but somewhat higher than the cost of building up. Average costs are larger in Sydney than in Melbourne or Brisbane. The differences between cities arise partly because land per square metre is more expensive in Sydney (Table 4). Moreover, apartment buildings tend to be shorter in Sydney, making land per apartment even more expensive.

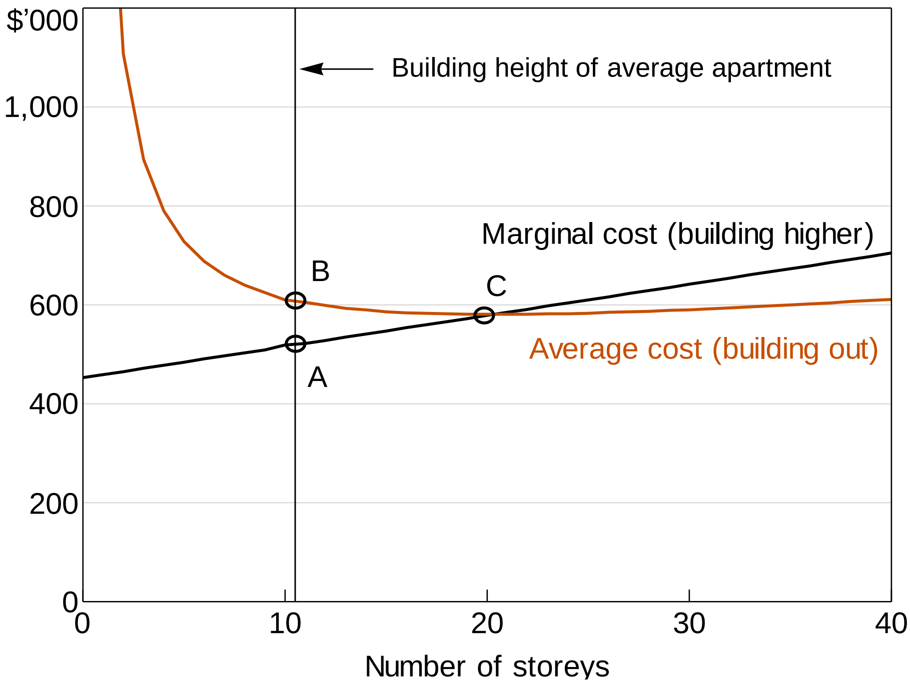
7. What is the Cost-efficient Height for Apartment Buildings?

Figure 7 compares the cost of building up with the cost of building out for different building heights. For illustration, estimates reflect average values for Sydney, where there is the most scope for changing building heights. The black line shows the marginal cost of adding an apartment on top of a building as a function of height, as calculated in Section 4. The orange line shows the average cost of replacing detached houses with apartment buildings of different heights, as calculated in Section 6. Average cost initially declines with height as the fixed land cost is spread among more apartments. However, this is partially offset by the increase in average cost with height discussed in Section 4.2. Parameter values and equations for the orange and black lines are given in Appendix C. Cheshire and Hilber (2008) discuss several variations on this figure. Chau *et al* (2007) discuss optimal building height in more detail.

The cost curves in Figure 6 vary height while holding other factors constant. This includes holding the value of land constant at $4,033 per square metre, even though, in practice, land zoned for high-rise apartments is much more expensive than land zoned for low rises. This is because a developer (or town planner examining the project in isolation) must decide where and how high to build, taking the cost of land as given. The average cost curve illustrates the consequences of different decisions. We also hold building and land area constant at 1,173 square metres and 2,397 square metres respectively. In practice, taller buildings tend to occupy more land, so a more intuitive description of the curve may be that it varies density (as measured by FSR).

Figure 7: How Cost Estimates Vary with Height

Sydney apartments, 2018



Sources: ABS; Authors' calculations; Centre for International Economics; CoreLogic data; Urbis

The vertical line represents the building height of the average apartment, 10.5 storeys. Point A is the marginal cost of building up from Table 3, $519,000. Point B is the average cost of building out from Table 5, $610,000. It is less expensive to go up (point A) than out (point B) until buildings reach 20 storeys, labelled point C, when building out becomes the less costly option. We call point C the 'efficient' building height, acknowledging that this is a narrow definition of the term – our estimate ignores externalities and the tendency of price to increase with height, considerations we briefly discuss in Section 9. At this height, it costs $581,000 to supply extra apartments by either approach.

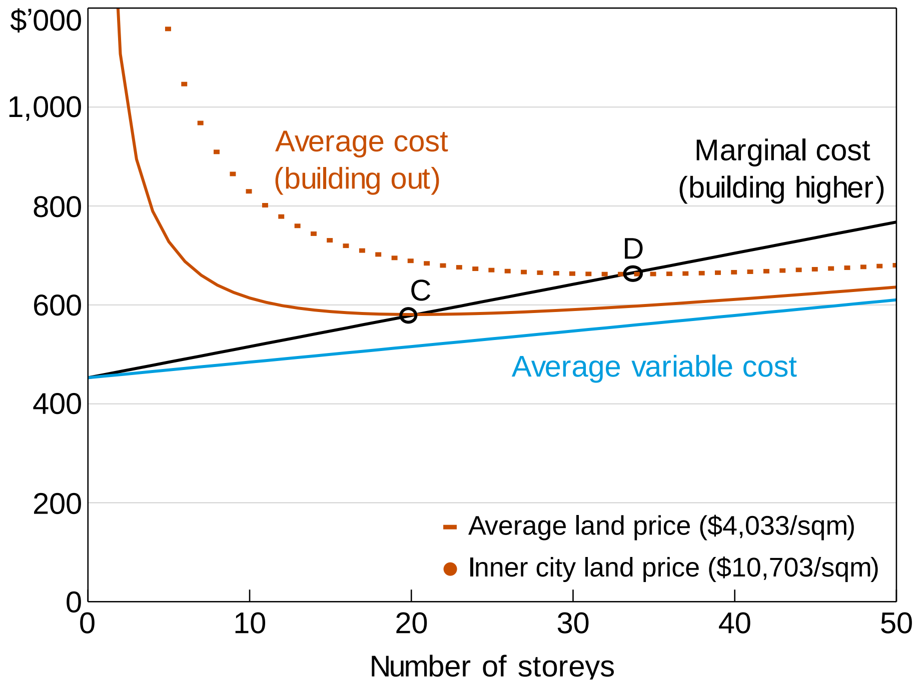
In Melbourne and Brisbane, the average cost curve would intersect with marginal costs much closer to the building height of the average apartment in those cities. The lowest cost at which apartments could be supplied would be $504,000 in Melbourne and $468,000 in Brisbane.

Point C in Figure 7 represents the density of development that a builder or planner would choose if they were free to purchase detached houses at their weighted average price and replace them with apartment buildings of any height. Economists will wonder if profits would be maximized by building up until marginal cost equals the price (not shown). Using the average Sydney sale price in 2018 of $873,000, this would be taller than any building in our database. However, this only applies to a builder or planner with access to a fixed amount of land (for instance, due to land use restrictions that prevent new building). If more land can be bought then costs are reduced by supplying more buildings at the efficient height.

Figure 8 reproduces the solid orange and black lines from Figure 7. The dotted orange line shows an increase in the price of land to $10,703 per square metre, the cost of single-dwelling properties in the Inner Sydney SA3. It would then become economic to build up to 33 storeys (point D). The blue line represents the average variable cost of building up or the limiting case of building out when land is free, as is approximately the case in agricultural areas. Then the least costly apartment buildings would be a single storey.

Figure 8: How Alternative Estimates of Cost Vary with Height

Sydney apartments, 2018

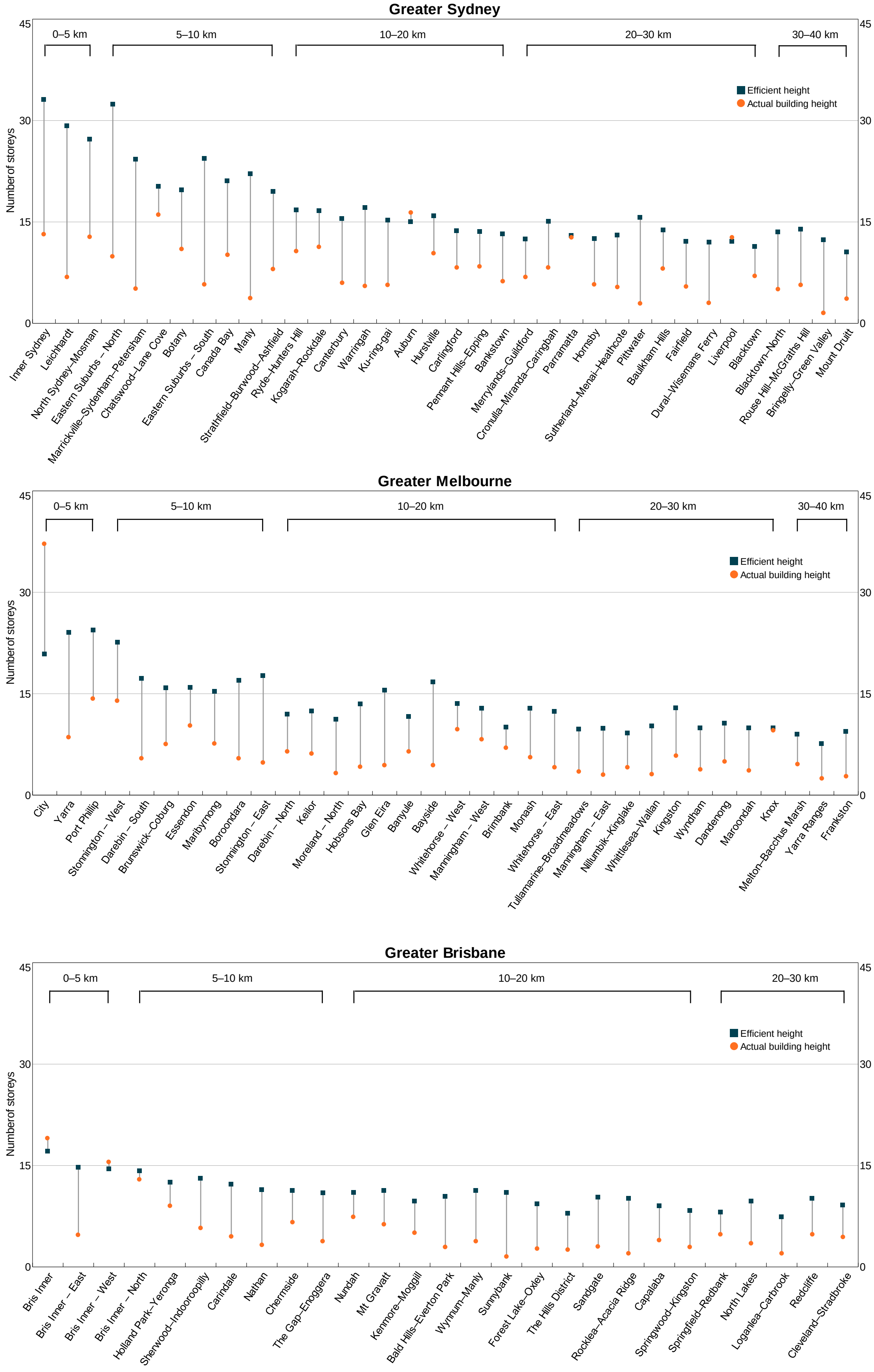


Sources: ABS; Authors' calculations; Centre for International Economics; CoreLogic data; Urbis

Figure 9 extends these results for a wide range of locations and land prices. Specifically, we take the average price of land being used for houses in each SA3 from CoreLogic. This tends to vary inversely with distance from the city centre, and the horizontal axis ranks regions on this dimension.[14] The dark blue squares show implied cost-minimising building heights, given these land prices, as discussed above. The leftmost observation, for Inner Sydney, represents point D in Figure 8. Orange circles show the building height of the average apartment built between 2013 and 2018. We only show estimates within 30 or 40 kilometres of the city centre. As shown in Figure 5, very few apartments are built further out than this. Moreover, the efficient height estimates are for infill. In outlying suburbs development tends to be of greenfield sites where the opportunity cost is less expensive vacant land.

14 SA3 proximity to the CBD is calculated by averaging the mean distance to the CBD of all properties sold within that SA3 during 2016, rather than the geographic centre of SA3 boundaries.

Figure 9: Efficient and Actual Building Heights – By SA3



Note: Efficient heights are for current land values

Sources: ABS; Authors' calculations; Centre for International Economics; CoreLogic data; Urbis

Strikingly, newly completed apartment buildings have been shorter than the lowest cost height in almost every area. The gap is most pronounced in central regions of Sydney: the Inner City, North Sydney, Eastern Suburbs and Leichhardt would reduce average apartment costs by increasing building heights by about 20 storeys. In contrast, buildings have been built up to their efficient height in inner areas of Brisbane and even higher in central Melbourne. Taken at face value, the result for central Melbourne would imply that developers would increase profits by building more but shorter buildings. We think this is unlikely and illustrates a limitation of our approach. We estimate building heights based on the average value of detached housing in each SA3. However, tall buildings are more likely to be located on the most expensive land, rather than the average. We suspect that a finer level of disaggregation would result in a higher efficient height for inner Melbourne. Other pockets of high-density building that may be interesting to note include Auburn, Parramatta and Liverpool in Sydney and Knox in Melbourne.

Although Figures 4 and 9 both show results disaggregated by SA3, they address different questions. Figure 4 compares costs with prices to ask: *whether* to build apartments in different locations? Figure 9 compares the cost of building up with the cost of building out to address the question: if apartments replace houses, how high should they be?

A striking feature of Figures 7 and 8 is how costly it is to supply medium-density housing. As shown by the solid orange line, it costs about $894,000 per apartment to replace detached houses with a three-storey building in Sydney.[15] Two-storey apartments would cost much more.[16] This is considerably more costly than providing high density. The reason is that land costs represent a large component of overall costs for low-rise apartments.

The extra cost of low-rise buildings can be compared to the extra amount that home buyers are prepared to pay to live in them. Real estate advertisements rarely mention being in a low-rise building as a selling feature, suggesting the value of this is small. To gauge this more precisely we regress Sydney apartment prices on a wide range of hedonic controls, including suburb dummies and the number of bedrooms and bathrooms. We include the number of dwellings at an address, constructed from the PSMA's Geocoded National Address File (G-NAF), as a measure of density. The most attractive density, as determined by willingness to pay, is buildings with fewer than ten dwellings, for which buyers pay a premium of 6.3 per cent (p-value < 0.01) or about $55,000. However, the cost of supplying housing at this density is hundreds of thousands of dollars more than at average building heights. We note that our regression has some puzzling features. For example, we expected proximity to train stations and light rail stops to significantly boost values but they do not. We also did not expect proximity to education facilities (e.g. TAFEs) and swimming pools to significantly reduce values but they do. Moreover, we are not aware that the G-NAF data have been used like this before. So our estimates should be treated cautiously. Regression output and further details are in Appendix D.

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15 This assumes new buildings are located near where other apartments have recently been built. If we instead assumed the new housing was located randomly in the Sydney metropolitan area (and hence the land was valued at the unweighted average price of detached housing), the cost would be $673,000 per apartment.

16 It is difficult to be more precise about low-rise apartments because the ABS aggregate buildings of one and two storeys.

These results have important implications for debates over urban planning. The Grattan Institute (Daley *et al* 2018, pp 53, 56) suggests that planners should prioritise medium-density housing in the middle ring of our cities, which they say is 'under-supplied'. Many planners and policymakers call for developing the 'missing middle' with terraces, townhouses and low-rise apartments. According to then NSW Minister for Planning Rob Stokes (2016),

> Medium density homes such as terraces are highly sought after, efficient and versatile forms of housing, but are in short supply compared with traditional quarter-acre blocks and high-rise apartments.

However, as noted above, expensive land makes medium-density housing considerably more costly than high density. And home buyers are largely indifferent between these options. So, on these narrow criteria, high rises would be more efficient. A free market would provide infill in the form of high density rather than medium density. Though, of course, policy decisions should also take externalities into account.

Medium-density housing is sometimes supported by reference to Kelly *et al* ((2011); updated by Daley *et al* (2018, Table 3.2)). This study surveyed home buyers about their preferences for different levels of density. For equivalent costs, survey respondents expressed a strong preference for more medium-density housing relative to detached housing. However, an under-emphasised finding of this survey is that respondents also expressed a strong preference for more high-density housing.

8. How Far Can Housing Prices be Lowered?

Some readers are especially interested in the amount that prices would fall in the absence of planning restrictions. A full answer would require estimation of general equilibrium effects (some of which are modelled in Kulish *et al* (2011)) and is beyond our scope. Nevertheless, as discussed in this section, our analysis suggests important elements of the answer and may provide a reasonable first approximation.

For context, 98,000 higher-density dwelling units were completed in 2018, representing about 1 per cent of the Australian housing stock. A mid-range estimate of the price elasticity of demand for housing is that a 1 per cent increase in dwellings would reduce housing prices by about 2½ per cent (Saunders and Tulip 2019, Section 5.3). So were the annual supply of new higher-density dwellings to double, the cost of housing would decline by an extra 2½ per cent per year. Costs of supply, shown in Table 6, provide a limit to this.

Table 6: Costs of Supply
Per apartment, $'000, 2018

	Sydney	Melbourne	Brisbane
Marginal cost of building up[(a)]	519	491	460
Minimum cost of building out[(b)]	581	504	468
Minimum cost if building is dispersed[(c)]	542	456	443

Notes: (a) From Tables 1 and 3
(b) Minimum cost estimates correspond to point C in Figure 7
(c) As in (b), except using the unweighted cost of land from Table 4

Sources: ABS; Authors' calculations; CoreLogic data

The estimates in row 1 represent the cost of supply by increasing building heights, reproduced from Tables 1 and 3. These estimates apply to a small increase in supply. For a large increase, after heights reach their efficient level, the lower-cost approach would then be to construct more apartment buildings. This point, which might be termed a 'long-run cost of supply' is represented by point C in Figure 7 and row 2 of Table 6. These estimates assume that new apartment buildings are built in the same areas as recently completed apartments. For a very large increase in construction, it seems possible that apartment buildings would spread throughout the metropolitan area. The final row of Table 6, which might be termed a 'very long-run cost of supply' assumes land is valued at the unweighted average price of detached housing.

The estimates in Table 6 provide benchmarks that are relatively straightforward to quantify. However, they are partial equilibrium, holding the price of inputs constant. In reality, costs would change if construction increased. For example, extra building would increase the demand for scarce inputs to the construction industry, such as materials and skilled labour. This would bid up their cost in the short run, until extra supply is forthcoming. However, a more important effect is on the price of land used for detached housing. Land constitutes a large proportion of housing costs and is supplied quite inelastically, so its price moves more than other factors. If new construction replaces each detached house with about 17 apartments, as the average values given in Tables 4 and A2 imply, then the net demand for detached housing will fall. This would alleviate both the physical and administrative scarcity of land used for detached housing and hence lower its price. By how far would depend on the elasticity of substitution between houses and apartments. Lower land prices would reduce the cost of building out. In terms of Figure 7, increases in the supply of apartments would lower the average (orange) cost curve and the equilibrium would move back along the black curve towards the origin. It could be possible to reduce housing costs further if, as discussed in Section 4.3, the risks in the planning process are reduced.

There are other considerations that a comprehensive assessment would take into account. For example, Kulish *et al* (2011, Section 3.2) argue that, while a relaxation of planning restrictions would reduce overall housing costs, the price of land near the centre and apartment sizes would both be expected to increase. Complications like these would affect quantification, however, they may matter more for the composition and density of housing than its overall price. It is not clear that they would outweigh the changes in costs noted above, of which the factors lowering prices seem to be more important than those raising prices. So apartment prices could fall well below the cost estimates in Tables 1 or 6.

9. Directions for Further Research

Our main conclusions were stated in the introduction and we do not repeat them here. Instead we offer a few comments on key uncertainties and where further work would be beneficial.

The greatest risk to our results is the possibility that our data do not capture all the costs of supplying new apartments. This may be because we interpret the data incorrectly or because we omit important costs. Developers have given us detailed valuation reports and ARGUS EstateMaster (common industry software) projections that they and their lenders use for financial planning, and we have attempted to align our estimates with these. However, individual reports vary and synthesising this information is difficult.

Within the components of costs we do measure, perhaps the greatest uncertainty is the threshold profit at which developers would be prepared to increase supply, as discussed in Section 4.3. We do not have good data on *ex post* margins and even less information on what might be needed *ex ante* in the absence of planning uncertainty.

With respect to prices, there are three uncertainties we would like to emphasise. The first is the difference between new and average apartment sales. We assume that sales within five years of construction are indicative of the returns developers might expect. However, as discussed in Appendix E, there are uncertainties about these estimates and new sale prices might be substantially larger than total sale prices.

Second is the Goods and Services Tax (GST). This is explicitly included in costs, so should also be included in prices. GST is payable on new properties but not on old. CoreLogic's policy is to quote prices including GST; however, it is not clear that their source data are always consistent with this. So some of our prices may be 10 per cent too low.

Third is the tendency of prices to increase with height. Glaeser *et al* (2005, p 362) estimate that each extra storey of height raises the price of Manhattan condominiums by about 0.08 per cent. A difficulty with estimates like these is that a view is more valuable if you can see over nearby buildings. So values increase more if other heights are constant than if all buildings were taller. We ignore this effect for reasons of simplicity and data availability. In doing so we underestimate the benefits of higher buildings.

We expect that these and other uncertainties could be narrowed with further effort. That said, our estimates seem qualitatively consistent with independent industry estimates of site values, discussed in Appendix B. Moreover, they are in line with international research, a large body of anecdotal evidence and expert judgement, discussed in Sections 1 and 2. So the uncertainty concerns precise quantification rather than the overall results.

With respect to future work, the top priority is to quantify the external costs and benefits of supply restrictions. Our paper estimates private costs. This provides a benchmark against which external benefits, such as those surveyed by Ahlfeldt and Pietrostefani (2019), can be compared.

Appendix A: Data

A.1 Prices

Table A1 shows details of the price estimates shown in Table 2. Specifically, it shows the effect various adjustments have on the number of sales and average prices.

Table A1: Apartment Prices and Sales

Effect of data filters, 2016

	Sydney		Melbourne		Brisbane	
	Price per dwelling ($)	No of sales	Price per dwelling ($)	No of sales	Price per dwelling ($)	No of sales
Unfiltered average unit price	884,261	28,540	578,162	25,319	475,413	10,472
Excluding townhouses, etc	899,529	26,476	578,467	16,773	521,192	7,070
Excluding misc outliers(a)	856,588	26,298	571,213	16,468	492,537	6,825
Restrict to new apartment sales	860,876	2,855	550,742	3,373	513,356	902
Trim top and bottom 1 per cent of sales	829,523	2,799	536,398	3,307	489,704	884
Memo: in 2018 prices	873,315		587,582		470,118	

Note: (a) Drops buildings with duplicate sales, blank or '0' unit numbers; drops sales more than three years before construction date

Sources: Authors' calculations; CoreLogic data

CoreLogic data on sale prices are often reported separately for houses and units. Within the latter category we make an effort to exclude townhouses, villas, estates and other types of strata dwellings that have a substantial land component. Since data on these characteristics are not always available, we exclude buildings where at least 10 per cent of sales are labelled as 'townhouse', 'triplex', 'quadraplex' or 'boarding house'. This is done for comparability with the ABS construction estimates which are for apartments. We additionally exclude some outliers and other implausible data entries, such as duplicate sales or sales occurring more than three years before the date of construction. We spot check these rules against photographs on real estate websites and they generally seem to rule in and rule out the right properties.

The profitability of supplying extra apartments is the difference between the cost and price of *new* dwellings. Accordingly, we exclude properties sold more than five years after construction. This filter is perhaps the most important step in Table A1 and we discuss its implications in Appendix E.

A small proportion of sales are anomalously high – in the tens or hundreds of millions of dollars – even though the building characteristics and location are little different from nearby apartments. We expect this occurs when an entire building is sold and its price is entered for individual apartments. To protect against data entry mistakes like this we exclude the top and bottom 1 per cent from our sample. In comparison, CoreLogic winsorise the top and bottom 5 per cent from many of the variables entering their indices.

Even after trimming, sale prices are heavily skewed. The median new sale price in Sydney or Melbourne is 11 per cent lower than the trimmed mean. Although some other research focuses on median housing prices, the mean is appropriate for calculating excess profits. Moreover, our cost estimates are only available on an average basis and presumably reflect the same skew, so consistency requires taking the difference between averages, not medians.

Finally, we multiply these estimates by the change in CoreLogic's unit sales price index for each city, to express in 2018 prices. This increases prices in Sydney and Melbourne and decreases them in Brisbane.

A troubling feature of our data is that the number of new apartment sales sometimes differs substantially from the number of apartment completions, especially at the end of our sample. We assume that the discrepancies between sales and completions are not systematically related to prices but were not able to verify this.

A.2 Unpublished Cost Estimates

Given that our estimates of average construction costs from the ABS Building Activity Survey are unpublished, Table A2 presents some summary statistics for the data, which may be of interest. Multiplication of units per storey by gross floor area per unit, and assuming that floor area per storey is constant, provides an estimate of building footprint, used in Section 7.

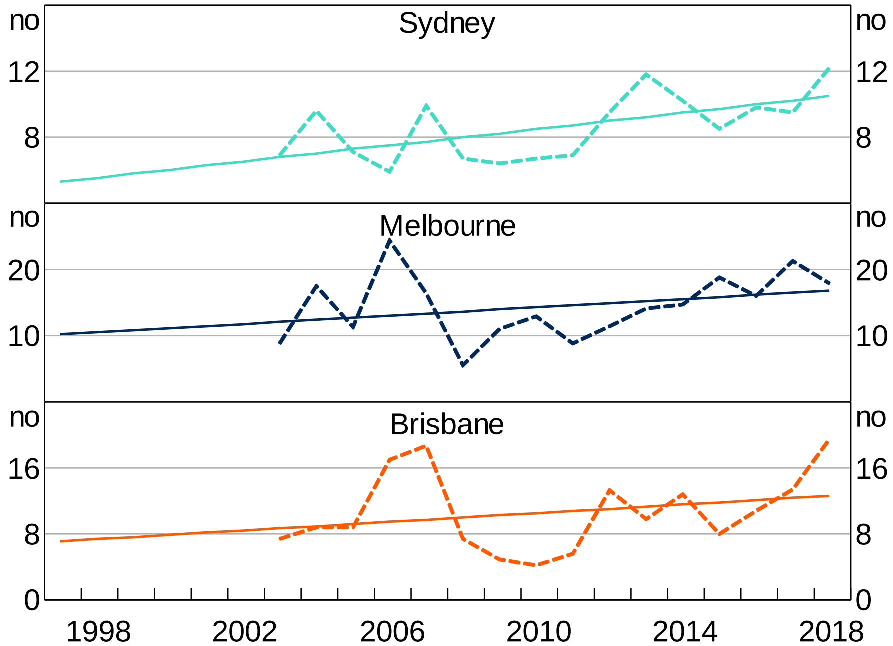
Table A2: Apartment Completions
By Greater Capital City Statistical Area, 2013–18

	Sydney	Melbourne	Brisbane
Average cost per unit ($'000)	**318**	**297**	**278**
Number of buildings	1,562	1,364	806
Number of apartments	98,929	80,421	38,116
Units per building	63	59	47
Gross floor area per unit (m^2)	105	105	118
Average units per storey	11.4	9.8	8.9
Average cost per gross m^2 ($)	3,040	2,839	2,359

Sources: ABS (unpublished); Authors' calculations

Figure A1 shows unpublished ABS estimates of building heights by year. As can be seen, these have fluctuated about rising trends. Measuring cost at actual building heights would result in transient movements in our cost estimates. This volatility does not seem relevant to building decisions, which are based on expected, rather than historic costs. Instead, we value both average and marginal cost at the trend building height. For Section 5.2, we extrapolate the estimated trends from 2003, when the height data begins, back to 1997. An alternative approach of holding each city's average apartment height constant at its estimated 2003 level makes little difference.

Figure A1: Building Height of Average Apartment
Number of storeys



Note: Dashed lines are raw building heights, solid lines are linear trends
Sources: ABS (unpublished); Authors' calculations

A.3 Government Charges

Charges for infrastructure and public goods are a private cost, but it is debateable whether they should be counted as a social cost. Assuming that planning regulations do not change overall population, an increase in infrastructure use in one area will mean a reduction in infrastructure use in the areas from where the new residents come. It seems inappropriate to include the extra use as a cost without also allowing for the offsetting savings elsewhere.

Our estimates come from Urbis (2011) and CIE (2011), which are the most recent estimates of which we are aware. Developers tell us that government charges have increased substantially since these estimates were published. In particular, Voluntary Planning Agreements (including for parks and affordable housing) often increase costs by more than the charges we allow for. Moreover, developers also suggest that current charges are much greater than needed to fund marginal increases in infrastructure and that they represent a large element of value capture.

Government charges are not a major cost, so a simple approach is to use the available published estimates. This judgement recognises that the considerations mentioned above are difficult to quantify and that some would imply higher estimates and some smaller.

A.4 Comparison to Other Cost Estimates

Table A3 compares our estimates of construction costs with estimates from Kendall and Tulip (2018), Urbis (2011) and CIE (2011). Each of these provide an estimate of the average construction cost of a typical Sydney apartment, shown in the first row. Definitions for these estimates differ and the subsequent rows attempt to include various components so that the alternative estimates represent the same concept. These estimates, shown in the final row, are of the average supply cost excluding the cost of land, finance and developer's profit.

Table A3: Estimates of Average Apartment Construction Cost Excluding Cost of Land, Finance and Developer's Profit

Sydney, 2018

	ABS	Kendall and Tulip	Urbis	CIE
Base estimate	340	244	283	257
Building efficiency	included	25%	included	included
Builder's margin	included	included	included	14
Architect fees	included		25	included
Legal and management fees	3%	10%	8	10
Marketing and sales	5%		14	14
Infrastructure contribution	18	0	14	16
GST	included	10%	10%	10%
Timing adjustment	0	6%	20%	20%
Average cost on consistent basis	388	391	455	411

Note: All estimates are in $'000, except percentage adjustments denoted with %

Sources: ABS; Authors' calculations; CIE (2011); Kendall and Tulip (2018); Urbis (2011)

Allowing for conceptual and timing differences, the ABS construction cost estimates are slightly smaller than the RLB-based estimates used by Kendall and Tulip (2018), offset by inclusion of infrastructure contributions, discussed in Appendix A.3. The ABS-based estimates are noticeably lower than those of Urbis (2011) and CIE (2011), perhaps reflecting the more representative ABS sample.

Appendix B: Comparison to Residual Land Valuations

Our estimates of the effect of height restrictions closely correspond to 'site values' or 'residual land valuations' that are part of everyday conversation among real estate developers. Indeed, components of our estimates are derived from the detailed valuations that are prepared for decision-making and sales within the industry. The typical site valuation represents what a plot of land would sell for prior to building. It is calculated as expected sales minus construction and related costs like those shown in Table 3. Site values are routinely quoted and compared on a 'per-apartment' basis, reflecting that the overall value tends to increase proportionately to the number of apartments allowed to be built. Like our estimate of the effect of building restrictions, it can be interpreted as the scarcity rent that accrues to landowners.

Our estimate of the effect of building restrictions is conceptually different in that it represents the increase in value that would arise if an extra apartment were allowed to be built. This is calculated in the same way as site valuations except we use marginal cost instead of average cost. As indicated by Table 3, this difference lowers our estimates of the effect of building restrictions relative to site valuations by $24,000 (Sydney), $38,000 (Melbourne) and $29,000 (Brisbane).

The main practical difference is that site valuations are often quoted at an earlier stage of development than our estimates. Our estimates implicitly assume that a development approval and building permit have been granted and ask what would be the change in value if a slightly larger project had been approved. In contrast, site valuations often precede development approval, when considerable uncertainty and delays are in prospect. At this earlier stage, higher margins and lower site values are appropriate.

Knight Frank is one of Australia's largest property consultancies. Their 'Australian Residential Development Review' regularly reports representative valuations for high-density sites, defined as sites with more than 4 storeys and 25 apartments.[17] These estimates are based on industry consultation and expert judgement. Table B1 shows their indicative estimates as of June 2019 (Ciesielski 2019). The site valuations for Sydney are lower than our estimates of the effect of building restrictions, whereas for Melbourne and Brisbane they are higher. Some of these differences can be attributed to differences in geographic scope (Knight Frank exclude the CBD) and the difference between average and marginal cost. Most of the differences seem to reflect the earlier stage of valuation noted above. This is especially so for Sydney, where delays and uncertainties about gaining development approval seem to be highest (NSW Productivity Commission 2019, p 126). The estimates are partly of interest for providing an independent crosscheck on our data. Differences of timing and definition make precise comparisons difficult, but the qualitative message is the same. The estimates are also of interest as providing an indication that building restrictions may be binding in other cities. Note, however, that high-density apartments (more than four storeys) represent a very small share of the housing stock in most of these other cities.

17 We are indebted to Michelle Ciesielski of Knight Frank for discussions about these data.

Table B1: Indicative Site Sale Values and the Effect of Building Restrictions
Per apartment, $'000

	Site values (June 2019)	Effect of building restrictions (2018)
Sydney	184	355
Melbourne	120	97
Brisbane	40	10
Perth	50	
Adelaide	40	
Canberra	92	
Hobart	89	
Gold Coast	72	
Darwin	58	
Average across cities	84	

Note: Indicative values of sites based on potential high density development, excluding CBD
Sources: Authors' calculations; Ciesielski (2019)

Appendix C: Equations and Parameters

This appendix explains the equations and parameter values for the costs of building up and out in Figures 7 and 8 and the efficient heights in Figure 9.

We start by rewriting Equation (1) for average construction cost, ACC, in abbreviated but hopefully obvious notation:

$$ACC = Base + Slope \times Height \tag{C1}$$

As discussed in Section 4.2, for Sydney $Base$ = \$316,337 and $Slope$ = \$2,291. We compound developer's margins, finance, managerial and professional fees. Values for these terms (as percentages) are in Table 3. Their product as a ratio, 1.37, is represented by θ. We enter $Infrastructure\ charges$ additively. This gives average variable costs, AVC, the blue line in Figure 8.

$$AVC = \left(Base + \left(Slope \times Height\right)\right) \times \theta + Infrastructure\ charges \tag{C2}$$

We multiply by number of apartments (= $Units\ per\ storey \times Height$) to get total cost. Differentiating with respect to height gives the marginal cost of supplying apartments by raising height. We then divide by $Units\ per\ storey$ (assumed to be constant) to express on a per apartment basis.

$$MC = \left(Base + 2 \times \left(Slope \times Height\right)\right) \times \theta + Infrastructure\ charges \tag{C3}$$

which is the black line in Figures 7 and 8. The average total cost of building out per apartment is:

$$ATC = Land\ cost\ per\ apartment + AVC \tag{C4}$$

$$\begin{aligned} ATC = {} & \left(\frac{Land\ cost_{per\ sqm} \times Land\ area\ required}{Units\ per\ storey \times Height}\right) \times \gamma + \left(Base + \left(Slope \times Height\right)\right) \\ & \times \theta + Infrastructure\ charges \end{aligned} \tag{C5}$$

In Figure 7, $Land\ cost$ = \$4,033 per square metre and $Land\ area\ required$ = 2,397 square metres are from Table 4. $Units\ per\ storey$ = 11.2 is apartments per building = 117, from Table 4, divided by predicted height in 2018 = 10.5, from Figure A1, after rounding. (Note that units per building in Table 8, 11.4, is for 2013 to 2018.) The land component of average costs is scaled by γ, equal to 1.5. This represents similar factors as θ but is larger, reflecting the greater uncertainty (and therefore larger margins and cost of debt) that exists at the beginning of a project.

The 'efficient' or lowest-cost building height is where marginal cost (Equation (C1)) equals average cost (Equation (C2)). That is

$$\left(\left(Base+\left(2\times Slope\times Height\right)\right)\times\theta+Infrastructure\ charges\right)=\left(\frac{\begin{array}{c}Land\ cost_{per\ sqm}\times\\ Land\ area\ required\end{array}}{Units\ per\ storey\times Height}\right)\times\gamma+\left(\begin{array}{l}\left(Base+\left(Slope\times Height\right)\right)\\ \times\theta+Infrastructure\ charges\end{array}\right) \tag{C6}$$

Re-arranging for height yields the expression:

$$Height=\sqrt{\frac{Land\ cost_{per\ sqm}\times Land\ area\ required_{sqm}\times\frac{\gamma}{\theta}}{Units\ per\ storey\times Slope}} \tag{C7}$$

In Figure 8 we hold all the right-hand side variables in Equation (C7) constant except the land cost, which we calculate from the CoreLogic data as the average value of houses sold for a given SA3, divided by the average land area of those properties.

Appendix D: Hedonic Regressions

As discussed in Section 7, we regress Sydney apartment prices on a wide range of hedonic controls and find that households do not have a strong preference for low-rise apartments (the 'missing middle') relative to high rises. Regression output is shown in Table D1. Most explanatory variables are discrete, with omitted categories denoted '--'. Coefficients are multiplied by 100 to be interpretable as approximate per cent changes. The first section of the table shows the value of architectural features (bedrooms, age, etc). The second section of the table shows the value of distance to nearby amenities.

The top rows show our key results. Being in a building with 10 or fewer dwellings adds 6.3 per cent to the value of an apartment, relative to being in a building with more than 100 dwellings, after controlling for apartment quality and spatial characteristics. Being in a building with 11 to 20 dwellings adds 0.3 per cent.

We do not include in our regression spatial variables whose coefficients are jointly insignificant. This includes train stations and large shopping centres. That surprised us given that real estate advertising and past research (Murray 2016; Pettit *et al* forthcoming) suggest that these locations are highly valued. We suspect that these variables are strongly correlated with other features (noise, parking, apartment quality) that are difficult to control for. Many other results from the regression are as expected. The number of bedrooms, number of bathrooms and proximity of the apartment to water were all associated with large and clear increases in price. Apartment age has large and clear effects. One interesting implication is that housing 'filters down' to lower price ranges as it ages. The large coefficients contrast with the small unconditional effects of age discussed in Appendices A and E. The difference may arise because new apartments are less expensive for other reasons – for example, if they are further from the city centre. For purposes of comparisons with the unconditional mean of supply costs the unconditional effect of age is relevant. For reasons of space we do not show coefficients on the approximately 650 suburb dummies, though these are collectively the most important influence on apartment prices. However, the general contour of suburb effects can be seen in Figure 4. Apartments near the city centre sell for several hundred thousand dollars more than those on the outskirts, other things equal.

Table D1: Hedonic Regression – Sydney
Dependent variable: log sale price; includes month and suburb fixed effects
(*continued next page*)

	Coefficients (multiplied by 100)
Building density (baseline > 100)	
≤10 dwellings	6.3***
11–20 dwellings	0.3
21–50 dwellings	–0.5
51–100 dwellings	–0.9
Bedrooms (baseline = 1)	
Two beds	24.7***
Three beds	41.5***
Four beds	46.9***
Five+ beds	48.1***
Bathrooms (baseline = 1)	
Two baths	11.5***
Three baths	24.8***
Four baths	34.0***
Five+ baths	34.3***
Bedroom/bathroom ratio	1.2
Parking spaces (baseline = 1)	
Two spaces	8.2***
Three spaces	17.8***
Four spaces	15.9***
Five+ spaces	33.1***
Extra features	
Swimming pool	0.7***
Air conditioned	2.5***
Ducted heating	1.8***
Scenic view	5.4***
Apartment age at sale	
2–5 years	–10.4***
5–10 years	–17.1***
10–15 years	–21.8***
15–20 years	–22.4***
20–30 years	–28.1***
30–40 years	–30.8***
40–50 years	–32.7***
50–60 years	–32.9***
60+ years	–15.8***
Arterial road/motorway (yes = 1)	–4.0***
Log distance to CBD	–10.7***

Table D1: Hedonic Regression – Sydney
Dependent variable: log sale price; includes month and suburb fixed effects
(*continued*)

Spatial feature	Distance from property			
	≤ 0.5 km	0.5–1 km	1–3 km	> 3 km
Beach	13.8***	8.3***	3.9**	--
Cemetery	–5.5***	–3.2***	–2.7***	--
Club	–2.4*	–3.0**	–3.2**	--
Community facility	9.9*	9.5*	8.5	--
Education facility (TAFEs etc)	–8.9***	–4.2**	–0.3	--
Fire station	–3.3**	–0.7	1.2	--
Headland	20.3***	7.3***	0.5	--
Library	2.9**	1.9	1.9	--
Mountain	1.7	1.3	–2.3***	--
Light rail stop	–6.1*	–3.2	2.9**	--
Sports centre	5.5*	5.2*	6.1*	--
Swimming pool	–3.5***	–3.1***	–2.5***	--
University	6.0***	1.4	1.1	--
Combined school	–3.1***	–1.9**	0.1	--
High school	–0.8	–1.0	0.3	--
Sewage works	–4.2	–3.5**	1.4	--
General hospital	1.7*	1.5*	–0.6	--
Number of observations	553,275			
R-squared	0.81			
Root mean squared error	0.25			

Notes: ***, ** and * denote statistically significantly different from zero at the 1, 5 and 10 per cent levels, respectively; -- denotes omitted category; standard errors (not shown) are clustered at buildings, there are 42,411 clusters; spatial categories are from Spatial Services (2019)

Sources: Authors' calculations; CoreLogic data; PSMA Australia; Spatial Services

Appendix E: Sensitivity Analysis

Some changes to our assumptions would change the results in obvious ways. For example, were we to assume that infrastructure charges or developer's margins were not a necessary cost of supply our estimates of the effect of building restrictions would increase substantially, other things equal. Were we to measure lower prices, the effect would be smaller. The following two subsections discuss variations that are less straightforward.

E.1 New versus Average Sale Prices

Glaeser *et al* (2005) note that construction costs for newly completed buildings should be compared with sale prices for *new* apartments, but consider adjusting for the depreciation of older units to be too difficult, so use prices for all dwellings. Kendall and Tulip (2018) followed this approach. We also face problems with data on building age, but believe these are surmountable. In particular, many sales are missing values for year of construction. However, there is very often an observation recorded for at least one apartment in a building. We assume that all apartments in a building are built at the same time and this can be estimated by the modal construction year of dwellings within that building. For Sydney, this increases the proportion of sales with year of construction data from 75 to 92 per cent.

We then exclude all sales more than five years after the estimated construction date. As shown in Table A1 this reduces our sample by 80 to 90 per cent. However, it has small effects on prices in 2016, raising them by 1 per cent in Sydney and 4 per cent in Brisbane, while lowering them 4 per cent in Melbourne. These effects are much smaller than earlier in the sample or the conditional estimates of depreciation from the hedonic regression in Appendix D. As noted earlier, our dataset contains substantially fewer new sales than completions at the end of our sample, raising concerns about the representativeness of the latest estimates. While our approach seems conceptually superior to others' assumption of zero depreciation, there is a chance that it may understate prices of new properties at the end of our sample.

An alternative approach would be to exclude sales of an apartment after the first sale, as is done by CoreLogic (reported in UDIA (2019, p 16)). However, for our dataset, which begins in 1997, this is impractical. It would involve assuming that almost all sales near the beginning of our sample are new sales.

Sales in the early part of our sample are more likely to be missing observations on building age. If we recalculate our historical estimates using average, rather than new, sale prices we find that the effect of building restrictions is still positive in all three cities over the past decade, and especially large for Sydney. However, when calculated this way, the effect of building restrictions in Melbourne and Brisbane is often negative prior to 2009. The effect remains positive in Sydney, but was relatively small in the late 1990s.

E.2 The Effect of Height

In Section 4.2 we estimate the effect of building up by regressing per unit construction costs on building height. In doing so, we weight observations by number of buildings, on the assumption that each building provides an independent observation on the cost–height relationship. Alternative approaches include using unweighted estimates, or weighting observations by the number of dwellings or gross floor area. Table E1 compares these alternative estimates with our baseline. In all cases, using a different weighting scheme would imply a flatter average cost curve than presented in the body of the paper. We argue that weighting by buildings both makes sense conceptually and provides a more conservative estimate of the slope coefficient and hence the ratio of marginal to average cost.

We also check the sensitivity of these results to outliers. A handful of observations – corresponding to very tall buildings – exert relatively high leverage. As a crosscheck, we exclude buildings above 50 storeys. This increases the slope coefficient by about 15 per cent, relative to the baseline. Base costs and the overall fit of the model are largely unchanged. We prefer to include the full sample since these differences are relatively modest and there is no obvious reason for disregarding the excluded observations. This exclusion result suggests that the slope of our cost curve might decline with height. However, most studies shown in Figure 3 show the opposite nonlinearity.

Table E1: Construction Cost Regression Comparison

By weighting method, 2013–18

	Unweighted	**Number of buildings** (baseline)[(a)]	**Number of dwellings**	**Baseline** Excl buildings > 50 storeys
Slope coefficient	1,405	2,163	1,396	2,470
Base cost				
Sydney	310,848	290,211	304,333	287,039
Melbourne	268,185	270,366	272,102	267,812
Brisbane	274,387	240,019	261,994	236,196
Adjusted R-squared	0.24	0.60	0.40	0.66

Note: (a) Differs from the numbers in the text which have been rescaled to 2018 prices; rounded to the nearest 10

Sources: ABS; Authors' calculations

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