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Measuring Housing Price Growth – Using Stratification to Improve Median-based Measures

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Abstract

Developments in housing prices are of interest to households, policy-makers and those involved in the housing industry. This has been the case both in Australia and in other countries where house price developments are having significant macroeconomic impacts. However, the construction of measures of city-wide or nationwide average housing prices is not a straightforward exercise. One problem is that the sample of dwellings transacted in any period may be far from random and the characteristics of the sample may change from period to period. As a result, widely used measures of growth in mean or median housing prices will reflect changes in the composition of dwellings sold as well as changes in demand and supply conditions. We demonstrate that median price measures in most major Australian capitals are significantly affected by such compositional change.

In this paper, we propose a simple measure of house price growth that addresses the problem of compositional change by stratifying individual transactions into different groups. Our measure differs from those commonly used internationally in that we group small geographic regions (suburbs) according to the long-term average price level of dwellings in those regions, rather than just clustering smaller geographic regions into larger geographic regions. This produces a measure of price growth that substantially improves upon median price measures, and one that is highly correlated with more sophisticated (but more computationally intensive) measures. While we focus on providing a basic framework for measuring house price growth, the stratification techniques contained in this paper have broader applications for dealing with datasets that are affected by compositional change.

JEL Classification Numbers: G12, R31

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MEASURING HOUSING PRICE GROWTH – USING STRATIFICATION TO IMPROVE MEDIAN-BASED MEASURES

Nalini Prasad and Anthony Richards

1. Introduction

Developments in housing prices are of great interest to households, policy-makers and those involved in the housing industry. This has been the case both in Australia and in other countries where house price developments are having significant macroeconomic impacts. However, the construction of aggregate measures of housing prices is not a straightforward exercise, and involves addressing a number of conceptual and practical issues. This paper aims to provide a computationally simple method of addressing some of these issues. While the focus of this paper is on measuring house price growth in Australia, the method outlined in this paper would also be feasible and readily adaptable for data from other countries.

One major problem in measuring housing price growth results from the infrequency of transactions and the heterogeneous nature of the housing stock. To be meaningful, price data should be based on transactions prices rather than valuations. But only a relatively small fraction of the housing stock is transacted in any period: in Australia the average turnover is around 6 per cent per year, or just 1½ per cent per quarter, and in other countries the turnover rate is often significantly lower. Given that the sample of transactions in any period may not be representative of the entire housing stock, changes in simple median or mean price measures may not provide good estimates of the pure price change, as they will also reflect compositional effects. In addition, problems associated with compositional change can be exacerbated by problems of data timeliness if there is a systematic lag between when particular sales are agreed to and when they are recorded in a database of transactions. Hence, early estimates of changes in housing prices may be quite unreliable, making it difficult to distinguish in real time between true movements in the housing market from spurious movements due to compositional effects.

If detailed and timely data on transactions are available, it is possible to use regression-based approaches to deal with the problems discussed above. For example, hedonic price regressions and repeat sales regressions can be used to abstract from compositional effects to derive estimates of pure price changes.[1] However, many of the housing price series produced internationally do not use such techniques but rely on simple measures such as median or mean sales prices. For example, the Real Estate Institute of Australia, the US National Association of Realtors, the Canadian Real Estate Organisation and the Real Estate Institute of New Zealand (REINZ) all publish house price data which are simple median or mean measures. The reason is presumably that the more advanced techniques require detailed data, are typically subject to revision as data for future periods become available, are less transparent, and require the use of statistical techniques that are not as widely used by organisations such as industry bodies.

We show that compositional change can have major impacts on estimates of price changes that are based on simple median measures. Accordingly, we outline and test a simple method for calculating changes in aggregate housing prices that controls for compositional change and which remains robust even when the initial sample of transactions is fairly small. In particular, we propose a method that stratifies individual house sales into different groups so as to minimise the impact of compositional change, and then uses the median prices from those groups to derive an estimate of the overall change in prices. We therefore demonstrate that median prices can be considerably more useful if taken from a stratified data sample compared with a single (unstratified) median taken from the entire data sample.

The particular innovation of the paper is the method of stratification. A standard method of stratification is to divide a city into broad geographical regions. However, changes in regional composition do not necessarily result in problems for median measures; compositional change will only be a significant problem if it results in changes in the proportion of high- and low-priced properties. Accordingly, we group small geographical regions (suburbs) into different strata based on the long-term average price level of houses in those regions, thereby directly addressing the main problem of compositional change. We find that

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1 See Case and Shiller (1987), Meese and Wallace (1997) and Hansen (2006) for further discussion of these methodologies.

stratifying sales in this manner produces a measure of price growth that is a considerable improvement over an unstratified median; our measure is significantly less noisy than a median and performs better in real time with limited data samples. As the aim of the paper is to look at computationally simple methods of calculating price growth, regression-based techniques are not considered, however, Hansen (2006) provides a complementary analysis using regression techniques. We find that the growth rates produced by our measure line up closely with the more advanced measures contained in Hansen. This leads us to conclude that it is possible to come up with estimates of overall changes in house prices that are very similar to regression-based measures, but are based on simple medians from stratification.

The rest of the paper is organised as follows. In Section 2 we present some data on median house prices and document the strong impact of compositional change. In Section 3, we outline how stratification techniques – a method commonly used in other contexts – can control for compositional change. Section 4 outlines our method of controlling for compositional change, while Section 5 provides an assessment of the resulting measure of housing prices. Section 6 concludes.

2. The Impact of Compositional Change on Median Price Measures

Median or mean house price series are produced in many countries.[2] One clear advantage of median price measures is that they are very easy to calculate. They also have a straightforward interpretation: they represent the price in a 'typical' transaction in any given period.

However, if one is interested in inferring the price change for the overall housing stock, these measures can be distorted by compositional change. In particular, the transactions that occur in any period may not be representative of the overall

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[2] In Australia, the price data produced by the Real Estate Institute of Australia and the Commonwealth Bank are simple unstratified medians (with no allowance for possible seasonality). In addition to the measures already mentioned, many house price measures in continental Europe also use a mean or median to measure prices, for example, measures constructed in Belgium, Denmark, Ireland, Luxembourg, Norway and Switzerland.

housing stock. Or more importantly for estimating price changes, the composition of the sample of transactions in one period may be quite different to the composition in the next period. As a result, changes in median and mean prices may contain substantial noise from compositional change and provide poor estimates of price changes that result from changes in demand and supply conditions.

2.1 Australian Evidence

We can illustrate the problems resulting from compositional change using quarterly data for median prices of houses transacted in Sydney between March quarter 1993 and September quarter 2005. The top panel of Figure 1 shows the quarterly median price (on a log scale). The middle panel shows the quarterly change in this series along with a line for the trend quarterly growth.[3,4] These series indicate that there was substantial growth in median prices over most of this period, but with substantial noise, which is apparent in the sometimes large divergences between the actual and trend change in the median.

In the bottom panel of Figure 1, we introduce a measure of compositional change which may be able to explain some of the noise in the median price. To construct this variable, the 659 suburbs in Sydney were ranked according to their median transaction prices over 2000–2004, and then allocated into 10 groups (or deciles), with an approximately equal number of suburbs in each group. Decile 1 consists of the 65 suburbs with the lowest median prices, while Decile 10 consists of the 66 suburbs with the highest median prices. For each quarter, we then calculate the proportion of transactions in the more expensive suburbs (Deciles 6–10). In the case of Sydney, this proportion averages somewhat below 50 per cent because the allocation of suburbs was done to ensure a similar number of suburbs, rather than

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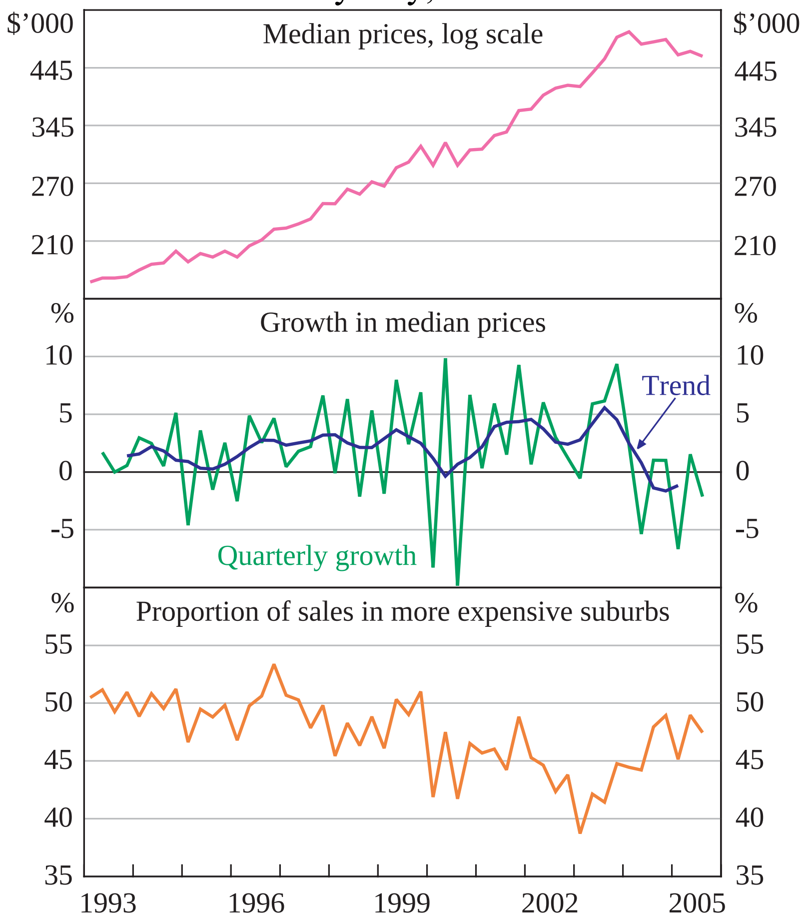
3 Through the rest of the paper, all calculations involving changes in prices use the change in the log of the price series. In cases where we show these in a table, they are the log change multiplied by 100 so as to correspond approximately to percentage changes.

4 The trend is calculated as the change in the five-quarter-centred moving average of (the log of) the median price series. The weights in the moving average are 0.125, 0.25, 0.25, 0.25, and 0.125, which should remove any seasonality from the trend.

Figure 1: Median House Prices

Sydney, nsa



Source: Authors' analysis using data from APM

transactions, in each decile.[5] The data show that there is significant quarterly variation in the proportion of transactions in the more expensive suburbs of Sydney.[6] This leads to noise in the median measure, as measured price growth reflects both changes that result from compositional effects as well as pure price changes. An illustration of the noise in quarterly growth of the city-wide median measure is that, in most cases, quarterly growth in this series is outside the range of the middle six decile growth rates. Indeed, in nearly half of all quarters in the data

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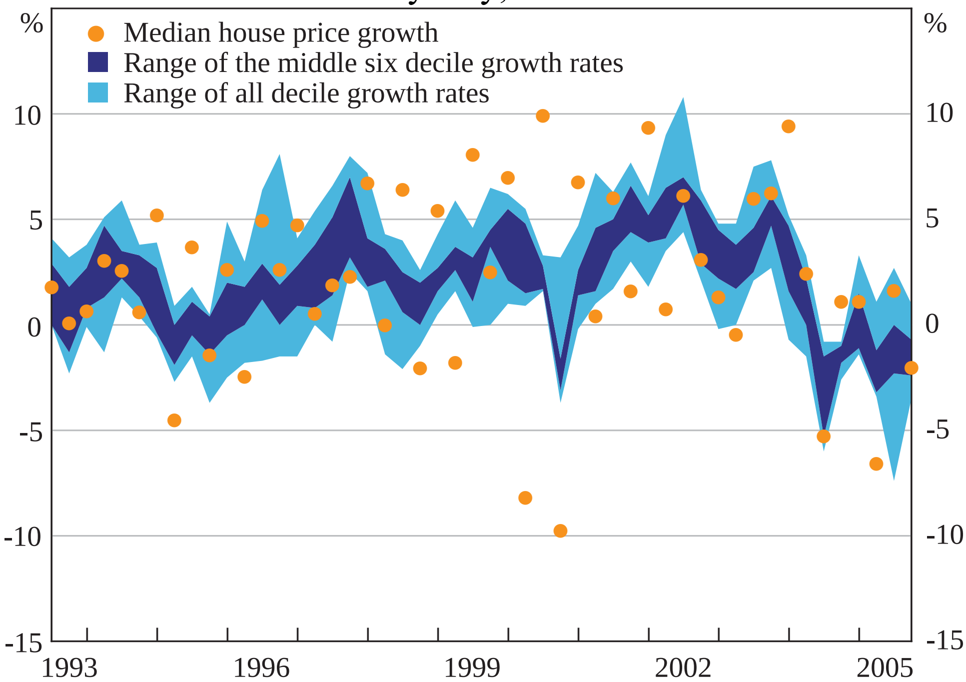
5 All the raw data used in this paper, including the division of data into deciles, has been provided by Australian Property Monitors (APM). The results in Sections 5.3 and 5.5 are based on unit record data provided by APM.

6 It is interesting that there also appears to be a downward trend in this ratio over most of the sample, perhaps because the growth in the city has been in suburbs relatively far from the centre, which tend to be less expensive suburbs. This suggests that measures of median prices might understate true longer-run price growth over the entire period. We do not address this issue, but instead focus on improving estimates of short-run changes in house prices.

sample, the quarterly changes in the city-wide median is actually outside the range of median price changes in all ten deciles (Figure 2).

Figure 2: Median House Price Growth and Compositional Change

Sydney, nsa



Source: Authors' analysis using data from APM

We can formally test the proposition that compositional change between higher- and lower-priced suburbs may be responsible for some of the observed noise in the change in median house prices. We regress quarterly changes in median prices on a constant and a compositional change variable, given by the quarterly change in the proportion of dwellings sold in more expensive suburbs. We estimate this equation using data from June quarter 1993 to September quarter 2005 for median house prices in the six largest cities (Sydney, Melbourne, Brisbane, Perth, Adelaide and Canberra).[7] We also estimate it for apartment prices in Sydney and Melbourne, which account for around 70 per cent of the stock of capital-city apartments. In most cases we proxy the proportion of house sales in more expensive suburbs by sales in the top five deciles. The exception is the house market in Canberra and the apartment market in Sydney and Melbourne. Given the smaller size of these markets, transactions were grouped into five groups (quintiles), and we classify the

7 Houses are defined to include both detached and semi-detached dwellings.

middle quintile in such a way as to have an approximately equal number of sales in the higher- and lower-priced segments.

Results are shown in Table 1. In all cases the compositional change variable takes the expected positive sign: an increase in the proportion of transactions in higher-priced suburbs leads to the change in the median price being higher.[8] For Sydney and Melbourne, the results indicate that a considerable proportion – around 60 per cent – of the quarterly variation in median house prices can be explained purely by shifts in the mix of sales between higher- and lower-priced suburbs. The effect of compositional change is notable, though less pronounced in the other markets, explaining around 20 to 40 per cent of quarterly price movements. The exception is Brisbane which appears to be much less affected by this form of compositional change. Overall, the results in Table 1 suggest fairly strongly that there may be significant gains from taking account of the effect of this simple form of compositional change on median price measures.

Table 1: Testing for the Impact of Compositional Change on Median Prices

Regression results

	Coefficient on compositional change variable	Adjusted R^2
Sydney houses	1.09***	0.60
Melbourne houses	0.77***	0.63
Brisbane houses	0.56*	0.05
Perth houses	0.70***	0.20
Adelaide houses	0.89***	0.26
Canberra houses	0.45***	0.18
Sydney apartments	0.70***	0.37
Melbourne apartments	0.92***	0.39

Notes: This table shows results from a regression to determine if the quarterly growth in median house prices over 1993:Q2–2005:Q3 is affected by changes in the composition of dwellings sold. The regression estimated is $\Delta p_t = \alpha + \beta \Delta \text{com}_t + \varepsilon_t$ where Δp_t is the quarterly change in median prices, Δcom_t is the quarterly change in the proportion of transactions in more expensive suburbs, and ε_t is the error term. Significance at the 1, 5 and 10 per cent levels is denoted by ***, ** and *, respectively.

8 We have also regressed the compositional change variable on our stratified measure of price changes, which account for compositional change. The results indicate that there is no tendency for the compositional change variable to be related to true changes in house prices, so the results in Table 1 reflect spurious compositional effects on median prices.

A close look at Figure 1 suggests that part of the quarterly variation in the composition of dwellings sold may be seasonal in nature. Accordingly, we test for identifiable seasonality in the composition of sales and in the level of prices using the US Census Bureau's X12 seasonal adjustment program. In addition, we regress the quarterly change in the proportion of dwellings sold in more expensive suburbs and the quarterly change in the median price on seasonal dummies. While X12 provides a more sophisticated approach to testing for seasonality (by differentiating between trend, cyclical and seasonal influences and allowing seasonal patterns to vary over time), the adjusted R^2 from the seasonal dummy variable regressions provides a straightforward way of comparing the importance of seasonality in different series.

Panel A of Table 2 contains results from testing for seasonality in the proportion of houses sold in more expensive suburbs and Panel B contains the results for median prices. Both median prices and the composition of transactions are found to be seasonal in most capital cities. Furthermore, cities where the composition of transactions is found to exhibit a seasonal pattern tend to be the ones where median prices are found to be seasonal, suggesting that at least part of the seasonality seen in median prices is the result of seasonality in the composition of sales.[9] The sign and size of the seasonal factors on the compositional change and median price also support this, with the quarters when median prices are seasonally high (typically the December quarter in most cities) tending to be the quarters when the proportion of sales in higher-priced suburbs is also seasonally high. The values for the adjusted R^2 suggest that seasonal influences are particularly strong in the market for houses in the two largest capitals, explaining as much as a third (Sydney) or half (Melbourne) of the variation in quarterly price movements. Given that there is significant seasonality in most capital cities, and that the pattern of seasonality in the two largest cities is very similar, it is not surprising that there is also seasonality in average nationwide prices (which are calculated as the weighted average of prices in each capital city market using dwelling stock weights). Seasonal factors can explain nearly 40 per cent of quarterly price movements at the national level.

9 It is beyond the scope of this paper to consider the reasons for the seasonality in the composition of sales. However, it is interesting that in each of the capital cities where sales volumes are found to be most seasonal, the seasonality comes more from variation in the sales volumes in higher-priced suburbs than in lower-priced suburbs. This would be consistent with some cities having particular 'selling seasons', especially in higher-priced suburbs.

Table 2: Testing for Seasonality

	Is identifiable seasonality present in X12?	Adjusted R^2 from regression of quarterly change in the dependent variable on seasonal dummy variables
Panel A: Testing for seasonality in the compositional change variable		
Sydney houses	Yes	0.60
Melbourne houses	Yes	0.83
Brisbane houses	No	0.14
Perth houses	Yes	0.29
Adelaide houses	Yes	0.47
Canberra houses	No	0.05
Sydney apartments	Yes	0.53
Melbourne apartments	Yes	0.31
Panel B: Testing for seasonality in median house prices		
Sydney houses	Yes	0.33
Melbourne houses	Yes	0.50
Brisbane houses	No	0.02
Perth houses	Yes	0.14
Adelaide houses	Yes	0.26
Canberra houses	No	–0.02
Sydney apartments	Yes	0.26
Melbourne apartments	No	0.09
Australian housing	*Yes*	*0.39*
Panel C: Testing for seasonality in selected international median and mean price series		
US		
Northeast	Yes	0.23
Midwest	Yes	0.45
South	Yes	0.55
West	Yes	0.18
United States nationwide	No	–0.02
Canada		
Toronto	Yes	0.29
Canada nationwide	Yes	0.11
NZ		
Auckland	No	0.02
Waikato/Bay of Plenty	Yes	0.11
Wellington	Yes	0.55
Canterbury/Westland	Yes	0.09
New Zealand nationwide	Yes	0.11

Note: The Australian sample covers 1993:Q1–2005:Q3; the overseas data covers varying periods (see Footnote 10).

However, the relationship between changes in median prices and changes in the proportion of houses sold in more expensive suburbs is not purely due to common seasonality. For each capital-city market, we have also regressed quarterly changes in seasonally adjusted median prices on a constant and the seasonally adjusted compositional change variable. The adjusted R^2s from these regressions are lower than those in Table 1. However, in nearly all cities (the exceptions are Brisbane and Adelaide) the seasonally adjusted compositional change variable can explain a notable amount of the quarterly change in the seasonally adjusted median price, with adjusted R^2s ranging from between 0.10 (for Perth houses) to 0.37 (for Melbourne apartments). Therefore, there also exist significant non-seasonal shifts in the proportion of sales in more and less expensive suburbs that will be reflected in movements in median prices.

2.2 International Evidence

We have not been able to do similarly detailed tests of the impact of compositional change on median prices for other countries due to the absence of similar time series data for the share of transactions in different segments of the market. However, in Panel C of Table 2 we apply similar tests for seasonality to some readily available international housing price series. These are the median series produced by the US National Association of Realtors and by the Real Estate Institute of New Zealand (only major regions are shown) and the mean series from the Real Estate Institute of Canada.[10] The results are comparable to Australian data, with median and mean prices in nearly all regions found to be seasonal. In some cases, seasonal dummies alone are able to explain a significant proportion of the quarterly variation in prices.

We can think of no compelling reason as to why pure house price changes should be seasonal. Accordingly, the results suggest that price measures in these countries are also being significantly affected by compositional change, consistent with observations made by others (for example, McCarthy and Peach 2004, p3 and REINZ 2005). It therefore appears that the problem that we address in this paper

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10 The series for the US, Canada and New Zealand refer to existing one-family homes, dwellings, and existing dwellings, respectively. The analysis uses data for 1975:Q2–2005:Q4 for the US, 1980:Q1–2005:Q4 for Canada and 1992:Q1–2005:Q4 for New Zealand. The US data have been converted to a quarterly series by averaging the monthly series.

may be a fairly general one, suggesting that the solution proposed here may also have wider relevance for house price measures published in some other countries.

3. Stratification

The problems illustrated in Section 2 reflect the fact that the prices recorded in any quarter relate to only a sample and not the entire population of houses. This would not be a significant problem if the sample was a random sample from the population of all houses. Despite the significant number of transactions available each quarter, the results above suggest that the observed samples in any quarter are far from random. Given that there is no *ex ante* way of ensuring a random sample of housing transactions, the issue becomes one of dealing *ex post* with the non-randomness of the sample.

The measure for the change in house prices that is proposed in this paper uses mix-adjustment, which in turn uses stratification, to control for compositional change. Stratification is a commonly used technique because it can increase the precision of sample estimates (Hansen, Hurwitz and Madow 1953). Indeed, it is a method employed in measuring house prices in a number of countries (Table 3).[11] However, as is discussed in more detail below, the method that we use to stratify our sample differs significantly from most other applications in one respect.

Stratification involves dividing a population into groups (strata) such that observations within each group are more homogenous than observations in the entire population. Within each stratum, it then becomes more likely that an observed change in a characteristic of interest represents a true change rather than a spurious one due to compositional effects. Once strata have been defined, a measure of central tendency from each strata is weighted together to produce an aggregate price measure.

[11] See ABS (2005, pp 6–8) for some additional discussion of the use of stratification in house price measurement.

Table 3: Mix-adjusted House Price Measures in Selected Countries

Index provider	Variables used in mix adjustment
Australian Bureau of Statistics (ABS)	Region, percentage of three-bedroom houses within a region and an index of the social and economic conditions in a suburb
Hong Kong Monetary Authority	The saleable area of a dwelling
Urban Redevelopment Authority (Singapore)	Dwelling type and region, with prices quoted in per square metre terms
Bank of Canada/ Royal Le Page	Region and dwelling type
Deutsche Bundesbank/ Bulwien AG	Region and dwelling type
Ministerio de Formento (Spain)	Calculates the average price of a house per square metre. Distinguishes between dwellings based on location and size of municipalities
Hometrack (UK)	Postcode and dwelling type
Rightmove (UK)	Postcode and dwelling type
Office of the Deputy Prime Minister (ODPM, UK)	Region, locations within region, dwelling type, old or new dwelling and first or repeat-home buyer purchase. A hedonic equation is used to calculate the price for each strata.

Sources: ABS (2005); BIS database; various national sources

Traditionally, the variable which has been used to group transactions is geography (Table 3).[12] Defining housing strata based on geography captures the notion that dwellings in a given area share amenities linked to the property's location. In addition, the literature on housing submarkets finds that geographic variables are an important determinant of housing prices (see Bourassa *et al* 1999 and Goodman and Thibodeau 2003). Similarly, work using Australian data by the ABS (2005) and Hansen (2006) finds that location is a fundamental price-determining characteristic of dwellings. Another reason for grouping by location is a practical one; geographic variables are readily available in most databases of housing transactions (Goodman and Thibodeau 2003).

12 In addition to location, most measures which use stratification also group transactions according to dwelling type. As well as the measures in the table, a number of countries in continental Europe (including Austria, Finland, Hungary and Portugal) make a rudimentary adjustment for quality by measuring prices in per square metre terms. Beyond this, most measures do not control for quality. This is probably because very few datasets contain comprehensive information on dwelling characteristics.

The increase in precision gained from stratification is dependent on how strata are defined. Hansen *et al* (1953) suggest that strata boundaries should be defined using information on all relevant variables that influence the characteristic being measured. Similarly, Lavallée (1988) notes that the most useful variables for stratifying data are those that are highly correlated with the variable of interest.

In the current case, we are particularly concerned about removing the noise in changes in median prices that results from the combination of compositional change and the extreme range in housing prices (the fact that prices of some houses in a city may be more than 10 times higher than the prices of other houses). For our exercise we have no particular interest in trends in house prices across different regions of a city. Furthermore, purely geographical stratification is unlikely to divide houses into strata with the maximal feasible similarity in prices within strata. Accordingly, we group houses and suburbs into strata based on the variable that is most likely on an *a priori* basis to explain the price in any transaction, namely the long-term level of prices for the suburb where the house is located.

4. A Measure of Average Price Changes which Controls for Compositional Changes

Based on the discussion in Sections 2 and 3, we propose a measure of changes in average housing prices that controls for one important form of compositional change. We refer to this hereafter as the change in the mix-adjusted measure.

4.1 Data and Method of Stratification

Our measure uses data for March quarter 1993 to September quarter 2005, prepared by APM. The dataset provided by APM contains virtually the entire population of housing transactions that occurred over this period.

As a starting point, transactions were grouped together by location, based on the suburb where the property is located.[13] However, because a city like Sydney has in excess of 600 suburbs, this would be too great a level of disaggregation to be

[13] The use of suburbs rather than postcodes allows a greater degree of disaggregation as postcodes often incorporate more than one suburb.

practical if simplicity of calculation is one of the key considerations for a simple mix-adjusted measure. Further, it is likely that during some quarters the number of sales within a suburb may be quite small (or zero), hindering the estimation of a price movement for that suburb. Therefore an additional criterion is required to cluster together individual suburbs and hence reduce the number of strata.

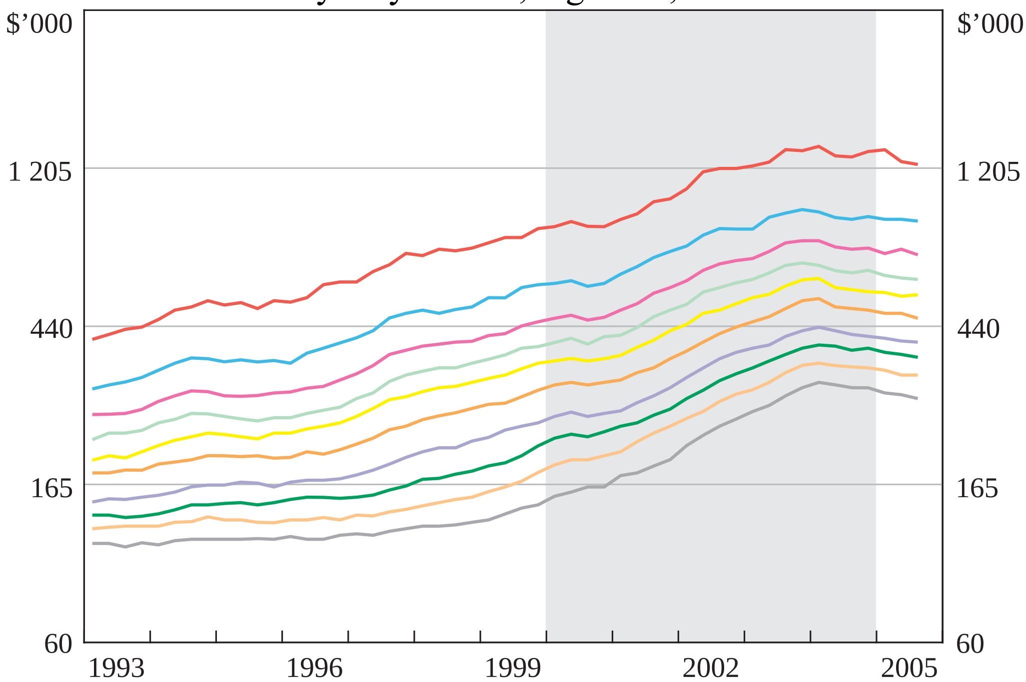
For simplicity, median sale prices in each suburb over the period 2000–2004 were used to group suburbs into strata. For the house price data, suburbs in the five largest cities were grouped into deciles, each with an approximately equal number of suburbs, based on median prices over 2000–2004. For example, of the 446 suburbs in Melbourne, the first stratum for Melbourne consists of the 44 suburbs with the lowest median prices, while the tenth stratum consists of the 45 suburbs with the highest median prices. In the case of house prices for Canberra and apartment prices for Sydney and Melbourne, there are fewer transactions, so we group them into quintiles of equal number of suburbs.

There would, of course, be many other ranking periods that we could use for grouping suburbs into strata based on median prices. For example, we could use the median price of suburbs in 1992 to form strata for 1993, then the median prices for 1993 to form strata for 1994, and so on. However, in practice there is a very high degree of stability in the relative price rankings of suburbs: suburbs that tend to be relatively expensive in one period will tend to be relatively expensive 10 years later. Figure 3 illustrates this using data for Sydney, showing that the price relativities in the 2000–2004 sorting period also hold outside that period.[14] The same result holds almost without exception for all cities and for both houses and apartments. Hence, any reasonable alternative price-based strategy for ranking suburbs would result in very similar strata, and very similar estimates of price growth.

[14] The Spearman rank correlation between median suburb prices in Sydney in 1996 and 2004 is 0.95, which confirms that suburbs tend to maintain their relative price rankings.

Figure 3: Median Decile Prices

Sydney houses, log scale, nsa



Notes: The lines represent the median price for each of the 10 deciles in Sydney. The shaded area shows the period used to sort the data.

Source: Authors' analysis using data from APM

4.2 Calculation of City-wide Quarterly Price Changes

Once suburbs were grouped into deciles (or quintiles), a median price was calculated for each strata for each quarter. The change in the median prices for each strata were then weighted together to calculate growth in city-wide prices.

There are a number of different weighting schemes that could be used to combine these ten (or five) growth rates. The simplest method would be to take an unweighted average of the changes. This is equivalent to constructing a city-wide index as the unweighted geometric average of median prices in each strata. Alternatively, we have also investigated the effect of using weights based on sales volumes over the 12-year period, and weights based on principal components (where changes in prices for any group can be thought as given by an unobservable city-wide movement plus an idiosyncratic component).[15]

However, different weighting schemes make very little difference to estimates of short-term price growth. In our sample, the different weightings yield measures of quarterly price changes which typically have a correlation of over 0.99. This reflects the fact that price changes in the different strata are typically reasonably highly correlated (see Appendix A). Nevertheless, in most cases, sales volumes and principal components imply weights for each stratum that are close to equal weights. Given that equal-weighting produces similar results to other weighting schemes and given that it is the simplest method of weighting the series, all the results shown in subsequent sections of this paper refer to the equally-weighted measure (which is labelled as the 'mix-adjusted measure').

5. Assessing the Mix-adjusted Median

We assess our alternative measure of changes in city-wide house prices by examining how well it addresses the problems with conventional unstratified median measures that were highlighted in Section 2. An additional benchmark is whether our measures outperform the change in the seasonally adjusted median price: this will indicate if the slightly greater data demands of our measure yields a significant improvement relative to a simple alternative approach to dealing with the problem of seasonality and compositional change. In addition, we also compare the correlation of our measure with regression-based measures. We then provide some additional perspective on the reasons for the good performance of our simple measure.

[15] If the intention is to measure changes in the value of the housing stock, the most appropriate weighting would be to use suburb-level dwelling stock weights. Data limitations prevented this for the current exercise, but the results are likely to be little different to the results presented here, especially for short-term price movements.

5.1 Volatility

Price movements that result from compositional effects can be considered as representing noise that adds volatility to quarterly price changes rather than being indicative of true trends in the housing market. Indeed, the results in Panel A of Table 4 indicate that quarterly changes in median housing prices in Australian cities are highly volatile.[16] In every case, simply seasonally adjusting the median price series (using the X12 program) results in a measure of price changes that is considerably less volatile than the change in the unadjusted median. However, in every case there is an additional improvement that can be gained from our simple mix-adjusted measure.

The reduction in volatility between the non-seasonally adjusted median and the mix-adjusted measure is greatest for Sydney and Melbourne houses, where the standard deviation is reduced by half. Indeed, it is noteworthy for Sydney and Melbourne houses that the standard deviation of price changes in every one of the ten deciles is noticeably smaller than the standard deviation of the change in the median for the entire city. To be provocative, these results for Sydney and Melbourne suggest that one might get better estimates of the trend in city-wide house prices by looking at developments in a sample of only about 10 per cent of all sales (albeit a carefully selected 10 per cent) than from a standard median measure using the full sample of data.

The comparisons in Panel A of Table 4 implicitly assume that the amount of ‘noise’ in a series for price changes can be proxied by its standard deviation, that is, by the variability relative to the average change over the entire sample period. An alternative would be to recognise that there are cycles in price movements, so we should assess different series for price changes based on how closely they match a measure of the ‘trend’ change in prices. Accordingly, we construct a moving-average measure of the trend change in prices for each city. For each price measure we then calculate a root mean squared error (RMSE) between quarterly

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[16] McCarthy and Peach (2004) find that US median prices are also volatile. Indeed, the growth rate in the nationwide median price series produced by the National Association of Realtors is 2½ times more volatile than the growth in the repeat-sales index produced by the Office of Federal Housing Enterprise Oversight.

growth in the measure and quarterly growth in the trend.[17] Since the trend measure can be thought of as capturing underlying housing price movements, the larger the deviations from trend, the less informative the series is about the underlying state of the housing market.

The results for the RMSE in Panel B of Table 4 again suggest that a seasonally adjusted median price series offers an improvement over the standard median, but that the mix-adjusted measure provides a more significant improvement for all capital cities. Taking the reduction in the Australia-wide measure as a simple metric for the reduction in the proportion of noise in the standard median, one might conclude that seasonal adjustment can typically reduce the extent of noise by nearly 40 per cent, but that the mix-adjusted measure results in a more significant reduction, with the average volatility falling by nearly 70 per cent.

The reduction in volatility from adjusting for compositional change appears to be significantly greater for houses in Sydney and Melbourne than in the other capitals. The gains from stratification will depend on several factors including: the extent of compositional change between higher- and lower-priced properties in each city; the extent of price differences between higher- and lower-priced properties; and the extent to which we can 'undo' the effects of compositional change via the suburb-level stratification strategy used here. We cannot be definitive about the reasons for the relatively larger gains for the larger cities, but they appear to reflect both a higher degree of compositional change in these two cities (including the seasonal component shown in Panel A of Table 2), and greater variation in the characteristics of the dwelling stock in Sydney and Melbourne (for example, the median house price for the tenth decile in Sydney is on average 2.7 times higher than the city-wide median, compared with around 2.2 times higher for most of the other capitals). In addition, since the largest cities have the largest number of suburbs (for example, 659 for Sydney versus 313 for a medium-sized city like Perth), it is possible to divide larger cities into more differentiated strata with

[17] The trend is calculated using the moving-average approach described in Footnote 4. We first construct two measures of trend, one from an index version of our mix-adjusted measure and the other using the seasonally adjusted median. The measure of trend used in the comparisons in Table 4 is the average of the two measures: we do this to ensure a fair 'horse-race' between our measure and the seasonally adjusted measure (though the results are not sensitive to the assumptions about the calculation of the trend).

greater variation in the average prices of suburbs in each strata. Hence it would be expected that there would be greater gains from stratification and greater control of compositional change in the larger cities.

Table 4: Volatility in Measures of Changes in Housing Prices

Per cent

	Median (nsa)	Median (sa)	Mix-adjusted measure	Range for deciles/ quintiles (nsa)
Panel A: Standard deviation of quarterly changes				
Sydney houses	4.35	3.30	2.16	2.36–3.61
Melbourne houses	4.62	3.00	2.26	2.24–3.86
Brisbane houses	3.10	2.92	2.92	2.92–5.21
Perth houses	2.29	1.98	1.80	2.46–3.62
Adelaide houses	2.90	2.36	2.27	2.73–6.17
Canberra houses	3.51	3.44	3.06	3.57–5.12
Sydney apartments	2.27	1.87	1.84	2.17–3.18
Melbourne apartments	3.87	3.50	2.70	3.36–5.73
Australian housing	*3.13*	*2.25*	*1.81*	
Panel B: Deviation from trend (quarterly RMSE)				
Sydney houses	4.04	2.80	1.08	1.41–2.99
Melbourne houses	4.40	2.54	1.40	1.36–3.48
Brisbane houses	1.91	1.61	1.26	1.73–4.88
Perth houses	1.90	1.49	1.07	1.73–3.10
Adelaide houses	2.20	1.37	1.27	1.71–6.07
Canberra houses	2.46	2.41	1.88	2.33–4.78
Sydney apartments	1.93	1.46	1.21	1.60–2.89
Melbourne apartments	3.45	3.01	2.11	2.78–5.59
Australian housing	*2.81*	*1.73*	*0.88*	

Note: The sample covers 1993:Q2–2005:Q3.

5.2 Seasonality

By construction, our mix-adjusted measure will remove any impact on measures of price changes that results from seasonality in the composition of sales *across* strata. However, it will not control for any seasonality from compositional effects *within* strata. To see if seasonality within strata is an issue, we have tested our measure for the presence of any residual seasonality. While median prices in nearly all capital cities were found to be seasonal, the results (available upon request) indicate that mix-adjusted changes are not seasonal in any capital city, nor at the nationwide level.

Therefore, by controlling for one form of compositional effect through stratification, we are providing a control for the seasonality that is apparent in median measures. In addition to this, it appears that we are also controlling for some degree of non-seasonal compositional change. Accordingly, our measure appears in Table 4 to be a significant improvement over the seasonally adjusted measure.

5.3 Revisions

An additional test of the mix-adjusted methodology is the extent to which it performs well in real time, as opposed to the previous comparisons in this paper which are based on more final data. The real-time data problem is the result of the decentralised nature of the housing market in Australia, which means that information on house prices has often used data from state land titles offices reported only after the settlement of transactions. This means that sales information is often not available until several months after the agreement on the transaction price. Therefore, initial estimates of prices in transactions occurring in any given quarter may be based on only a small sample of all transactions that will eventually be available.

If there are systematic differences in the lag between agreement on a sale and the reporting of the sale, early samples of transactions may be quite unrepresentative of the final population of sales. For example, a simple median will be biased downwards if more expensive houses are under-represented in initial samples. Hence, early estimates of changes in housing prices may be unreliable, making it difficult to discern true movements in the housing market from those that result from small sample size or compositional effects. Indeed, the pattern of upward revisions to real-time estimates of median house prices in most Australian capitals suggest that lower-priced houses are over-represented in initial samples of transactions.[18]

To examine potential problems with early estimates, we use data on individual sales in Sydney, provided by APM, to estimate 'real-time' city-wide price growth. We calculate an 'initial' estimate of house price growth using data available one month after the end of each quarter and compare this with 'final' estimates calculated from the latest available vintage of data; this corresponds to an initial sample that is typically less than half the size of the final sample.[19] A RMSE is then calculated between the 'initial' and 'final' estimate of price growth for each measure. The results show that the standard median is subject to considerably greater revision (a RMSE of around 7½ percentage points) than the mix-adjusted measure (a RMSE of about 1½ percentage points). Hence, our technique of stratification appears to offer an even greater improvement over a simple median in real time. The improved real-time performance of the mix-adjusted measure is not entirely surprising given that one of the rationales for stratification is that it can reduce the size of a sample required to produce reliable statistics (Briggs and Duoba 2000).

5.4 Comparison with Regression-based Measures

One clear advantage of a mix-adjusted measure is its relative simplicity. However, more sophisticated approaches are possible, most notably the two regression-based measures studied in Hansen (2006). Of course, these approaches are not without shortcomings. For example, hedonic regressions will only be as good as the data on housing characteristics that are available. Repeat-sales estimates are likely to have significant problems in real time and can be subject to non-trivial revisions, given

[18] We will not focus on the question of why there appears to be some correlation between the sale price of houses and the time taken for settlement, reporting and recording of transactions. However, possible explanations would be that settlement conventions tend to be longer in more expensive areas (this could be because buyers of more expensive houses are more likely to be repeat-home buyers who may want a longer settlement period so that they can finalise selling their previous dwelling), that such buyers may tend to perceive benefits from delaying reporting their transactions, or that the processing of title changes in older (more expensive) suburbs might take longer than those in newer (less expensive) suburbs.

[19] The individual sales data used contain sales recorded up to September quarter 2005. The RMSEs are calculated on data for sales from the March quarter 1996 to the June quarter 2005.

that estimates of price growth in any quarter will be affected by sales that occur in subsequent quarters.

In Table 5, we use correlation coefficients and a measure of deviations from trend to compare our measure and the estimates from Hansen (2006) of quarterly price changes for houses in the three large capitals from hedonic and repeat-sales regressions. Panel A of Table 5 indicates that the change in the simple median often has a fairly modest correlation with the regression-based measures. Seasonal adjustment of the median produces quarterly growth rates that are slightly more correlated with these measures. However, our measure of the quarterly growth in prices is considerably more correlated with the regression-based measures. Indeed, the mix-adjusted measure tends to have a slightly higher correlation with each of the regression-based measures than the correlation between those more advanced measures.

Panel B indicates the extent to which each of the measures of house price growth deviate from a proxy of underlying house price movements.[20] Confirming the earlier results in Table 4, changes in the median and seasonally adjusted median are volatile with relatively high RMSEs. In contrast, our mix-adjusted measure and the two regression-based measures provide estimates of underlying house price movements that are comparable in terms of their apparent noise.

It is reassuring that the results from the mix-adjusted measure are similar to those from regression-based measures, suggesting that simple stratification techniques can control for a significant proportion of compositional change. However, it is not especially surprising that our measure is highly correlated with the hedonic measures. The results in Hansen (2006) indicate that the vast majority of the explanatory power in standard hedonic regressions comes from the location of properties, which (in combination with information on average suburb-level price levels) is the variable used for stratification in our methodology.

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[20] We construct a measure of trend growth for each of the mix-adjusted, hedonic and repeat-sales measures (using the moving-average approach outlined in Footnote 4) and then average these three trends to obtain a proxy for underlying growth in house prices for each city.

Table 5: Correlation between Various House Price Measures

	Median (nsa)	Median (sa)	Mix-adjusted	Hedonic	Repeat-sales
Panel A: Correlation coefficients, quarterly changes					
Sydney					
Median (nsa)	1.00				
Median (sa)	0.77	1.00			
Mix-adjusted median	0.52	0.65	1.00		
Hedonic	0.58	0.65	0.97	1.00	
Repeat-sales	0.38	0.57	0.90	0.89	1.00
Melbourne					
Median (nsa)	1.00				
Median (sa)	0.69	1.00			
Mix-adjusted median	0.65	0.71	1.00		
Hedonic	0.66	0.70	0.92	1.00	
Repeat-sales	0.42	0.57	0.76	0.69	1.00
Brisbane					
Median (nsa)	1.00				
Median (sa)	0.95	1.00			
Mix-adjusted median	0.87	0.87	1.00		
Hedonic	0.89	0.90	0.96	1.00	
Repeat-sales	0.77	0.81	0.93	0.93	1.00
Panel B: Deviation from trend (quarterly RMSE)					
Sydney	4.11	2.95	0.97	1.02	0.86
Melbourne	4.48	2.64	1.40	1.25	1.57
Brisbane	1.96	1.69	1.25	1.25	1.03

Notes: Correlation coefficients and RMSEs across the various measures of quarterly price growth were calculated over 1993:Q2–2005:Q3. The data vintage used to calculate the hedonic and repeat-sales measures in Hansen (2006) does not correspond precisely with that used to calculate the mix-adjusted median here. In addition, Hansen uses data from a different source (Real Estate Institute of Victoria) to calculate the repeat-sales measure for Melbourne, so the results across measures are not fully comparable for Melbourne.

5.5 Why Does the Mix-adjusted Measure Perform Well?

The preceding analysis indicates that the mix-adjusted approach overcomes many of the problems associated with unstratified median measures. A major reason for the substantial improvement appears to be the particular method we have used to stratify transactions. By stratifying properties on the basis of the median price for their suburb, we are controlling for much of the compositional change in sales movements between higher- and lower-priced properties. However, other stratification strategies are possible, an obvious alternative being on a broad geographical basis, which is a common strategy internationally. Accordingly, in this section we compare the results of price-based and geographic stratification strategies.

We use unit record data for Sydney to construct two alternative mix-adjusted measures of price changes. Two standard geographical classifications of Sydney are based on statistical local areas (SLA) and statistical subdivisions (SSD), of which there are 49 and 14 groups respectively. We construct measures using both of these geographic groupings. To produce a city-wide measure of price growth, the median house price in each geographic region is weighted by the region's share of sales over the whole sample period. In order to evaluate the relative performance of the geography-based measures of price growth, we calculate the deviation (RMSE) of each measure from the trend growth series used in Panel B of Table 5.

For greater comparability, we also calculate some alternative price-based mix-adjusted measures. Instead of dividing Sydney into 10 price-based groups, we divide it into 14 and 49 groups (the same number of groups as the geographic measures) based on the median price of that suburb over 2000–2004. However, to shed further light on the stratification issue, we implement some additional price-based measures. In particular, instead of forming measures based just on 10, 14 and 49 strata, we assess the robustness of price-based measures using everything from 1 stratum (equivalent to the simple city-wide median) all the way up to 60 strata (each with just 10 or 11 suburbs).

The results are shown in Figure 4.[21] A first point to note is that price changes estimated from the geographic-based stratifications are less noisy than the simple city-wide median. The RMSEs based on the 14 and 49 groups are 1.95 and

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[21] Due to some constraints in the unit record data, the results here differ somewhat from the results in Tables 4 and 5. The measures in this section are constructed using unit record data that are of a different vintage and cover a different time span (March quarter 1996 to June quarter 2005) to most of the data used in the rest of the paper.

1.62 per cent respectively, versus 4.70 per cent for the city-wide median. However, the price-based stratification measures provide a significant additional improvement over the geography-based measures, with RMSEs of 1.15 and 1.14 per cent, respectively, for the measures based on 14 and 49 groups. This provides evidence in support of grouping data on the basis of median suburb prices rather than on a geographic basis, as the former provides a better control for changes in the mix of sales between more and less expensive properties.

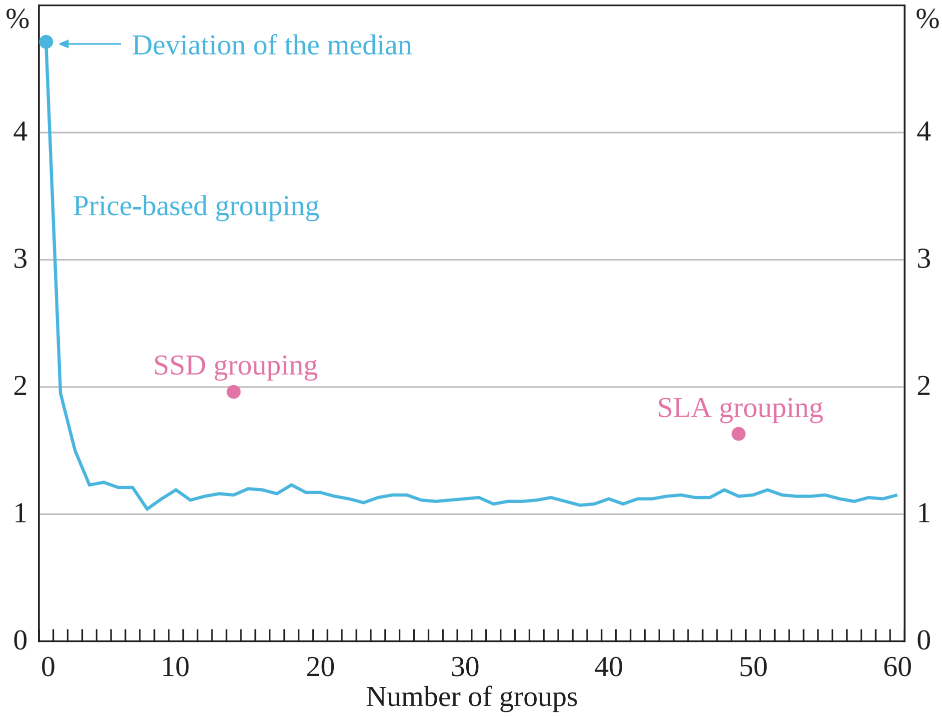
An important additional result in Figure 4 concerns the 'granularity' of stratification in our price-based measures. The line on the graph shows how the deviation from trend (as a RMSE) varies according to the number of strata used to calculate price growth. We see that simply dividing all transactions into two groups of about 330 suburbs produces notable gains over the median measure. There are further significant gains from splitting the sample into four groups, but thereafter the RMSE is fairly constant. This implies that one can get fairly comparable estimates of movements in Sydney house prices by dividing Sydney's 659 suburbs into anything from 4 to 60 groups: this is also confirmed by correlation analysis. Therefore, the results for Sydney that we have shown earlier in the paper are not particularly sensitive to our decision to divide suburbs into 10 groups: indeed there is a wide range of price-based stratification schemes that yield robust results.

We conjecture that the results for other cities are also not especially dependent upon our decision to group suburbs into deciles (or quintiles). We have not aimed to fit the suburbs in each capital city into an 'optimal' number of groups: the choice of deciles was fairly arbitrary on our part, though in cases of smaller sample sizes (houses in Canberra, and apartments in Sydney and Melbourne) we decided to instead work with quintiles to avoid small sample sizes in particular strata, especially in the incomplete real-time samples. For other applications, there will no doubt be benefits to empirically testing the optimal degree of stratification, and smaller sample sizes will presumably warrant a different number of groups, but our preliminary results here suggest that a range of strategies can yield significant benefits over simple medians.[22]

[22] See Hansen *et al* (1953) and Everitt (1980) for more information on the theoretical issues in the optimal grouping of data.

Figure 4: Geographic and Price-based Groupings

Deviation from trend, RMSE



Source: Authors' analysis using data from APM

6. Conclusion

One of the problems inherent in measuring housing price growth is that the sample of dwellings transacted in any period may be far from random and the characteristics of the sample may change from period to period. As a result, simple measures of growth in mean or median housing prices will reflect changes in the composition of dwellings sold as well as pure price changes. In this paper, we have proposed a simple non-regression-based measure of house price growth that addresses the problem of compositional change by stratifying individual transactions into different groups. Our measure differs from those commonly used internationally in that we group small geographic regions (suburbs) according to the long-term average price of dwellings in those regions, rather than simply clustering smaller geographic regions into larger geographic regions. That is, our method of stratification is specifically designed to control for what appears to be the most important form of compositional change, namely changes in the proportion of houses sold in higher- and lower-priced regions in any period.

We find that stratifying sales in this manner produces a mix-adjusted measure of price growth that substantially improves upon standard unstratified median measures. In particular, when compared with a median measure, our mix-adjusted measure of price growth is considerably less volatile, is not subject to seasonality, and performs better in real time with limited data samples. Our results suggest that seasonal adjustment should be considered a 'bare minimum' response to such compositional effects. However, house prices are not truly seasonal: seasonality in median prices arises because of seasonality in the composition of transactions that occur. Our measure improves significantly upon seasonally adjusted medians, because we are also able to account for compositional effects that are non-seasonal in nature. In addition, our mix-adjusted growth rate lines up quite closely with more advanced regression-based measures of price growth. Overall, this indicates that it is possible to develop computationally simple estimates of price growth that control for compositional change.

Given the recent run-up in house prices in many other countries and the macroeconomic effects associated with this, developments in house prices are now of significant interest to policy-makers. Therefore, the methodology outlined in this paper may be applicable for measuring price growth in a number of countries.

Furthermore, the stratification techniques contained in this paper have broader applications than just the measurement of house prices. Many industry bodies, not just in the housing industry, use simple means or medians as a summary measure because they are simple to compute. However, if samples are not random, compositional change may be a major issue. This paper shows that if a sample is stratified appropriately (by the variable that is most related to what is obscuring the underlying movements of interest) substantial benefits can be achieved over a median measure.

Appendix A: Using the Information in Individual Strata – Assessing the Strength of Intra- versus Inter-state Influences

Although the proposed new measure of price changes was designed to look at house prices on an aggregate city-wide level, the price movements in the individual strata may also be of interest in answering questions about the behaviour of house prices in different segments of the market. Accordingly, we briefly consider the extent to which price movements in a particular segment of a capital city market, as proxied by the median price of each decile (quintile), are correlated with price movements of other market segments. Since our strata are defined in terms of average prices for suburbs, they correspond to economic segments (e.g. the 'higher end' and the 'lower end' of the market) rather than regional segments (e.g. the inner or outer suburbs).

The average correlation coefficient between year-ended price changes in strata medians *across* capital cities is 0.52, compared with an average correlation coefficient of 0.79 for strata medians *within* the same capital city. The first of these numbers points to a reasonable amount of co-movement in housing price growth across different cities, suggesting the existence of a national housing cycle. This is not surprising given that state business cycles are highly correlated and the presence of many common national influences.[23] However, within-city correlations tend to be even higher. This suggests the existence of significant regional effects within individual markets.

To more fully examine the relationship of price growth between different market segments, we calculated the correlation coefficients between quarterly changes in median price in the 65 different strata. Using the 2 080 different correlation coefficients, we then estimated a regression to assess what factors are associated with higher correlations between strata. This allows us to test for same-city versus across-city effects in price growth. It also allows us to test if there is any tendency for some degree of segmentation between the markets for houses and apartments and if higher-price strata tend to be more correlated with other higher-price strata,

23 Norman and Walker (2004) find a significant degree of co-movement across state business cycles, with the major source of cyclical fluctuations in state cycles arising from shocks that are common to all states.

and vice versa. To test the latter effect, we define the economic 'distance' between two strata as the absolute magnitude of the difference between the decile rankings of two strata. For example, the distance variable between decile 6 in Sydney and decile 8 in Perth would be 2.[24] If we find that strata which are economically relatively 'close' to each other tend to have higher correlations, this might be evidence for the existence of factors working on a national level that have differential effects on the higher- and lower-end of the nationwide property market.

We obtain the following regression result:

$$corr_{xy} = 0.40 + 0.21 samecity - 0.02 dist_{xy} - 0.10 diffdwelltype \qquad \text{(A1)}$$

$$\quad (0.01)\ (0.01) \qquad (0.00) \qquad (0.01) \qquad \text{Adjusted } R^2 = 0.25$$

where: $corr_{xy}$ refers to the correlation coefficient between median quarterly price movements in strata x and y (where $x \neq y$); *samecity* is a dummy variable which is equal to 1 if x and y are in the same city (and 0 otherwise); $dist_{xy}$ refers to 'economic distance' between two strata, as defined above; and *diffdwelltype* is a dummy variable taking the value of 1 if x and y refer to different types of dwellings. Heteroskedasticity-consistent standard errors are shown in parentheses below the parameter estimates.[25]

The results are as expected. The significant constant term suggests a noticeable co-movement in price growth across different segments of the national market, with its value of 0.40 indicating the average correlation between quarterly price movements in two strata that are in different cities, of the same dwelling type, and in the same economic segments (zero distance). The most important variable for explaining differences in the strength of correlations is whether or not the two

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24 In the case of quintiles, we number quintiles by the midpoint of two corresponding deciles: for example, quintile 1 is considered to be decile 1.5, quintile 2 would be 3.5 and so on.

25 For ease of understanding, we show results using ordinary least squares (OLS). OLS may not be the most appropriate estimator for this equation, given that the dependent variable is bounded by 1 and –1. However, similar results hold when we run the regression using the Fisher z transformation which can be used to transform the correlation coefficients into normally distributed variables. An additional economic problem may result because as the 2 080 observations come from only 65 data series, this may bias the standard errors downwards.

strata are in the same city, with this variable explaining around half of the fit of Equation (A1).

The results also show that price movements are less correlated the greater the economic distance between the two strata. This provides evidence of socio-economic factors on a national level that have different impacts on price growth in higher- and lower-priced suburbs. In addition, the results show a higher correlation in price movements within dwelling types as opposed to across dwelling types, suggesting that there may be factors which tend to affect nationwide house prices more than apartment prices, or vice versa. This could be additional evidence of some type of common socio-economic effects, as household type tends to differ across dwelling types.[26]

Overall, the results suggest that there is a reasonably high degree of correlation in movements in dwelling prices across segments of the Australian housing market, especially in cases where there is a higher degree of similarity between two market segments in terms of location, dwelling type and 'economic background'.

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[26] In other work, we have also used Granger causality tests to look for the existence of any systematic lead-lag relationship between the higher- and lower-priced segments of the market. The results differ across cities, with some cities suggesting Granger causality from the high end to the low end, other cities suggesting the opposite, and others suggesting either no causality or causality running in both directions. Overall, it appears there is no systematic lead-lag relationship; rather, there is a high degree of contemporaneous correlation between price movements in the higher- and lower-priced segments in each city.

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