Exploring the Many Housing Elasticities of Supply: The Case of Australia

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Draft: December 30, 2022

Abstract: The housing elasticity of supply (HES)—how housing supply responds to price rises—has been a major preoccupation of policymakers in the face of worsening housing affordability in many countries. Yet we lack an understanding of just how this quantity varies across regions, and within cities, or the factors which drive it. We address this question by estimating the HES for 341 spatially disaggregated Australian local government areas (LGAs) from 2001-2019 for houses and units (attached homes). Our estimates document considerable variation in HES estimates across LGAs. For houses, we find that the median HES is 0.27 with a lower 25th percentile of 0.17, less than half that of the 75th percentile at 0.44. For units, the median HES is considerably higher at 1.03, but there is again significant variation across LGAs with 25th and 75th percentile values of 0.56 and 1.17, respectively. Interestingly, we find no correlation between the LGA HES estimates for houses and units. We explore how variation in the local HES relates to potential housing supply drivers such as accessibility to central business districts, topography, temperature range, annual precipitation, and political orientation. The most important driver of the HES is accessibility—LGAs on the city-fringe have the highest HES for houses, while for units it is highest in the inner-city. We find political orientation and annual precipitation have some impact on the HES for units.

Keywords: Housing elasticity of supply, urban and regional economics, local government areas, Australia, instrumental variables.

JEL Classification Codes: R31, C23, R12.

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1. Introduction

Declining housing affordability remains one of the paramount concerns of housing policymakers globally. A recurrent theme in the affordability debate, across many countries, is the weak supply-side response to rising prices (see for example, Barker, 2004 for the UK; Glaeser and Gyourko, 2018 for the US; Li et al. 2020 for major Chinese cities). The challenges for policymakers are formidable because a feeble supply-side of the housing market has broader implications beyond affordability concerns. The UK's Barker Review (2004, p.1), for instance, claims that: "A weak supply of housing contributes to macroeconomic instability and hinders labour market flexibility, constraining economic growth". Indeed, after more than a decade, the UK's economic agenda continues to embrace housing supply issues, with a recent Treasury report citing concerns over the adverse impacts on productivity and labour market flexibility (HM Treasury, 2015; Heslop and Ormerod, 2020). In the US, there are similar anxieties prompted by insights from theoretical models that link housing and labour markets (Glaeser and Gottlieb, 2009). For example, Hsieh and Moretti (2017) estimate that real GDP in the US could be 9 per cent higher if there were plentiful new housing construction in New York, San Francisco, and San Jose housing markets, where productivity is relatively high. The responsiveness of housing supply to rising prices has also been a major preoccupation of policymakers in New Zealand (Preval et al, 2016), China (Tian et al, 2020), Australia (McLaughlin, 2012a, 2012b), and the 27 countries of the EU (European Construction Sector Observatory, 2019).

A key focus in understanding the supply-side of housing markets is the *housing elasticity of supply* (HES), defined as the percentage change in housing supply relative to the percentage change in housing prices. While this is expected to be positive, the magnitude of the HES is important. If it is small, then an increase in demand for housing will mostly result in increased prices. But if the HES is large then prices will increase much more modestly in response to a rise in demand, as the quantity of housing will expand to meet it.

A large body of work has been devoted to estimating the HES (see Ball et. al., 2010 for an international review). Yet there remain significant deficits in our understanding of this important parameter. We seek to better understand the extent of variation in the HES and the drivers of this variation across spatially disaggregated localities. This provides useful guidance to policymakers in identifying the particular spatial segments of the housing market where supply is weakest. Tying the HES to observable characteristics—such as locational, topographical, climatic, and political factors—provides a basis for benchmarking a local area's HES. We focus on local government areas (LGAs) in Australia. LGAs are sub-metropolitan geographic areas that are more spatially disaggregated regions than has been typical in HES studies (Green et al., 2005). The average Australian LGA has a population of around 180,000 over the period we examine. Importantly, LGAs are also administrative regions. They levy rates, and provide services such as waste and environmental management, and road maintenance. They also have a key role in overseeing the numerous rules and regulations around planning and development, a feature common in the Anglosphere (e.g., UK, USA) and among municipalities in numerous European countries. Thus, our results feed into the international debate around the sources and nature of sluggish housing supply response to higher prices, and the role of local planning rules (Yan et al, 2014; Phibbs and Gurran, 2021). We construct measures of each LGA's housing stock—for both houses and units (attached homes)—by extrapolating census data using annual building approvals. HES is estimated using an instrumental variables approach which relates log prices to the log of the housing stock for each LGA by each structure type.

Our results, across 341 LGAs in Australia from 2001-2019, highlight a generally low HES for houses—it averages 0.34 across LGAs. For units, the HES is substantially higher—on average it equals 0.96. However, they exhibit substantial variation across LGAs. In the case of houses, the 25th and 75th percentiles are 0.17 and 0.44. For units, the comparable numbers are 0.56 and 1.17. A particularly interesting finding is obtained from those LGAs where we have HES values for houses and units. In these LGAs, the HES for houses and units are unrelated. This finding signals the importance of structural factors that are influencing different housing supply responses across LGAs. We follow Green et al. (2005) and explore what drives the substantial variation in the HES by running auxiliary regressions. The dependent variable is the LGA HES estimates. A range of explanatory variables are used including; state indicators, city accessibility (inner-, middle-, outer-metropolitan ring, or non-city), topographical structure (the prevalence of steep land gradients), temperature range, annual precipitation, and political orientation (left-leaning, centrist or right-leaning). We find that an LGA's state and its city accessibility have sizable explanatory power, as does precipitation and political orientation for units.

In section 2, we begin by reviewing the relevant literature. This is followed by a description of the modelling strategy and data sources in section 3. Section 4 reports our key findings. In the conclusion, section 5, we summarize our findings.

2. Related Literature

The international literature features papers that range widely in terms of timeframe and geographical breakdown. They typically draw on one of two econometric frameworks. Early studies invariably modelled dwelling prices as a reduced form function of supply and demand predictors. While the price elasticity of housing supply cannot be identified in the reduced form equation, it can be calculated under a series of assumptions about the demand elasticities (see Muth 1960; Follain 1979; Malpezzi and Maclennan 2001).[2] These investigations typically estimated national HES and so mask heterogeneity that is due to what can be

[2] Malpezzi and Maclennan (2001, p283) calculated the price elasticity of supply assuming that price elasticities of housing demand ranged between -0.5 and -1.0, and the income elasticity of demand was either 0.5 or 1.0.

substantial variation in structural factors across local housing markets. They also must confront econometric limitations arising because national times series can be short in duration.

More recent studies have been based on measurement of the own price responsiveness of the flow of new housing, or alternatively estimates of housing stock responses to price changes. Studies using the flow of new housing typically obtain price elasticity estimates from log-transformed models of new housing supply regressed on changes in real dwelling prices. The flow of new supply is usually represented by measures that emerge from the planning approval process (e.g., housing approvals, starts and completions), or the real dollar value of housing investment (see for instance, Topel and Rosen 1988; Mayer and Somerville 2000a; Mayer and Somerville 2000b; McLaughlin 2011 and 2012). Lagged price effects are commonly allowed for as new housing takes many months or even years to complete from planning application stage, and therefore responds sluggishly to price shocks (see for example Mayer and Somerville 2000b; Hwang and Quigley 2006; McLaughlin 2012).[3]

The stock response approach is less common. In the UK, Ball et al. (2010) exploits a housing stock measure obtained from Medium Level Super Output Areas (MSOAs) in the Thames Gateway between 2004 and 2007. Gitelman and Otto's (2012) stock measure is the Australian Census based number of private dwellings recorded in metropolitan Sydney LGAs 1991 - 2006. Stock measures are prone to measurement error because they fail to capture additions to housing stocks attributable to home extensions and renovations, a weakness that can be addressed by using flow measures of new housing since data from planning approval processes can include approvals for extensions and renovations.

Spatially disaggregated housing market models occupy an important position in the urban and regional literature. This reflects idiosyncrasies that are due to topography and climate, for example, and result in heterogenous local housing markets. Leishman and Bramley (2005) typify the local approach. They examined the dynamics of housing supply, migration, and incomes of local district councils in Central Scotland. More recently, Fingleton, Fuerst and Szumilo (2019) undertake simulations looking at the responsiveness of housing prices to increases in the supply of housing in each of London's 32 boroughs. We extend previous studies by allowing for heterogeneity in model parameters across regions. This means we can offer a more complete picture of inter-regional differences and similarities. There is certainly demand for such analysis, given the increasing interest in exercises such as Fingleton, Fuerst and Szumilo (2019) and the likely spatial variation in key parameters such as HES. Our focus on LGAs is consistent with that of Leishman and Bramley (2005) and Fingleton, Fuerst and Szumilo (2019), who also focus on local administrative regions. It acknowledges the important role that administrative and political boundaries have in driving housing markets dynamics (McKee, Muir and Moore, 2017).

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[3] In the Australian context Hsieh et al. (2012, p13) claim that from conversion of farmland to completion of residential development typically takes around 6 years.

Our study also feeds into the burgeoning debate around the sources of high housing prices. A growing literature considers the role of the planning process in constraining housing supply. Several papers have argued that planning has curbed housing supply—particularly influential in the US was Glaeser and Gyourko (2003) (see also; Mayer and Somerville, 2000b; Hilber and Vermeulen, 2014). There are also several relevant Australian studies (see Ball et al. 2014, Jenner and Tulip 2020, Lejcak et al. 2020 and Kendall and Tulip, 2018). However, Meen and Nygaard (2011) argue that despite common national planning policies, supply responses to housing market pressures varied greatly at the local level due to differences in historical land uses. The party-political voting patterns of regions has been used in past studies as a proxy for local attitudes toward regulation and residential development (Mayer and Somerville 2000). Rowley et al. (2020) highlight the importance of political appetite for new housing supply. The study suggests that uneven Australian supply responses to prices are inevitable due to variations in planning schemes, permissible development, and political stance across local areas. However, there is increasing push-back against the idea that planning processes are the predominant driver of inadequate supply and high housing prices (Rodríguez-Pose and Storper, 2020). Murray (2021) and Phibbs and Gurran (2021) are both critical of the Glaeser and Gyourko (2003) approach, which infers the 'planning effect' from the difference between marginal and average prices of land. Our study contributes to this debate by estimating the variability in HES across Australian LGAs and the drivers of variation. Our approach to identification of these drivers is influenced by an important group of papers that highlight the significance of topographical constraints (Saiz, 2010; Ong et al., 2017) and climatic conditions (Fergus 1999).

Finally, our study contributes to the Australian and global literature measuring the magnitude of the HES. Our main contribution is nationwide estimates for Australia at a spatially disaggregated level. Generally, estimates of the HES are sensitive to location, timeframe, dwelling type, and modelling approach. Thus, supply elasticities can vary greatly across countries (Fuerst et al, 2010) and across regions or cities within a country (Wang et al, 2012; De La Paz, 2014). In the US, Mayer and Somerville (2000a) reported a very high price elasticity of housing supply of 15—estimated over a 5-quarter time interval and across 44 metropolitan markets. However, modelling over a two-year interval, such as in Zabel and Paterson (2006) and Hanak (2008), lower HES estimates were found for Californian cities that range between 1 and 5. A consistently lower HES estimate is obtained in the UK. In flow models, estimated over a long observation period beginning immediately after World War II, Malpezzi and Maclennan (2001) discover high US price elasticities of housing supply ranging from 6 to 13, but report much lower UK estimates of between 0 and 1. When a stock adjustment model is estimated, price elasticities span values from 1 to 6 in the US, though they remain between 0 and 1 for the UK. Whitehead (1974) uses a 1955-1972 time series and reports relatively low UK price elasticities of supply, ranging from 0.5 to 2. Caldera and Johansson's

(2011) comparison of price elasticities of supply across OECD countries confirm a relatively price inelastic supply response in the UK with an elasticity estimate of around 0.4 compared to approximately 2 in the US.

In Australia, McLaughlin (2011) documents supply elasticities of between 4 and 6 for five quarter time intervals between 1996 and 2010. Using a longer 1983-2010 time period, McLaughlin (2012a) reports a high 5.4 estimate for the price elasticity of new house supply. Ong et al.'s (2017) estimate for houses over the shorter timeframe 2005-06 to 2013-14 is not dissimilar at 4.7. However, while McLaughlin (2012a) estimates a very high price elasticity of 17.3 when modelling the supply of strata units, Ong et al.'s (2017) estimate is only 3.9. Gitelman and Otto (2012) document an inelastic supply of residential properties in metropolitan Sydney over the period 1991-2006. However, on a breakdown of housing supply, units are found to have a HES (0.64) three times that of houses (0.19). Ball et al.'s (2010) Australian estimates of the price elasticity of private housing starts are around 0.55 for the period 1983-2008, while Caldera and Johansson (2011) report a price elasticity of residential investment of 0.53 over a 1982-2009 timeframe. Caldera and Johansson (2011) also measure Australian price elasticities of housing supply that place them at the mid-point of a range of estimates obtained for OECD countries.

Thus, our study touches upon several strands of the housing supply literature. First, and most importantly, the results sit within a small but expanding literature examining spatial heterogeneity in housing dynamics and urban and regional phenomena more generally. Second, we contribute to the growing debate around the sources of housing affordability challenges. Third, our results add to the international literature estimating the HES and build upon the modest Australian evidence base in this area.

3. Methods and Data

3.1. Model

Our modelling strategy employs an instrumental variables (IV) approach. This is a commonly used approach to estimating the HES and features in numerous studies (Topel and Rosen, 1988; Mayer and Somerville, 2000b; Saiz, 2010; Gitelman and Otto, 2012; Liu and Otto 2017). Fundamental to our approach is a hypothesized housing supply function of the form:

$$\ln H_{it} = \alpha_i + \beta_i \ln P_{it} + u_{it} \quad (1)$$

This relates the stock of properties H_{it} in LGA i in year t to P_{it}, the real median price of properties in LGA i in year t; α_i captures the level of the housing stock in LGA i; u_{it} represents the model's error term. The primary interest is in β_i. It can readily be seen that this measures the HES in LGA i, i.e., the percentage change in the housing stock for a given percentage change in housing prices, $\beta_i = \frac{\partial \ln H_{it}}{\partial \ln P_{it}} = \frac{\Delta H_{it}/H_{it}}{\Delta P_{it}/P_{it}}$.[4]

The key estimation challenge posed by (1) is that movements in the price and stock of housing generally result from shifts in both demand and supply. Thus, price is an endogenous variable and simply estimating (1) on the observed data will not recover a consistent estimate of the HES, β_i. The IV approach isolates movements in price resulting from movements in demand and hence traces out the supply curve. We suppose that the (inverse) housing demand curve has the following form:

$$\ln P_{it} = \gamma_i + \theta_i \ln H_{it} + \delta_{iP} \ln Pop_{it} + \delta_{iR} \ln R_t + \delta_{ir} \ln \mathrm{r}_t + v_{it} \quad (2)$$

Here γ_i captures the housing price level of LGA i, H_{it} is the stock of properties in LGA i in time period t; Pop_{it} denotes the LGA population; R_t is the nominal mortgage rate; r_t is the real mortgage rate (the nominal rate net of the rate of inflation); v_{it} is the model's error term.

Higher population is a natural demand shifter because a population shift will increase or decrease demand for homes. Changes in the real mortgage rate reflect the real cost of borrowing and so are intrinsic to housing demand. We also include the nominal interest rate because it is a key determinant of the monthly cost of servicing a mortgage. For many households, it is their ability to service mortgages that can be a binding constraint on their capacity to purchase homes. Change in the nominal interest rate is then a critical influence on affordability. We do not estimate the demand curve separately. Instead, we include these three variables—population, real and nominal mortgage rates—as IVs for identification of the supply equation (1).[5]

Our method is consistent with more recent approaches to IV estimation of the HES, which base HES estimates on the flow of new housing, or alternatively, estimates of housing stock responses to price changes (see studies such as Mayer and Sommerville 2000a in the US; Ball et al. 2010 in the UK; Gitelman and Otto 2012 in Australia). Our approach is most like that of Gitelman and Otto (2012). They use a low-frequency five-yearly Australian Census stock measure that allows observation of movement from one

[4] The Online Appendix explores an extension of this model that adds lagged prices, P_{it-1}, as well as contemporaneous prices, P_{it}. This model accounts for any inherent lags in the construction process. We find broadly similar results compared with a model which only includes contemporaneous prices, so favour the simpler model.

[5] Our instruments are like those employed by Gitelman and Otto (2012) and Liu and Otto (2017). These authors also included household income at the LGA level. Unfortunately, this is not consistently available across all LGAs or for the time span we examine. Fingleton et al. (2019) used interest rates as a housing demand shifter. A range of other instruments have been used in the literature reflecting data availability. Mayer and Somerville (2000a) account for potential endogeneity between housing starts and regulation via IVs such as the number of jurisdictions with land use control, Reagan's share of the presidential vote in US metropolitan statistical areas (MSAs), a traffic congestion index, 1975 per capita MSA income, 1980 MSA population, the share of the adult population whose highest qualification is a high school degree, and whether a state has citizen referendums.

long-run equilibrium to another, and thus estimation of the long-run price elasticity of supply.[6] Their stock measure is the number of private dwellings recorded in metropolitan Sydney LGAs for the years 1991, 1996, 2001 and 2006. They estimate both a "levels" model, the log of housing stock as a function of the log of dwelling price as in (1), and a "first difference" model, the change in the log of housing stock as a function of the change in the log of dwelling price.

We estimate equation (1), using IV methods, for each LGA and for houses and units. This provides a range of estimates of the HES for LGAs across Australia that are analysed in two ways. First, we explore the extent of heterogeneity in HES estimates. Second, we estimate an auxiliary regression model which seeks to explain this heterogeneity as a function of factors that include the state in which an LGA is located, city accessibility, topography, temperature range, annual precipitation, and political orientation. Next, we describe our data and in the following section we discuss our results.

3.2. Data and Variable Measurement

The housing stock measure is drawn from the 2011 Australian Bureau of Statistics (ABS) Census of Population and Housing. Census LGA housing stock estimates are available at five-yearly intervals. The measure of new housing supply is LGA building approvals data available from ABS (ABS Catalogue Number 8731.0). We construct annual housing stock estimates by adding post-2011 housing approvals to (and subtracting pre-2011 approvals from) the 2011 ABS Census estimate of housing stock. This interpolation is conducted throughout the 2001-2019 period of analysis.[7] The period we examine, stretching to almost two decades, covers several housing cycles.

Building approvals capture additions to the housing stock through the construction of new housing and ignores demolitions as well as conversions. However, these sources of change in the stock of housing are of minor importance in Australia.[8] Another well-known limitation is that not all approvals are converted into completions and hence additions to the housing stock. Building commencements or completions are a more accurate measure of new supply. There is also a delay between the timing of building approvals and completions, so approvals may not translate into new supply for several months or longer. However, commencements and completions data are only available for Greater Capital City Statistical Areas (GCCSA), a limitation that is common in the local area housing supply literature. But at the national level, there is a reassuringly strong correlation between approvals and commencements. Hwang and Quigley

[6] In a later paper, Liu and Otto (2017) estimate a stock response model using an *annual* series for the stock of houses and apartments in each of Sydney's LGAs.
[7] 2011 is the preferred base year upon which to construct our stock estimates as it is in the middle of our data span. However, we did experiment with the 2006 census as the base and obtained similar results.
[8] Ong et al. (2017) report evidence from Melbourne and Perth which suggests that demolitions are roughly 12% of housing approvals. Conversions are not as important at less than 1% of housing approvals.

(2006) find that the correlation coefficient between US national approvals and commencements was 0.95 over the timeframe 1959-2000, and 0.99 for the shorter 1987-1999 period. In Canada, Somerville (2002) reports that around 90 per cent of approvals are converted into commencements within two quarters. Using ABS data, Ong et al. (2017) find that the correlation coefficient between annual new building approvals and new dwelling commencements over the period 2005-06 to 2015-16 is 0.996 for houses and 0.986 for units.

The price variable is real median house and unit prices calculated from all housing sales transactions recorded at the LGA level and sourced from CoreLogic—a property information, analytics, and services provider. The median price data is available at a monthly frequency and is computed as the median sales price of homes sold in the previous 12 months. We used the December value to represent the median price in the calendar year. The ABS produce a CPI for each of the state capital cities (ABS catalogue number 6401.0). Real housing prices are constructed by dividing an LGA's housing prices by the CPI for the capital city of the state within which the LGA is located.

Population is derived from LGA population estimates sourced from the ABS and covering each year of the modelling timeframe (ABS catalogue number 3218.0). The nominal mortgage rate is obtained from the Reserve Bank of Australia. We used the standard variable mortgage rate recorded for each month averaged over the year.[9] The real mortgage rate is calculated by netting off the annual change in the All-Groups CPI for Australia.

One of our focuses is geographic variation in housing supply. To aid understanding, we classify city-LGAs into three groups based on their distance from CBDs: inner-, middle- and outer-metropolitan ring LGAs. LGAs outside a GCCSA are defined as non-city LGAs. We assign LGAs to the inner metropolitan ring if the latitude and longitude of its central point is up to 10km from the CBD, the middle metropolitan ring includes LGAs that are more than 10km but no more than 25km from the CBD, and the outer metropolitan ring captures LGAs that are more than 25km from the CBD but within a GCCSA.

We also explore variation in the HES by a LGA's topography, annual precipitation, temperature range, and political orientation. For topography, we follow Saiz (2010) and calculate the percentage of an LGA's land area with a gradient greater than 15 per cent. To derive this measure, we sourced (from Geoscience Australia) a Digital Elevation Model (DEM) at 90-square metre resolution (Gallant et al. 2009). The DEM provides the maximum elevation above sea level in each 90m-square of the Australian topography. Using GIS software, we then calculated a slope map containing the maximum rate of change (maximum gradient) between each square and its eight neighbouring squares (including diagonal neighbours). Our measure of topographical constraint in a LGA is obtained by taking its land area with a

[9] The data can be found in table F5 available here: https://www.rba.gov.au/statistics/tables/.

gradient greater than 15 per cent, dividing it into the LGA's total land area, and then converting this into a percentage. Outside of the USA, topographical measures are rarely employed so this extension to the analysis is an opportunity to investigate whether topography matters in a different country's institutional context. To account for weather variations, annual precipitation levels and annual temperature ranges are obtained from interpolated weather maps in ArcMap. Each LGA's temperature range is measured as the difference between its average maximum temperature in the warmest month of the year, and the average minimum temperature in the coldest month of the year. Climatic conditions are a potential driver of the HES because extremely hot or cold weather can temporarily slow or stop construction activity. As Australia is a large country there is significant variation in climate across its landmass and this may go some way to explaining variation in the HES. To reflect political orientation, we focused on the 2010 Federal election—roughly in the middle of our observation period. We constructed indicators for whether an LGA was left-leaning, centrist or right-leaning based on vote-shares. If a majority vote for the Labor Party was recorded then the LGA is defined as left-leaning, while if the Liberal-National Parties obtained a majority it is defined as right-leaning. Otherwise, an LGA is defined as centrist. The political orientation variable allows us to investigate whether differences in ideological perspectives impact on the planning process and hence housing supply.

Table 1 provides some insight into the data used in the model estimation that follows. As can be seen, real house prices grew strongly at 4.3% per year. Real price growth for units was more modest at 2.9% per year. This compares with a relatively modest contemporaneous growth in the stock of houses that reaches around 1.4% per year and the healthier 3.2% annual growth for the stock of units. The average prices, and size of housing stock, ranged widely across sampled LGAs, as can be seen from the high standard deviation for these variables. The LGAs are located across Australia. For houses, the observations in our data are distributed across states broadly in line with their population shares. For units, most of the observations are in NSW and VIC, because these are the states which include the country's largest cities of Sydney and Melbourne, where most of the units are located. On a weighted basis, around 35% of the observations for houses come from non-city LGAs with broadly similar numbers in the inner-, middle- and outer-metropolitan rings. For units, more than two-thirds of weighted observations come from the inner rings of major capital cities. The average population of an LGA for which we have houses data is around 180,000 persons. It is somewhat smaller for units. For major city LGAs, the average distance to the CBD is 21.6 km for those where houses are present, but less for units. The average temperature range is a little more than 20 degrees Celsius, and precipitation is roughly 900 mm per year, with some variation across LGAs. Left-leaning is the most common political orientation of our LGAs. This reflects the somewhat stronger representation of metropolitan LGAs in our data. But there are also a sizable number of centrist and right-leaning LGAs.

Table 1: Summary Statistics

(By Dwelling Type, 2001-2019)

	Houses			Units		
	N	Mean	SD	N	Mean	SD
Price:						
Real Level ($000 in 2019)	6,424	542.57	334.51	1,369	571.91	223.02
Real Change (% per year)	6,072	4.33	9.23	1,273	2.88	7.73
Stock:						
Level	6,424	16,405	26,343	1,369	5,932	10,942
Change (% per year)	6,072	1.43	1.15	1,273	3.15	2.31
State:						
NSW	6,424	0.28	0.45	1,369	0.51	0.50
VIC	6,424	0.31	0.46	1,369	0.31	0.46
QLD	6,424	0.13	0.34	1,369	0.00	0.06
SA	6,424	0.11	0.31	1,369	0.07	0.25
WA	6,424	0.13	0.34	1,369	0.07	0.26
TAS	6,424	0.04	0.19	1,369	0.03	0.18
NT	6,424	0.01	0.08	1,369	0.00	0.07
Ring:						
Inner	6,424	0.21	0.41	1,369	0.69	0.46
Middle	6,424	0.21	0.41	1,369	0.10	0.30
Outer	6,424	0.22	0.42	1,369	0.06	0.23
Non-City	6,424	0.35	0.48	1,369	0.15	0.35
Population (‘000)	6,424	179.32	249.13	1,369	123.56	65.16
Distance to CBD (km, city LGAs)	2,198	21.60	16.48	605	8.41	7.79
Temperature Range (Celsius)	6,424	21.87	2.65	1,369	20.41	2.15
Precipitation (mm per year)	6,424	904.08	313.06	1,369	983.71	310.64
Political Orientation:						
Left-Leaning	6,424	0.40	0.49	1,369	0.50	0.50
Centrist	6,424	0.38	0.49	1,369	0.17	0.38
Right-Leaning	6,424	0.22	0.41	1,369	0.33	0.47

Notes: An observation is indexed by year and LGA. N denotes the number of observations. SD denotes the standard deviation. The statistics, other than ‘Stock: Level’, are weighted by the housing stock. The state abbreviations are: NSW=New South Wales, NT=Northern Territory, QLD=Queensland, SA=South Australia, WA=Western Australia, VIC=Victoria, TAS=Tasmania.

4. Empirical Results

4.1. Heterogeneity in the HES Across LGAs

We estimate the HES using equation (1) and an IV approach. As previously noted, the instruments are population, nominal, and real interest rates. These instruments are invariably strong. The first stage regressions of housing prices on the instruments generally have F-statistics above 10 as recommended in

Staiger and Stock (1997).[10] The results are summarized in Table 2, which reports the mean HES, along with the 25th, 50th (median) and 75th percentiles of the HES distribution across LGAs. We separately summarize results for all LGAs and for only those LGAs which have coefficients that are statistically significant (at the 10 per cent level or better) and positive—as is required for the housing supply curve to slope upwards.[11]

Table 2: The Housing Elasticity of Supply Across LGAs

	Houses					Units				
			Percentiles					Percentiles		
	N	Mean	25th	50th	75th	N	Mean	25th	50th	75th
All	341	0.34	0.17	0.27	0.43	74	0.94	0.51	1.03	1.17
Significant	316	0.34	0.17	0.27	0.44	64	0.96	0.56	1.03	1.17

Notes: 'All' includes all LGAs for which we estimated coefficients. 'Significant' includes only results for LGAs which are statistically significant at the 10 per cent level or better and are positive. The statistics are weighted by an LGAs average housing stock as a share of the total housing stock across all LGAs.

One of the key features of the results is the high proportion of statistically significant and positive coefficients. For houses, we estimated elasticities for 341 LGAs and find 316, or 93 per cent, are positive and significant at the 10 per cent level or better. As can be seen, the distribution of the HES for all LGAs is similar to those LGAs for which the HES is positive and statistically significant. Our preferred results, and those focused on in subsequent analysis, are estimates where the coefficient is positive and significant.

The results shown in Table 2 indicate that the mean HES is 0.34 for houses, while for units it is around three times higher at 0.96. Thus, we find that across LGAs the HES tends to be inelastic. These results are broadly consistent with Caldera and Johansson (2011), who rank Australia 9th out of 21 OECD countries with an overall price elasticity of new supply of 0.53. This also ranks Australia as inelastic relative to most EU member states such as France, Finland, Italy, Portugal and the Czech Republic, where recent elasticity estimates exceed 0.53 (European Construction Sector Observatory, 2019). They do not report estimates stratified by housing type. The significantly higher price-responsiveness we report for units than houses confirms findings from prior Australian studies (Gitelman and Otto, 2012; McLaughlin, 2012a; Liu and Otto, 2017; Saunders and Tulip, 2019). The typically stronger supply response in the higher density segment of the housing market likely reflects the greater priority that Australian state governments have accorded infill development and urban consolidation with new supply targets featuring in most capital

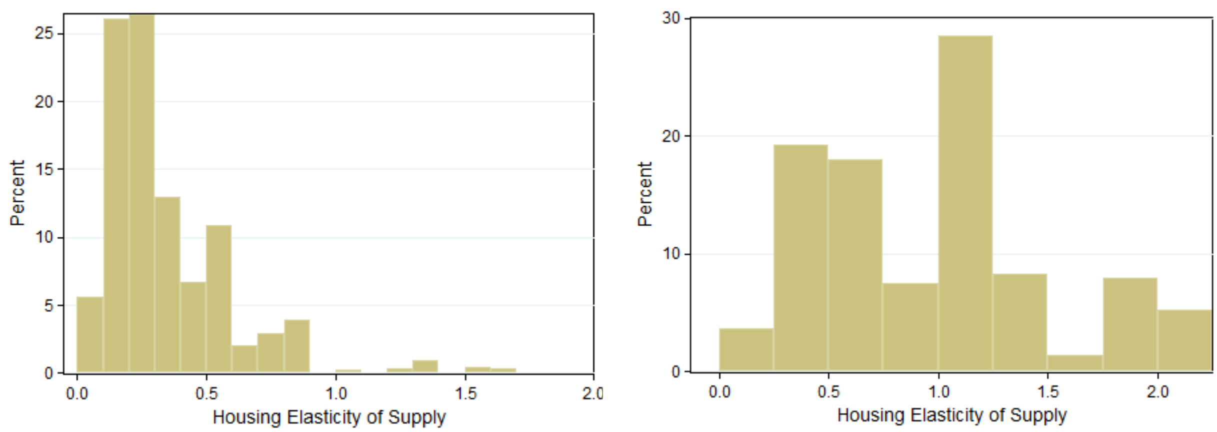
[10] In the Online Appendix we provide full details of the instrument strength tests, and also report results where lagged prices are included in the models. In this case, lagged price is instrumented using lagged values of the instrumental variables. The results from these models are broadly similar to those including only contemporaneous price. Hence, we favour the simpler specification.
[11] We use Newey-West standard errors with one lag. These are robust to heteroscedasticity and autocorrelation in the residuals.

cities' metropolitan plans (McLaughlin, 2012a, p615). Another possibility is that higher density housing is more appealing when the price of housing increases as it is largely driven by rising land prices (Saunders and Tulip, 2019).

Of particular note is the wide variation in estimates across LGAs. To illustrate this, Figure 1 plots the distribution of HES estimates by structure type. For houses, the median elasticity is 0.27 while the 25th and 75th percentiles differ by a factor of more than two at 0.17 and 0.44 respectively. There are also significant local area differences in the HES for units. It varies from 0.56 at the 25th percentile to 1.17 at the 75th percentile.

Figure 1: The Distribution of the Housing Elasticity of Supply Across LGAs (Weighted by Average Housing Stock)

(a) Houses **(b) Units**

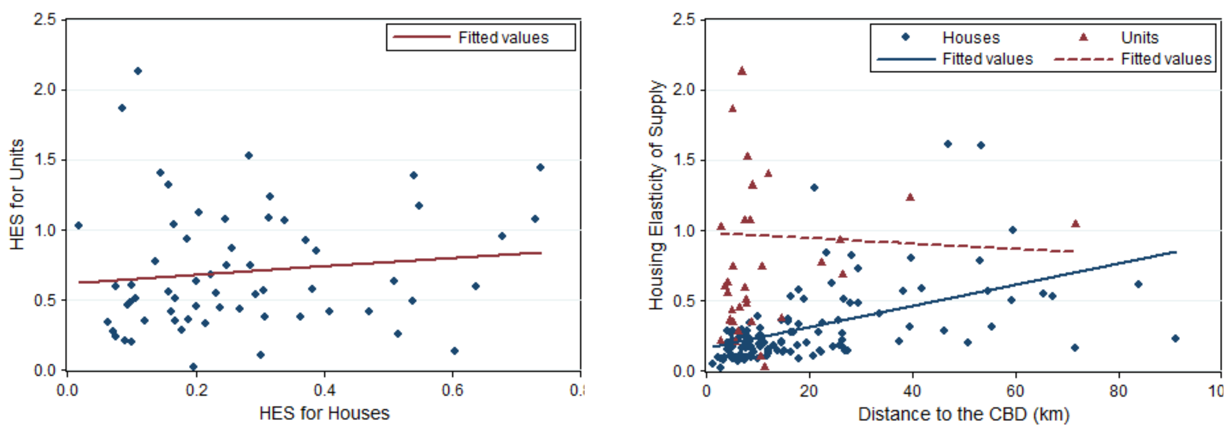


To explore these results further, in Figure 2(a) the correlation between the HES for houses and that for units is plotted for the same LGAs. The figure highlights a weak relationship between the two groups of HES estimates. In fact, the correlation is just 0.12, which is not statistically significantly different from zero (the p-value is 0.3437). This disconnect between the responsiveness of unit supply as compared to houses in an LGA, is interesting. It suggests that there is no uniform policy approach that an LGA can adopt to be good overall at encouraging housing supply. If there were, then LGAs with a relatively high HES with respect to the supply of houses would also have relatively high HES with respect to the supply of units. It also implies that the location specific characteristics of an LGA may have an important role in driving the HES, rather than just their approach to planning. We turn to this issue in the following section.

Figure 2(b) explores the HES across LGAs for houses and units based on their distance to the CBD. A regression line is fitted in each case. The figure emphasizes the clear and statistically significant rise in the HES for houses further from the CBD, which supports international findings confirming greater supply elasticities on the urban fringe (Brasington, 2002; Baum-Snow, 2019). This is likely to reflect the fact that land closer to the city-centre has typically been built on, and vacant land is therefore scarce and more expensive (see also Saiz, 2010 for the US and Baum-Snow, 2019 for Toronto). On the urban fringe a more ample supply of greenfield sites is forthcoming. These factors favour infill developments and conversions from industrial, commercial, and recreational use as the predominant sources of supply in and around the CBD. Thus, a different pattern is evident among the HES for units in Figure 2(b), with the HES exhibiting a gentle statistically insignificant decline with distance from CBD. In the middle ring suburbs, the externalities generated by medium and high-density construction is especially acute, and so planning impediments and resistance to such new residential development is more likely (Hsieh et al. 2012). In the outer ring of suburbs low density developments take advantage of the cheaper greenfield sites. The results in Figure 2 are suggestive of structural factors impacting on the HES to which we now turn.

Figure 2: The Housing Elasticity of Supply for Houses and Units

(a) Correlation **(b) Distance to the CBD**



4.2. Explaining the Housing Elasticity of Supply

In this section we explore whether location specific characteristics can explain the high degree of variation in the HES across LGAs. We run a regression with the estimated HES ($\hat{\beta}_i$) as the dependent variable and a range of independent variables that include; state indicators, city accessibility, topography, temperature range, annual precipitation, and political orientation. For topography, we construct two equally sized groups (representing low and high) based on the percentage of the LGA with a slope of 15 degrees or more. In the case of temperature range and precipitation, we also divide the LGAs into two equally sized low and high groups. For political orientation, we create three groups—left-leaning, centrist, and right-leaning—as previously outlined. We also use our indicator for city accessibility that is based on an LGA's average distance from the CBD. We estimate a regression using all observations, as well as separate regressions for houses and units (see Table 3).

Table 3: Explaining the Housing Elasticity of Supply Across LGAs

		All	Houses	Units
Structure Type:	Unit	0.7391***	–	–
(base=House)		(0.1046)	–	–
State:	NT	0.0166	0.0446	-0.1070
(base=NSW)		(0.1124)	(0.1108)	(0.2236)
	QLD	0.1314**	0.1101*	–
		(0.0627)	(0.0616)	–
	SA	0.0693	0.1015*	-0.7007**
		(0.0642)	(0.0615)	(0.2900)
	TAS	-0.1099*	-0.0902	-0.4010*
		(0.0575)	(0.0573)	(0.2349)
	VIC	0.2006***	0.1776***	0.2777*
		(0.0656)	(0.0670)	(0.1524)
	WA	0.1856***	0.1896***	0.0323
		(0.0524)	(0.0517)	(0.2262)
City Accessibility:	Middle	0.0570	0.0743	0.0698
(base=Inner)		(0.0495)	(0.0481)	(0.1136)
	Outer	0.2265***	0.2450***	-0.1734
		(0.0659)	(0.0659)	(0.3107)
	Non-City	0.1898***	0.2112***	-0.1254
		(0.0419)	(0.0378)	(0.2479)
Topography:	High Slope	0.0362	0.0549	-0.2180
(base=Low Slope)		(0.0543)	(0.0561)	(0.1994)
Temperature Range:	High	0.0069	0.0078	-0.3416
(base=Low)		(0.0420)	(0.0432)	(0.2717)
Precipitation:	High	-0.0440	-0.0141	-0.5879**
(base=Low)		(0.0653)	(0.0597)	(0.2245)
Political Orientation:	Left-Leaning	0.0331	0.0215	0.3298*
(base= Centrist)		(0.0487)	(0.0486)	(0.1669)
	Right-Leaning	-0.0213	-0.0217	0.1553
		(0.0447)	(0.0407)	(0.1905)
Constant		0.1066	0.0697	1.2603***
		(0.0796)	(0.0750)	(0.2950)
Observations		380	316	64
R-squared		0.3913	0.2203	0.6966

Notes: Standard errors are shown in parentheses. Significance: * p-value<10%, ** p-value<5%, *** p-value<1%. Base categories for each of the categorical variables are indicated. The regression uses the average of the housing stock for each LGA over the period examined as weights. The state abbreviations are: NSW=New South Wales, NT=Northern Territory, QLD=Queensland, SA=South Australia, WA=Western Australia, VIC=Victoria, TAS=Tasmania.

The overall picture painted by the results reinforces previous conclusions; there is a statistically significant and large difference in the HES between houses and units, and city accessibility plays an important role. The unit indicator variable in the all houses and units regression is strongly and significantly positive at 0.74, suggesting that even after control variables are added, there is a much larger nationwide HES for units. In this sample the HES for LGAs in the outer rings of metropolitan areas is significantly larger as compared to inner ring LGAs.

The separate house and unit regressions offer further insights. In cities the geography of the HES house estimates implies a steep, and statistically significant, rise in its value further from the CBD. But we find that no statistically significant spatial pattern is evident in the unit estimates, despite the large negative coefficient estimate on the HES inner – outer differential. These findings are consistent with Daley et al.'s (2018) interpretation of the Australian evidence as well as Gitelman and Otto's (2012) price elasticity estimates for house supply in Sydney. They also support international evidence that price elasticities can vary greatly across regions within the same country (De La Paz, 2014).

As Phibbs and Gurran (2021) note, State governments, the tier of government in Australia that sits above LGAs, have taken an increasing role in controlling the regulations around housing supply. We find strongly positive Victorian and WA effects for houses in our results and to a lesser extent for Queensland and SA. The HES is also particularly high in Victoria for units. The states of SA and Tasmania have large negative effects for units implying a weak supply response in these jurisdictions. In the unit regression the constant estimate implies that the supply of units in inner metropolitan NSW LGAs with low levels of precipitation, and a centrist political orientation, is elastic at 1.26; it rises to 1.59 if the political orientation is left-leaning. Our results also provide some evidence that higher annual precipitation reduces the HES for units.[12] The other variables have relatively modest and insignificant effects on the HES. Despite some overseas evidence to the contrary, topography and temperature range appear to be unimportant in Australia. It may be the case that in countries such as the US, the topographical terrain is less forgiving. It is to be noted that most Australian state capital cities are built on gently undulating coastal plains. Furthermore, the Australian climate does not feature temperatures at very low extremes that hinder construction activity, whereas many North American cities are vulnerable to such extremes in their winter months.

5. Conclusion

Housing affordability challenges in many cities in Australia, and around the world, have led to an increasing focus on the supply responsiveness of the housing market. In this study we have focused on estimating the

[12] This may relate to the higher unionisation rates on large construction sites building units and the greater observance of health and safety regulations when there are difficult working conditions, such as heavy rain.

HES, using IV methods, across local government areas from 2001-2019. The objective being to explore variation in the HES across these small areas and identify what drives differences in the HES. We found that for Australia the HES averaged 0.34 for houses and 0.96 for units and varies greatly across the sample of 341 LGAs. In the case of houses, the 75th percentile of the HES distribution is more than twice the 25th percentile. The difference is even larger for units. Despite this variation it is reasonable to conclude that Australia has an inelastic housing supply relative to OECD and EU countries (see Caldera and Johansson, 2011; European Construction Sector Observatory, 2019).

We analysed possible causes of these large differences by running an auxiliary regression on LGA HES estimates. This revealed statistically significant differences across states and for LGAs at different distances from the city-centre, reflecting similar findings from other cities as reported in Brasington (2002) for Ohio and Baum-Snow (2019) for Toronto. However, while we also included a range of other factors including topography, temperature range, annual precipitation and political orientation, there is weaker evidence in support of their role which contrast with US studies such as Saiz (2010). Also of note are some differences in results when auxiliary regressions are separately estimated for houses and units. A key finding is the stronger and larger *house* HES estimates in the outer ring of metropolitan suburbs, a pattern that is not evident in the *unit* HES estimates. Furthermore, HES estimates across property types are not correlated. LGAs with low (or high) HES in respect of houses will not necessarily have low (or high) HES in respect of units.

These empirical results have several potentially important implications for policy makers and practitioners. The heterogeneity in local HES estimates suggests that a 'one size fits all' approach to planning mechanisms guiding housing supply is likely to be blunt and inefficient. Planning practitioners could benefit from the kind of modelling approach implemented in this paper, because the local HES estimates for housing of different types aid the design of zoning and building regulations that are tailored to match local circumstances. For example, we discovered that in Australian cities generally the uncorrelated LGA HES estimates for houses and units reflect a relatively elastic supply of houses in LGAs on the urban fringe, while units have a relatively elastic supply in central city LGAs. But in the middle ring LGAs HES estimates for both residential property types are comparatively low. Australian metropolitan strategies are striving to curb expansion at the fringe of cities, which therefore highlights the importance of strategies that could make housing more responsive to price in the middle ring of city suburbs, especially as the scope for infill residential development in inner cities is inevitably limited given the prominence of commercial and retail activity. The pattern of local HES estimates can then aid the identification of particular segments of cities where reform is required if housing is to better match demand, but also those areas where housing supply has proved price elastic, and so can be relied on to quickly expand housing supply in response to shifts in demand.

Our empirical findings also have a resonance within wider urban policy debates. Overall, the spatial patterns in the price elasticity of housing supply reflect urban spatial inequalities favouring inner city apartment dwellers at the expense of urban fringe house dwellers. Firstly, there is concern that residents of disadvantaged areas on the urban fringe lack empowerment to engage with planning processes in their local areas. Hence, governments may opportunistically exploit this by accommodating growth in disadvantaged areas in the outer rings, where community resistance is weaker. Indeed, Uddin et al. (2022) points out that new dwelling growth in Greater Sydney from 2020-21 to 2024-25 has been largely targeted in low socio-economic communities in western Sydney areas that have poor access to jobs and urban facilities. Such urban planning practices have the unfortunate consequence of further widening the gap between the more well-to-do residents of inner suburbs and the lower income residents of outer suburbs.

Furthermore, the greater focus on inner city infill development in more recent Australian metropolitan strategies, has in part been driven by the practical challenges and costs of providing multidimensional infrastructure to greenfield development sites on the city's edge, though this is where the supply of new houses is highly responsive to price movements. For instance, the renewed focus on metropolitan planning in Melbourne in the early 2000s was in part driven by the need to limit greenfield infrastructure costs (Henderson, 2019). Governments have tended to focus more on improving infrastructure in existing metropolitan areas at the expense of greenfield infrastructure to facilitate more compact urban development (Henderson, 2005). Infrastructure deficits in outer metropolitan rings are therefore widening and are compounded by fiscal constraints as well as a lack of transparent, forward-looking and coordinated planning (Gleeson et al., 2012; Henderson, 2019). The housing affordability crisis in Australian cities is aggravated by this tension between the changing spatial pattern of infrastructure investment, and the spatial pattern of HES that for houses favours the city's edge. Knowledge of local HES can better inform policy makers about where these tensions are likely to emerge and the importance of their mitigation through complementary housing planning reforms.

Acknowledgements

We would like to thank Christopher Phelps and Jack Hewton, Curtin University, for research assistance. This work was partially supported by the Australian Housing and Urban Research Institute (AHURI) under grant number 81073. Rachel Ong ViforJ is the recipient of an ARC Future Fellowship (project FT200100422) funded by the Australian Government.

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Online Appendix (Not for Publication)

Appendix A: HES Estimate for the Model Including Price and Lagged Price

Table A1 reports All and Significant coefficients for the model which includes both price and lagged-price as regressors in the housing supply function. In this case the contemporaneous and lagged values of population, nominal and real interest rates are used as IVs.

Table A1: The Housing Elasticity of Supply Across LGAs
(Housing Supply Equation Includes Price and Lagged-Price)

	Houses					Units				
			Percentiles					Percentiles		
	N	Mean	25th	50th	75th	N	Mean	25th	50th	75th
All	341	0.29	0.12	0.20	0.36	74	0.83	0.40	0.77	1.42
Significant	256	0.35	0.15	0.28	0.40	44	0.98	0.53	0.99	1.43

Notes: 'All' includes all estimated coefficients. 'Significant' includes only results which are statistically significant at the 10% level or better and are positive, as required if the supply curve slopes upward. In the model with lagged-price the reported HES is the sum of both coefficients. The statistics are weighted by an LGAs average housing stock as a share of the total housing stock across all LGAs.

Appendix B: Significance of HES and Strength of the Instruments

In Table B1 we provide statistics on the proportion of the coefficients which are significant as well as the strength of the instruments used in our modelling. The table reports results across all LGAs for the price model and the model which includes both price and lagged-price. As was discussed, a high proportion of the coefficient estimates are statistically significant. The lower half of the table shows that the instruments are generally strong. The R^2 of the first stage regression is relatively high on average and the F-statistic, testing the null hypothesis that the coefficients in the first-stage regression are zero, has a value on average above 10—a common rule of thumb value used to judge the strength of the instruments (Staiger and Stock, 1997).

Table B1: Significance of HES and Strength of the Instruments

	Price		Price and Lagged-Price	
	Houses	Units	Houses	Units
Number of Estimated Coefficients	341	74	341	74

% of LGAs with Significant and Positive HES Coefficients:				
10% Level	92.67	86.49	75.07	59.46
5% Level	91.20	85.14	72.73	56.76
1% Level	88.27	77.03	66.57	45.95
% of LGAs with Significant First Stage Regression:				
10% Level	92.96	83.78	96.19	91.89
5% Level	91.20	82.43	93.55	86.49
1% Level	80.06	72.97	82.99	77.03
R^2 of First Stage Regression:				
Mean	0.7186	0.6614	0.8116	0.7874
Median	0.7684	0.7427	0.8465	0.8288
F-Statistic of First Stage Regression:				
Mean	22.59	19.08	30.67	23.74
Median	14.01	10.94	15.57	15.80