HOUSE PRICES IN AUSTRALIA: 1970 TO 2003
FACTS AND EXPLANATIONS

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ABSTRACT

This paper describes and explains changes in real house prices in Australia from 1970 to 2003. In the first part of the paper, we develop a national index of real house prices. We then discuss the main factors that determine real house prices and some previous attempts to model Australian house prices. We develop and estimate a long-run equilibrium model that shows the real economic determinants of house prices and a short-run asymmetric error correction model to represent house price changes in the short run. Consistent with economic theory, we find that in the long run real house prices are related significantly and positively to real income and to the rate of inflation as represented by the consumer price index. They are also related significantly and negatively to the unemployment rate, mortgage rates, equity prices, and the housing stock. Employing our short-run asymmetric error correction model, we find that there are significant lags in adjustment to equilibrium. When real house prices are rising at more than 2 per cent per annum the housing market adjusts to equilibrium in four quarters. When real house prices are static or falling, the adjustment process takes six quarters.

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1 Introduction

As the Productivity Commission (2004) observes, 'most Australians have an abiding interest in house prices'. However, we have not been well served with information about house prices (Reserve Bank, 2004). Nor do we know with any exactitude why house prices change up and down as they do. In a recent paper, Abelson and Chung (2004) provide a detailed account of nominal and real house prices in Australia from 1970 to 2003. In this paper we seek to explain the changes in real house prices in Australia over this period.

In Section 2 we describe real house prices in the capital cities from 1970 to 2003 and a corresponding national index of real house prices. There are strong correlations between house prices in the capital cities, between house and apartment (unit) prices in the cities, and between city and non-city house prices. Accordingly, a national, capital city, house price index is a meaningful measure of Australian housing prices. In Section 3 we discuss how house prices are determined and the main factors that seem likely to have determined changes in real house prices in Australia. Section 4 briefly describes some previous attempts to explain various Australian house prices, though not a national housing price index. In Section 5 we describe the basis for our econometric modelling. Sections 6 and 7 give the results of our econometric modelling work. A final section summarises the main points.

2 House Prices in Australia: 1970 to 2003

Drawing on Abelson and Chung (2004), we show estimated real median house prices indices for the Australian capital cities from 1970 to 2003 in Table 1. Although house price *levels* differ markedly between the cities, *changes* in city house prices have been similar, especially in recent years. Between 1990 and 2003, real house prices rose between 47 per cent and 77 per cent in all cities, compared with an estimated weighted average figure of about 64 per cent. Even over a longer period, the large cities exhibited similar price movements. From 1970 to 2003, there were the following correlations between real house price indices: Sydney-Melbourne (0.93); Sydney-Brisbane (0.92); Melbourne-Adelaide (0.92), Melbourne-Perth (0.81).

Price changes in the smaller or outlying cities deviated sometimes from the norms. Real house prices in Perth fell in the early 1970s and rose in the early 1990s, when they were rising and falling respectively in other cities. Canberra experienced house price booms after Labor party general election wins in 1972 and 1983 and again in the early 1990s, whereas real house prices elsewhere were falling in 1983 and flat in the early 1990s.

Table 1 **Real annual median house price indices – capital cities (1990 = 100)**

									Australia	
Year	Sydney	Melbourne	Brisbane	Adelaide	Perth	Hobart	Darwin	Canberra	AC (a)	Treasury
1970	56.6	57.4			101.6				64.0	58.8
1971	60.5	56.7		67.8	97.2			82.6	65.7	61.2
1972	63.8	59.8		71.1	90.4	80.3		88.0	68.0	64.2
1973	67.5	72.3	74.1	79.9	89.1	88.6		106.3	75.1	70.4
1974	68.0	80.7	78.9	94.7	77.3	103.7		109.9	79.0	75.0
1975	63.7	78.9	75.5	96.9	87.2	113.5		100.2	77.9	70.9
1976	60.3	79.8	73.9	97.4	103.7	122.3		92.9	78.7	70.2
1977	57.2	79.9	71.6	94.9	101.8	119.0		86.0	76.7	69.4
1978	58.3	75.2	69.5	89.2	100.0	108.6		80.9	74.3	68.9
1979	62.8	69.7	66.9	83.4	91.7	101.8		77.6	71.9	70.5
1980	77.4	65.7	68.4	80.7	87.0	96.4		80.7	74.6	78.5
1981	80.9	66.8	79.8	80.0	86.2	90.0		95.1	77.8	83.4
1982	73.2	63.8	87.2	78.8	85.3	87.9		87.4	75.1	78.9
1983	68.2	65.1	79.8	80.2	78.7	84.2		91.7	72.3	75.6
1984	69.2	77.6	81.6	98.5	74.5	85.3		109.1	78.5	78.9
1985	66,7	84.1	79.8	108.8	75.4	99.1		109.9	80.8	81.2
1986	68.0	84.0	74.9	101.5	77.0	92.9	115.7	101.4	79.9	80.3
1987	76.6	84.5	69.5	94.8	74.9	95.8	98.8	92.4	80.6	77.8
1988	83.9	96.0	72.5	95.4	89.0	95.9	97.8	96.7	88.3	88.6
1989	94.5	108.1	91.1	99.8	108.7	101.1	95.9	102.2	100.4	104.4
1990	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1991	90.9	93.9	102.9	103.6	95.3	103.2	106.5	109.5	96.2	98.0
1992	90.6	91.5	109.5	106.9	97.2	109.3	119.2	123.3	97.5	97.6
1993	91.3	90.6	113.8	107.8	105.1	116.8	139.7	124.4	99.4	97.8
1994	91.7	91.8	117.0	108.0	112.6	121.5	143.8	123.2	101.2	100.2
1995	89.6	87.0	115.0	101.4	110.8	112.1	144.0	113.8	97.6	99.2
1996	93.7	86.1	112.8	97.5	107.8	110.6	139.4	108.7	97.4	98.1
1997	103.3	93.1	114.0	100.3	113.9	111.1	149.4	108.7	103.5	100.3
1998	109.2	100.8	120.2	103.9	118.8	108.6	145.6	109.7	109.2	106.3
1999	117.9	112.1	119.6	109.7	122.4	112.0	148.4	112.3	116.2	112.8
2000	118.9	117.2	120.9	111.6	124.2	112.5	147.9	120.3	118.7	118.5
2001	128.0	132.2	121.7	118.8	128.2	110.3	142.6	131.5	127.3	127.1
2002	149.3	147.2	135.6	138.4	139.9	121.8	148.9	144.9	144.0	146.7
2003	170.3	153.2	160.2	168.3	147.4	149.1	151.4	176.9	165.9	163.2

(a) This index uses the 1991 Census data on houses for weights, applied to city indices where they are available.

Source: Abelson and Chung, 2004.

Median unit prices exhibited similar changes to median house prices in most cities. As shown in Abelson and Chung (2004), house and unit prices *within* Sydney and *within* Melbourne were highly correlated (these two cities account for three-quarters of the units in Australia). There was also a high correlation (0.98) between their estimated national house and unit price indices from 1974 to 2003. In recent years, the national unit price index rose marginally more than the house price index (see Figure 1), most likely due to the strength of investor demand for units (Reserve Bank, 2003).

Accordingly, a national capital city house price index is quite representative of prices of houses and units within most cities and indeed outside them.[1] Table 1 shows two national indices. Abelson and Chung (2004) estimated a real price index from their best estimates of city house prices by weighting the cities according to the number of houses in each city in the 1991 Census. The weights are Sydney (0.30), Melbourne (0.29), Brisbane (0.14), Adelaide (0.10), Perth (0.11), Hobart (0.02), Canberra (0.03) and Darwin (0.01). When data for some cities are not available in the 1970s, the cities were re-weighted to reflect the available data.

Table 1 also shows the (unpublished) Australian Treasury, real house price index.[2] This index is based on Treasury estimates of median house prices in Sydney, Melbourne, Brisbane, Adelaide, Perth and Canberra. The series draws on ABS data on house prices from December quarter 1985 to the present, Real Estate Institute of Australia data from 1980 to September quarter 1985, and data from the consulting company Bis-Shrapnel for the earlier years. The Treasury weights are drawn from the 14th CPI series namely Sydney (0.36), Melbourne (0.29), Brisbane (0.13), Adelaide (0.08), Perth (0.11) and Canberra (0.03).[3]

The two estimated Australian indices are similar, especially since the mid-1980s. The correlation is 0.99 from 1986 to 2003 and 0.77 from 1970 to 1985.[4] As noted, the two series use different weights, with the Treasury giving more weight to Sydney houses.[5] Also price data in the early 1970s are less reliable than later data. The Treasury index in that period is based on the estimated median prices of auction sales reported in the media (the basis for the Bis-Shrapnel figures). The Abelson-Chung index is sensitive to the values of median houses in Perth, about which there is some uncertainty.

However, both Australian indices show significant house price booms from 1971 to 1974, from 1979 to 1981, from 1987 to 1989, and from 1996 through to 2003 (the most prolonged price boom). After each of the first three booms, real prices tended to fall. However, in the long run real price rises exceeded falls, resulting in a substantial long-run real price increase in observed real house prices. Real house prices rose by about 180 per cent between 1970 and

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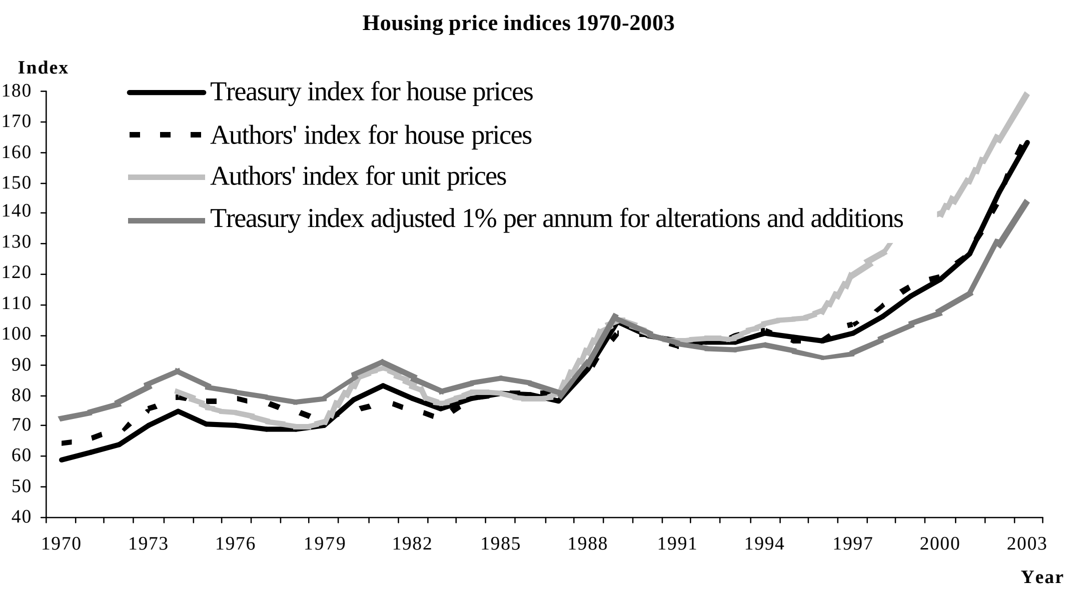
[1] Abelson and Chung (2004) show that house prices outside cities changed in similar ways to house prices in cities.
[2] Treasury nominal and real prices indices were supplied by the Productivity Commission. The index shown in Table 1 is the average quarterly Treasury figure converted to a real index with 1990 = 100.
[3] Communication from a Treasury officer.
[4] The correlation for the whole period 1970 to 2003 is 0.99.
[5] Sydney weighting in Abelson and Chung (2004) is lower because Sydney has relatively few houses and more units in its dwelling stock than do other cities.

2003 (a compound rate of about 3.3 per cent per annum). However this may be a misleading figure in that 2003 was almost certainly a peak price year and 1970 was not.

Also, these figures do not allow for quality changes in existing and new houses. Abelson and Chung (2004) estimate that expenditure on alterations and additions equals about 1 per cent of the value of the housing stock in most years, which suggests that the quality of the established housing stock rises by about 1 per cent per annum on average.[6] This expenditure on alterations and additions does not include expenditure on fittings (which tend to improve) or any non-market household or black economy time spent on improving dwellings. Moreover, the size of new buildings is increasing at well over 1 per cent per annum. Between 1984-85 and 2002-03, the average floor area of new houses rose by 40 per cent (from 162m^2 to 227m^2) and the average floor area of other new dwellings rose by 35 per cent (from 99m^2 to 134m^2).

Figure 1 shows four indices of real median house and unit prices in Australian capital cities. They include the Abelson-Chung indices for observed median house and unit prices; the Treasury index for observed median house prices; and a quality-adjusted house price index that discounts the observed Abelson-Chung index by one per cent per annum to allow for quality increases. On a quality-adjusted basis, real house prices rose by about 2.3 per cent per annum and approximately doubled between 1970 and 2003.

Figure 1 Housing price indices 1970:2003



3 Possible Explanations of Australian House Prices

Real house price changes can be expressed generally as:

$$P_t - P_{t-1} = \alpha_1 (D_t - S_t) \quad (1)$$

where P is the real price of housing, *D* is the estimated demand for housing which includes consumption and investment demand, *S* is the supply of housing, and subscript *t* refers to the period. The difference between estimated demand and supply picks up the disequilibrium influence on prices.

Following standard demand theory, the demand for housing can be viewed as a function of disposable income (Y), user cost (UC), and demographic factors (*DEM*) such as population growth or household formation.

$$D_t = f(Y, UC, DEM)_t \text{ and} \quad (2)$$

$$UC_{t} = g(P_t, r, P_{t+1}, TS_t) \quad (3)$$

where *r* is the rate of interest and *TS* is taxes or subsidies (as relevant). The future house price represents capital gain which drives investment demand. Depreciation and maintenance costs are not included in this user cost equation. Depreciation is subsumed in the expected real house price. Maintenance expenditures do not vary much from one year to another.

To incorporate investment motivation, we may also allow for the relative return on housing and other assets in so far as they are not captured in Equations (2) and (3). The user cost of housing includes part of the rate of return on housing through the expected capital gain (P_{t+1}). Also the borrowing rate of interest (*r*) reflects the (pre-tax) return on alternative cash investments. A full investment model could include rents from housing, the return on other assets such as equities, and taxation effects.

Taxation (subsidy) effects may reflect specific housing taxes or subsidies (such as grants for first-home owners or the exemption of owner-occupied homes from capital gains tax) or general taxes. When house buyers purchase a home with their own funds, the user cost is the *after-tax* interest that is foregone. This falls, and the demand for housing rises, with high marginal tax rates. Also, when nominal income is taxed and capital gains are not taxed, a combination of high inflation and taxation increases the demand for housing

[6] Expenditure on alterations and additions has been around 2 per cent of GDP each year, but a higher proportion after 2000.

Turning to the supply of housing, the stock does not change much from year to year. In 2001 there were 7.1 million residential dwellings in Australia. Dwelling completions average about 2 per cent of the housing stock per annum. However, net increases in stock are lower after allowing for losses of housing stock. The inelastic nature of housing supply is doubtless one reason why housing stock is rarely included in short-run house price models. Another reason may be the difficulty of estimating housing stock on a quarterly basis. However, omitting housing stock from explanatory models may be a major error. We find that the housing stock has a substantial long-run impact on house prices and hence on the short-run model as well.

Some models of house prices include the costs of building new houses (for example Bourassa. and Hendershott (1995) and Bodman and Crosby (2003). However, there is little justification for this. In the short run, the prices of new houses are determined by the value of the existing housing stock. The costs of new houses can affect the price of existing housing only if new house supply significantly affects the size of the housing stock (which is better included as a separate variable). In other circumstances, changes in the costs of new houses (be they changes in construction costs or taxes on developers or GST) reduce the value of land for new housing, but do not affect the price of new or established houses (Abelson, 1999).

Accordingly, in the econometric literature (see Hendry, 1984; Meen 1990; Muellbauer and Murphy, 1997) the house price model is most often an inverted demand equation of the following general kind:

$$P_{\mathrm{t}} = \mathrm{f}\,(Y, r, P^{e}, DEM, TS) \qquad (4)$$

where P^{e} is expected real house price and the other variables are as before. However, economic theory does not provide a finite list of variables. Investment factors, such as housing rents, return on equities, and the consumer price index combined with marginal tax rates, could affect house prices. Indeed, in an open economy, or for an international city such as Sydney or Melbourne, the exchange rate could influence house prices (a low exchange rate increases the attractiveness of housing assets to foreigners). Moreover, care is required with respect to multicollinearity and endogeneity. For example, household formation may be a function of house prices. Importantly, Equation (4) says nothing about possible lagged or speculative effects or other disequilibria in the market. We address these issues in our empirical work below.

Before attempting to sketch explanations for house price movements in Australia, especially for the four price booms, it may be useful to make some further observations about the main possible determinants of house prices.

Many commentators put interest rates at the heart of any explanation of house prices. Writing about the 1996 to 2003 boom, the Productivity Commission (2004) observed: 'cheaper and more accessible housing finance is a central part of the story'. Whether this is so or not, there are three important issues with interest rates. First, do real or nominal interest rates matter more? Economic theory suggests that real rates are more important because the nominal component of interest costs should be offset by nominal increases in house prices. However, when financial institutions set mortgage repayments in constant dollar amounts that do not rise with inflation, as they often do, high nominal interest rates can create a repayment problem in the early years for some borrowers and restrict their borrowing. Second, which interest rate is the most relevant one—housing mortgage rates, general short or long-term market rates, or some other rate? In a competitive finance market, the mortgage rate would be the obvious choice. In a regulated mortgage market, as existed until 1986 in Australia where mortgages were controlled and housing finance limited, an unregulated interest rate may reflect real borrowing costs better. Thirdly, when the interest rate is regulated, access to finance may be important. In this case a money, or loan, supply variable may help to explain house prices. However, it is not clear that this is relevant when financial markets are not regulated.

Expected capital gains also play a large part of many explanations of house prices in equilibrium or disequilibrium models. An obvious modelling problem is that expected house prices are generally not observable. Inflation may be a proxy variable.

Income is generally an important explanator of house prices, especially of the long-run increase in housing quality. The preferred form of the variable is disposable income per household or individual. This requires estimates for household formation or population growth that may not be available quarterly. In the short run, the rate of unemployment may be a proxy for people's expectations of economic performance.

Wealth may also influence housing demand. But estimates of wealth are not regularly available. Equities are an important component of wealth and may be related positively to house prices because of the wealth effect. Also, when equities are high, the return on them falls and investors substitute housing. On the other hand, investors apparently fled into housing following the stock market crashes in 1987-88 and 2001-02.

Demographics may refer to simple population change, to changes in population of first house buying age, or to household formation itself. Of these, the population of first house buying age would appear most relevant, but is difficult to define and measure. A proxy for this could be net migration. Australia experienced high migration in 1969-73, 1981-82, 1987-90, and 2001-03, which could have influenced house prices. Total population changes only slowly.

Turning to taxes and subsidies, there are so many and they change so often that it is difficult to know which ones may be important or how to isolate the impacts in econometric work. The issue is further complicated because of the interaction of taxes with inflation. Here we briefly consider four major subsidies to housing.

- Limited tax deductions for mortgage interest payments were introduced to assist home purchase in 1973, but abolished in 1985.

- Home owners were exempt from capital gains tax (CGT) throughout the period. Investors were also exempt from CGT up to 1985 when the government introduced a CGT on real gains for investors. In September 1999 the government replaced this CGT with a tax of 50 per cent of the nominal gain. Many people, including the Productivity Commission (2004), perceived the change in 1999 to be a further subsidy to investors. Actually, when the nominal gain is more than twice the real gain (as often happens), the new CGT *increases* the tax liability.

- Investors were allowed full negative gearing rights throughout the period, except between August 1985 and September 1987, when negative gearing was disallowed and investors had to carry forward losses. Rental investment declined in this period.

- In the 1970s the Australian government ran a number of grant schemes for first home owners. These schemes were phased out in the early 1980s. However, in July 2000 the government reintroduced the first home grant to compensate for the alleged effects of GST on house prices. This has cost a little over $1 billion a year and has doubtless increased demand. But relative to the value of housing stock of $1500 billion, it can have had very little impact on prices.

These observations illustrate the complexity of the data and the modelling task. Given these observations, what could explain the four main housing price booms in Australia since 1970?

1972-74: This period was characterised by high income growth, rising commodity prices with the first oil crisis, high migration, and *negative* real mortgage rates. The combination of high inflation, full negative gearing and no capital gains tax produced high returns to investors.

1979-81: The second oil crisis sparked a renewed commodity price and income boom; real interest rates were low; the policy setting continued to be favourable for investors.

1987-89: There was high growth in income and in migrants. The collapse of the stock market in September 1987 sparked a flow of funds into housing. However, unlike in earlier booms, nominal and real interest rates were high.

1996-2003: This period was again characterised by high growth in income and migrants (at least later in the period). Nominal interest rates were especially low. Investor demand for housing was high. The boom appeared to get a second wind from the fall in world stock markets and from favourable policy settings for investors, including negative gearing combined with high marginal tax rates and a perceived lowering of the CGT.

After each of the first three booms, real prices tended to flatten or fall as the net returns in housing rose closer to returns from other assets. However, after allowing for housing improvements, there is a substantial long-run increase in house prices to explain. The other point that emerges from this review is that different combinations of factors may explain each price boom. The explanations of house price changes may have changed over the 1970-2003 period. This further complicates econometric modelling.

4 Studies of House Prices in Capital Cities

Possibly reflecting the paucity of data at least until recently, there have been few attempts to model house prices in Australia. We report below on three studies that appear to have been the main attempts at explaining house prices, in each case based on capital city house prices. . Two studies modelled the capital cities separately. The third study employed a pooled time-series / cross-section analysis of the data to derive a single (national) set of parameter estimates. Table 2 summarises the variables employed and their significance. Three crosses indicate that the explanatory variable was clearly significant at the 95 per cent level. Two crosses indicate that the variable was sometimes significant at the 95 per cent level or was significant at the 90 per cent level.

In 1989, concerned by the house price inflation, the Commonwealth commissioned the consulting companies Applied Economics and Travers Morgan (AETM) to assess housing affordability and report on the determinants of house prices. Drawing on data from Bis-Shrapnel and state Valuer-General offices, AETM (1991) modeled annual house prices

Table 2 Summary results for models of city house prices (a)

	Applied Economics / Traves Morgan 1991	Bourassa / Hendershott, 1994	Bodman / Crosby, 2003
Dependent variable	per cent change in real house prices p.a. in 3 cities 1965-89	per cent change in real house prices p.a. in 6 cities (pooled) 1980-93	per cent change in real house prices per qtr in 5 cities 1980-2002
Explanatory factors (b)			
Prices in other cities	XXX		
Real GDP	XXX		
Real GDP / capita			X
Real wages		XXX	
Employment		XXX	
Real interest rate	XX		X
Real after-tax interest rate		X	
Real rental return			X
Population			XX
Net national immigration	XX		
Net city immigration		XXX	
Real material costs		XXX	XXX
All ordinaries index	XX		
Policy variable dummies	XX		
Lagged real house price	XXX	XXX	X
per cent difference between equilibrium and actual price levels (error correction)		XXX	XX
Number of observations	25	84	128
R^2 reported	0.87 to 0.95	0.51	0.19 to 0.44

(a) A cross indicates that the variable was included as a potential explanatory. Two crosses mean that some significance was found. Three crosses indicate that the variable appeared to be robustly significant and of the appropriate sign.
(b) Usually percentage change in variable unless a ratio like interest rates.

separately for Sydney, Melbourne and Adelaide from 1965 to 1989.[7] The study found that the main explanatory variables for each city were lagged house prices, house prices in other cities, GDP or average weekly earnings in the relevant state,, real interest rates, net migration, and two policy variables (the provision of housing assistance and the disallowance of negative gearing policy from 1985 to 1987). Lagged house prices played an important role in the models in reducing, but not eliminating, problems associated with serial correlation. AETM interpreted the coefficients on lagged prices as adjustment parameters, which indicated that

[7] The most accessible brief summary of the results can be found in Abelson (1994).

the long-run elasticities of the explanatory variables were about 2.5 times impact elasticities. The consultants planned to use quarterly data but found models worked poorly with these data possibly because of weak data and unstable lagged relationships. Consequently the study suffered from relatively few annual observations.

Drawing on house price data from the Real Estate Institute of Australia (REIA), Bourassa and Hendershott (1995) employed pooled time-series cross-section data to analyse house prices in six cities (Sydney, Melbourne, Adelaide, Brisbane, Perth and Canberra) from 1980 to 1993. Thus the study has 84 observations, with 14 from each city. Like AETM (1991), the authors employed income, migration, interest rates, and lagged house prices. But the study differed in that it employed local rather than national income and migration variables and a real after-tax interest rate. Also the study also introduced a specific disequilibrium price variable based on the difference between the estimated equilibrium price and the actual price in the previous period. The introduction of lagged and disequilibrium effects improved the explanatory power of the model (compared with other reported results without them) and the significance of the other explanatory variables. The authors conclude plausibly that the key explanatory factors were growth in real wage income (employment and real wage per employee have elasticities above 1) and growth in population caused by net migration (elasticity 4.5). Real interest rates had little effect. The study was constrained by the limited years of data which included only a generally flat period, one price boom, and one decline. The level of explanation is modest with an R^2 of 0.51 and there is no discussion of serial correlation issues.

In a more recent study, Bodman and Crosby (2003) draw on REIA data to model changes in real quarterly house prices in five capital cities (the above except Canberra) from 1980 to 2003. This study combines economic fundamentals with an attempt to measure ‘persistence’ and ‘bubble bursting’ for the cities separately. The assumed fundamentals are income per capita, real interest rates, real rentals, real materials costs and city population. Persistence is modelled with lagged house prices and bubble bursting with an error correction variable that reflects the difference between the estimated equilibrium price and the actual price. In Table 2, we summarise the results, which differed across the cities. The only ‘fundamental’ variable that was regularly significant was real material costs, which for the reasons given above is unlikely to be a driver of real house prices. The study also found weak relationships between house prices and city population. However, it found no significant relationships between house prices and income per capita, real or nominal interest rates, or real rental rates. The coefficients on the error correction term were positive and significant for Sydney, Melbourne and Brisbane, but not for Adelaide and Perth. Also the coefficients on the lagged term were generally not significant.

What conclusions can be drawn from these studies? Not surprisingly, income and population or migration influence house prices. AETM (1991) found that real interest rates influenced house prices; the other studies did not. Although house prices and construction costs are positively related, the causal connections are questionable. No study showed housing stock to affect house prices. The AETM study found no effect of house completions on prices. The other studies did not model house supply. Undoubtedly all three studies were handicapped by poor city specific data. Another major difficulty in modelling house prices is the apparent presence of market disequilibrium. Models that employ error correction mechanisms have to model a variable representing the difference between the estimated equilibrium and the actual price, which requires estimates of the real determinants of that equilibrium.

5 A Long-run and a Short-run Model of House Prices

In this paper we model the quarterly real Australian house price index estimated by Treasury from 1970 to 2003[8] in the long and short-run. We assume that, in the long run, real house prices adapt to economic fundamentals. In the short run, house prices may deviate from this equilibrium, but they continually readjust to it in a non-linear fashion through an asymmetric error correction term. Asymmetry arises because we expect that adjustments to equilibrium will be faster when prices are rising than when they are flat or falling. Our observation is that buyers are keen to get into the housing market when prices are rising for fear that delay will mean paying still higher prices. On the other hand, sellers are often unwilling to reduce prices when markets are flat. Transaction times are typically shorter when real prices are rising than in flatter periods.

More specifically, we:

- specify the variables to be included in the long run relationship;
- examine the time series properties of those variables—specifically unit roots and cointegration tests are performed;
- estimate the long run equilibrium relationship; and
- we derive and estimate a non-linear error correction model of house prices.

The long-run model in this analysis is:

[8] The Productivity Commission supplied this index to the authors. Abelson and Chung (2004) did not estimate a quarterly national index.

$$log(P_t)=g_1+g_2 log(Allords_t)+g_3 R_t+g_4 log(HDI_t)+g_5 log(ER_t)+g_6 log(UE_t)+g_7 log(CPI_t)+g_8 log(H_t)+u_t \quad (5)$$

where P_t is real house prices, R_t is the real mortgage interest rate (quarterly yield), $Allords_t$ is the real All Ordinaries index, HDI_t is real household disposable income per capita, ER_t is the trade weighted exchange rate, CPI_t is the consumer price index, UE_t is the unemployment rate, H_t is the housing stock per capita, and u_t is a stationary error term. The All Ordinaries index is included to capture a possible substitution effect with the stock market. The exchange rate is a potentially important variable since it may influence overseas demand for Australian real estate. The consumer price index is included to capture the after-tax investment advantages of housing as an asset in conditions of rising prices. The unemployment rate is included as a barometer of economic conditions and is expected to influence the price of houses negatively. The housing stock is included as a supply variable, which would be negatively related to house prices.

Further details of the data are described in the Appendix. We report below the results for the full sample of observations, 1970q1 to 2003q1, and for a sub sample, 1975q1 to 2003q1. Due to concerns with the early 1970's house price data we comment only on the results for the sub sample which we deem are more reliable.

In order to examine the time series properties of the variables, we define the vector z_t as:

$$z_t = (log\ (P_t)\ ,\ log(Allords_t),\ R_t,\ log(HDI_t),\ log(ER_t), log(UE_t),\ log(CPI_t),\ log(H_t)) \quad (6)$$

We test the elements of z_t for unit roots and then test z_t for multivariate cointegration using the Johansen tests. The long-run equilibrium relationship is estimated using Stock and Watson dynamic ordinary least squares (DOLS) and finally a non-linear error correction model of house prices is derived and estimated.

Unit root tests

Before we test for cointegration between the variables of the price equation we need to ensure that the variables are integrated of order 1 (I(1)). We conduct unit root tests for each variable using the Dickey-Fuller (1979, 1981) tests and Phillips-Perron (1988) tests. The results are summarized in Table A2 of the Appendix. The unit root tests reveal that all the variables have a unit root and it is therefore appropriate to test for cointegration among those variables.

Tests for multivariate cointegration

To test for cointegration we employ the Johansen (1988, 1991) maximum likelihood procedure[9] for z_t and an unrestricted constant term.[10]

Table 3 presents the trace and maximum eigenvalue statistics for two sample periods: 1970q2 to 2003q1 and 1975q1 to 2003q1. On the basis of the maximum eigenvalue and trace tests we conclude that there are five cointegrating vectors in the full sample period and four cointegrating vectors in the period excluding the early 70's. Therefore from the Johansen tests for cointegration we conclude that z_t is cointegrated.

Table 3 Tests for the Cointegration Rank: 1975q1 to 2003q1

H_0:	λ_{trace}	$\lambda_{trace}(0.95)$	λ_{max}	$\lambda_{max}(0.95)$
r = 0	274.78	156.00	88.73	51.42
r ≤ 1	186.05	124.24	68.02	45.28
r ≤ 2	118.04	94.15	41.78	39.37
r ≤ 3	76.26	68.52	38.10	33.46
r ≤ 4	38.16	47.21	19.90	27.07
r ≤ 5	18.26	29.68	11.98	20.97
r ≤ 6	6.28	15.41	6.28	14.07
r ≤ 7	0.01	3.76	0.01	3.76

[9] It should be noted that the Johansen cointegration tests (and the Engle and Granger (1987) test) are misspecified if the adjustment is asymmetric. Enders and Siklos (2001) generalize the Engle-Granger test to allow for threshold adjustment toward a cointegrating relationship. They concur with Balke and Fomby (1997) that in the presence of threshold adjustment the Engle-Granger test can be used to determine whether the variables are cointegrated and if non linearity is suspected a non-linear adjustment process should be estimated. However the Engle-Granger and the Enders-Siklos tests suffer from low power and the usual problems associated with a single equation approach, consequently we chose to test for cointegration using the Johansen method.

[10] We include seasonal dummy variables and four dummy variables: one taking the value one in the fourth quarter of 1987 (stock market crash), one taking the value one in the fourth quarter of 1976, one taking the value one in the third quarter of 1986 and one taking the value one in the first quarter of 1981. The number of lags in the unrestricted VAR is set to $k+1 = 3$, it is chosen such that the residuals fulfill the required assumptions and in order to minimize the conventional information criteria. The constant is not restricted to the cointegrating space (such a choice was confirmed by testing the joint hypothesis of both the rank order and the deterministic components).

\1970q2 to 2003q1

H_0:	λ_{trace}	$\lambda_{trace}(0.95)$	λ_{max}	$\lambda_{max}(0.95)$
r = 0	255.00	156.00	70.31	51.42
r ≤ 1	184.69	124.24	49.89	45.28
r ≤ 2	134.80	94.15	48.35	39.37
r ≤ 3	86.45	68.52	34.24	33.46
r ≤ 4	52.21	47.21	31.53	27.07
r ≤ 5	20.68	29.68	10.51	20.97
r ≤ 6	10.17	15.41	8.37	14.07
r ≤ 7	1.79	3.76	1.79	3.76

Critical values from Osterwald-Lenum (1992) are denoted by $\lambda_{trace}(0.95)$and $\lambda_{max}(0.95)$

6 Estimation of the Long-run Price Equation

The cointegration vectors can be estimated using the Johansen estimation method. However, given the large number of variables included in the model relative to the number of observations, we adopt a more robust method proposed by Stock and Watson (1993).

We partition z_t into *log(P$_t$)* and x_t = *(log(Allords$_t$), R$_t$, log(GDI$_t$), log(EX$_t$), log(UN$_t$), log(CPI$_t$), log(H$_t$))'*. *Log(P$_t$)* is then regressed on a constant, x_t, and k leads and lags of x_t.

$$\log(P_t) = a_0 + q x_t + \sum_{j=-k}^{k} d_j \Delta x_{t-j} + v_t \qquad (7)$$

The DOLS estimator of q in (7) is the OLS estimator of q in (7). If *log(P$_t$)* and x_t are cointegrated, the DOLS estimator of q is efficient and consistent in large samples even if x_t includes some endogenous variables. The usual tests of hypothesis on the coefficients of equation (7) are also valid if robust standard errors, such as the Newey-West (1987) standard errors, are used.

The DOLS estimation results are presented in Table 4 for both sample periods. For both samples, the value of k was chosen to be 2 as was the case for the multivariate VAR model. Except for the coefficient of the real interest rate, those estimates are the long-run elasticities of the real house price with respect to the individual variables.

If we look at the sub sample period excluding the early 1970's, we see that all signs of the coefficients accord to expectations. The coefficients are significant, except for the coefficients of the exchange rate.[11]

Several results are of considerable interest. Note first the high long run elasticity of real house prices with respect to real disposable income which is significantly larger than one at the 5 per cent significance level. Real prices would increase by 1.71 per cent on average following an increase of 1 per cent in real disposable income. Second, a 1 per cent increase in the CPI index results in an estimated 0.76 per cent increase in real house prices.[12]

Table 4 Stock-Watson DOLS long run coefficients[a]
Dependent variable log(P_t)

Variable	**1970q2-2003q1 Estimated Coefficient (SE)**	**1975q1-2003q1 Estimated Coefficient (SE)**
Constant	-5.0415*	-5.5212
	(2.6898)	(3.3698)
Log(Allords)	-0.0804	-0.1421**
	(0.0528)	(0.0690)
R	-0.0424	-0.0542*
	(0.0263)	(0.0318)
Log(HDI)	1.4051**	1.7097**
	(0.3547)	(0.3619)
Log(ER)	0.0254	-0.0034
	(0.1132)	(0.1051)
Log(UE)	-0.2558**	-0.1895**
	(0.0528)	(0.0582)
Log(CPI)	0.7172**	0.7632**
	(0.1738)	(0.2113)
Log(H)	-3.3364**	-3.5980*
	(1.5639)	(1.8836)
R^2 adjusted	0.9616	0.9565

[a] ** and * indicate 5 per cent and 10 per cent significance level respectively.
Standard errors are the Newey-West standard errors computed with 3 lags.

On the other hand, an increase of 1 percentage point in the real mortgage rate will lead to a fall in house prices of 5.4 per cent on average. The coefficient of the All Ordinaries is significant and also negative, pointing to an asset substitution effect from stocks to housing after the 1987 and 2000 stock market down turns. The coefficient of unemployment is very significant and negative, suggesting that this is an indicator of economic conditions. Of

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[11] We have kept the exchange rate in the equation even though it is insignificant in the long run because it is significant in the short run. Moreover we expect the exchange rate to be an important factor in determining Sydney house prices. Bewley et al. (2004) show that Sydney house prices lead other capital cities prices, consequently the inclusion of the exchange rate appears warranted.

[12] A recent international study (Tsatsaronis and Zhu, 2004) found that inflation accounted for over half the total variation in house prices in 17 developed countries over the period 1970 to 2003.

special interest, because this has not been estimated in other studies and because of its potential policy importance, the coefficient of the housing stock variable is significant at the 5 per cent level. A one per cent increase in housing stock per capita leads to an estimated decrease in real house price of 3.6 per cent on average.

7 An Asymmetric Error Correction Short-run Model of House Prices

To estimate the short run parameters we estimate an asymmetric error correction price equation. The model is:

$$\Delta \log(P_t) = b_0 + a_1 I_{t-1}(\log(P_{t-1}) - \hat{q} x_{t-1}) + a_2(1 - I_{t-1})(\log(P_{t-1}) - \hat{q} x_{t-1}) + \sum_{j=1}^{k} b_j \Delta z_{t-j} + e_t \qquad (8)$$

where $\hat{?}$ is the estimated DOLS cointegrating vector and I_t is the Heaviside indicator function which defines "boom" observations as observations for which the real price growth over the past year has been over 2 per cent. We chose the value of 2 per cent because this represents the average annual value of improvements plus selling costs.[13]

$I_t = 1$ if $log(P_t)$-$log(P_{t-4}) > 0.02$

$I_t = 0$ otherwise

The only exceptions are observations 2000q3, 2003q4 and 2001q1 which would be classified as 'non-boom' observations due to the introduction of the GST in 2000q3. To redress this distortion, those observations were classified as "boom" observations.

The existence of cointegration between some variables implies that those variables move together through time, tracing a long-run path from which they are disturbed by temporary shocks but to which they continually readjust.[14] The significance tests on the differenced explanatory variables give us information on the strength of the short term effects. The coefficients on the lagged error correction terms represent the proportion by which the long-term disequilibrium in the log of real house prices is being corrected in each period. In our model we posit that those speeds of adjustment are different in boom and non-boom years. Estimation results for equation (8) are presented in Table 5.

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[13] It is also the value chosen by Muellbauer and Murphy (1997) in a different model specification.

[14] Note that, because we have not estimated the full VECM system and identified all the cointegrating vectors, it is not meaningful to comment on whether or not the system is in equilibrium at any point in time by considering this single equation estimated error correction term.

For both samples the speeds of adjustment α_1 and α_2 are significant at the 1 per cent and 5 per cent levels respectively (although using the Dickey-Fuller critical values only α_1 is significant at the 5% level). They are both negative indicating adjustment to equilibrium. For both periods the speeds of adjustment are not significantly different during boom and outside boom times. Excluding the early 1970's if an external shock throws the variables out of equilibrium during "boom" time, and assuming no further shocks, the price adjusts to its long run equilibrium with about 21 per cent of the adjustment taking place in each quarter. Such an adjustment speed is reasonably fast. Outside "boom" time the price adjusts to its long-run equilibrium with about 14 per cent of the adjustment taking place per quarter.

Those results show that if there is an external shock, such as a tax shock for example, prices will adjust rapidly during boom times and about 30 per cent slower during flat or falling times. Our model does not provide precisely determined lags, because it does not account for feed-back effects. However, when real prices are rising at more than 2 per cent per annum, the housing market adjusts to equilibrium in around four quarters. When real prices are static or falling, the adjustment process takes about six quarters.

Table 5 Asymmetric error correction model of real house prices[a]

Variable	**1970q2-2003q1** **Estimated Coefficient (SE)**	**1975q1-2003q1** **Estimated Coefficient (SE)**
α_1	-0.1446**	-0.2100**
	(0.0492)	(0.0503)
α_2	-0.1402*	-0.1396*
	(0.0573)	(0.0575)
R^2 adjusted	0.2958	0.3971
Serial correlation		
B-P-L1 $c^2(1)$	0.0069	0.0467
B-P-L2 $c^2(2)$	0.1043	0.0806
B-P-L4 $c^2(4)$	0.2666	1.7815
Heteroscedasticity $c^2(1)$	2.063	0.179
ARCH(1) $c^2(1)$	0.629	0.416

[a] ** and * indicate 1 per cent and 5 per cent significance level respectively. B-P-L1, B-P-L2 and B-P-L4 stand for the Box-Pierce-Ljung autocorrelation tests for first, second and fourth order autocorrelation respectively. The heteroscedasticity test is based on a regression of the squared residuals on a constant and the squared fitted values. According to the diagnostic tests there is no problem of heteroscedasticity, autocorrelation, or ARCH(1) effects for both periods.

8 Conclusions

Between 1970 and 2003, Australian real house prices rose by over 3 per cent per annum. On a quality-adjusted basis, house prices rose by about 2.3 per cent per annum. Over this period, there were four house price booms: 1972-74, 1979-81, 1987-89 and 1996 to 2003. In between these booms, real house prices tended to fall.

In this paper we have estimated a long-run equilibrium model of house prices that shows the real economic determinants of house prices and a short-run asymmetric error correction model to represent house price changes in the short run. Consistent with economic theory, we find that in the long-run real house prices are determined significantly by real disposable income, the consumer price index, unemployment, real mortgage rates, equity prices, and the supply of housing. These results have significant policy implications.

The estimated long-run elasticity of real house prices is 1.7 with respect to real disposable income and 0.8 with respect to the CPI (reflecting a mixture of expected capital gains and tax benefits). There is a strong negative relationship between real house prices and real mortgage: a one percentage point rise /fall in the real mortgage rate will lead to a fall/rise in house prices of 5.4 per cent on average. Also the coefficient of unemployment is very significant and negative, suggesting that this is an indicator of economic conditions. The estimated long-run elasticity of real house prices is -0.2 with respect to unemployment (a measure of economic confidence) and -0.14 with respect to the All Ordinaries index (indicating that equities and housing assets are substitutes). Also of particular interest, there is a significant and strong relationship between real house prices and the housing stock, with the estimated long-run elasticity with respect to housing stock: -3.6.

Employing our short-run asymmetric error correction model, we found that there are significant lags in adjustment to equilibrium. Although our model does not provide precisely determined lags, when real prices are rising at more than 2 per cent per annum the housing market adjusts to equilibrium in four quarters. When real prices are flat or falling, the adjustment process takes six quarters.

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Appendix

A.1. Data Description and Sources

The data set used in this study consists of quarterly series on eight variables including: real house price index, exchange rate, All Ordinaries share price index, unemployment rate, consumer price index, real mortgage rate, gross disposable income per capita, and the estimated national stock of detached houses per capita. The quarterly real house price index is an unpublished index estimated by the Australian Department of Treasury. We obtained the series for the unemployment rate, All Ordinaries, CPI, gross disposable income and the exchange rate from the dX database for the period March 1970 to March 2003. The exchange rate variable used is a trade weighted index value of the Australian dollar. Real gross disposable income per capita is derived by dividing the real gross disposable income by population and the real All Ordinaries share price index by deflating the All Ordinaries index by CPI. The real mortgage rate variable was estimated by adjusting the standard variable mortgage rate (from the Reserve Bank website) for inflation.

We constructed the (detached) housing stock variable from census data 1981 and 1986 and from completion data for the whole period. We used the housing stock data from the 1981 and 1986 censuses (because these censuses used consistent definitions of housing) together with completion data between 1981 and 1986 to compute a quarterly depreciation rate between those two dates: δ. We then constructed a housing stock for the whole period by using the formula: $H_t = (1-\delta)H_{t-1} + C_t$ where H_t is the housing stock at time t and C_t is the completion at time t. The source for the completions data was ABS, Table 8752.23a.

A.2 Unit Root Tests

In order to identify degrees of integration of the above mentioned series we perform the Augmented Dickey-Fuller (1979) and the Phillips-Perron (1988) tests. Both procedures test the null hypothesis of a unit root in the autoregressive representation of the series. The Augmented Dickey-Fuller (ADF) test constructs a parametric correction for higher-order correlation by assuming that the series follows an AR(p) process and adding lagged difference terms of the dependent variable to the right-hand side of the test regression:

$$\Delta y_t = a_0 + g y_{t-1} + a_1 t + \sum_{i=1}^{p-1} b_i \Delta y_{t-i} + e_t .$$

Table A 1 Unit Root Tests

Variable:	ADF	PP
	-2.609	-1.666
log(*P*)	(0.277)	(0.761)
	0.621	-0.051
log(CPI)	(0.999)	(0.995)
	-2.765	-3.362
log(HDI)	(0.213)	(0.061)
	-3.107	-3.148
log(Allords)	(0.109)	(0.099)
	-2.063	-1.856
log(UE)	(0.561)	(0.672)
	-1.772	-2.045
log(ER)	(0.713)	(0.571)
	-1.951	-1.026
log(H)	(0.622)	(0.936)
	-1.962	-7.939
R	(0.616)	(0.000)
Variables in First Difference:		
	-6.605	-6.751
log(P)	(0.000)	(0.000)
	-5.018	-8.492
log(CPI)	(0.000)	(0.000)
	-10.983	-15.489
log(HDI)	(0.000)	(0.000)
	-11.384	-11.384
log(Allords)	(0.000)	(0.000)
	-7.251	-7.370
log(UE)	(0.000)	(0.000)
	-10.202	-10.194
log(ER)	(0.000)	(0.000)
	-3.984	-9.264
log(H)	(0.011)	(0.000)
	-11.476	-26.005
R	(0.000)	(0.000)

Test statistics under the null hypothesis of unit root are presented with their p-values in brackets.

The unit root test is carried out by testing the null $g = 0$ using MacKinnon (1991) critical values. The number of lagged difference terms p is determined using the Schwartz Information Criterion. Phillips-Perron differs from the ADF test in that it accounts for serial correlation non parametrically when testing for unit root. This procedure estimates the non-augmented DF specification:

$$\Delta y_t = a_0 + g y_{t-1} + a_1 t + e_t$$

and modifies the *t-ratio* of the *g* coefficient so that serial correlation does not affect the asymptotic distribution of the test statistic. Thus the corrected *t-ratio* has the same asymptotic distribution as the ADF statistic. The tests statistics presented are for the model including a trend term. Sequential testing after exclusion of the nuisance parameters when necessary did not change the results. Table A1 presents the ADF and PP tests on both the series in levels and first differences.

Except for the real mortgage rate, all variables appear to be I(1) processes according to both the Augmented Dickey-Fuller and Phillips-Perron tests. The real mortgage rate appears to be integrated of order one according to ADF test and stationary according to PP test. However, both these tests suffer from a lack of power as noted in Campbell and Perron (1991) and DeJong *et al*. (1992). Because the two tests provide contrary conclusions for the real mortgage rate, we further perform the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS, 1992) test. The KPSS test differs from the other unit root tests employed here in that the series is assumed to be (trend-) stationary under the null. Rejecting the null would lead us to conclude that the series is non-stationary. Table A2 presents KPSS test results for the real mortgage rate variable.

As indicated by the KPSS test statistic we can reject the null hypothesis of stationarity at the 1 per cent significance level. In combination with evidence from the ADF test we conclude that the real mortgage rate is I(1).

Table A 2 Additional unit root test for the real mortgage rate

Variable Tested: *R*		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.840683
Asymptotic critical values*:	1 per cent level	0.739000
	5 per cent level	0.463000
	10 per cent level	0.347000

A.3 Additional Figures

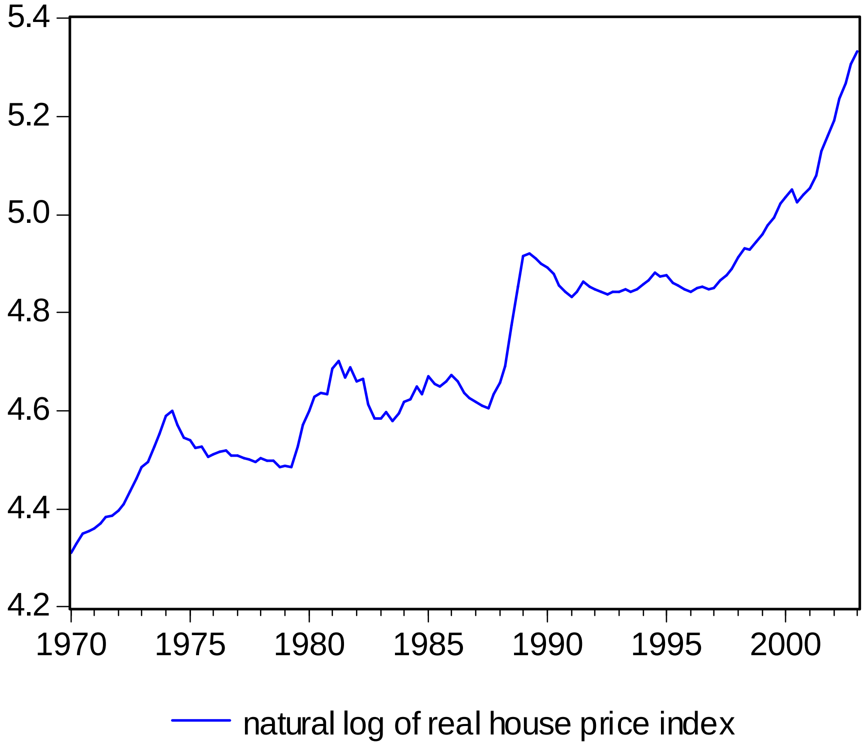


Figure A1

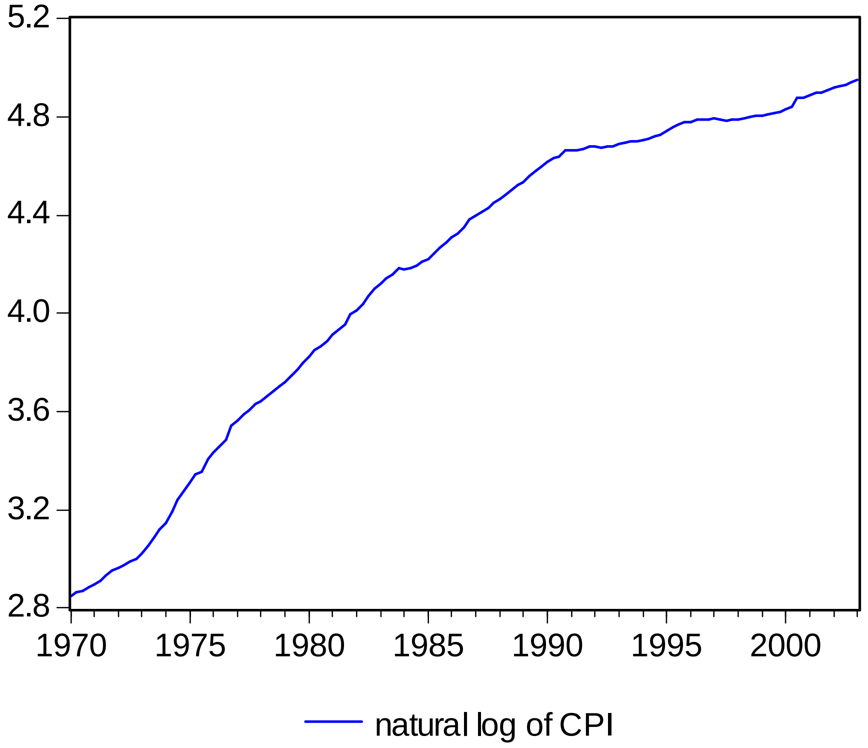


Figure A2

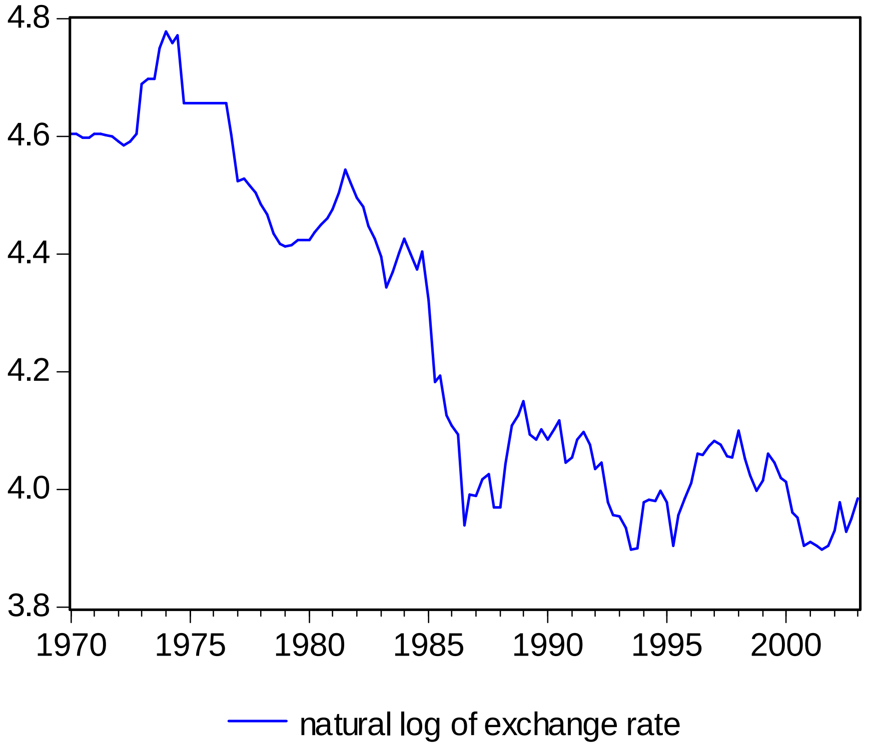
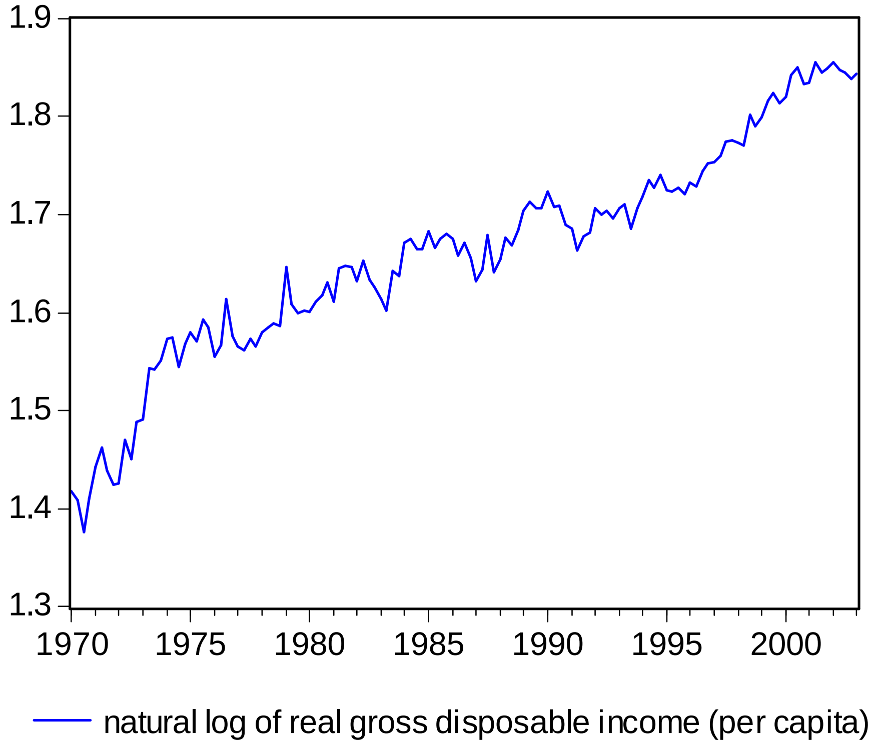


Figure A3



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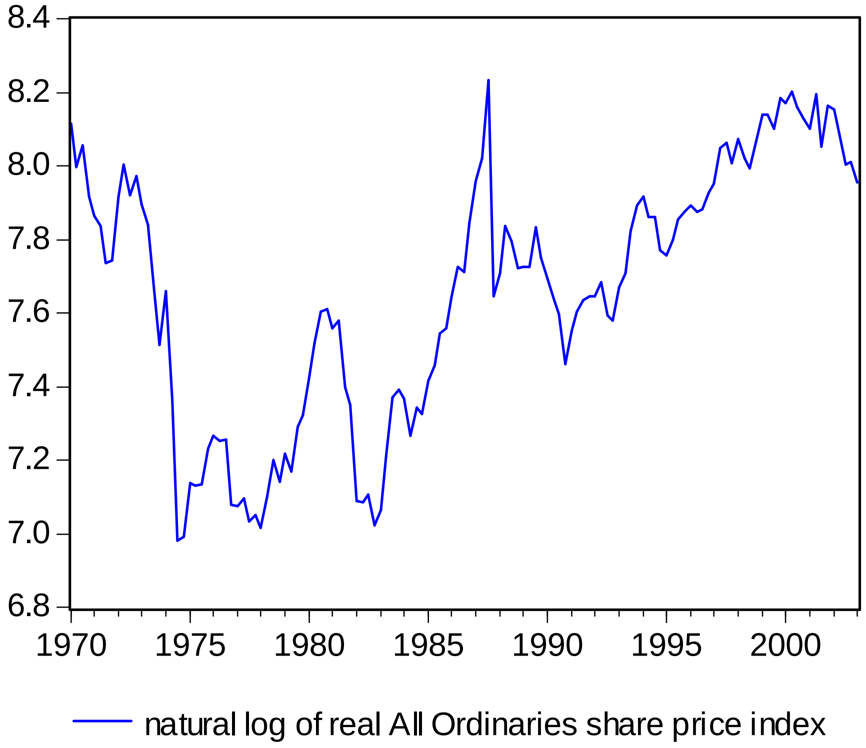

Figure A5

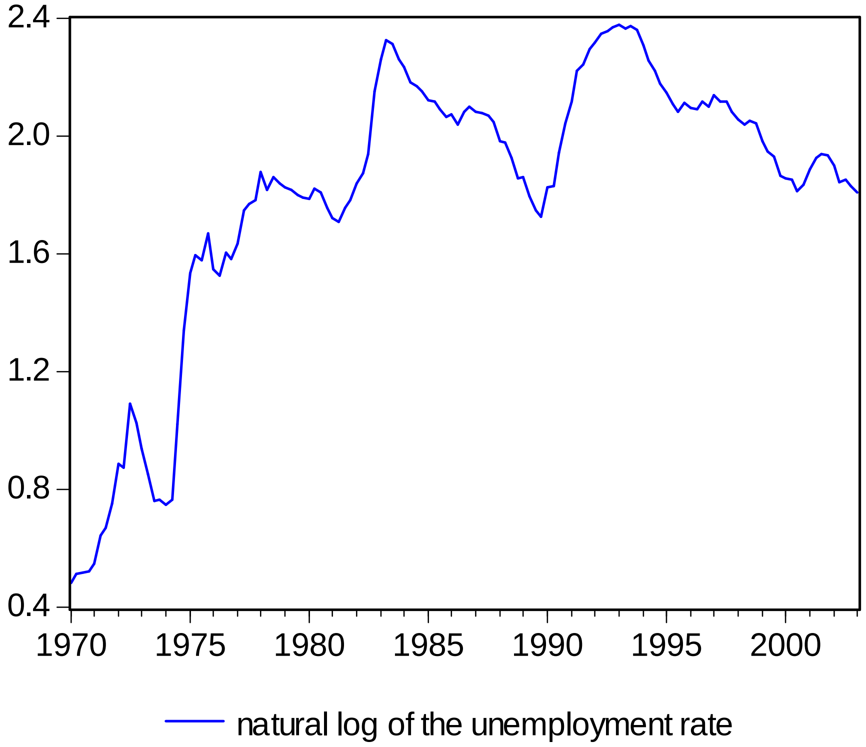

Figure A6

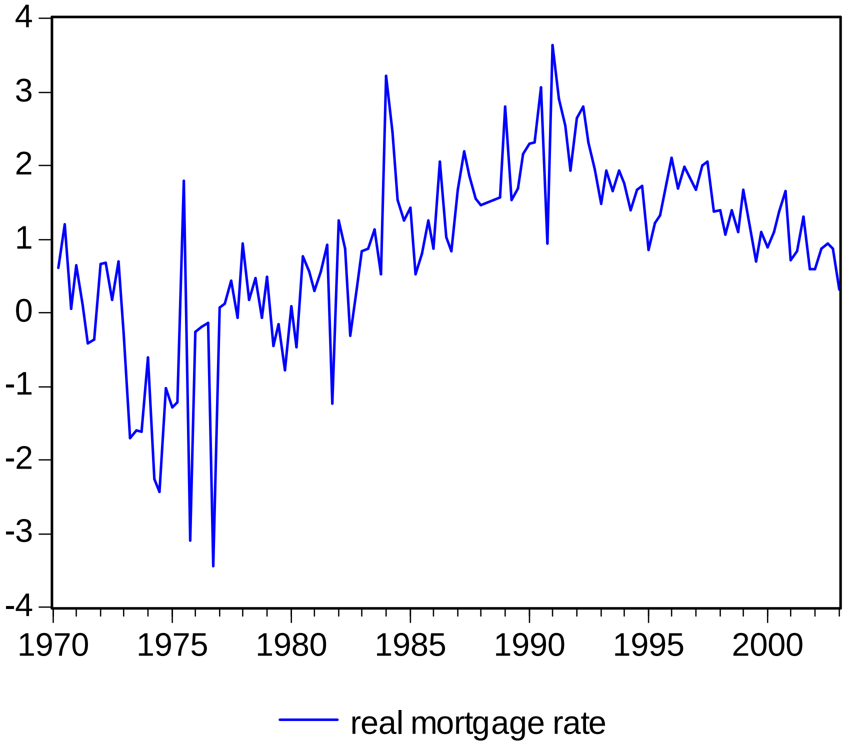

Figure A7

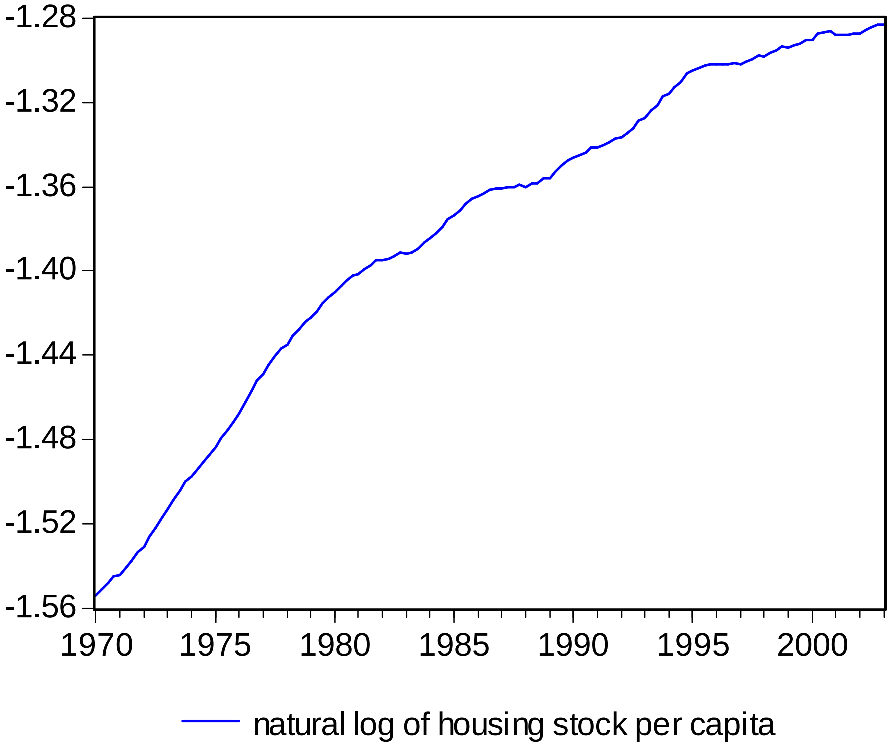

Figure A8