Housing Prices in Australia 1901-2007:
Macro-economic and other influences

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JEL Code: G12; N97; R21; R31; R38

Key words: Australia, house prices, dwelling rents, price and rent controls, adult population, housing stocks, interest rates, housing cycles.

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Acknowledgements:

The author wishes to thank....
1 Introduction

House prices have risen substantially in real terms since the 1970s in most countries and have also tended to rise significantly relative to incomes. In Australia's case median capital city house prices having risen on average 3% per annum in real terms while the ratio of prices to incomes has risen from about one and a half times income in 1970 to just over three in 2007. The rises have not been even with some clear cycles evident and of interest but the major puzzle is explaining what factors have driven this substantial overall rise in prices or whether or not it is sustainable. If the period since the mid 1980s is observed, a substantial decline in interest rates has occurred over roughly the same period and hence offers a potential explanation: a study by Otto (2007) found interest rates to be the most significant factor explaining variation in house price growth in Australia's capital cities in the period from 1986-2005. However, most attention seems to be focused on the role of income with the rise in the price to income ratio argued to be an indicator of probable overvaluation of house prices. For example, The Economist (2002, 2003) used historical mean measures of the price to income ratio to assert that a housing bubble existed. On a simple comparison with the average ratio over the period 1975-2002, prices in Australia and the UK in 2002 were asserted to be 31% and 34% overvalued, while prices in the US were 15% over-valued.\footnote{These estimates are from The Economist report of 31 May, 2003. That report also looked at price rent ratios but, in the absence of adequate series for more than a few countries, resorted to price-income ratios as second best. The report also presented crude dwelling price-yield ratios based on ratios of price indexes and rent indexes for the period 1975-2002 and showed that the US, Australian and UK markets were 16%, 38% and 42% above average for period 1975-2002.}

This paper utilizes an annual series spanning 1880-2007 on house prices for Australia (Stapledon, 2007a) to bring some longer term perspectives on this debate. This longer history of prices indicates that in the 70 odd year period from 1880 till the mid 1950s, there was negligible real growth in house prices (Figure 1) and little movement in the ratio of price to income (Figure 2). The price picture is muddied by controls imposed during WW2 which spanned 1943-1949 and fixed house prices at their 1942 levels. As this was a period punctuated by high war-time inflation, the impact on real house prices was quite pronounced. The other measure of the value of housing is rents and a series of real gross rental income per dwelling (Stapledon 2007a) also shows negligible growth in this series in the period 1901-1939 (Figure 3). War-time controls then also distorted the picture for rents but more so than for house prices: for rents the period of controls started in 1939 and was subsequently only gradually lifted in the 1950s. While this period in the mid 20th century is muddied by these controls, observation of Figures 1-3 makes an acceleration in the pace of growth in both prices and rents from about the 1950s pretty clear. From negligible real growth to the mid-1950s, house prices have shown growth of an average 2.5% per annum in real terms, lifting the ratio of price to income from closer to one to its current level of over three. Similarly, while not matching that growth in prices, rents have shown average growth of just under 2% in real terms.

If the demand variables of growth in income and population and interest rates, the staples of most house price models, are observed over this longer time period, it is not evident that there has been a shift in direction which would explain the house price story. Increasingly, reflecting the difficulty in explaining events solely in terms of demand factors,
the housing literature has been focusing on supply side variables. A number of studies of the
US market (e.g. Malpezzi (1996), Glaeser, Gyourko and Saks (2003)) have identified supply
constraints and their interaction with demand variables, particularly income, as the likely
explanation for the different experience of the California market to the general US experience.
Given the similarity of the Australian market to that of California, both in terms of geography
(climate, concentration on the coast) and in terms of propensity to regulate and constrain
supply, this points to the need to account for supply side factors. An objective of this paper is
to present and test a model of the growth of house prices on demand and supply variables, to
shed light on the relative importance of demand factors and the probable role of supply
factors, including the interaction with income, in explaining the house price story.

In addressing this question, the choice of a model for the growth rate of house prices
rather than a model for the level of house prices in part reflects the observation from Figure 2
that there appears to be no fixed relationship between house prices and income. Those
observations are confirmed by tests for cointegration which together provide some further
evidence that challenge the ‘majority’ view that there is a cointegrating relationship between
prices and income: as a cointegrating relationship is a pre-condition for a model in terms of
price levels, that explains the choice of a model in terms of growth rates. In arguing for the
‘right’ to assume a cointegrating relationship between prices and income, some contend a
cointegrating relationship between rents and income, including on theoretical grounds (Holly,
Pesaran and Yamagata, 2007). On that score, observation of the ratio of rents to income
(Figure 2) and tests for cointegration presented in this paper also challenge that contention on
empirical grounds. It is also not evident that there is anything in urban economic theory which
points to any fixed relationship between rents and income.

Interestingly, the broad trend for house prices in Australia is very similar to that
observed by Eichholtz (1997) for Amsterdam, while estimates from various sources for the US
suggest a broadly similar long-term picture for that country (Stapledon, 2008c), so there will
be lessons beyond Australia from understanding what has driven the Australian experience.

The remainder of the paper proceeds as follows.

2 Macro model

One common starting point for a price model (Abelson, 1994) is take the demand for
houses as a function of price and a group of variables influencing demand and supply as a
function of price and a group of other variables influencing supply. The equilibrium identity
can then be used to give price as an inverted function of those demand and supply variables:

\[ D = f(P, X); S = f(P, Y) \]

\[ S = D \]

\[ P = f(X, Y) \]

\[ [1] \]

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2 Most argue for the relationship but with little theoretical argument as such; eg Meen (2002)
3 In Stapledon (2007b) evidence is presented for the US and Eichholtz (1997) shows similar timing of
cycles for Amsterdam.
Urban economic theory then provides a good framework for assessing the supply and demand candidates which influence urban land and house prices. This theory is typically presented in terms of the rental value of urban land which is the predominant driver of house prices. Capozza and Helseley (1989) have the rental value \( R_f \) as the sum of three elements: the rental value of agricultural land at the fringe, \( A \); the capital cost of converting rural land to urban use, \( kC \), which would be a function of construction costs \( (cc) \) and the discount rate \( (k) \), and the location rent, \( LR \).

\[
R_f = A + kC + LR
\]  
[2]

Capozza and Helseley defined the location rent as a function of distance from the urban centre to the fringe which would in turn be a positive function of the number of households \( (\text{pop}) \), while the value attached to the location rent would be positively related to income \( (y) \), wealth \( (w) \) and transport costs \( (tc) \). The stock of housing \( (\text{stock}) \) is a measure of supply and would be expected to be negatively related to price. And to those variables, courtesy of Rose (1989a, 1989b), Manning (1989) and Malpezzi (1996), can be added measures for natural and artificial or regulatory supply constraints \( (\text{nat}, \text{reg}) \) which would shift out the location rent gradient.

Making the simplifying assumption that landowners have perfect foresight, Capozza and Helseley (1989) had the price of urban land as a function of the discounted present value of the rent and the discounted present value of expected future rent increases. Their model assumed that it was expectations for growth in the location rent component of total rent which would drive expected future growth in rent which would be related to expectations for growth in income, wealth, population and transport costs. However, bearing in mind that construction costs have tended to rise faster than general prices (i.e. rise in real terms) and that the rental value of agricultural land can also rise or fall, there is scope for all the elements of rental value to influence future growth in the rental value of urban houses. Thus the additional simplifying assumption I would make is that expectations are expressed in terms of aggregate rent. Using asset pricing formulation the price of houses can be written as:

\[
P_f = \frac{R_n}{k - rg}
\]  
[3]

where \( rg \) is expected rate of growth in real rental income. If the rental income is expressed in net terms, that is expenses are ignored, the denominator terms are equivalent to the standard user cost formulation of real interest rates \( (\text{rir}) \) less expectations for real house price growth \( (\text{EP}_f) \). In equilibrium expected real house price growth and expected real rental income growth should equate. Now, taking equations [2] and [3] and the variables which determine the elements of those equations, this says that a reduced form linear equation for house prices could be written in terms of the following variables:

\[
P_f = \beta_1 \text{pop} - \beta_2 \text{stock} + \beta_3 y + \beta_4 w + \beta_5 tc + \beta_6 \text{nat} + \beta_7 \text{reg} + \beta_8 cc - \beta_9 \text{rir} + \beta_{10} \text{EP}_f
\]  
[4]

\[\quad 4\] See for example Mills and Hamilton (1989) and McDonald (1997)

\[\quad 5\] Capozza and Helseley did not specifically refer to wealth but as wealth is a determinant of expected future income (Muth and Goodman, 1989), it is included in most housing models.

\[\quad 6\] Sharpe, Alexander and Bailey (1999)

\[\quad 7\] Equilibrium being with no change in the price-to-rent ratio.
where pop is adult population/households; stock is the supply of dwellings; \( y \) is real income per adult/household; \( w \) is a measure of wealth; tc is transport costs; nat is natural constraints; reg is artificial constraints; cc is real dwelling construction costs; rir is real interest rates, and \( \Delta P_t \) is expectations for house price appreciation.

3 Actual empirical model

If the object is a reduced form linear regression for the rate of growth in house prices, the natural constraint is fixed and can be dropped. This linear regression would be expressed in terms of growth in the variables, and it can be written as follows.

\[
\Delta P_t = \beta_1 \Delta pop + \beta_2 \Delta stock + \beta_3 \Delta y + \beta_4 \Delta w + \beta_5 \Delta tc + \beta_6 \Delta reg + \beta_7 \Delta acc + \beta_8 \Delta rir + \beta_9 \Delta \Delta P_t [5]
\]

The combination of variables used in the empirical model(s) tested will vary from this theoretical model in some respects. Firstly, not all the variables in this model are available: there are no long term series of transport costs or regulatory controls for Australia. Secondly, a number of dummy variables have been introduced to account for several factors, giving the following version of equation [5]:

\[
\Delta P_t = \beta_1 \Delta C + \beta_2 \Delta Y + \beta_3 \Delta \omega + \beta_4 \Delta pop + \beta_5 \Delta stock + \beta_6 \Delta acc + \beta_7 \Delta rir + \beta_8 \Delta \pi + \beta_9 \Delta \Delta P_t + \beta_{10} D4349* \pi + \beta_{11} D1950 + \beta_{12} D5507 + \beta_{13} D8607 [6]
\]

where \( C \) denotes the constant term; \( D \) denotes dummy variables; \( \omega \) is nominal interest rate measure, and \( \pi \) is the consumer price inflation measure. The latter two are the real interest rate split into its two component parts. In terms of the dummy variables, \( D4349 \) is dummy variable for price controls in the years 1943-1949 which interacts with the rate of inflation for those years; \( D1950 \) is dummy variable for the lifting of price controls; \( D5507 \) is the time dummy for structural change in the direction of house prices after 1955 which could incorporate the impact of some of the missing variables such as transport costs and regulatory costs and, given the shift in expectations for house price growth after 1950 could also capture some of that effect; \( D8607 \) is a time dummy for financial deregulation. As is usual practice with these models, most of the variables are presented in log form to show constant elasticities, the exceptions being the interest rate and dummy variables for which the values show no trend.

4 Data

The median capital city house price series is from an annual price series constructed by the author for the period 1880-1970 which has been spliced with post-1970 series to give a series for the period 1880-2007 (Stapledon, 2007, 2008a). The series is adjusted for changes in the location and quality of median houses over this time span and is measured in real terms using the measure of consumer inflation. There are a number of issues with house price series

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8 It is noted that one of the benefits of using a reduced form equation are that issues of identification are avoided.
which mean that, while the medium and long-term trends are a good guide, caution is required in relying too precisely on individual estimates of annual changes.

The sources of the other data series are in the Appendix but I would note the following. For the demographic variable I have used a measure of the adult population[20+ years]. This measure owes its origins to Mankiw and Weil (1989) and McFadden (1994). They constructed measures which were the sum of the age-specific housing demand of the population. Because their analysis showed children were low users of housing, the demographic demand series so constructed turned out to be, as Mankiw and Weil themselves observed and Swann (1995) later confirmed, closely aligned with a simple measure of adult population. A number of studies in Australia (Abelson, 1994; Bourassa and Hendershot, 1995) have found total population not to be a significant influence on changes in house prices but that immigration had a measurable influence. Those studies indirectly support use of adult population because, by dint of migrants being skewed to adults, adult population growth will be more sensitive to immigration than total population. In theory, a measure of households is a better demographic demand measure. However, what would be needed is a measure of population of households, not just actual households renting or owning a house, but also including potential households, including those presently sharing, but seeking a separate dwelling if supply allows. Households are typically defined in terms of groups of persons per occupied dwelling, so in practice this measure more approximates to a measure of supply rather than demand: it will be highly correlated with the stock measure, which is an estimate of the stock of occupied and unoccupied houses, the latter being a relatively small component. The stocks series and the adult population series still show some correlation, with a coefficient of 0.45 (refer Table xx).

For income, I use real GDP per adult, for consistency with the demographic variable. This GDP measure is deflated by the consumer price measure rather than the GDP deflator because of the volatility in, and unreliability of the GDP deflator in the period prior to 1947/48 when the ABS started to construct its official measures. For the period since 1960 there are other measures of income which can be used, but GDP is the only consistent series spanning the period 1901-2006 and the post-1960 measure are reasonably highly correlated with GDP. The income, population and stock variables are aggregate measures for Australia, not the capital cities, but there is likely to have been a high correlation between measures for Australia and the capital cities, so I take them as reasonable proxies.

For interest rates I use estimates of the long-term bond rate. This is the only series which spans this period. While mortgage rates in Australia have historically been variable rate, a fixed term series has the advantage that it incorporates expectations about the future course of variable rates. Being a government instrument the bond yield is a risk free rate so an implicit assumption is that the risk premium attached to housing is roughly constant over the time horizon. The dummy variable for 1955-2006 is to account for the shift in direction in house prices and the price-to-income ratio after 1955 and could reflect a mix of demand and supply variables not specified in the regression - the specific candidates which might be accounting for this dummy variable are discussed below.

5 The Relationship between Price and Income

The use of price to income ratios as per The Economist above has also been cited by central banks, including the Reserve Bank of Australia (2002), and the OECD (2005).

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Although those bodies still cite them as an indicator of potential under-/over-valuation, they are generally more circumspect in the conclusions they draw from observing the history of the ratio. For example, the OECD (2005) stated that "if this ratio rises above its long-term average, it could be an indication that prices were over-valued." However, the OECD then argues that income by itself "is not a sufficient metric to evaluate housing affordability" or presumably under-/over-valuation of housing. More specifically, for eighteen countries for the periods 1970-2000 and 1970-2004, the OECD conducted ADF unit root tests of the price to income ratio. In only four instances (out of a possible 36) was there any evidence of a stable long term relationship between income and prices. The results are included in Table 1 below.

The use of this ratio also has support in empirical studies in the economic literature. The notion of some mean relationship between prices and income is central to most equilibrium models. That is, house prices and incomes are thought to be linked by a stable long-run relationship; they may drift apart temporarily but their tendency is to return to their long run equilibrium. This idea is formalized in the housing literature by positing a cointegrating relationship between house prices and fundamentals such as income and then estimating an error correction model. Capozza et al (2002) and Holly, Pesaran and Yamagata (2007) for the US, Meen (2002) for the UK, and Abelson et al (2005) for Australia are recent examples. Gallin (2006) has challenged this assumption and finds that the evidence of cointegration is weak, while Gurkaynak (2005) and Stevens (2004) have questioned the value of these cointegration models.

To supplement the observations from Figure xx and Figure xx made earlier, I have conducted tests for stationarity (refer Table 1). Over the whole period the tests for stationarity do not show evidence of a long term stable relationship between income and prices. For the period 1901-1955, when the ratio broadly moved sideways, the tests are much less convincing in rejecting a cointegrating relationship. For the shorter period 1901-1940, which takes out the period of war and war-time/post-war price controls, the evidence for a cointegrating relationship weakens and this might reflect the impact of the 1930s rise giving the ratio somewhat of a slight upward trend. In the period 1956-2007, the evidence against a stable relationship between prices and income is fairly compelling. While these tests may lack power in distinguishing stationary from non-stationary behaviour, the test statistics are well above critical levels and that result is consistent with observation of the data.

The picture of the gross rent to income ratio over the period 1901-2007 is distorted by the rent controls which existed in full and partial form from 1939 to the mid 1960s and also perhaps by the impact of the Great Depression. In the period 1901-1929, the ratio appears to be relatively stable with a mean ratio of 0.065. However, the ratio had been on the rise in good economic times of the 1920s, with ratio rising from 0.061 in 1920 to 0.083 in 1929. As with the house price ratios, the decline in nominal GDP in the Great Depression years of the early 1930s was greater than the decline in rents and this pushed the gross rent to income ratio up. In the five year period 1930-1934, the ratio averaged 0.093. Over the period of rent controls the ratio declined from 0.090 in 1939 to a low of 0.036 in 1951. As rent controls were gradually lifted, the ratio climbed back to 0.055 in the mid 1960s. In the period 1965-2007, the

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10 OECD (2005), pp 198.
11 Op cit, pp 199.
12 It is noted that all three of these critical evaluations are from central banks which have a strong interest in understanding whether housing markets are under/over-valued. Gallin and Gurkaynak are from the US Federal Reserve Board. Stevens was Deputy Governor of the Reserve Bank of Australia in 2004, and Governor from 2006.
ratio averaged 0.084. However, the ratio was on an upward trajectory until the 1990s. From 0.055 in 1965, with some cyclical moves along the way, the ratio climbed steadily to an historical peak of 0.102 in 1992. Then from 1992-2007, the ratio could be said to have edged lower to a ratio of 0.095 in 2007.

The upshot is that it is very difficult to see any evidence of a stable relationship between gross rents and income at any time in the period 1901-2005 apart from perhaps the early period 1901-1929. I have conducted tests for stationarity (refer Table 3.2). Over the whole period and over the period 1966-2007 the tests for stationarity confirm that observation of no long term stable relationship between rents and incomes. The results also discount a stable relationship in the period 1901-1929.

Nonetheless, allowing for the distortions caused by rent controls, it can be reasonably argued that the broad trends in rent-to-income ratios are consistent with the broad trends in the house price to income ratio. That is, from the mid 1950s to the mid 1990s the ratios were broadly on an upward trend, with the rent to income ratio paralleling the upward trend in the house price to income ratio. In the 1990s, the rent and price ratios have diverged, with the rent ratio steady and the price-to-income ratio rising sharply.

Theory and the ratios

The empirical evidence against a stable relationship between prices/rents and income seems compelling but is there any theory to support a stable relationship? Holly, Pesaran and Yamagata (2007) argue that there is a theoretical basis for positing a mean relationship between prices and income. They construct a theoretical model to show this but the critical assumption in their model is that there is a stationary relationship between rental value of housing and income or equivalently that the fraction of income allocated to rental expenses is stationary. However, no theoretical reason is presented for making this fairly crucial assumption.

Gallin (2003) argues that theoretical models do not show house prices must be cointegrated but rather show the reasons why such a cointegrating need not exist. For example, “the price elasticity of supply may not be stable over time because of changes in regulatory conditions or the price elasticity of demand may not be stable because changing demographics.” To expand on Gallin’s point, urban economic theory is agnostic about whether there is a fixed or variable positive relationship between income and rent/price. However, it does allow for the possibility that, as incomes change, households might choose to spend a rising (or falling) share of their income on the consumption of housing. The key here is the time cost of travel and location premiums (for say beach locations). The expectation would be that as income rises, the value that households place on travel time and preferred locations might rise faster than income. Looked at from another perspective, consumption of goods and services can be notionally divided into two parts: “basic” and “luxury” goods. As real incomes rise, a lesser share is spent on the basics, whether it is food, clothing, durable goods or “basic housing”. However, that gives households more scope to spend on luxuries. So, we observe a rising share being spent on eating out and travel and other leisure activities. In the case of housing, we observe the shift to “luxury housing”: a shift to much larger and higher quality dwellings and the preparedness to pay larger premiums for preferred lifestyle locations e.g. inner city locations and, in the case of coastal cities, beach-side locations. This can also be characterised in terms of demand and supply elasticities. For the preferred locations, the income elasticity of demand will be higher and because of natural constraints, supply is more inelastic, so that increases in income translate into higher prices. Gyourko, Mayer and Sinai (2006) have linked the ever-widening differences in house prices in US cities to a parallel
widenings in differences in income. They refer to the cities with high prices as the “superstar cities”. High income earners are expected to value location premiums more highly so relatively faster growth in incomes could be expected to translate into a potentially steeper rate of growth in prices.

The upshot of this is that it would not be unreasonable to expect to see a rising share of income spent on housing, particularly in coastal cities and particularly those “superstar cities” that might be attracting high income industries. As Australian capital city urban areas are, with the exception of Canberra, located on the coast, there might be an a priori expectation for a long term rise in the ratios of price/rent to income. And, as Sydney probably qualifies as a “superstar city”, there might also be an expectation that there is a higher price to income ratio in Sydney.

6 Results of Linear Regression of Macro Model

A number of variants of the linear regression have been tested and the results for a number of key ones are shown in Table 2 and Table 3. The first point to note is that the variables for price controls (dummy 1943-1949 interacting with the inflation rate) and the variable for the lifting of price controls (dummy 1950) are significant in both statistical and economic terms.

The more interesting point is the performance of the dummy variables for structural change 1955-2007 (time) and financial deregulation 1986-2007 (dereg). By themselves, that is in the absence of the other and not interacting with any of the exogenous variables, both are significant in both statistical and economic terms. Looking at the results in Table 2, the adjusted R² results for the regression without either of these dummies (Column 1) explain about 63% of changes in house prices. Addition of these two dummies has the regression explaining 66% of the change in house prices (Column 4). The time dummy performs marginally better than the dereg dummy in that its statistical significance is higher and its impact on lifting the adjusted R² is larger (Column 2 vs. 3). However, the two are jointly significant and, as a priori we might expect deregulation to be an influence on house prices, the version with both (Column 4 in Table 2) is the preferred regression of those with no interaction with the exogenous variables. In terms of economic significance, the economic factors represented by the two dummies appear to explain a significant portion of growth in houses prices in the period 1955-2007. The coefficients say that, leaving aside the effects of income, demographics and stocks in this period, these other economic factors would have accounted for just over 1ppt per annum of house price growth in the period 1955-1986 and almost 2ppt per annum of the price growth in the period 1986-2007.

As will be observed in discussing the other exogenous variables, these two dummies perform better, that is explain more of house price change, when they interact with income and other variables. Specifically, the version of the regression in which the time dummy (1955-2007) interacts with changes in income, equities, population, stock and costs, and the deregulation dummy interacts with changes in interest rates and inflation, appears to perform best (Column 4 in table 3).

Turning to the exogenous variables, with the exception of lagged house price growth and interest rates, each has the a priori effect on prices that we might expect. That is changes in the rate of growth of income, equity prices, population and construction costs each have positive effects and a change in the growth of stocks has a negative effect.
Lagged house price growth is often used as a proxy measure for price expectations, and most studies find it has a positive effect on house price growth, e.g. Otto (2007). In this case, as illustrated in Column 5 in Table 3, it was found to have a negative effect, albeit small and statistically insignificant. It also tended to subtract from the explanation of price moments (i.e. lower adjusted R²) and for those reasons this variable has been dropped from the equation. Given the shift in the rate of growth in house prices between the first and second halves of the 20th century, any shift in expectations is likely to be largely captured by the dummy variable for structural change. One possible explanation for the different effect with these long-run regressions is that the data is annual rather than quarterly. Annual data will tend to capture a significant amount of the information contained in lagged periods in quarterly time series.

The negative relationship reflects the mean-reverting characteristics of growth rates: high growth rates likely to be followed by lower growth rates.

The most significant variable in most studies is the income variable and the interesting point here is the interaction with the time dummy for the period 1955-2007. By itself the income variable is statistically significant and shows the positive sign we expect but the coefficient of 0.4 says that a one percentage point lift in the rate of growth of income will lead to a 0.4 percentage point lift in the rate of growth in house prices, that is the income elasticity is significantly less than one. When interacted with the structural dummy for 1955-2007, the coefficient for the period before 1955 drops below 0.2, but for the period after 1955 the aggregate coefficient for income rises to 1.1 making it much more economically more significant in this later period: it should also be noted that the combination is jointly statistically significant. When the structural dummy and income interact, the model also explains more of house price changes: adjusted R² rises from about 66% to 70%. What these results in combination appear to be saying is that if the dummy reflects changes in supply side factors, its interaction with income is important.

The importance of the time variable can also be seen with the equity variable. By itself, the coefficient for equity prices of 0.05 says that a one percentage point lift in the rate of growth of equity prices will lead to a 0.05 percentage point lift in the rate of growth in house prices, which is not economically significant and in addition the T-statistic suggests that it is not statistically significant. However, when it interacts with the time variable, it becomes statistically significant but, its economic significance is a mixed story. Changes in equity prices can work one of two ways – declines in share prices can mean less capacity to invest in housing which makes it a negative; alternately, in different circumstances not necessarily captured by the other exogenous variables, a decline in share prices might induce investors to shift their preference to housing. Thus it might be ambiguous which way changes in equity prices impinge on house prices. What interaction with the dummy for 1955-2007 indicates is that it had a much more significant positive effect on house prices in the period prior to 1955 with the coefficient being 0.2. For the period after 1995, equity prices have a slightly negative (almost insignificant) effect in the period after 1955. This will reflect the fact that in several periods post-1955, eg 1988-1989 and 2002-2003, falls in the stock market were associated with a rise in the housing market as investors arguably reacted to falls in equity markets and switched their asset preference from equities to property. By contrast, the 1930s depression saw both equity and property prices fall in tandem.

The adult population variable shows a consistently positive coefficient which is the effect we would expect. The magnitude of the coefficient implies a significant impact on house prices: the coefficients say that a one percentage point lift in the rate of growth of adult population will lead to a 1.5 percentage point lift in the rate of growth in house prices, that is, in contrast with income, the population elasticity is significantly greater than one. It also
suggests that, given the mean growth rate of the adult population was 1.9% per annum in the period 1901-2007, that it contributed about 3ppt to the mean 2% per annum real growth in house prices. Several cautions there. Firstly, the statistical significance is not high which means that result should be treated with caution. Secondly, over the long-term that is going to be offset by the response of stock variable. The change in the stock of houses shows a negative coefficient which is the effect we would expect although, as with the population variable, the low statistical significance is not high. The magnitude of the coefficient is -1.0: the supply elasticity is about one. While the elasticity is lower in magnitude than the population elasticity, a partial offset is that the mean growth rate of the stock of houses was higher at 2.3% per annum in the period 1901-2007. That is, the growth of stocks subtracted 2.3ppt to the mean 2% per annum real growth in house prices. Netting population and stocks together, the net contribution of the increase in the size of the market was to add 0.6ppt per annum to the growth in prices.

When population and stock variables interacts with the supply dummy, the picture changes in economic effect although statistical significance is still low. For the period 1901-1955, the (coefficients) elasticities for both are lower, and the net effect is to subtract from, not add to, the growth of real house prices. By contrast, in the period post-1955, the elasticities are larger and the net effect is to add 1.0ppt per annum to the growth in house prices. While the magnitudes need to be taken with caution, the contrast between the two periods for population and stocks is consistent with the increase in income elasticity between the two periods.

Construction cost exhibit the expected positive effect on house prices but the effect is not significant in statistical or economic terms. With no interaction, the coefficient say that a one percentage point lift in the rate of growth of costs will lead to a 0.04 percentage point lift in the rate of growth in house prices. With the interaction with the dummy for 1955-2007, the coefficients (0.06 for 1901-1955 and 0.19 for 1955-2007) are larger but still relatively insignificant in explaining house prices. The puzzle is particularly so for the period 1901-2005, a period in which the structure was the major component of the price of a house, so that the replacement cost of the structure would be expected to be a major influence on house prices. It is less of a puzzle in the period 1955-2007 when coefficient is larger and the land (structure) component is significantly larger (smaller) share of the price of houses. Part of the answer may be that growth in costs is correlated with other variables which capture the effect: there is some weak correlation with growth in income. Another possible explanation for the period 1901-1955 might be that it reflects the poor quality of the construction cost series.

Changes in interest rates and change in inflation are the two variables which are the components of changes in real interest rates. What the results indicate is that changes in nominal interest rates appear to show a positive correlation, while change in inflation has a negative relationship. Looking at the results with no interaction, the coefficient says that a one percent rise in interest rates would be associated with the growth rate in house prices being 0.3% per annum higher. For inflation, the coefficient says that a one percent rise in the inflation rate would be associated with the growth rate in house prices being 0.1% per annum lower. This implies a positive relationship between house prices and real interest rates. These two variables interact marginally better with the financial deregulation dummy: the adjusted $R^2$ is slightly higher vis-à-vis when the time dummy is used. With this interaction, the interest rate and change in inflation coefficients remains the same for the period before 1986 but for the period after 1986 the coefficient becomes zero (a neutral effect) while change in the inflation rate has a bigger effect: a one percent rise in the inflation rate would be associated with the growth rate in house prices being 1.7% per annum lower.
Causation is an issue with interest rates – a priori we expect a rise in interest rates to cause house prices to fall. However, the two variables are not exogenous. Interest rates can be rising/falling because house prices are rising/falling: for example, rises in house prices will be associated with periods of strong economic growth which will tend to lead to higher interest rates which means that empirically the relationship can go both ways. The difficulties with the interest rate variable and the finding that it is not statistically significant is consistent with the results of Abelson (1994) and Bourassa and Hendershott (1995) for Australian capital cities covering the periods 1965-1989 and 1978-1993 respectively, although Otto (2006) found a strong, negative relationship for the later period 1986-2006. The period 1986-2006 incorporates a period of significant falls in interest rates which were at historically high levels in the mid 1980s so the strong result found by Otto is perhaps not unsurprising.

In the case of changes in the inflation rate, the small negative for the period prior to 1986 might reflect lags in the housing market responding to a change in the inflation rate. For the period after 1986, this has seen a marked fall in the inflation rate from 7% in 1986 to 2.5% in 2007 which in turn has allowed a sharp fall in nominal interest rates. Now, while a priori it is expected that changes in the inflation rate would expect to produce subsequent changes in interest rates, that connection will be a weak one in a regulated market in which the government controls interest rates. However, in a deregulated environment and in the period from the mid 1990s, a decline in the rate of inflation (the news of which comes out with a lag) has been associated with expectations that the central bank would could cut nominal interest rates. Hence, there is perhaps some rationale to falls in inflation being associated with higher growth in houses prices.

7 Conclusion

To come.

Appendix of Data Sources

To come.
List of References


### Table 1  Correlation Matrix for Data Series

<table>
<thead>
<tr>
<th></th>
<th>( \Delta \log H_p )</th>
<th>( \Delta \log Y )</th>
<th>( \Delta \log \text{equ} )</th>
<th>( \Delta \log \text{pop} )</th>
<th>( \Delta \log \text{stock} )</th>
<th>( \Delta \log \text{cc} )</th>
<th>( \Delta \text{ir} )</th>
<th>( \Delta \log \text{infl} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta \log H_p )</td>
<td>1</td>
<td>0.280628</td>
<td>0.215641</td>
<td>0.171733</td>
<td>0.020609</td>
<td>0.082399</td>
<td>0.079368</td>
<td>-0.1053</td>
</tr>
<tr>
<td>( \Delta \log Y )</td>
<td>0.280628</td>
<td>1</td>
<td>0.203785</td>
<td>0.004779</td>
<td>0.08107</td>
<td>0.198895</td>
<td>0.09547</td>
<td>-0.10607</td>
</tr>
<tr>
<td>( \Delta \log \text{equ} )</td>
<td>0.215641</td>
<td>0.203785</td>
<td>1</td>
<td>-0.02028</td>
<td>-0.14968</td>
<td>-0.07608</td>
<td>-0.07574</td>
<td>-0.05912</td>
</tr>
<tr>
<td>( \Delta \log \text{pop} )</td>
<td>0.171733</td>
<td>0.004779</td>
<td>-0.02028</td>
<td>1</td>
<td>0.482492</td>
<td>0.071551</td>
<td>0.059562</td>
<td>0.110664</td>
</tr>
<tr>
<td>( \Delta \log \text{stock} )</td>
<td>0.020609</td>
<td>0.08107</td>
<td>-0.14968</td>
<td>0.482492</td>
<td>1</td>
<td>0.020219</td>
<td>0.106065</td>
<td>0.00106</td>
</tr>
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<td>( \Delta \log \text{cc} )</td>
<td>0.082399</td>
<td>0.198895</td>
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<td>0.071551</td>
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<td>0.102348</td>
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<tr>
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<td>-0.10607</td>
<td>-0.05912</td>
<td>0.110664</td>
<td>0.00106</td>
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<td>-0.1505</td>
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</table>

### Table 2  Stationarity test for price and rent to income ratios

<table>
<thead>
<tr>
<th>Price-to-income ratio</th>
<th>Tests</th>
<th>ADF critical values</th>
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<td></td>
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<td>1%</td>
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<tr>
<td><strong>United States (3)</strong></td>
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<tr>
<td>1970Q1-2004Q4</td>
<td>-1.15</td>
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<tr>
<td>1970Q1-2000Q4</td>
<td>-0.98</td>
<td>na</td>
</tr>
<tr>
<td><strong>Australia (3)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1970Q1-2004Q4</td>
<td>-1.47</td>
<td>na</td>
</tr>
<tr>
<td>1970Q1-2000Q4</td>
<td>-1.76</td>
<td>na</td>
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<tr>
<td><strong>Australia</strong></td>
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<td></td>
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<tr>
<td>1901-2007</td>
<td>-1.24</td>
<td>1.34</td>
</tr>
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<td>1901-1940</td>
<td>-2.31</td>
<td>-2.29</td>
</tr>
<tr>
<td>1956-2007</td>
<td>-1.03</td>
<td>1.26</td>
</tr>
<tr>
<td><strong>Australia: Rent-to-income ratio</strong></td>
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<td>1%*</td>
</tr>
<tr>
<td>1901-2007</td>
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<td>-1.55</td>
</tr>
<tr>
<td>1901-1929</td>
<td>1.33</td>
<td>0.53</td>
</tr>
<tr>
<td>1966-2007</td>
<td>0.24</td>
<td>0.19</td>
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</tbody>
</table>

Notes on Table:

1. Augmented Dickey-Fuller test. The lag structures for the ADF equations are chosen using the Schwarz Information criterion. The critical values are from MacKinnon (1996).
2. Phillips-Perron test. The bandwidth for the PP equations is chosen by Newey-West criterion. The critical values are also from MacKinnon (1996). Note: Test equations for both ADF and PP tests included both constant and trend. Without trend, results even more convincing in rejecting the hypothesis that ratios had a unit root.
3. Source: OECD (2005), Appendix, Table III.8
Table 3 Regression of determinants of changes in house prices 1901-2007

<table>
<thead>
<tr>
<th>Dependent variable is change in real house prices (Δ Log Ph)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<td>Coeff.</td>
<td>t-stat</td>
<td>Coeff.</td>
<td>t-stat</td>
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<td>ΔC</td>
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<td>0.59</td>
<td>-</td>
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<td>-0.43</td>
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<td>Δ Log Ph(-1)</td>
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<td>3.63***</td>
<td>0.40</td>
<td>3.35***</td>
<td>0.43</td>
</tr>
<tr>
<td>Δ Log Y</td>
<td>0.06</td>
<td>1.55</td>
<td>0.06</td>
<td>1.60</td>
<td>0.05</td>
</tr>
<tr>
<td>Δ Log equ</td>
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<td>0.61</td>
<td>1.54</td>
<td>1.22</td>
<td>1.22</td>
</tr>
<tr>
<td>Δ Log stock</td>
<td>-0.84</td>
<td>-1.18</td>
<td>-1.18</td>
<td>-1.70</td>
<td>-0.68</td>
</tr>
<tr>
<td>Δ Log cc</td>
<td>0.04</td>
<td>0.44</td>
<td>0.05</td>
<td>0.59</td>
<td>0.02</td>
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<tr>
<td>Δ ir</td>
<td>0.003</td>
<td>1.00</td>
<td>0.003</td>
<td>1.03</td>
<td>0.004</td>
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<td>ΔLog infl</td>
<td>-0.09</td>
<td>-0.72</td>
<td>-0.12</td>
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<td>-0.09</td>
</tr>
<tr>
<td>Log</td>
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<td>3.00***</td>
<td>-0.95</td>
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</tr>
<tr>
<td>infP*D4349</td>
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<td>11.6***</td>
<td>0.29</td>
<td>12.2***</td>
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<td>Dummy 1950</td>
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<td>2.50</td>
<td>0.008</td>
<td>1.07</td>
<td>0.008</td>
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<tr>
<td>D5507 (dereg)</td>
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<td>3.00</td>
<td>0.011</td>
<td>1.92</td>
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<td>R²</td>
<td>0.661</td>
<td>0.691</td>
<td>0.683</td>
<td>0.695</td>
<td>0.695</td>
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<td>R² adj</td>
<td>0.629</td>
<td>0.658</td>
<td>0.649</td>
<td>0.659</td>
<td>0.655</td>
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<tr>
<td>Durbin-W</td>
<td>1.81</td>
<td>1.92</td>
<td>1.94</td>
<td>1.96</td>
<td>1.94</td>
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<td>White P-value</td>
<td>0.234</td>
<td>0.247</td>
<td>0.0998</td>
<td>0.136</td>
<td>0.205</td>
</tr>
</tbody>
</table>

Notes to Table: ***, **, * indicate that the test statistics are above the 1%, 5% and 10% critical levels for significance. Critical values for the test statistics for individual co-efficients are from Wooldridge (2003), Table G.2, page 817. For the joint significance tests, the critical values are from Wooldridge (2003), Table G.3, page 818-20. D-W values are for Durbin Watson test for serial correlation. White p-values are the White (1980) test for heteroskedasticity.
### Table 4: Regression of determinants of changes in house prices

<table>
<thead>
<tr>
<th></th>
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<th>3</th>
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<th>5</th>
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<tbody>
<tr>
<td></td>
<td>co efficient</td>
<td>t-stat</td>
<td>co efficient</td>
<td>t-stat</td>
<td>co efficient</td>
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<tr>
<td>ΔC</td>
<td>0.002</td>
<td>0.18</td>
<td>-0.001</td>
<td>-0.11</td>
<td>-0.001</td>
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<tr>
<td>Δ Log Y</td>
<td>0.15</td>
<td>1.19</td>
<td>0.16</td>
<td>1.21</td>
<td>0.17</td>
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<tr>
<td>Δ Log Y*time</td>
<td>1.19</td>
<td>4.01**</td>
<td>0.95</td>
<td>2.73**</td>
<td>0.98</td>
</tr>
<tr>
<td>ΣΔ Log Ys (joint F-dist)</td>
<td>1.35</td>
<td>12.85***</td>
<td>1.10</td>
<td>1.15</td>
<td>1.11</td>
</tr>
<tr>
<td>Δ Log equ</td>
<td>0.19</td>
<td>3.49**</td>
<td>0.20</td>
<td>3.63**</td>
<td>0.19</td>
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<tr>
<td>Δ Log equ*time</td>
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<td>-2.83***</td>
<td>-0.21</td>
<td>-2.97***</td>
<td>-0.22</td>
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<tr>
<td>ΣΔ Log equus (joint F-dist)</td>
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<td>6.09***</td>
<td>-0.01</td>
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<td>0.79</td>
<td>0.79</td>
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<td>0.79</td>
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<tr>
<td>Δ Log pop*time</td>
<td>2.06**</td>
<td>0.98</td>
<td>1.99**</td>
<td>0.95</td>
<td>1.71</td>
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<tr>
<td>ΣΔ Log pops (joint F-dist)</td>
<td>2.85***</td>
<td>2.78***</td>
<td>2.48***</td>
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<td></td>
</tr>
<tr>
<td>Δ Log stock</td>
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<td>-1.42</td>
<td>-0.87</td>
<td>-1.20</td>
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<tr>
<td>Δ Log stock*time</td>
<td>-0.78</td>
<td>-0.48</td>
<td>-0.76</td>
<td>-0.46</td>
<td>-0.64</td>
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<tr>
<td>ΣΔ Log stocks (joint F-dist)</td>
<td>-1.65</td>
<td>-1.59</td>
<td>-1.49</td>
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<tr>
<td>Δ Log cc</td>
<td>0.06</td>
<td>0.76</td>
<td>0.06</td>
<td>0.73</td>
<td>0.06</td>
</tr>
<tr>
<td>Δ Log cc*time</td>
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<td>0.21</td>
<td>0.13</td>
<td>0.46</td>
<td>0.13</td>
</tr>
<tr>
<td>ΣΔ Log ces (joint F-dist)</td>
<td>0.002</td>
<td>0.70</td>
<td>0.002</td>
<td>0.84</td>
<td>0.001</td>
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<td>Δ ir</td>
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<td>Δ ir*dereg</td>
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<td>0.27</td>
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<td>ΔLog infl</td>
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<td>-1.65</td>
<td>-0.19</td>
<td>-1.63</td>
<td>-0.15</td>
</tr>
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<td>ΔLog infl*dereg</td>
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<td>-1.40</td>
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<td>ΣΔ Log infls (joint F-dist)</td>
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<td>-0.70</td>
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<td>-0.73</td>
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<td>Dummy 1950</td>
<td>0.29</td>
<td>12.72***</td>
<td>0.29</td>
<td>12.85***</td>
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<td>R2</td>
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<td>0.735</td>
<td>0.741</td>
<td>0.747</td>
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<td>R2 adj</td>
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<td>D-W stat</td>
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<td>1.955</td>
<td>1.977</td>
<td>1.979</td>
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</tbody>
</table>

Notes to Table: ***, **, * indicate that the test statistics are above the 1%, 5% and 10% critical levels for significance. Critical values for the test statistics for individual co-efficients are from Wooldridge (2003), Table G.2, page 817. For the joint significance tests, the critical values are from Wooldridge (2003), Table G.3, page 818-20. D-W values are for Durbin Watson test for serial correlation. White p-values are the White (1980) test for heteroskedasticity.
<table>
<thead>
<tr>
<th>House prices</th>
<th>Income</th>
<th>Equity prices</th>
<th>Popn</th>
<th>Stock</th>
<th>Costs</th>
<th>Aggregate</th>
<th>Stocks</th>
</tr>
</thead>
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<tr>
<td>1901-2007</td>
<td>2.01</td>
<td>1.51</td>
<td>2.26</td>
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<td>2.30</td>
<td>0.71</td>
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</tr>
<tr>
<td>1901-1955</td>
<td>0.74</td>
<td>1.16</td>
<td>1.82</td>
<td>1.95</td>
<td>2.23</td>
<td>0.92</td>
<td>na</td>
</tr>
<tr>
<td>1955-2007</td>
<td>3.34</td>
<td>1.89</td>
<td>2.73</td>
<td>1.81</td>
<td>2.37</td>
<td>0.49</td>
<td>na</td>
</tr>
</tbody>
</table>

Regression with no interaction with time dummy 1955-2007

| Co-efficient | 0.41 | 0.05 | 1.58 | -1.02 | 0.04 |
| Contribution to % growth in house prices | 0.620 | 0.113 | 2.975 | -2.343 | 0.028 | 1.394 | 0.632 |
| % explained | 30.9 | 5.6 | 148.3 | -116.8 | 1.4 | 69.5 | 31.5 |

Regression with interaction with time dummy

| Co-efficient | 0.16 | 0.2 | 0.77 | -0.85 | 0.06 |
| Contribution to % growth in house prices | 0.185 | 0.363 | 1.503 | -1.894 | 0.055 | 0.212 | -0.391 |
| % explained | 25.1 | 49.1 | 203.5 | -256.5 | 7.4 | 28.7 | -53.0 |

Period 1955-2007

| Co-efficient | 1.11 | 0 | 2.48 | -1.49 | 0.19 |
| Contribution to % growth in house prices | 2.093 | 0.000 | 4.491 | -3.527 | 0.093 | 3.150 | 0.964 |
| % explained | 62.7 | 0.0 | 134.5 | -105.7 | 2.8 | 94.4 | 28.9 |
Figure 1 All Capitals Median House Prices 1880-2006

Figure 2 Price to Income ratio: Market Value of Private Dwelling Assets to GDP 1901-2007
Figure 3  
Real Rental Income per Dwelling

Figure 4  
Rent to Income Ratio: Gross rental income to GDP 1901-2007