House prices and financial liberalisation in Australia

Williams, David M

Oxford University

1 May 2009

House prices and financial liberalisation in Australia *

David M Williams †

1 May 2009

Abstract

Financial liberalisation and innovation (FLIB) in Australia over the 1980s and 1990s provided the institutional backdrop for one of the most rapid increases in household balance sheets and house prices in the world. An equilibrium correction model of quarterly Australian house prices for 1972-2006 identifies the key long run drivers as real non-property income per house, the working age population proportion, the unemployment rate, two government policy changes, real and nominal interest rates and non-price credit conditions. All else equal, easing credit supply conditions attributable to FLIB directly raised the long run level of real house prices by around 51 per cent while higher real interest rates subtracted 29 per cent from long run prices. Real interest rates are shown to have a significant impact on real house prices after financial liberalisation but play no role before. These findings suggest that FLIB fundamentally relaxed binding credit constraints on households and enhanced opportunities for intertemporal smoothing. The model also explicitly captures short run overshooting dynamics in Australian house prices. Whenever lagged real house price growth is greater than about 4 per cent, for example during booms, house prices tend to display "frenzy" behaviour measured as a cubic of lagged house price changes.

Key words: House prices, mortgage markets, financial liberalisation
JEL classification: E21, G21

*This paper represents work in progress and comments are welcome. I am grateful to Professor John Muellbauer for his supervision and to colleagues at the Australian Treasury, Reserve Bank of Australia and Department of the Prime Minister and Cabinet for their help with data. The paper has benefited from the helpful comments of seminar participants at the International Monetary Fund, Oxford University Economics Department's Gorman Workshop Series and the January 2009 Annual Meeting of the American Economic Association in San Francisco, USA. From the latter I particularly thank Richard Dennis of the San Francisco Federal Reserve for his comments. Any errors or omissions are my own.

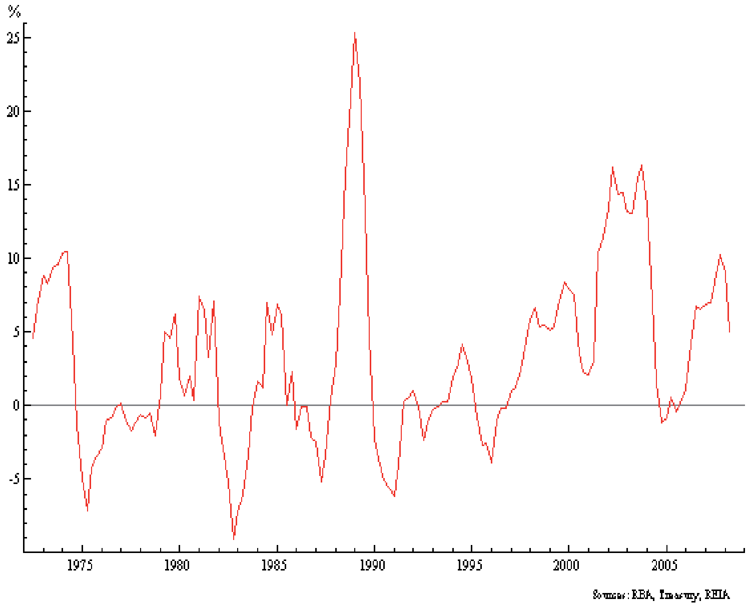
†Department of Economics, University of Oxford, Manor Road Building, Manor Road, Oxford, OX1 3UQ, UK
david.williams@economics.ox.ac.uk

Contents

1 Introduction

Australia has witnessed four house price booms over the past 34 years, from: 1971 to 1974; 1979 to 1981; 1987 to 1989; and 1996 to mid-2008 (Chart 1). The latter two booms are particularly interesting because they occurred in the context of financial liberalisation and innovation (FLIB) and a fundamental transformation of household balance sheets. Australia's ratio of household debt to disposable income quadrupled over 1980 to 2008, while gearing ratios (debt to assets) and debt servicing ratios (repayments to income) more than doubled. House prices have risen from around 4 times annualised average incomes[1] in the early 1980s to around $7\frac{1}{2}$ times average incomes in the 2000s.[2] The OECD (2005) cited Australia's average annual real house price gains across 1995-2004 as the 6th largest in the world.

Chart 1 : Real annual house price growth – Australia



This paper estimates an equilibrium correction model of Australian national house prices using quarterly data from 1972(3) to 2006(2).[3] Long run house prices are shown to be driven by real non-property income per house, non-price credit supply conditions, real and log nominal interest rates, the unemployment rate, the working age population proportion and the introduction of the first home owners' scheme (FHOS). In the short run, house price dynamics are governed by real income growth, the quarantining of negative gearing deductions during the mid-1980s, and "frenzy" dynamics whenever lagged real quarterly house price changes are greater than 4.1 per cent.

Two key influences on house prices are emphasised. The first is the impact of easing credit supply conditions due to FLIB - the proverbial "elephant in the room" in current housing and mortgage market analysis. The process of FLIB across the 1980s and 1990s included several institutional developments[4]: government deregulation; changes in market structure (new entrants and bank consolidation); debt product innovation[5]; and innovations in bank lending practices (automated credit

[1] Annualised average weekly earnings (national accounts basis) from RBA Bulletin Table G06.

[2] See Charts 9-15 at Appendix A.

[3] As robustness checks, the parsimonious model is also estimated using an updated dataset (including revisions) over 1972(3) to 2008(2) and 1979(1) to 2008(2).

[4] Appendix B provides a summary table.

[5] The 1990s witnessed a proliferation of cheaper and more flexible mortgage products. Examples for owner-occupiers include mortgage equity loans allowing redraw and offset facilities (often with no penalty for prepayment), fixed rate

scoring and underwriting, widespread use of mortgage-backed securities and mortgage insurance) leading to changes in lending standards (notably the relaxation of downpayment and repayment-to-income constraints). FLIB affected household behaviour in four dimensions, by: promoting intertemporal substitution, lowering the deposit constraint on first time buyers, unlocking the collateral value of housing wealth for older, existing owners and relaxing the balance of payments constraint on the financial sector.

A "credit conditions index" (CCI) is constructed in this paper to measure the effect of FLIB on Australian house prices.[6] This paper finds that the relaxation of non-price credit supply conditions across the 1980s and late 1990s engendered a large, structural increase in demand for housing assets. This forced higher established house prices against a highly price inelastic supply of housing assets[7]. The model suggests that easing credit constraints on Australian households, attributable to FLIB, directly increased the long run level of real house prices by around 51 per cent over the sample period. Furthermore, when the CCI is interacted with interest rates, real interest rates are shown to become significantly more important after financial liberalisation, a finding consistent with the UK work of Cameron, Muellbauer and Murphy (2006). Real interest rates rose 4.1 percentage points between 1979 and 2006, subtracting around 29 per cent from long run real house prices, all else equal. By contrast, nominal interest rates were 2.0 percentage points lower and raised long run house prices by only about 9 per cent.

The second key influence is that of "frenzy" dynamics, modelled as a cubic of lagged real house price changes, that assist in explaining house price booms and overshooting behaviour. Whenever real quarterly house price growth exceeds around 4.1 per cent, the cubic provides a short run impulse to quarter-ahead house price growth. The autoregressive dynamics, including frenzy effects, assist or dampen equilibrium correction in the short run depending on the direction of the equilibrium correction (that is, whether real house prices are under- or over-valued relative to the steady state path determined by fundamentals) and the sign and magnitude of short run real house price changes.

Two explanations of this phenomenon are possible. One is that trading costs - transaction and information costs for example - deter continuous optimisation by households. These trading costs are only overcome during booms because there is more information (about prices of comparable dwellings for example) or the potential capital gains are greater. Furthermore, real estate agents turn over properties more frequently during booms which facilitates their matching of preferences. An alternative explanation flows from Morris and Shin's (2002) model of strategic interaction. Agents seek not only to match their actions with fundamentals, but also to minimise the distance between their actions and the actions of other agents (similar to "herd behaviour"). Thus, agents have a natural tendency to overreact to public information at the expense of private information. The corollary is that public information (market and political commentary, television programming) tends to increase during booms and hence may exacerbate price volatility. Under either approach - market frictions or strategic interaction under uncertainty - large, non-linear price adjustments are induced when the market is highly active and help explain Australian house price booms.

---

loans and non-conforming loans. Examples for investors also include interest only loans, deposit bonds and split-purpose loans.

[6] Muellbauer and Murphy (1997) and Fernandez-Corugedo and Muellbauer (2006) have developed a similar measure for the UK; Aron and Muellbauer (2006) have constructed a measure for South Africa.

[7] Australia's population is concentrated in the capital cities, particularly on the east coast, where natural boundaries and/or planning restrictions hinder greenfield development. As a result, the composition of new housing investment has increasingly shifted towards renovation of the existing residential housing stock. Real annual growth in housing supply averaged around 5.6 per cent from 1960 to 1980 but thereafter average growth slowed to 4.0 per cent between 1980 to 2008 (and only 3.6 per cent on average since 1990). Meanwhile the average age of the dwelling net capital stock has risen from series low of 17.1 years in 1982 to 20.2 years in 2008. See Charts 13-15 of Appendix A.

2 Theory

The canonical housing demand function takes the following log-linear form:

$$\ln h = \alpha \ln y - \beta \ln r^h + \ln D \tag{1}$$

where h is per capita demand for housing services, y is per capita real disposable non-property income, r^h is real housing rent[8] and D represents other demand factors. α and β are the income and price elasticities respectively.[9] The equilibrium condition $r^h = p^h ucc$ is commonly imposed where p^h is the real established house price and ucc is the real after-tax housing user cost of capital. The user cost of capital can be derived as the outcome of a multi-period utility optimisation problem between housing and non-housing consumption[10]. Expressed as a rate, the housing user cost of capital is:

$$ucc = \frac{MU_h}{MU_c}\frac{1}{p^h} = (r + t^h + \delta - \frac{\dot{p}^{he}}{p^h}) \tag{2}$$

where MU_h and MU_c are the marginal utilities of housing and non-housing consumption, r is the real tax-adjusted interest rate, t^h is the net tax rate on housing[11], δ is the depreciation rate and $\dot{p}^{he}$ is expected house price appreciation.

The housing demand function can then be inverted as follows:

$$\ln p^h = \frac{\alpha}{\beta}\ln y - \frac{1}{\beta}\ln h - \ln ucc + \frac{1}{\beta}\ln D \tag{3}$$

The conditional inverse housing demand function above forms the basis of many empirical housing models in the UK and US literature[12]. The income elasticity (α) is typically estimated at around unity, allowing the following simplification:

$$\ln p^h = \frac{1}{\beta}\ln(y/h) - \ln ucc + \frac{1}{\beta}\ln D \tag{4}$$

whereby real house prices are determined by real income per house, the user cost of capital and other demand factors.[13] Furthermore $\frac{1}{\beta}$ is typically estimated at around two. The function is advantageous since it has clear interpretation from consumption theory, incorporates the portfolio and household formation motivations of housing demand and can be used to evaluate policy and structural shifts in D. Variables in D that will be considered for the Australian context include credit conditions, demographics, uncertainty, government policy changes and nominal interest rates. Furthermore the model conditions on the previous end of quarter housing stock (h_{t-1}) enabling observed changes in established house prices to be interpreted as shifts in the demand curve rather than movements along it. Finally, the model estimated in equilibrium correction form also captures the short run disequilibrium between supply and demand and can be augmented with additional relevant structural dynamics.[14]

---

[8] r^h is unobservable and must be imputed. To the extent that private rental data are available, they are unlikely to be representative of r^h since the private rental sector in Australia is relatively small, comprising a little over one quarter of the dwelling stock.

[9] Note, a complete model of the housing market would also include equations governing new housing supply (h^n) and the evolution of the dwelling capital stock ($\dot{h} = h^n - \delta h$). These are beyond the scope of the paper.

[10] See Jorgenson (1963) and Dougherty and Van Order (1982) for the seminal works.

[11] This is a highly simplied representation of tax effects. In actuality, the housing user cost of capital will be affected by: transaction taxes on purchases; local government taxes on capital values; mortgage interest deductibility; capital gains tax exemptions for owner-occupiers and discounts for investors; and expensing of depreciation for investors. Tax treatments vary considerably across countries.

[12] Examples include Buckley and Emirsch (1982), Meen (1990, 1996, 2000, 2002) and Muellbauer and Murphy (1997) for the UK; and Poterba (1984, 1991) and Mankiw and Weil (1989) for the US.

[13] The user cost of capital is sometimes negative so in empirical work the level of ucc is commonly used rather than $\ln ucc$ (alternatively a constant can be added to ucc to ensure non-negatively). Although impossible to verify, in this paper the cubic may be capturing some of this non-linearity.

[14] Note that the conditional model (4) forms only one component of a general equilibrium solution. A general

3 Literature

There is a small but growing empirical literature on Australian house prices. Tu (2000), Oster (2005) and Abelson, Joyeaux, Milunovitch and Chung (2005) base their models on the inverse housing demand function. These models tend to have higher explanatory power than the specifications used by Bourassa and Hendershott (1995) and Bodman and Crosby (2003)[15]. Nonetheless their explanatory power is below comparable UK studies (see footnote 12). There are several possible reasons for this.

First, to my knowledge no Australian study to date has employed a measure of income that excludes property-related earnings (capital gains and rent), is post-tax and that includes secondary income such as transfer payments. Non-property disposable income is the most appropriate household income metric according to consumption theory (Blinder and Deaton, 1985). Abelson *et al* (2005) and Oster (2005) adopt household gross disposable income from the national accounts[16], which is at least post-tax and includes transfer payments. However the national accounts measure includes realised property income (including rent but not capital gains) and excludes losses on assets (or gains on liabilities) due to inflation. It will therefore be distorted during swings in inflation (Lattimore (1994), Muellbauer (1994)). Alternative income measures that perform less favourably in the Australian literature include employment and real wages (Bourassa and Hendershott, 1995), real weekly earnings per employee (Tu, 2000), GDP per capita (Bodman and Crosby, 2003), employment (Chowdhury and Mallik, 2004), and the change in state final demand and unemployment rate (Otto, 2007).

Second, house prices should be conditioned on the lagged housing supply so that house price changes can be interpreted as demand curve shifts. Abelson *et al* (2005) and Hendry (1984) condition on the previous end-of-quarter real net dwelling capital stock while Muellbauer and Murphy (1997) and Meen (1990) use the number of houses[17]. Australian models that perform less well use housing completions (Tu, 2000), which are small relative to the overall dwelling capital stock, population (Oster, 2005), dwelling approvals per capita (Otto, 2007) and, under an urban growth framework, construction costs (Bourassa and Hendershott (1995), Bodman and Crosby (2003)). Chowdhury and Mallik (2005) do not control for housing supply.

Third, a wider range of explanatory variables could be considered. To my knowledge, no Australian study to date has attempted to quantify the impact of financial liberalisation and innovation over the 1980s and 1990s, nor its interaction with real and nominal interest rates. Most studies include *either* real or nominal interest rates, but the degree of financial liberalisation may make interest rates important at different times. Nominal interest rates may be important for credit constrained

equilibrium approach would endogenise (in a highly stylised manner) household choices concerning housing and non-housing consumption, leisure and tenure; as well as new housing supply and dwelling stock growth. And to be realistic, the approach would need to incorporate complex labour, credit and housing market frictions and structural shifts. Such exercises are beyond the scope of the paper.

[15] The latter base their specifications on the so-called "housing bubbles" approach by Abraham and Hendershott (1993, 1996) as follows. Actual house price changes (Δp) are argued to be a function of "fundamental" price changes (Δp^*) - based on changes in key economic or demographic variables (Δx_i) - plus a dynamic component (θ):

$$\begin{aligned} \Delta p_t &= \Delta p_t^* + \theta_t \quad \text{where} \\ \Delta p_t^* &= \sum \hat{\beta}_i \Delta x_{it} \\ \theta_t &= \lambda_0 + \lambda_1 \Delta p_{t-1} + \lambda_2 (P_{t-1}^* - P_{t-1})/P_{t-1} + \Phi_t \end{aligned}$$

The first term, the lagged price change (Δp_{t-1}), acts as a so-called "bubble builder" by making price changes persistent across periods (if $\lambda_1 > 0$). This is offset by a "bubble burster" term ($(P_{t-1}^* - P_{t-1})/P_{t-1}$), which is the percentage difference between equilibrium and actual price levels and acts to bring the model back into equilibrium after a short term disturbance. The random error is Φ.

The equilibrium level of house prices (P^*) is computed by assuming that house prices are in equilibrium at some initial point (P_0) and then scaling by the estimated Δp^* from that point:

$$P_{t-1}^* = P_0 \prod_{i=1}^{t-1} (1 + \Delta p_i^*)$$

[16] Australian Bureau of Statistics (ABS): 5206, Table 68.

[17] The latter time series is not available for Australia.

households in tightly regulated financial markets. However real interest rates may become important in liberalised markets because the price mechanism is used to clear the credit market rather than quantity controls, and because greater intertemporal smoothing is possible (Cameron *et al*, 2006). To measure risk, so far only the unemployment rate has been tested but in some cases this was included as a proxy for income. Muellbauer and Murphy (1997) and Fernandez-Corugedo and Muellbauer (2006) develop a richer representation of risk by including the unemployment rate, interest rate volatility, inflation volatility and a dummy for negative housing returns over the previous year. Furthermore, few measures of demographics have been explored for Australia. Bodman and Crosby (2003) had poor results using the proportion of the population aged 60-64. Tu (2000) found net immigration to be insignificant although an earlier study by Bourassa and Hendershott (1995) found the converse. Oster (2005) and Otto (2007) tested population in their models, though in the former's case this proxied for an omitted housing supply variable. In the latter's case, population growth was wrongly signed in two of the six models.

Fourth, the US literature (see Cho (1996) for a summary) suggests that house price models should not be strictly based on rational expectations since house prices are shown to be less than fully informationally efficient. Extrapolative expectations are instead approximated in this paper by including lagged real house price changes and cubed house price changes (that is, "frenzy" dynamics).

Finally, only three known studies have attempted to explain the boom and bust dynamics of Australian house prices. Bourassa and Hendershott (1995) and Bodman and Crosby (2003) employ the methodology of Abraham and Hendershott (1993, 1996; see footnote 15), however their so-called "bubble-builder" and bubble-burster" terms did not provide strong evidence of boom and bust behaviour and the fit of their models overall was poor. Abelson *et al* (2005) employ an asymmetric equilibrium correction mechanism showing that equilibrium correction is 50 per cent faster during house price booms. However, the R^2 of the model is only 0.4. In the UK, Hendry (1984) and Muellbauer and Murphy (1997) find highly significant non-linear "frenzy" dynamics (that is, cubed lagged real house price changes) and the explanatory power of their models is substantially higher.

In summary, modelling house prices as an inverse demand function allows a clear consumption theory interpretation and, when estimated in equilibrium correction formulation, also captures the short term disequilibrium between demand and supply. The long run equation ideally should include a measure of non-property household disposable income, the lagged housing stock, demography, risk and a representation of non-price credit conditions (CCI) interacted with real and nominal interest rates. Furthermore the dynamics of the model should seek to explain the "boom and bust" cycles of Australian house prices.

4 Specification and estimation methodology

The log run empirical version of (4) can be specified as:

$$rhp_t = a + \psi(y - h)_{t-1} + Z_{t-1}\gamma \tag{5}$$

where rhp is the log real established house price ($\ln p^h$), ψ is the inverse price elasticity ($1/\beta$, implying a unity constraint on the income elasticity of housing demand (α)), y and h are henceforth respectively log real per capita non-property income and the log real per capita net dwelling capital stock. Z is a vector of other long run variables (in levels) that shift the demand curve incorporating ucc and D from (4).

The long run model is parameterised into a dynamic specification as follows:

$$\begin{aligned} \Delta rhp_t &= \phi(a + ecm_t + Z_{t-1}\gamma) + \Delta X_t\beta + \varphi\Delta p_t + \varepsilon_t \qquad (6) \\ \text{where } ecm_t &= \psi(y - h)_{t-1} - rhp_{t-1} \end{aligned}$$

where ϕ is the speed of adjustment, ecm_t incorporates real income per house and ΔX is a vector of I(0) structural dynamics.[18] Preliminary regressions showed the coefficient on current inflation (φ) to be approximately minus one, indicating that the dependent variable can be reparameterised as the change in nominal house prices (Δnhp_t). The general unrestricted model (GUM) thus takes the following form[19]:

$$\Delta nhp_t = \phi(a_0 + ecm_t + Z_{t-1}\gamma) + \Delta X_t \beta + \varepsilon_t \tag{7}$$

The GUM is estimated in AutoMetrics (Doornik, 2007) which employs a general-to-specific model reduction strategy to omit insignificant Z and ΔX variables and deduce a parsimonious specification[20]. Strong priors are held about the variables in the GUM as guided by consumption theory, previous Australian studies and by institutional features of the Australian market. The steady state and dynamic solutions are *jointly* estimated. Direct estimation is supported by Banerjee, Dolado, Hendry and Smith (1986), Kremers (1989) and Kremers, Ericsson and Dolado (1992) who argue that this approach provides a more efficient estimation of the long run parameters where there is a unique cointegrating vector suggested by economic theory. In combining a general-to-specific model reduction strategy with a direct estimation cointegration strategy, an encompassing parsimonious model is sought that while congruent with theory is also flexible to the nuances of the data. The parsimonious empirical model is shown to deliver greater explanatory power of house price movements in terms of adjusted R^2 and similar to comparable UK specifications.

4.1 Data

The national house price index used in this paper has been spliced together from four sources: BIS Shrapnel (1972(3) to 1978(2)) via Treasury; the Real Estate Institute of Australia (REIA: 1978(3) to 1986(1)); the ABS "old" series (1986(2) to 2001(4)); and the ABS "renovated" series (2002(1) to 2006(2)).[21] The log of this composite index is *nhp*. Chart 2 highlights the different volatility in each series which motivates the use of heteroskedasticity and autocorrelation consistent standard errors (HACSEs) to conduct model reduction in AutoMetrics. A log real house price series (*rhp*)

[18] The long run model is estimated under the constraint that the inverse price elasticity of housing demand (ψ) is 2 (that is, α and β in the housing demand equations at constrained at 1 and $\frac{1}{2}$ respectively). UK estimates for ψ range from 1.5 to 2 (see Muellbauer and Murphy (1997, 2006)). Tu (2000) found ψ to be around 2 for Australia.

The justification for the constraint on ψ is that the general specification is a highly parameterised model that contains a variety of dynamic adjustment terms in addition to the long run solution. The constraints on the inverse price (and income) elasticities bring additional information to bear in the model selection procedure carried out using AutoMetrics. The ecm_{t-1} variable is expected to have a positive coefficient and is critical component of the error correction process. In any case, supplementary estimations relax the constraint on ψ and show it to be around 1.75 and within a standard error of 2.

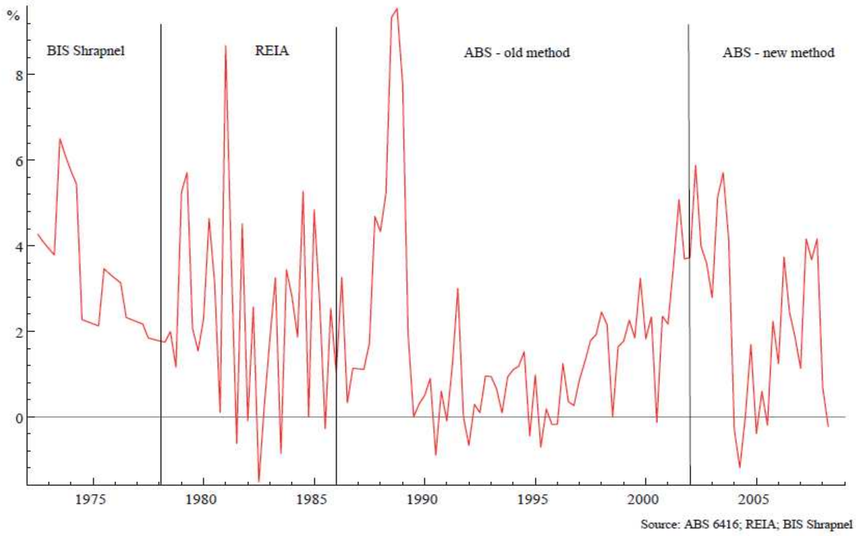
[19] Note again that the model is conditional on the lagged economic and demographic explanatory variables and therefore does not attempt to provide a general equilibrium solution enabling long range house price forecasts.

[20] AutoMetrics applies a general-to-specific model reduction strategy to deliver a data-congruent, undominated parsimonious specification. The basic methodology is as follows. A GUM is initially specified by the modeller, consonant with economic theory and including all potentially relevant information about the data generating process (DGP). Second, pre-selection checks in AutoMetrics omit highly insignificant variables from the GUM and add dummy variables for quarters where residuals exceed 2.6 standard errors. The GUM is then tested for congruency with the DGP using mis-specification tests that verify white-noise errors, conditionally and unconditionally homoscedastistic errors, normally distributed errors and constant parameters. Fourth, the model is simplified by omitting statistically insignificant variables. Mis-specification tests are conducted on each reduction, and each reduced model is compared on the basis of congruency with the DGP and minimisation of the information loss from the previous stage. The final model chosen is the model that encompasses rivals, including the GUM, satisfies mis-specification tests and conforms with priors.

[21] There is a trade-off between sample length and the potential for measurement error in the earlier (non-ABS) data. The ABS series are superior to the REIA and BIS Shrapnel data because they use compositional adjustment (that is, houses traded across time period are roughly matched by location and size). The ABS new method is more timely than the old method because it is based on the exchange of contracts date rather than settlement date. REIA data shows the most volatility and this is likely due to the lack of compositional adjustment and incomplete coverage of housing transactions.

is constructed by subtracting the log household consumption implicit price deflator (p) (ABS 5206, Table 12) from nhp.

Chart 2 : Australian nominal house prices
(quarterly changes)



The GUM incorporates the key elements of the inverse housing demand function[22]: log real income per house ($y_{t-1} - h_{t-1}$); the user cost of capital (real interest rates (r_{t-1}) and expected housing capital gains proxied by autoregressive terms ($\Delta_4 rhp_{t-1}$, $\Delta rhp_{t-1,t-2}$, $frenzy_{t-1}$)[23] assuming extrapolative expectations); and other factors that shift the demand curve. Other demand factors include: a credit conditions index (CCI) represented by a time trend (t) beginning in 1972(3) and three split trend dummies (CCI_{79}, CCI_{92}, CCI_{98})[24]; log nominal interest rates (Li), relevant for credit-constrained households; interaction effects between CCI and interest rates (($CCI^* \times r_{t-1}$), ($CCI^* \times Li_{t-1}$))[25]; demographic variables (WA_{t-5}, $\Delta_4 dem1_{t-1}$, $\Delta_4 dem2_{t-1}$, $\Delta_4 pop_{t-1}$)[26], the log unemployment rate (Lue_{t-1}) and the first home owners' grant ($FHOS_{t-1,t-5}$). The dynamic terms include changes in: per capita income ($\Delta_4 y_{t-1}, \Delta y_{t-1,t-2}$)[27]; log nominal interest rates ($\Delta_4 Li_{t-1}, \Delta Li_{t-1,t-2}$); inflation ($\Delta\Delta p_{t-1,t-2}$); share prices ($\Delta_4 s_{t-1}$, $\Delta s_{t-1,t-2}$); the imposition of restrictions on negative gearing deductibility (NG_t); risk variables (inflation volatility ($infvol_{t-1}$), nominal interest rate

[22] In the notation that follows, $\Delta rhp_{t-1,t-2}$ is an abbreviation for Δrhp_{t-1} and Δrhp_{t-2}.

[23] $frenzy$ is defined in Section 4.2.4.

[24] These are four quarter moving averages of linear trends beginning in 1979(1), 1992(1) and 1998(1) corresponding to the turning points identified in Section 5.1.

[25] Real and log nominal interest rates are de-meaned using the post-1979 arithmetic means of r and Li respectively. These are interacted with a composite CCI variable: $CCI^* = CCI_{79} - 1.5 \times CCI_{92} + CCI_{98}$.

Note that initial estimations were conducted with unitary constraints on each of CCI_{79}, CCI_{92} (negative) and CCI_{98} to construct CCI^*. The constraints correspond to the STAMP analysis of Section 5.1. However, subsequent estimations showed that CCI^* should be refined with a 1.5 times weight on CCI_{92}.

[26] Respectively these are: the proportion of the resident population of working age (15-64 years); annual growth in the population of first home buyer aged persons (22-34 years); annual growth in the population of investor aged persons (35-64 years); and the annual change in the resident population.

Net immigration was not tested although it forms part of the demographic impulses for household formation outlined above. Net immigration might be more appropriate for model of capital city house prices (especially Sydney).

[27] Note that preliminary estimations showed Δy_{t-1} with a negative coefficient of around 0.2 indicating that real income per house in ecm_t could be reparametised as $y_{t-2} - H_{t-1}$. This is a purely cosmetic change to show Δy_{t-1} with a positive coefficient. Equivalently it suggests that long run house prices are a function of real income per house with income as a lagged two quarter moving average.

volatility ($intsup_{t-1}$), change in the unemployment rate ($\Delta_4 Lue_{t-1}, \Delta Lue_{t-1,t-2}$); downside risk ($DSrisk_{t-1,t-5}$)); and seasonal and outlier dummies. Appendix C provides more detail.[28]

Table 1 : Explanatory variables in the GUM

Type		**Long run variables** (Z)	**Short run variables** (ΔX)
Credit conditions		t, CCI_{79}, CCI_{92}, CCI_{98}	
Log income per house		$y_{t-1} - H_{t-1}$	
Interest rates		r_{t-1}, Li_{t-1}	$\Delta_4 Li_{t-1}$, $\Delta Li_{t-1,t-2}$
CCI interaction terms		$CCI^* \times Li_{t-1}$, $CCI^* \times r_{t-1}$	
Demographics		WA_{t-5}, $\Delta_4 dem1_{t-1}$, $\Delta_4 dem2_{t-1}$, $\Delta_4 pop_{t-1}$	
Policy dummies		$FHOS_{t-1}$, $FHOS_{t-5}$	NG_t
Risk -	unemployment rate	Lue_{t-1}	$\Delta_4 Lue_{t-1}$, $\Delta Lue_{t-1,t-2}$
	interest rate volatility		$intsup_{t-1}$
	inflation volatility		$infvol_{t-1}$
	downside risk		$DSrisk_{t-1,t-5}$
Share price dynamics			$\Delta_4 s_{t-1}$, $\Delta s_{t-1,t-2}$
Inflation dynamics			$\Delta\Delta p_{t-1,t-2}$
Autoregressive terms			$\Delta_4 rhp_{t-1}$, $\Delta rhp_{t-1,t-2}$ $frenzy_{t-1}$

4.2 Explanation of key variables

4.2.1 Non-property income

A measure of per capita log real *non-property* household disposable income (y) for Australia (Blinder and Deaton, 1985) is constructed from the household income account (ABS 5206, Table 68). To calculate y, the log household consumption deflator (p) and log resident population (pop) are subtracted from log nominal non-property household disposable income (npy). To calculate npy, a measure of "non-property income payable" (*npy payable*) is deducted from a measure of "non-property income receivable" (*npy receivable*). The measures are in gross terms (before depreciation) but net of tax. Non-property income *receivable* is defined as gross compensation of employees (wages and salaries), gross mixed income (profits of unincorporated businesses owned by households, (GMI)) plus secondary income receivable (social benefits such as workers' compensation payouts, social assistance benefits etc). Alternatively, this can be constructed as total income receivable (*total income rec*) less "gross operating surplus on dwellings" (*GOS on dwellings*) less "property income receivable" (*prop income rec*).

Non-property income *payable* is defined as total income payable less *interest on dwellings* and less income tax attributable to dwellings[29]. Note, there is no tax on imputed rent for owner-occupiers however, unlike the US (and the UK until 2001), mortgage interest is not deductible for owner-occupiers. "Income tax payable" includes taxes on wages and salaries, unincorporated profits as well as property related taxes. This presents a problem: property related tax applies to commercial rents (at marginal tax rates) and capital gains (of which owner-occupied dwellings are exempt but investor properties attract different CGT treatments depending on the time of purchase). National accounts data, Australia Tax Office tax statistics and Treasury Budget data do not provide sufficient detail on

[28] Note that exchange rate effects on house prices were also investigated in early GUMs without significance. Abelson *et al* (2005) similarly did not find exchange rate effects.

[29] The main components of "total income payable" are income tax payable, property income payable (interest on dwellings and consumer debt interest), net non-life insurance premiums and social contributions to workers' compensation. The objective is to strip out the property related components of "total income payable".

personal tax revenue to separately identify revenue related to the taxation of rent and capital gains for investors.

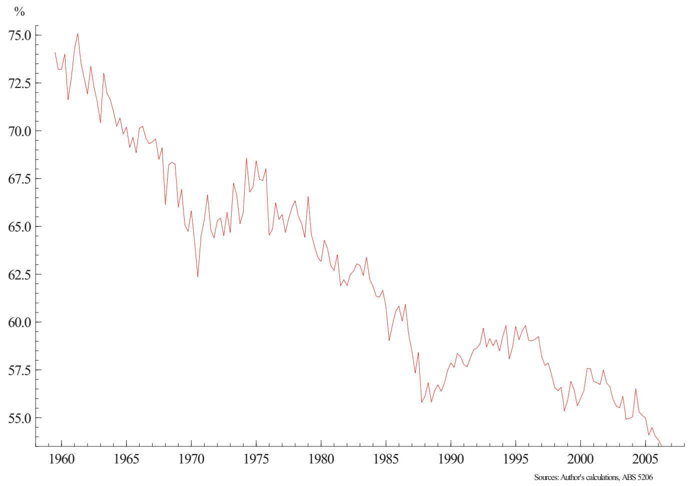
To overcome this dilemma, "income tax payable" is multiplied by a proxy for the proportion "likely" to be attributable to dwellings. This proxy is based on the proportion of total income *received* from dwellings - that is, property income receivable ("gross operating surplus (GOS) on dwellings" plus "property income receivable") as a proportion of total gross income receivable. This proportion is multiplied by income tax payable to derive the estimate.

The methodology is summarised as follows:

$$\begin{aligned} npy &= npy\ receivable - npy\ payable \\ npy\ receivable &= gross\ comp\ of\ employees + GMI + secondary\ income\ rec \\ &= total\ income\ rec - GOS\ on\ dwellings - prop\ income\ rec \\ npy\ payable &= total\ income\ payable - interest\ on\ dwellings \\ & \quad - \left(\frac{GOS\ on\ dwellings + prop\ income\ rec}{total\ income\ rec} \right) \times income\ tax\ payable \end{aligned}$$

Chart 3 shows the ratio of household disposable non-property income to GDP for Australia. The downward trend reflects a rising profit share (in part due to the increasing incorporation of small businesses since the 1980s) as well as an increasing share of income from dwellings.

Chart 3 : Non − property household disposable income
(as a proportion of GDP)



4.2.2 Government policy changes

The effects of two major government policy changes on house prices are tested in this paper. First, negative gearing deductions were quarantined[30] between 17 July 1985 and 15 September 1987 resulting in a collapse in investor demand. An impulse dummy (NG) is constructed that equals 1 between 1985(3) and 1987(3) and equals 0 otherwise.

Second, the first home owners' scheme (FHOS) introduced in July 2000 provided a $7,000 grant for first time owner-occupying home buyers purchasing new and established dwellings. The government

[30] Losses in relation to rental properties could only be deducted against rental income (not ordinary income) for this period.

extended the grant in March 2001 by providing an *additional* \$7,000 for first time buyers of newly constructed dwellings. The *additional* FHOS was reduced to \$3,000 from January to June 2002 and ceased thereafter[31]. During 2000 and 2001 around 147,126 grants were approved at a cost of around \$1 billion (Chowdhury and Mallik, 2004). Chowdhury and Mallik (2004) found a significant FHOS effect measured a simple binary step dummy. However their measure did not reflect the additional grant provided from 2001(1) and the nominal grant amount was not scaled relative to its purchasing power against nominal house price levels.

The $FHOS$ dummy in this paper is calculated as a four quarter moving average of the nominal amount of the grant divided by the nominal median Australian house price level. A median house price level series is constructed using a point estimate (September quarter 2004) from the REIA's "Market Facts" publication and then scaling this by the change in the nominal house price index (Δnhp).

4.2.3 Risk

Movements in risk may play an important role in house price dynamics. Four measures of risk are introduced by Muellbauer and Murphy (1997) for UK house prices and by Fernandez-Corugedo and Muellbauer (2006) for UK mortgage credit: inflation volatility, nominal interest rate volatility or surprise; the unemployment rate and downside (asymmetric) risk. Inflation volatility ($infvol$) is a four quarter moving average of the absolute annual change in annual inflation ($abs(\Delta_4 p_t - \Delta_4 p_{t-4})$). Interest rate surprise ($intsup$) is defined as unanticipated changes in the log nominal mortgage interest rate (Li). To measure unanticipated changes, a general model of log mortgage interest rates (Li_t) is estimated in AutoMetrics using lagged mortgage interest rates, four lags of the 90 day bank bill rate, four lags of the 10 year Treasury bond rate and one lag (owing to data limitations) of the 5 year Treasury bond rate. $intsup$ is the residual of the parsimonious model[32]. The log unemployment rate appears in the long run solution as well as in the dynamics. Higher unemployment indicates labour market instability and increases the risk of mortgage default.

Downside risk ($DSrisk$) reflects potential asymmetric risk aversion. Households may be highly averse to periods of negative rates of returns, but are neutral to receiving positive returns. This aversion may be acute for liquidity constrained households who can increase saving but not borrowing in response to fluctuating capital values. A measure of the nominal rate of return on housing (ror) is calculated as:

$$ror_t = \Delta_4 nhp_{t-1} + 0.02 - \frac{i_t}{100} \tag{8}$$

where 0.02 is an estimate of rental returns net of maintenance and depreciation and i_t is the real interest rate. $DSrisk$ is thus defined as:

$$\begin{aligned} DSrisk_t &= 0 \quad \text{if } ror_t \geq 0 \\ &= ror_t \text{ if } ror_t < 0 \end{aligned} \tag{9}$$

4.2.4 Frenzy

Non-linear adjustment dynamics are modelled in the form of "frenzy" effects[33]. Hendry (1984) pioneered the use of a cubic of lagged real house price changes ($(\Delta rhp_{t-1})^3$) to approximate periods of

[31] On 14 October 2008 the new Labor Government doubled the grant in relation to established dwellings (from \$7,000 to \$14,000) and tripled the grant in relation to newly constructed dwellings (from \$7,000 to \$21,000). The increases apply until 30 June 2009.

[32] The expected sign on $intsup$ in the house price equation is negative. Housing debt is the main liability carried by households and so unanticipated movements in nominal interest rates impact on the short term cash flow of credit constrained households.

[33] Also known as "threshold" dynamics.

excess demand or large disequilibria. Muellbauer and Murphy (1997) find cubic effects significant in their UK model using annual data. The advantage of the cubic is that it preserves the sign of the price change - so has the advantage of acting symmetrically - and becomes infinitesimal when price changes are small. Because $(\Delta rhp_t)^3$ is collinear with other autoregressive terms in the GUM, the cubic is reparameterised in this paper as the residual of the following regression: $(\Delta rhp_t)^3 = \alpha + \beta \Delta rhp_t + \varepsilon_t$. That is, $frenzy_t = (\Delta rhp_t)^3 - \hat{\alpha} - \hat{\beta}\Delta rhp_t$. This reparameterisation ensures othogonality between $frenzy_{t-1}$ and Δrhp_{t-1} in the house price regression. OLS estimation of the cubic regression produced $\hat{\alpha} = 2.5745 \times 10^{-7}$ and $\hat{\beta} = 0.002434$. These fitted values, combined with the coefficients on $frenzy_{t-1}$ and Δrhp_{t-1} from the house price regression, can be used to recalculate the actual coefficients on $(\Delta rhp_t)^3$ and Δrhp_{t-1}.

There are at least two possible reasons that Walrasian price adjustment might be non-linear in housing markets. One hypothesis is that high transaction, computation, measurement or information costs deter trade during normal market periods. Shefrin and Thaler (1988) argue that agents adopt "rules of thumb" behaviour because trading costs discourage continuous intertemporal optimisation. These (threshold) costs are overcome when activity is high and price changes are large. Households may, for example, lack information about the price of comparable dwellings in their location except during periods of high market activity. The coordination role of real estate agents in matching demand and supply through time may be enhanced when housing turnover is high. These periods may provide agents with an opportunity to trade to restore optimisation and relieve pent-up excess demand. Abelson *et al* (2005) provide partial support for this logic finding that equilibrium correction is 50 per cent faster during house price booms.

An alternative justification for non-linear dynamics is derived from Morris and Shin's (2002) game theoretic model on the social value of public information. The model has its origins in the "sunspots" literature pioneered by Jevons (1884), the "beauty contest" analogy of Keynes (1936) and the "island economy" models of Phelps (1970) and Lucas (1972, 1973). Morris and Shin posit that public information has a dual role: conveying information about fundamental values (the "true state"); and as a focal point for beliefs about the actions of other agents. The assumption is that agents in their objective function care about the distance between their action and the true state *and* the distance between their action and the average action of the other agents.

If there is perfect information for all agents about the true state then the unique equilibrium of the players' game is also the social welfare maximising outcome. When information about the true state is *imperfect*, there are two possible outcomes. If agents possess no private information, greater precision in public information always increases social welfare. However, if agents possess some private information, greater precision of public information may not necessarily improve social welfare. This is because agents, in forming beliefs about the likely strategies of the other players, have a tendency to overweight the importance of public information relative to private information and so overreact to public signals. The key welfare implication is that if agents care more about aligning with the beliefs of other agents (relative aligning actions to the true state), and if their private signal is relatively precise (that is, agents are already privately well informed), then the authorities should avoid providing additional public information about the true state unless that information is of very high quality.

In the context of housing markets, periods of high activity tend to coincide with potentially noisy market and political commentary. High activity also prompts, for example, a plethora of housing-related media programming purporting to provide information to home-owners and housing market participants. During the peak of the house price boom during the early 2000s there were as many as eight housing-related lifestyle programmes between just two of the three commercial television networks in Australia.[34] It seems plausible that public information about true housing values becomes noisier during boom periods and leads to greater volatility in house price dynamics.

[34] These programs include: *Auction Squad* (2004) (Seven Network); *Australia's Best Backyards* (2007-) (Seven); *Backyard Blitz* (2000-) (Nine Network); *Better Homes and Gardens* (1995-) (Seven); *Burke's Backyard* (1987-2004) (Nine); *DIY Rescue* (2003) (Nine); *Ground Force* (1999-2004) (Seven); *Hot Property* (1999-2004) (Seven); *Renovation Rescue* (2006-) (Nine); and *The Block* (2003-2004) (Nine).

5 Preliminary analysis

5.1 Unobserved components analysis

The next step is to develop a representation of non-price credit supply conditions. The general model is estimated in STAMP[35] omitting all constants, trends and outlier dummies to examine its time series components. STAMP uses algorithms such as the Kalman filter to fit the unobserved components of time series models such as trends, seasonals, cycles and irregular components. After controlling for a wide range of economic and demographic factors (Table 2), the remaining unobserved stochastic trend present in the house price data arguably has a direct interpretation as the impact of credit conditions which structurally shift the level of real house prices.[36]

The general model is estimated as a stochastic (local linear) trend model with fixed level. This specification is imposed to show changes in credit conditions as a smooth, evolutionary process:

$$\Delta nhp_t = \mu_t + \eta_t + X_t\beta + \varepsilon_t \qquad \varepsilon_t \sim NID(0, \sigma_\varepsilon^2) \tag{10}$$

where μ_t is the trend, η_t is a trigonometric seasonal component, X is a vector of the (long and short run) economic and demographic explanatory variables, and ε_t is the irregular component. The stochastic trend component (μ_t) is estimated as:

$$\mu_t = \mu_{t-1} + \nu_{t-1} \tag{11}$$

$$\nu_t = \nu_{t-1} + \zeta_t, \qquad \zeta_t \sim NID(0, \sigma_\zeta^2) \tag{12}$$

where ν_t is the slope of the trend and ς_t is the random error.

Table 2 provides the STAMP estimation results. STAMP is not used here for model selection or evaluation purposes - this role is played by AutoMetrics. It is nonetheless worth noting that the key long run variables ecm_t, real (r_{t-1}) and nominal interest rates (Li_{t-1}) are significant at the 5 per cent level and appropriately signed. The standard error of the model is 0.0142 and the coefficient on the ecm_t indicates a speed of adjustment of around 17 per cent per quarter. This is consistent with other Australian equilibrium correction models.

The more important result is that, after conditioning on a wide range of economic and demographic factors, STAMP reveals an unobserved stochastic trend in the house price model. The stochastic trend, plotted in Chart 4, broadly corresponds with the pattern of financial sector changes described in Appendix B. The stochastic trend also broadly corresponds with the experiences of the UK (Fernandez-Corugedo and Muellbauer, 2006) and South Africa (Aron and Muellbauer, 2006) although the timing of the turning points are country-specific.

The turning points from the STAMP analysis for Australia can be used to construct a measure of credit conditions in a general house price model.[37] The estimated stochastic trend is basically flat from 1972(3) to about 1979(1), rises steeply from 1979(1), slows down between approximately 1992(1) to 1998(1), and accelerates again thereafter. The steep rise between 1979 and 1992 can be attributed to substantial government deregulation, while the rise after 1998 may reflect debt product innovation. The pause between the two periods corresponds with a period of negative returns for the banking

[35] Structural Time Series Analyser, Modeller and Predictor (Koopman *et al,* 2000).

[36] Since credit conditions are measured as a residual impact, there is the possibility of the stochastic trend measuring for some other unobserved variable. For this reason the model is estimated on a fairly exhaustive set of economic and demographic variables. Furthermore, strong priors are held about the likely shape of the CCI process (see Appendix B).

Alternative measures of the non-price influences on credit markets or consumption include: the stock of personal credit to GDP (Bayoumi, 1993); interest spreads between borrowing and lending rates (Scott (1996), Bacchetta and Gerlach (1997), Japelli and Pagano (1989)); the proportion of young households likely to be credit constrained (Japelli and Pagano, 1989); and a measure of mortgage rationing constructed by Meen (1990). Nonetheless with the exception of Meen's measure, all suffer from endogeneity with other economic and demographic variables - income, interest rates, risk, expectations - and thus fail to be non-price in nature.

[37] Note that STAMP cannot estimate the interaction effects between the stochastic trend and economic variables, such as interest rates, so the estimated stochastic trend can only be treated as an approximation.

sector in which the poor loan books of major banks (after the business lending excesses of the 1980s) constrained new lending and necessitated recapitalisation.

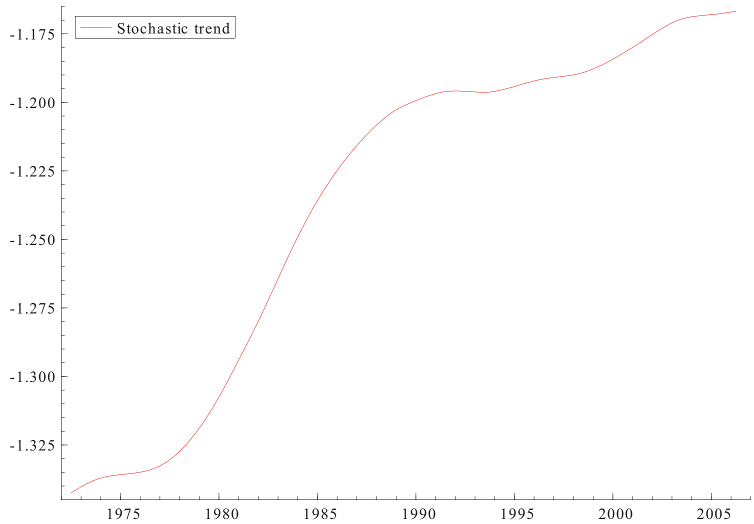
Table 2 : General specification STAMP results[38]

Dependent $= \Delta nhp_t$

1972(3) *to* 2006(2)

Variable	Coefficient	Rmse	**Variable**	Coefficient	Rmse
Li_{t-1}	-0.0679**	0.0289	$\Delta_4 Li_{t-1}$	0.0053	0.0306
r_{t-1}	-0.4585**	0.1752	$\Delta_4 s_{t-1}$	-0.0453**	0.0138
ecm_t	0.1659**	0.0695	Δs_{t-1}	0.0420*	0.0217
Lue_{t-1}	-0.0075	0.0270	Δs_{t-2}	0.0613**	0.0223
WA_{t-5}	0.0516	0.0447	$\Delta\Delta p_t$	-0.3832	0.2731
$\Delta_4 pop_{t-1}$	2.5391	1.9374	$\Delta\Delta p_{t-1}$	-0.2797	0.3116
$\Delta_4 dem1_{t-1}$	0.0886	0.1173	$\Delta\Delta p_{t-2}$	0.0608	0.2583
$\Delta_4 dem2_{t-1}$	-0.03444	0.0811	$\Delta_4 Lue_{t-1}$	0.0030	0.0222
NG_t	-0.0201**	0.0092	ΔLue_{t-1}	0.0203	0.0343
$FHOS_{t-1}$	0.0021	0.0037	ΔLue_{t-2}	-0.0573	0.0379
$FHOS_{t-5}$	-0.0000	0.0000	$intsup_{t-1}$	0.1022	0.0866
$\Delta_4 y_{t-1}$	0.0458	0.0993	$infvol_{t-1}$	-0.5253**	0.2645
Δy_{t-1}	0.2528*	0.1356	$DSrisk_{t-1}$	0.0367	0.0961
Δy_{t-2}	0.0216	0.1125	$frenzy_{t-1}$	0.0313	0.1126
ΔLi_{t-1}	-0.0714	0.0819	$\Delta_4 rhp_{t-1}$	-0.0694	0.0713
ΔLi_{t-2}	-0.0012	0.0483	Δrhp_{t-1}	0.1953*	0.1077
			Δrhp_{t-2}	0.17323	0.1069
Diagnostics					
R^2	0.65282				
Std error	0.014166				
Normality	8.5228				
DW	2.0748				

Chart 4 : STAMP model – unobserved stochastic trend



[38] ** and * denotes t-test significance at the 5 and 10 per cent levels respectively.

Table 3 : Estimation results[39]
(dependent variable is Δnhp_t)

	Model A	**Model B**	**Model C**	**Model D**
	1972(3)-2006(2)	*1972(3)-2006(2)*	*1972(3)-2008(2)*	*1979(1)-2008(2)*
Constant	-1.5064*** (0.3553)	-1.6843*** (0.3691)	-1.0981*** (0.2874)	-1.0814 (0.9329)
ecm_t	0.1797*** (0.0228)	0.2006*** (0.0221)	0.2428*** (0.0270)	0.2558*** (0.0336)
Li_{t-1}	-0.0951*** (0.0189)	-0.0727*** (0.0113)	-0.0545*** (0.0092)	-0.0619*** (0.0100)
CCI_{79}	0.0020*** (0.0003)	0.0019*** (0.0003)	0.0021*** (0.0003)	0.0020** (0.0008)
CCI_{92}	-0.0030*** (0.0004)	-0.0030*** (0.0004)	-0.0027*** (0.0004)	-0.0024** (0.0011)
CCI_{98}	0.0018*** (0.0005)	0.0020*** (0.0005)	0.0020*** (0.0004)	0.0021*** (0.0008)
$CCI^* \times Li_{t-1}$	0.0012* (0.0006)			
$CCI^* \times r_{t-1}$	-0.0213*** (0.0040)	-0.0167*** (0.0030)	-0.0163*** (0.0028)	-0.0153*** (0.0038)
WA_{t-5}	0.0574*** (0.0073)	0.0653*** (0.0069)	0.0672*** (0.0069)	0.0693*** (0.0124)
$DSrisk_{t-1}$	0.1104** (0.0462)		0.0907* (0.0525)	
Lue_{t-1}	-0.0308*** (0.0087)	-0.0361*** (0.0080)	-0.0338*** (0.0076)	-0.0295** (0.0128)
Δy_{t-1}	0.2234*** (0.0508)	0.2578*** (0.0470)	0.3308*** (0.0466)	0.3534*** (0.0549)
Δrhp_{t-1}	0.2267*** (0.0743)	0.2178*** (0.0751)	0.2592*** (0.0711)	0.2135** (0.0841)
$\Delta_4 rhp_{t-1}$	-0.1248*** (0.0420)	-0.0730** (0.0362)	-0.0877** (0.0364)	-0.0398 (0.0358)
$frenzy_{t-1}$	190.917*** (20.03)	195.655*** (21.72)	181.495*** (20.33)	193.895*** (24.15)
NG_t	-0.0208*** (0.0019)	-0.0207*** (0.0020)	-0.0160*** (0.0023)	-0.0155*** (0.0023)
$FHOS_{t-5}$	0.0104*** (0.0020)	0.0099*** (0.0022)	0.0109*** (0.0019)	0.0105*** (0.0021)
$Seasonal_{t-1}$	0.0064*** (0.0018)	0.0066*** (0.0018)	0.0053*** (0.0018)	0.0055** (0.0021)
$dum81(1)$	0.0583*** (0.0035)	0.0590*** (0.0037)	0.0603*** (0.0037)	0.0588*** (0.0040)
$dum81(4)$	0.0309*** (0.0036)	0.0298*** (0.0040)	0.0296*** (0.0036)	0.0284*** (0.0048)
$dum88(3)$	0.0518*** (0.0037)	0.0563*** (0.0039)	0.0478*** (0.0038)	0.0535*** (0.0038)
$dum91(3)$	0.0394*** (0.0029)	0.0409*** (0.0028)	0.0393*** (0.0028)	0.0388*** (0.0031)
Std error	0.00956679	0.00975616	0.00981951	0.0102485
R^2	0.831148	0.821317	0.814213	0.815453
F test	F(21,114): 26.72	F(19,116): 28.06	F(20, 123): 26.95	F(19,98): 22.79
DW	2.00	1.98	1.99	1.98
T	136	136	144	118
Diagnostics	*(p-values):*			
AR 1-5 test	0.2439	0.2174	0.5605	0.5399
ARCH 1-4 test	0.2642	0.2558	0.2793	0.2737
Normality test	0.5306	0.3263	0.5616	0.8392
Hetero test	0.8271	0.8927	0.6014	0.2371
RESET test	0.4189	0.2276	0.4457	0.4849

6 General model estimation

6.1 Overview

The general unrestricted model (GUM) is estimated in AutoMetrics over 1972(3) to 2006(2) (Table 3 above).[40] Four proxy variables are included in the GUM to mimic the turning points of the credit conditions process (t, CCI_{79}, CCI_{92}, CCI_{98}). Interaction effects with real and log nominal interest

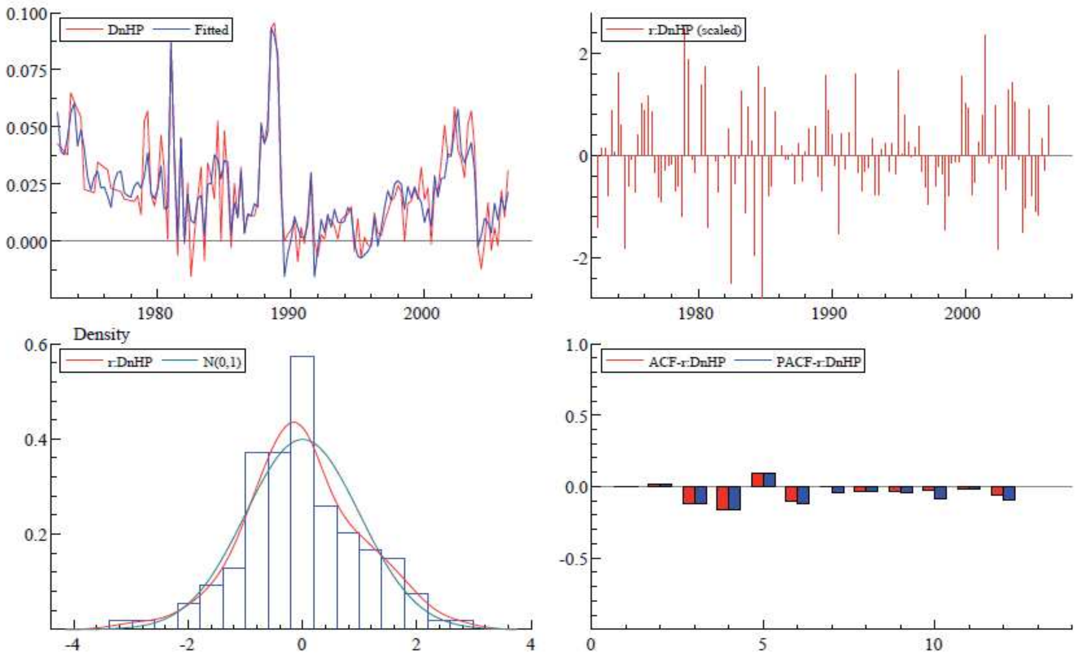
[39] ***, ** and * denote significance at the 1, 5 and 10 per cent levels respectively.
[40] The only term that cannot be excluded during the model reduction process is the intercept.

rates are also incorporated ($CCI^* \times r_{t-1}$ and $CCI^* \times Li_{t-1}$)[41].

Model A and B show the parsimonious specifications after model reduction using target p-values of 0.05 and 0.001 respectively. Both models display high explanatory power and satisfy diagnostic tests for autocorrelation, heteroskedasticity, normality and misspecification. Model A is the richer specification since it retains $DSrisk_{t-1}$ and $CCI^* \times Li_{t-1}$ which are significant at the 5 and 10 per cent levels respectively[42]. With these two exceptions, all regressors are significant at the 1 per cent level in both models with very similar coefficients. Model B is the more parsimonious equation and for this reason is slightly preferred to Model A. Model B has a standard error of 0.00976 meaning that 95 per cent of the fitted values of quarterly nominal house price changes predicted by the model are within 1.95 per cent (0.00976×2 standard errors) of the actual price change. This is a satisfactory level of explanatory power considering the standard deviation of the dependent variable (Δnhp) over 1972(3)-2006(2) is 2.14 per cent.

Chart panel 5 shows the residuals of Model B. The scaled residuals show slightly higher variation in the first part of the sample period. This is likely due to measurement error (and higher variance) in the house price data because of a lack of compositional adjustment and narrower survey coverage before 1986 (that is, pre-Australian Bureau of Statistics data). The ACF/PACF chart also shows some mild negative autocorrelation present at the third, fourth and sixth lags. Although these findings do not present serious concerns - since the models satisfy diagnostic tests for autocorrelation and heteroskedasticity tests even at the 1 per cent level - they support the use of HACSEs for model reduction.

Chart panel 5 : Residual analysis of Model B



[41] The STAMP estimation of Section 5.1, excluding interaction effects, suggested that the stochastic trend (as a proxy for the credit conditions index) flattens out between 1992 and 1998. However, initial estimations in AutoMetrics inclusive of interaction effects that CCI_{92} is about (negative) 1.5 times as large as CCI_{79} and CCI_{98}. That is, credit conditions tightened between 1992 and 1998. Hence CCI^* for the interaction terms is defined as $CCI_{79} - 1.5 \times CCI_{92} + CCI_{98}$.

[42] AutoMetrics includes $CCI^* \times Li_{t-1}$ even though its significance is outside the target p-value of 0.05. This is because AutoMetrics tests multiple model reduction paths and finds that a parsimonious model including $CCI^* \times Li_{t-1}$, for the sample period, outperforms a model excluding the variable in terms of data congruence (fit, diagnostics etc) using the target p-value.

As robustness checks, the parsimonious specifications can also be estimated over an updated dataset with an extra two years of data (and incorporating ABS data revisions since the original estimations were conducted). Model C estimates a hybrid of Model A and B - including $DSrisk_{t-1}$ but excluding $CCI^* \times Li_{t-1}$ - across 1972(3) to 2008(2).[43] Model D estimates the model across 1979(1) to 2008(2) excluding both variables (that is, with the same specification as Model B). The latter sample excludes the pre-FLIB period and only includes ABS and REIA house price data. Model C and Model D incorporate the start of the Global Financial Crisis (GFC) from about 2007(3) and one would expect credit conditions to tighten around this time. For the estimation of Models C and D only, CCI_{98} is redefined as $CCI_{98} - 1.5 \times split2007(3)$ where $split2007(3)$ is a linear trend beginning in 2007(3). The -1.5 constraint imposes an identical contraction on post-2007(3) credit conditions as experienced during the 1992-1998 period. The CCI interaction terms are redefined accordingly.

With an additional eight quarters of data, including the global financial crisis, Model C has a slightly poorer fit (0.00982) than either Model A or Model B. All terms retain a 1 per cent significance level with the exceptions of $\Delta_4 rhp_{t-1}$ (5 per cent) and $DSrisk_{t-1}$ (10 per cent).[44] The speed of adjustment for Model C is faster (0.243) while the coefficient on CCI_{92} weakens a little (closer to negative 1.3 times CCI_{79} and CCI_{98}). Model C also satisfies diagnostic tests of the residuals for autocorrelation, ARCH, normality, heteroskedasticity and misspecification.

Model D, estimated across a shorter sample, lends further support to Model B. The standard error of the model is about 5 per cent higher than Model B. Diagnostic tests are again satisfied. All variables remain significant and correctly signed however the long run solution of Model D is not as robustly determined. CCI_{79}, CCI_{92}, CCI_{98} and Lue_{t-1} are significant at the 5 per cent rather than 1 per cent level.[45] The slightly diminished performance of the CCI-related terms, which measure structural change in credit markets, in the long run equation is to be expected given the missing contrast provided by the tightly regulated 1970s sample period. The diminished performance may also reflect that a greater proportion of the sample is constituted by REIA data (which shows higher volatility given the narrower coverage and lack of compositional adjustment). Measurement issues may also be the cause of the non-significance of $\Delta_4 rhp_{t-1}$ which, as well as having the economic explanation below, may have been capturing some of the negative autocorrelation caused by measurement error in the pre-1978 data. The corollary is that Model C and Model D strongly support the parsimonious specifications achieved through model reduction for 1972(3) to 2006(2).

6.2 Cointegration

Model B implies the following long run relationship[46]:

$$\begin{aligned} rhp_t \;=\; & -8.39 + 2(y_{t-2} - H_{t-1}) + 0.326WA_{t-5} \\ & -0.180Lue_{t-1} - 0.362Li_{t-1} - 7.064r_{t-1} \\ & +0.049FHOS_{t-5} + 0.009CCI_{79} - 0.015CCI_{92} \\ & +0.010CCI_{98} + \mu_t \end{aligned}$$

[43] $DSrisk_{t-1}$ is significant at the 10 per cent level over the extended sample while $CCI^* \times Li_{t-1}$ is not. This specification performed slightly better than specifications based on Models A or B in terms of the significance of key variables, equation standard error and diagnostic tests.

[44] If $DSrisk_{t-1}$ is excluded, the equation standard error rises to 0.00991.

[45] The level (ue) instead of the log of the unemployment rate (Lue) was also tested over the post-1979 sample. ue weights percentage point changes in the unemployment rate, which are greater after 1979. The unemployment rate peaked at 10.3 per cent in 1983(3) and at 10.8 per cent in 1991(4). By contrast, Lue weights proportionate changes in the unemployment rate which are much greater before 1979. The unemployment rate tripled from only 2.1 per cent in 1973 to 6.4 per cent in 1979.

Lue_{t-1} performed better than ue_{t-1} in models estimated over the post-1972 periods however the difference is minimal for the post-1979 sample. ue_{t-1} has a t-stat of -2.27 when included in Model D rather than Lue_{t-1} (-2.31).

[46] Unit root tests are provided at Appendix C.

The steady state variables accord with economic theory, are correctly signed and robustly significant at the 1 per cent level. Cointegration occurs between the following I(1) variables.[47] The positive long run influences are easing credit conditions across 1979(1) to 1992(1) and 1998(1) to 2006(2), real non-property income per house (as part of ecm_t)[48], the proportion of the population of working age (15-64 years) (WA_{t-5})[49], the introduction of the first home owners' scheme ($FHOS_{t-5}$). The negative long run influences are nominal interest rates (Li_{t-1}) which matter for credit constrained borrowers, the tightening of credit conditions between 1992(1) and 1998(1) and the log unemployment rate (Lue_{t-1}). Real interest rates are also a negative influence on house prices but only after financial liberalisation ($CCI^* \times r_{t-1}$).

The results support cointegration following the strategy of Banerjee *et al* (1986), Kremers (1989), Kremers *et al* (1992) and Muellbauer and Murphy (1997). Direct estimation of the cointegrating relationship uses information contained in both the structural and equilibrium correction dynamics. Cointegration implies and is implied by stationarity in the residual of the long run equation. An ADF test was conducted on the residual of the long run equation ($\hat{\mu}_t$), which showed stationarity at the 1 per cent level (t–adf = -5.663).

The equilibrium correction speed is 20.1 per cent per quarter implying that shocks to house prices take about 5 quarters to unwind. This is comparable to Abelson *et al* (2005), who in a different specification, found adjustment to the steady state to be around 21 per cent per quarter during boom periods (5 quarters) and around 14 per cent during non-boom periods. (7 quarters) Tu's (2000) adjustment speed was around 13 per cent per quarter (7.5 quarters).

In the dynamic equation, the structural dynamics include the following I(0) variables: income growth (Δy_{t-1}), the quarantining of negative gearing deductions between 1985 to 1987 (NG_t), households' extrapolative expectations about future housing capital gains (based on Δrhp_{t-1}, $\Delta_4 rhp_{t-1}$ and $frenzy_{t-1}$), and seasonal and outlier dummies.[50] These structural dynamics may in the short run offset or reinforce the equilibrium correction dynamics. For example a one standard deviation impulse to real per capita non-property income growth raises nominal house price growth by 0.4 per cent. The seasonal dummy indicates that nominal house price growth, all else equal, will be 0.7 per cent higher in the June quarter.[51]

6.3 Interpretation

Real house prices increased by 91 per cent after financial liberalisation (between 1979-2006) and by 65 per cent between 1992-2006. It is instructive to examine the sensitivity of real house prices to the steady state explanatory variables based on their conditional impacts (that is, holding all other variables constant). However, it is important to stress again that the model by no means represents a general equilibrium.[52] That caveat aside, the economic interpretation of Model B is as follows.

[47] Interest rate elasticities are calculated incorporating the CCI interaction effects as at 2006(2).

[48] Note that when y_{t-1} and Δy_{t-1} are included in the dynamic specification, the latter returns a significant and mildly negative sign. A reparameterisation is made to include y_{t-2} in the steady state which allows Δy_{t-1} to have a mildly positive sign. This reparameterisation is purely cosmetic.

[49] It is difficult to be conclusive about the order of integration of WA since it is an interpolated variable and the ADF test is based on only 30 annual observations. An alternative strategy would be to exclude all interpolated annual variables because of their ambiguous orders of integration. However this approach would be asserting that demography plays no role in the determination of house prices, which consumption theory suggests is implausible.

[50] Model A additionally includes downside risk in recent housing returns ($DSrisk_{t-1}$) as part of the structural dynamics, significant at the 5 per cent level. Model A suggests that households' aversion to negative housing returns subtracted on average around 1 per cent from nominal house price growth across 1983-85, 1986-88 and 1990-1997 (peaking at -1.4 per cent in 1991). Downside risk also subtracts around 0.5 per cent from nominal house price growth across 2005-06 due to higher nominal interest rates. $DSrisk_{t-1}$ equals zero at all other times.

[51] Outlier dummies are automatically added by AutoMetrics for a boom quarter, 1988(3), a recession quarter 1991(3), and also 1981(1) and 1981(4). The inclusion of the latter two dummies is unsurprising given the volatility of the REIA data during the 1978-86 period.

[52] The model is not inclusive of feedback effects between incomes, credit conditions, interest rates, demography, the unemployment rate etc.

Real non-property income per house is a key component of the steady state equation confirming the theory of Section 2. The inverse price elasticity of housing demand is (ψ) constrained at two.[53] The rising share of property income as a proportion of household disposable income, especially over the 1980s, saw a long run decline in real non-property income per house. Holding other variables constant, Model B suggests that the decline in real non-property income per house between 1979 and 2006 subtracted 62 per cent from the long run real house price level. After 1992 however, rising real non-property income per house contributed 2 per cent to the level of real house prices.

The long run elasticity of real house prices to the unemployment rate is -0.18. This suggests that the 1.3 percentage point decline in the unemployment rate between 1979 and 2006, all else equal, contributed 4 per cent to the long run real house price level. However between 1992 and 2006 the unemployment rate declined by 4.9 percentage point, contributing 12 per cent to real house prices.

The long run coefficient on the working age population proportion (WA_{t-5}) is 0.326. The five quarter lag on the demographic variable indicates a delay in household formation after an increase in the working age proportion of the population over the previous year.[54] The model indicates that the conditional impact of the 2.3 percentage point increase in the working age population between 1979 and 2006 contributed 74 per cent to real house prices. The 0.5 percentage point increase in WA_{t-5} after 1992 contributed 12 per cent to real house prices. Other important effects are discussed below.

6.3.1 Policy effects

Policy effects are clearly evident. According to Model B, the quarantining of negative gearing deductions between 1985(3) and 1987(3) depressed quarterly nominal house price growth over the period by 2.1 per cent. The July 2000 introduction of the $FHOS$ subsidy also had a strong impact, raising long real house prices by 9.4 per cent by 2006(2) (conditional impact). In terms of short run effects, with a five quarter lag the $FHOS$ promoted quarterly nominal house price growth by 0.6 per cent in the December quarter of 2001. Its impact rose, as the grant and its scope increased, to a peak of 4.7 per cent in 2003(3). After 2003(3), the positive quarterly effect of the $FHOS$ on nominal house price growth waned to about 1.8 per cent by 2006(2).

6.3.2 Credit conditions

Non-price credit conditions are represented by t, CCI_{79}, CCI_{92}, and CCI_{98} corresponding to the turning points of the STAMP analysis of Section 5.1. CCI_{79} and CCI_{92} and CCI_{98} are retained after model selection and are freely estimated. Model B suggests that the CCI process may be represented by a (four quarter moving average) of a deterministic trend that rises from 1979, diminishes after 1992, and rises again after 1998. Large t-statistics of 6.66 and -7.30 and 4.02 on CCI_{79}, CCI_{92} and CCI_{98} respectively indicate that they are important part of the long run house price story. CCI effects also feed into house prices via the interest rate interaction terms discussed in the next section.

The estimated shape of the CCI process accords with the broad pattern of financial market developments (Appendix B). After financial repression during the 1970s, a turning point was reached in 1979 with the establishment of the Campbell Committee, the replacement of the Treasury "tap" system on T-bonds and the dismantling of interest rate ceilings on trading and savings bank deposits. Financial liberalisation accelerated during the 1980s: interest ceilings on fixed deposits and restrictions on savings banks were removed in 1982; the Australian dollar was floated and licenses for 10 new banks were announced in 1983; remaining controls on bank deposits were removed and the Australian stock exchange and securities industry were deregulated in 1984; the first foreign bank began operations in 1985; interest rate ceilings on owner-occupier housing loans were removed in 1986; Basel I capital adequacy regulations were introduced in 1989 and so on.

[53] As discussed in Section 4, this incorporates the twin constraints that the elasticity of housing demand with respect to income (α) and house prices (β) are 1 and $\frac{1}{2}$ respectively. Supplementary estimations of Model B relaxing the constraint on ψ estimate it at 1.75 and within a standard error of 2. The freely estimated coefficients α and β are 1.00 and at 0.57 respectively.

[54] Equivalently, it indicates that the population proportion aged 16-65 years affects house prices.

The upward CCI trend was halted, or indeed the estimated coefficients suggest partially reversed, after 1992. This is ponderous given the continuing institutional changes over the 1990s. On the regulatory front, foreign banks were allowed to operate (lending) branch networks and limits on the establishment of new banks were removed from 1992. The market itself was transforming: in 1992, the first mortgage originator ("Aussie Home Loans") commenced operations; in 1995, Westpac was allowed to acquire Challenge Bank under the "Five Pillars Policy" and Advance Bank purchased the Bank of South Australia; in 1996, banks removed the one percentage point differential between investor and owner-occupier loans; and in 1997, St George merged with Advance Bank.

An explanation for tightening credit conditions after 1992 may found in the precipitous decline in major bank return on equity suffered in 1992. Return on shareholder equity fell from an average of 20 per cent across 1986-1991 to -3.4 per cent in 1992.[55] Bank capital ratios also increased from around $9\frac{1}{2}$ per cent in 1990 to a peak of 12.3 per cent in 1995(1).[56] It seems likely that the banks spent much of the mid-1990s recovering from loan losses and consolidating their capital bases. The entry of mortgage managers and foreign banks from about 1994, while promoting the diffusion of new lending and back office technologies, was not sufficient to make up for the overall contraction in major bank credit supply during this period.

After the mid-1990s banking sector profitability improved substantially. The bank share price index (ASX/S&P200 (Banks)) increased from around 1.3 times the aggregate share price index across the early 1990s to around 3.1 times by mid-2003 and the banking sector capital ratio declined after 1995 to an average of around $10\frac{1}{2}$ per cent. Model B suggests that further regulatory changes and debt product innovation loosened credit conditions from the late 1990s.

Chart 6 shows the long run impact of CCI as implied by Model B. CCI appears on the right hand scale expressed in terms of its long run impact on real house prices. On the left hand scale is the level of the real interest rate (four quarter moving average). The latter is discussed below. The estimated short run coefficients on CCI_{79}, CCI_{92} and CCI_{98} are 0.0019, -0.0030 and 0.0020 respectively. Dividing the short run coefficients by the speed of adjustment, the long run coefficients are 0.0094, -0.0149 and 0.0101 respectively. These can be multiplied by the index level to compare the impact of CCI at different points in time. The split trends all have values of zero before 1979(1) so changes can be compared to that point. At 1992(1) for example, the values on CCI_{79}, CCI_{92} and CCI_{98} are 51, 0.2 and 0 respectively. This means that the conditional long run impact of CCI on the level of real house prices relative to 1979 was around 0.48. At 1998(1), the split trends were 75, 23 and 0.2 so the net impact of CCI compared to 1979 was 0.37. And finally at 2006(2), the split trend values are 108, 56 and 32 so the conditional impact of CCI on the level of real house prices relative to 1979 was 0.51.

The corollary is that, all else being equal, Model B implies that easing credit conditions directly raised real house prices by around 51 per cent over 1979 to 2006. The bulk of the impact of CCI was during the deregulation period of the 1980s. Real house price levels lost around 11 per cent of their value over 1992 to 1998 due to tightening financial conditions but debt product innovation saw prices completely recover after 1998. Models A, C and D provide slightly higher estimates of the conditional long run impact of credit conditions on real house prices (Chart 7). Model A suggests that easing credit conditions raised real house prices by 58 per cent over 1979 to 2006 and Models C and D suggest a similar impact over 1979 to 2008. Models C and D however suggest a more modest tightening of credit conditions between 1992 and 1998 and a more pronounced easing thereafter.[57]

[55] RBA Financial Stability Review March 2007, Graph 32.

[56] RBA Bulletin Table B06: Consolidated group bank total capital ratio (Tier 1 and 2 capital).

[57] It is worth re-emphasising that these are conditional models and do not constitute general equilibrium outcomes because financial liberalisation feeds back on to other economic variables - such as income, the housing stock, inflation - which are endogenous in the long run.

Chart 6 : CCI and the real interest rate

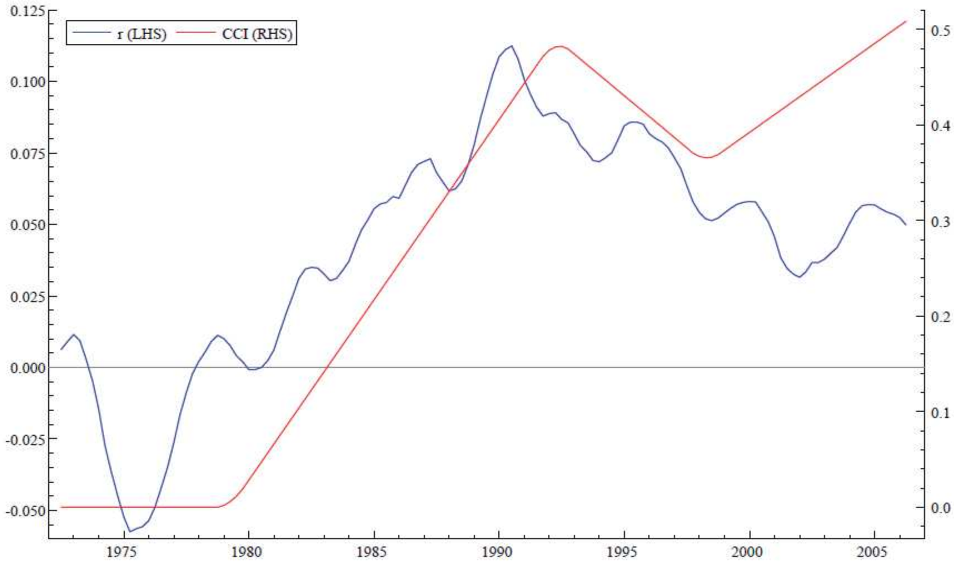
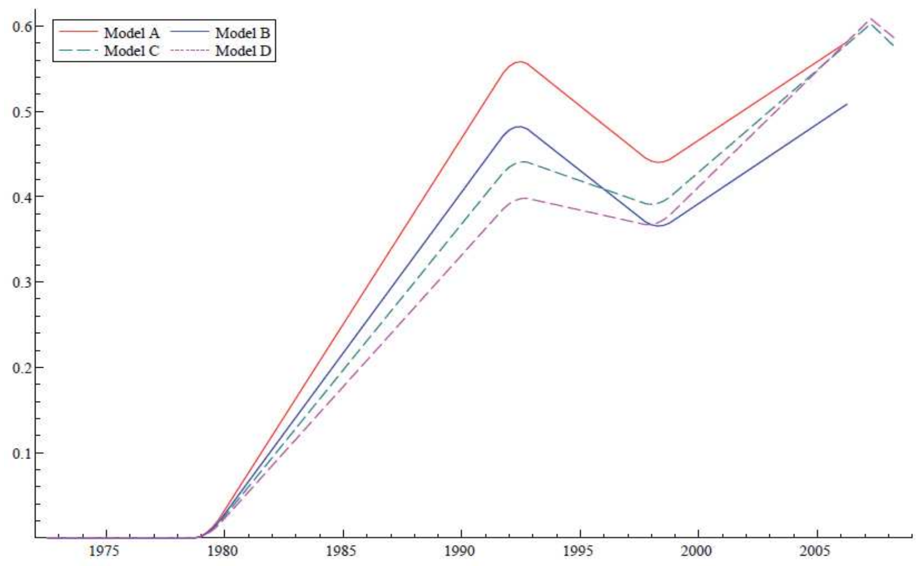


Chart 7 : CCI – alternative models



6.3.3 Interest rates

Interest rates affect house prices *directly* via Li_{t-1} and *indirectly* via the interaction term between credit conditions and real interest rates ($CCI^* \times r_{t-1}$).[58] Nominal interest rates were 2.0 percentage

[58] De-meaned interest rates are interacted with a constrained version of the CCI process, $CCI^* = CCI_{79} - 1.5CCI_{92} + CCI_{98}$. Post-1979 arithmetic means are used rather than post-1972 means. The justification is that negative real interest rates during the 1970s are likely to reflect credit conditions at their tightest rather being a true reflection of the price of credit.

points lower at 2006(2) relative to 1979 and, all else equal, raised long run real house prices by 9 per cent. Relative to 1992 however, nominal interest rates were 5.0 percentage points lower at 2006(2) and therefore had a conditional impact on real house prices of 19 per cent. The insignificance of the interaction term ($CCI^* \times Li_{t-1}$) in Model B indicates that the (conditional) role of nominal interest rates has not been affected by credit market liberalisation.[59]

The significance of the real interest rate interaction term along with the insignificance of the direct term (r_{t-1}) suggests that real interest rates only mattered after Australian credit markets were liberalised.[60] Furthermore, it implies that negative real interest rates during the mid-1970s provided no fillip whatsoever for real house prices because of quantity-based restrictions of credit supply. Real interest rates are necessarily higher in a liberalised credit market because of the diminished reliance of quantity-based controls on lending. The relationship between CCI and the real interest rate is depicted in Chart 6. Cameron *et al* (2006) found a similarly positive relationship between the level of the real interest rates and the degree of credit market liberalisation for the UK.

Real interest rates were 4.1 percentage points higher at 2006(2) relative to 1979 and so, all else being equal, subtracted around 29 per cent from long run real house prices according to Model B. However, between 1992 and 2006, real interest rates fell by 3.5 per cent and so the conditional impact on real house prices was +25 per cent. These real interest rate effects offset the direct effect of CCI above.

In terms of short run effects, Model B suggests that a one standard deviation increase in the nominal interest rate depresses nominal house price growth by 2.1 per cent. This impact is unaffected by credit market liberalisation. The real interest rate had zero impact prior to financial liberalisation (pre-1979) since CCI^* equaled zero. However after financial liberalisation the situation is very different. By 1992(1), a one standard deviation increase in real interest rates reduced nominal house price growth by 3.4 per cent. By 2006, a one standard deviation increase in real interest rates lowered nominal house price growth by 5.7 per cent. That is, nominal house price growth at 2006 was nearly three times as sensitive to changes in real interest rates as to changes in nominal interest rates. The corollary is that FLIB appears to have relaxed binding credit constraints on households and enhanced opportunities for intertemporal smoothing.

6.3.4 Autoregressive dynamics

In the structural dynamics, the autoregressive terms - lagged real house price changes (Δrhp_{t-1} and $\Delta_4 rhp_{t-1}$) and $frenzy_{t-1}$ - are particularly interesting. The significant negative coefficients on Δrhp_{t-1} and $\Delta_4 rhp_{t-1}$ (after reparameterisation[61]) suggest that households expect past house price changes, with an extra weight on the most recent lag, to be partially reversed in subsequent quarters.[62]

STAMP analysis in Section 5 initially suggested constraints on the components of CCI^* of 1, -1 and 1. Estimation of the model in AutoMetrics, inclusive of interaction effects, suggested the above refinement (1, -1.5 and 1) based on the directly estimated coefficients on CCI_{79}, CCI_{92}, and CCI_{98}.

[59] The t-stat on $CCI^* \times Li_{t-1}$ in Model A is only 1.9.

[60] r_{t-1} can be forced into the model but is not significant. If included in Model B, the t-stat on r_{t-1} is -1.01. If included in Model A, the t-stat is -1.48.

[61] Using the fitted values of the cubic regression (Section 4.2.4), the coefficients from the house price equation can be reparameterised as:

	Reparameterised coefficient
Δrhp_{t-1}	-0.2585
$\Delta_4 rhp_{t-1}$	-0.0730
$(\Delta rhp_{t-1})^3$	195.655

[62] As well as having an economic interpretation, negative autocorrelation can be interpreted as indicating measurement error in house price data (see Hendry, 1995). In particular, house price data data before 1986 is not compositionally adjusted so, for example, infrequent sales of high value houses can artificially inflate nominal house price growth in a given quarter. Chart panel 5 showed mild negative autocorrelation in the residuals at the third, fourth and sixth lags although diagnostic tests are satisfactory.

Previous Australian studies of house prices changes have also found evidence of negative autocorrelation, for example Bourassa and Hendershott (1995). Bodman and Crosby (2003) found a negative coefficient on Δrhp_{t-1} in their model of Melbourne house prices (however, Perth house prices showed a positive sign on Δrhp_{t-1} while the term was not

Meanwhile $frenzy_{t-1}$, with a mean of zero, acts symmetrically for positive and negative lagged house price changes. The term is highly significant ((t-stat = 9.01). When lagged real house price changes are small, the cubic's effect is infinitesimal but it becomes non-linearly larger (by a power of three) as the magnitude of the lagged real house price change increases.

Consider the *combined* autoregressive impact on contemporaneous nominal house price growth.[63] Table 4 and Chart 8 demonstrate the net effect of a one-quarter lagged real house price change on nominal house prices: that is, via the cubic $(\Delta rhp_{t-1})^3$ and the non-cubic autoregressive terms (Δrhp_{t-1} and $\Delta_4 rhp_{t-1}$). If real house prices grow at their mean quarterly rate (across the full sample period) of +0.7 per cent, the net effect of the three autoregressive terms is to subtract 0.2 per cent from nominal house prices in the next period. This is entirely due to the effect of the lagged house price terms (Δrhp_{t-1} and $\Delta_4 rhp_{t-1}$) because the cubic's offsetting impact is infinitesimal. In fact, the net sign of the three terms is negative whenever lagged real house price changes are less than 4.1 per cent. However whenever real house price changes exceed 4.1 per cent (or 5.3 per cent under the alternative assumption[64]), the cubic effect dominates and pushes Δnhp_t in the same direction as Δrhp_{t-1}. As another example, real house price growth peaked in the late-1980s boom at +8.1 per cent in 1988(4). The net effect on one quarter ahead nominal house price growth was +7.7 per cent. This consists of an +10.4 per cent boost from the cubic term and a -2.7 per cent subtraction from Δrhp_{t-1} and $\Delta_4 rhp_{t-1}$.[65]

Table 4 : Sensitivity of contemporaneous nominal house price growth to one quarter lagged real house price changes
(all changes are percentages)

Real price change	**Cubic effect**	$\mathbf{\Delta rhp_{t-1}}$ **and** $\mathbf{\Delta_4 rhp_{t-1}}$	**Net effect**
-10.0	-19.6	+3.3	-16.3
-7.5	-8.3	+2.5	-5.8
-5.0	-2.5	+1.7	-0.8
-2.5	-0.3	+0.8	+0.5
-1	0.0	+0.3	+0.3
+1	0.0	-0.3	-0.3
+2.5	+0.3	-0.8	-0.5
+5.0	+2.5	-1.7	+0.8
+7.5	+8.3	-2.5	+5.8
+10.0	+19.6	-3.3	+16.3

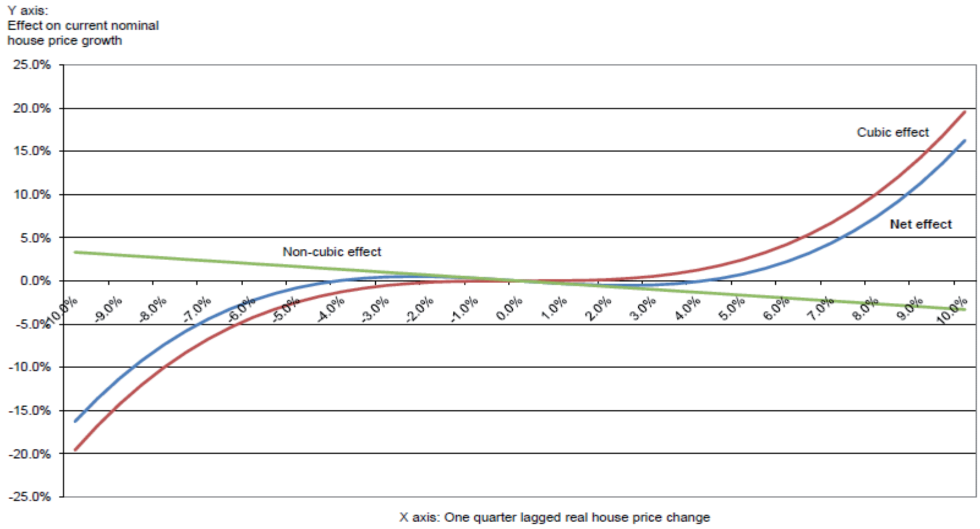
significant for any other city house price model). Conversely, Tu (2000) found a positive coefficient on Δrhp_{t-1} using national prices over 1989-99.

[63] To simulate the effect of Δrhp_{t-1} on Δnhp_t, the lagged quarterly and annual real house price changes were treated as equivalent (that is, $\Delta_4 rhp_{t-1} \equiv \Delta rhp_{t-1}$ and Δrhp_{t-2}, Δrhp_{t-3}, Δrhp_{t-4} are ignored). A less conservative strategy might calculate the lagged annual real house price change as simply the annualised quarterly figure (that is, $\Delta_4 rhp_{t-1} \equiv 4 \times \Delta rhp_{t-1}$). This would arguably represent an upper limit on negative autocorrelation in the model.

[64] If lagged annual real house price changes are simulated as the annualised quarterly change $\Delta_4 rhp_{t-1} \equiv 4 \times (\Delta rhp_{t-1}))$, the cubic dominates whenever Δrhp_{t-1} growth exceeds 5.3 per cent.

[65] If lagged annual real house price changes are simulated as the annualised quarterly change $\Delta_4 rhp_{t-1} \equiv 4 \times (\Delta rhp_{t-1}))$, then the net impact of this boom quarter on quarter ahead nominal house price growth is only +5.9 per cent. This consists of a +10.4 per cent boost from the cubic an offsetting -4.5 per cent effect from Δrhp_{t-1} and $\Delta_4 rhp_{t-1}$.

Chart 8 : Net effect of lagged real house price changes on nominal house price growth



Frenzy behaviour provides a cogent explanation for overshooting in house prices. Houses prices correct (at 20.1 per cent per quarter) to the steady state run equilibrium path determined by non-property income per house, interest rates, credit conditions, demographics and so on. The long run equilibrium correction dynamics dominate the short run structural dynamics for all plausible values of Δrhp_{t-1}, but the short run autoregressive dynamics may be either reinforcing or offsetting.

The autoregressive dynamics may arise from households having extrapolative expectations about the direction of future house price changes. They operate symmetrically but become larger non-linearly for larger values of Δrhp_{t-1}. When lagged real house price changes are small, the short run autoregressive dynamics are negative in sign but become positive in sign when real house price changes are large. The (net) "sign-switching point" for the short run autoregressive dynamics is about where lagged real house price changes exceed 4.1 per cent but possibly as high as 5.3 per cent.

Whether the short run autoregressive dynamics reinforce or offset the long run equilibrium dynamics depends on: whether real house prices (at time $t-1$) are over- or under-valued according to the steady state; and the size and sign of recent real house price changes. If for example real house prices are under-valued so that equilibrium correction is positive, the short run autoregressive dynamics will dampen equilibrium correction if real house price growth (at time $t-1$) is positive and small but assist equilibrium correction if real house price growth is positive and large.[66] If real house prices are over-valued relative to the steady state path so that equilibrium correction is negative, then the short run autoregressive dynamics will dampen equilibrium correction for small negative house price changes but assist equilibrium correction for large negative house price changes.[67]

The above approach contrasts with Abelson *et al*'s (2005) house price model using a linear and *asymmetric* equilibrium correction process. Their approach relies on separate equilibrium correction terms for boom and non-boom periods showing the speed of adjustment during booms to be 50 per cent faster (a boom is arbitrarily defined as whenever Δrhp_{t-1} exceeds 2 per cent). This paper instead explicitly models the short run dynamics and in this respect corresponds to the spirit of Bourassa and

[66] The reverse will be true if short run real house price growth is negative. That is, the structural dynamics will support equilibrium correction for small negative real house price changes but will offset equilibrium correction for large negative real house price changes .

[67] The reverse will be true if short run real house price growth is positive. That is, the structural dynamics will support equilibrium correction for small positive real house price changes but will offset equilibrium correction for large positive real house price changes.

Hendershott (1995) and Bodman and Crosby (2003) who represented house price dynamics using a so-called "bubble builder" persistence term and a "bubble-burster" correction term.

The main advantage of the approach used in this paper is that (non-linear) short run house price overshooting is explained against the backdrop of equilibrium correction to a well-specified long run equation. A drawback to the approach is that even with the cubic, outlier dummies are required to explain two boom quarters, $dum81(1)$ ($\Delta nhp = 6.3$ per cent) and $dum88(3)$ ($\Delta nhp = 7.8$ per cent). However, reassuringly, no outlier dummies are required to explain the house price boom starting in the mid-1990s. The highly significant autoregressive terms are therefore important short run dynamic elements of the model and help explain overshooting and boom behaviour in house prices.

7 Conclusion

Australian long run real house prices are driven by real non-property income per house, credit conditions, real and log nominal interest rates, the log unemployment rate, the working age population proportion and the introduction of the first home owners' grant (FHOS). All else equal in a partial equilibrium, easing credit conditions directly raised the real level of house prices by about 51 per cent between 1979 and 2006. Conversely, the 4.1 percentage point increase in real interest rates relative to 1979 subtracted around 29 per cent from real house prices while the 2.0 percentage point reduction in nominal interest rates added only about 9 per cent to long run house prices. Real interest rates became especially important after financial markets were liberalised because of the diminished reliance on quantity controls to clear the credit market. Although by no means a general equilibrium result, the conditional model confirms that easing credit conditions associated with FLIB after 1979 substantially relaxed credit constraints on households and promoted opportunities for intertemporal smoothing.

The long run equation shows an equilibrium correction speed of around 20 per cent per quarter, indicating that shocks to fundamentals take about 5 quarters to unwind. In addition, the short run structural dynamics of the model include income growth, negative gearing policy, and autoregressive dynamics that reflect extrapolative expectations by households and incorporate "frenzy" behaviour. The latter, modelled as a cubic of lagged real house price changes, is a contributing factor in Australian house price booms. Whenever real house price growth is greater than 4.1 per cent per quarter, the model's autoregressive structural dynamics are dominated by "frenzy" behaviour. The autoregressive dynamics assist or dampen the equilibrium correction speed in the short run depending on the direction of the equilibrium correction and the sign and magnitude of short run real house price changes. The model thus explains Australian house price overshooting in terms of explicitly modelled non-linear and symmetric short run autoregressive dynamics in contrast to Abelson *et al*'s (2005) use of a linear, asymmetric equilibrium correction process.

The significance of the cubic is consistent with Morris and Shin's (2002) model of strategic action under uncertainty. Public information becomes more prevalent during boom periods and the cubic captures the natural tendency of agents to overreact to public information at the expense of private information. If agents care more about other agents' beliefs (relative to correctly guessing the true state) and if public information is relatively less precise than private information, then these "frenzy" effects may be detrimental to social welfare. Alternatively, frenzy effects may highlight the role of transaction, information and other costs that deter continuous optimisation and thus dampen price adjustment during quiet market periods. In this case, frictions are overcome when markets are highly active ("boom" periods) and so price adjustment to conditions of excess demand is rapid.

There are four contributions to the literature. First, the paper provides to my knowledge the first indicator non-price credit supply conditions for Australia and estimates its impact on housing markets. After controlling for economic and demographic factors, an unobserved stochastic trend is revealed that appears to provide a reasonable approximation of the likely net impact of credit conditions and that can be represented by a combination of linear split trend dummy variables. Second, a measure of non-property gross disposable income, which better conforms to economic theory, is constructed from the national accounts and applied to an Australian house price model. Third, the paper quantifies the impact of two key government policy changes. The quarantining of negative gearing deductions from 1985(3) to 1987(3) subtracted around 2 per cent from quarterly house price growth, while the introduction of the FHOS from 2000(3) to 2006(2) boosted the level of long run established real house prices by about 9 per cent. Fourth, frenzy dynamics help explain the short term dynamics of housing booms in Australia. The significance of the frenzy term suggests that more precise public information regarding housing markets (for example, better data) could assist in overcoming some of the noise generated by increased political and market commentary and media programming during boom periods. Equilibrium adjustment might also be accelerated by reducing transaction-based taxes (such as conveyancing) levied at state and local government level.

The results suggest that policy-makers can viably incorporate non-price credit supply conditions into their long run models. The paper has demonstrated that credit conditions affect real house price levels directly and indirectly via the interaction with real interest rates. Take the current global credit freeze for example. If credit conditions were to tighten by similar magnitude as witnessed following the early 1990s recession then, all else equal, the CCI terms would directly subtract about 11 per cent from the level of real house prices. However, in response to a decelerating economy (including two quarters of negative house price growth), the Reserve Bank cut nominal interest rates by 400 basis points between September 2008 and March 2009. Standard variable bank mortgage rates fell by 375 basis points in response, significantly easing repayment pressures on households (as depicted in Chart 11 at Appendix A). The model suggests this reduction in nominal interest rates, all else held constant, would provide a 20 per cent fillip to real house prices. In additional, annual inflation has fallen from 5.0 per cent in September 2008 to 2.5 per cent in March 2009 reducing the ex-post real interest rate by 1.3 percentage points. The conditional impact of this would raise long run real house prices by about 9 per cent. The model therefore lends support to the aggressive and early action taken by the Reserve Bank across September 2008 to March 2009 partly as insurance against a downturn in credit supply conditions.

References

Abelson, P. and R. Joyeaux, G. Milunovitch and D. Chung (2005). "Explaining House Prices in Australia: 1970-2003." Economic Record 81(0): S96-103.

Abraham, J. M. and P. H. Hendershott (1996). "Bubbles in Metropolitan Housing Markets." Journal of Housing Research 7(2): 191-207.

Abraham, J. M. and P. H. Hendershott (1993). "Patterns and Determinants of Metropolitan House Prices 1977-1991" in Real Estate and the Credit Crunch. L. E. Browne and E. S. Rosengren. Boston, Federal Reserve Bank of Boston: 18-42.

Aron, J. and J. Muellbauer (2006). "Housing Wealth, Credit Conditions and Consumption." Centre for the Study of African Economies WPS/2006-08, Oxford.

Australian Bureau of Statistics Catalogue Numbers: 3101; 3222; 4102; 5204; 5205; 5206; 5609; 6202; 6401; 6416; 6417; 6464.

Bacchetta, P. and S. Gerlach (1997). "Consumption and Credit Constraints: International Evidence." Journal of Monetary Economics 40:207-238.

Banerjee, A, Dolado, J, .Hendry, D. and G. Smith (1986). "Exploring Equilibrium Relationships in Econometrics through Static Models: Some Monte Carlo Evidence." Oxford Bulletin of Economics and Statistics 48(3): 253-77.

Bayoumi, T. (1993). "Financial Deregulation and Consumption in the United Kingdom." The Review of Economic Studies 75(3): 536-539.

Blinder, A. and A. Deaton (1985). "The Time Series Consumption Function Revisited." Brookings Papers on Economic Activity 0(2), 465-511.

Bodman, P. M. and M. Crosby (2003). "How Far to Fall? Bubbles in Major City House Prices in Australia." Melbourne Business School Working Paper.

Bourassa, S. C. and P. H. Hendershott (1995). "Australian Capital City Real House Prices, 1979-1993." Australian Economic Review 0(111): 16-26.

Buckley, R. and J. Ermisch (1982). "Government Policy and House Prices in the United Kingdom: An Econometric Analysis." Oxford Bulletin of Economics and Statistics, 44(4), 273-304.

Cameron, G, Muellbauer, J. and A. Murphy (2006). "Was There A British House Price Bubble? Evidence From A Regional Panel." Centre for Economic Policy Research (CEPR) Discussion Paper 5619.

Cho, M. (1996). "House Price Dynamics: A Survey of Theoretical and Empirical Issues." Journal of Housing Research 7(2): 145-72.

Chowdhury, M. and G. Mallik (2004). "Effects of Housing Allowances on Housing Prices in Australia: A Cointegration Analysis." Economic Analysis and Policy 34(1): 37-51.

Commonwealth Treasury (2005). Tax Expenditures Statement, CanPrint Communications, Canberra.

Doornik, J.A. (2007). An Introduction to OxMetrics 5. London, Timberlake Consultants Press.

Dougherty, A. and R. Van Order (1982). "Inflation, Housing Costs, and the Consumer Price Index." American Economic Review 72(1): 154-64.

Ellis, L. and D. Andrews (2001). "City Sizes, Housing Costs, and Wealth," Reserve Bank of Australia Research Discussion Paper No. 8, 2001.

Fernandez-Corugedo, E. and J. Muellbauer (2006). "Consumer Credit Conditions in the U.K." Bank of England Working Paper No. 314.

Hendry, D. F. (1984). "Econometric Modelling of House Prices in the United Kingdom." Econometrics and Quantitative Economics, (ed. D.F. Hendry and K.F. Wallis). Oxford: Basil Blackwell.

Hendry, D. F. (1995). "Dynamic Econometrics." Oxford University Press, Oxford, United Kingdom.

Hendry, F. D. and H.-M. Krolzig (2001). Automatic Econometric Model Selection Using PcGets 1.0. London, Timberlake Consultants Press.

Jappelli, T. and M. Pagano (1989). "Consumption and Capital Market Imperfections: An International Comparison." The American Economic Review 79(5): 1088-1105.

Jevons, W. (1884). Investigations in Currency and Finance, Macmillan Publishers, London.

Jorgenson, D. (1963). "Capital Theory and Investment Behaviour." American Economic Review, 53(2), 247-259.

Keynes, J. (1936). The General Theory of Employment, Interest and Money. Macmillan Cambridge University Press.

Koopman, S. J., A. C. Harvey, J.A Doornik and N. Shephard (2000). Stamp: Structural Time series Analyser, Modeller and Predictor. London, Timberlake Consultants.

Kremers, J. J. M. (1989). "U.S. Federal Indebtedness and the Conduct of Fiscal Policy." Journal of Monetary Economics 23(2): 219-38.

Kremers, J. J. M., N. R. Ericsson and J. Dolado (1992). "The Power of Cointegration Tests", Oxford Bulletin of Economics and Statistics 54(3): 325-48.

Lucas, R. E. Jnr (1972). "Expectations and the Neutrality of Money." Journal of Economic Theory 4(2): 103-24.

Lucas, R. E. Jnr (1973). "Some International Evidence on Output-Inflation Tradeoffs." American Economic Review 63(3): 326-34.

Mankiw, N. G. and D. N. Weil (1989). "The Baby Boom, the Baby Bust, and the Housing Market." Regional Science and Urban Economics 19(2): 235-58.

Meen, G. (1990). "The Removal of Mortgage Constraints and the Implications for Econometric Modelling of UK House Prices." Oxford Bulletin of Economics and Statistics, 32(1): 1-23.

Meen, G. (1996). "Ten Propositions in UK Housing Macroeconomics: An Overview of the 1980s and Early 1990s." Urban Studies 33(3): 425-44.

Meen, G. (2000). "Housing Cycles and Efficiency." Scottish Journal of Political Economy, 47(2), 114-40.

Meen, G. (2002). "The Time-Series Behaviour of House Prices: A Transatlantic Divide?" Journal of Housing Economics 11(1): 1-23.

Morris, S. and H. S. Shin (2002). "Social Value of Public Information." American Economic Review 92(5): 1521-1534.

Muellbauer, J. (1994). “The Assessment: Consumer Expenditure.” Oxford Review of Economic Policy, 10(2), 1-41.

Muellbauer, J. and R. Lattimore (1995). "The Consumption function: A Theoretical and Empirical Overview" in Pesaran, M. H. and M. R. Wicks, Handbook of Applied Econometrics, Vol 1, Blackwells Publishers, Oxford.

Muellbauer, J. and A. Murphy (1997). "Booms and Busts in the UK Housing Market." Economic Journal 107(445): 1701-27.

OECD (2005). "Recent House Price Developments: the role of fundamentals." OECD Economic Outlook 78.

Oster, A. (2005). "House Prices - Drivers and Links to the Broader Economy: Rational or Irrational Exuberance," Shann Memorial Lecture, University of Western Australia.

Otto, G. (2007). "The Growth of House Prices in Australian Capital Cities: What Do Economic Fundamentals Explain?" The Australian Economic Review, 40(3), 225-38.

Phelps, E. S. (1970). "Introduction" in Microeconomic Foundations of Employment and Information Theory, E.S. Phelps *et al* eds., Norton Publishers, New York.

Poterba, J. M. (1984). "Tax Subsidies to Owner-occupied Housing: An Asset-Market Approach." Quarterly Journal of Economics 99(4): 729-52.

Poterba, J. M. (1991). "House Price Dynamics: The Role of Tax Policy and Demography." Brookings Papers on Economic Activity 0(2): 143-83.

REIA (September 2004). "Market Facts: A Quarterly Review of Major residential Property Markets in Australia", Canberra.

RBA Bulletin Data: Tables B06; D01; D05; F01; F05; F07.

RBA (2007) Financial Stability Review (March), Sydney.

Real Estate Institute of Australia (2004). "Market Facts: a quarterly review of major residential property markets in Australia" (September), Canberra.

Scott, A. (1996). "Consumption, 'Credit Crunches' and Financial Deregulation." Centre for Economic Policy Research, Discussion Paper No 1389.

Shefrin, H. M. and R. H. Thaler (1988). "The Behavioural Life-Cycle Hypothesis." Economic Inquiry 26(4): 609-43.

Tu, Y. (2000). "Segmentation of Australian Housing Markets." Journal of Property Research 17(4): 311-327.

Wallis, S., B. Beerworth, *et al.* (1997). Financial System Inquiry Final Report, Australian Government Printing Service.

Appendix A: Background charts

Chart 9 : Australian median house prices
(relative to annualised average weekly earnings)

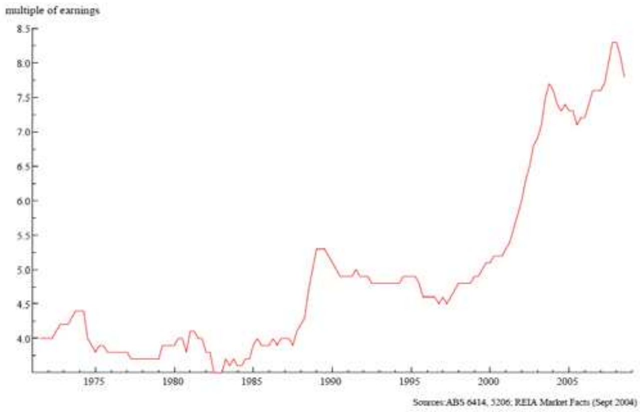


Chart 10 : Household debt (%)
(as a proportion of household disposable income)

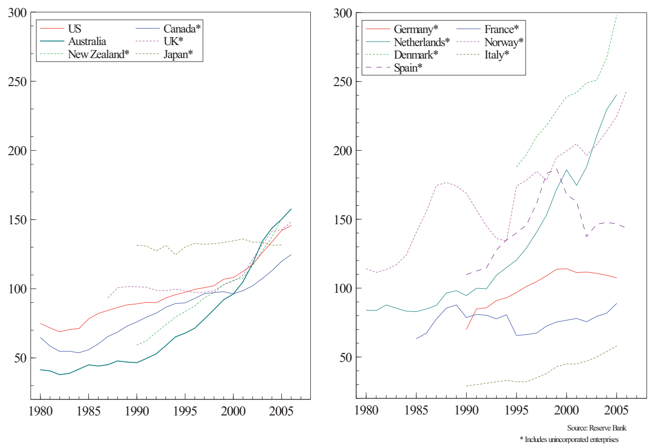


Chart 11 : Household interest payments (%)
(as a proportion of household disposable income)

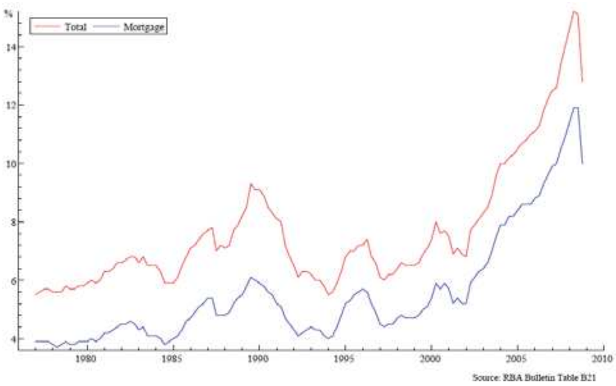


Chart 12 : Gearing ratios
(% of assets)

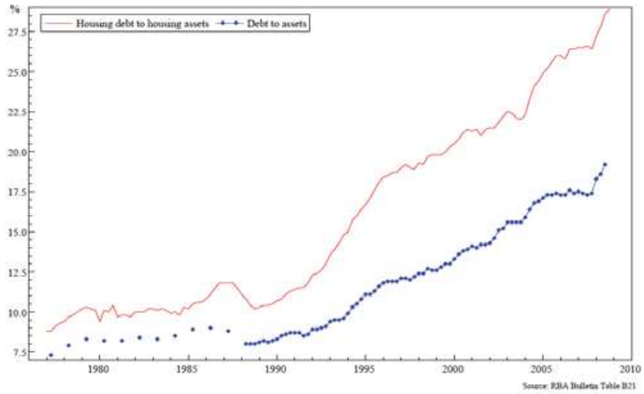


Chart 13 : Real net dwelling capital stock
(annual growth)

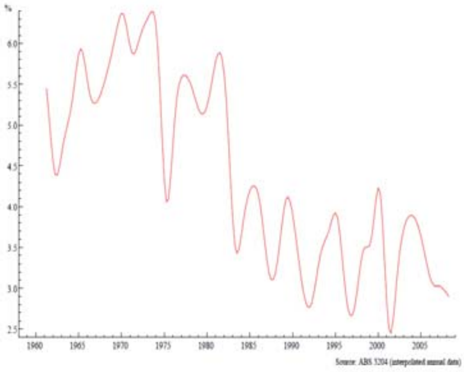


Chart 14 : Dwelling capital formation
(gross, as a percentage of real GDP)

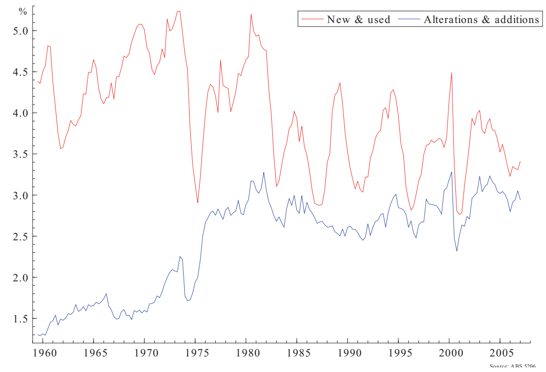
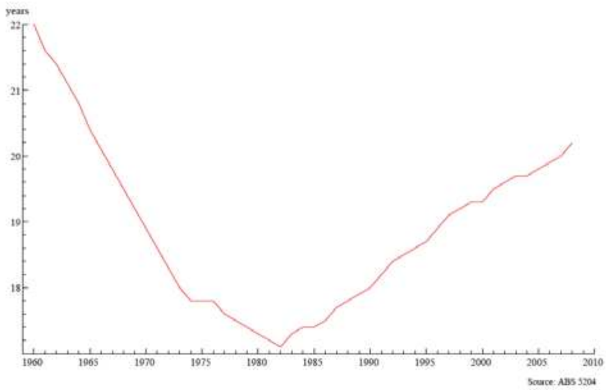


Chart 15 : Average age of dwelling capital stock



Appendix B: Summary of institutional developments

Selected timeline of major financial sector policy changes and events

1979	The Treasury (T-Note) tender system replaces the "tap" system: the price of government debt is now set by the market.
	Australian Financial System Inquiry (Campbell Committee) is established.
1980	Interest rate ceilings on trading and savings bank deposits are dismantled from this time; some limits on minimum and maximum terms on fixed deposits remain.
1981	Australian Financial System Inquiry (Campbell Committee) tables its final report
1982	Savings banks are allowed to accept deposits of up to $100,000 from trading or profit making bodies.
	The minimum term on trading bank fixed deposits is reduced from 30 to 14 days for amounts greater than $50,000, and from 3 months to 30 days for amounts less than $50,000.
	The Treasury Bond (T-Bond) tender system is approved.
1983	The Commonwealth Government announces that it will allow entry of 10 new banks, including foreign banks.
	The Australian dollar is floated and most exchange controls are abolished.
	The Treasurer announces the formation of the Martin Committee of Review to assess the Campbell Report.
1984	The Martin Committee of Review endorses the Campbell Report.
	All remaining controls on bank deposits are removed: minimum and maximum terms on deposits, savings bank exclusions from offering chequeing facilities, and the prohibition of interest on cheque accounts.
	The Australian stock exchanges and the securities industry are deregulated.
1985	Sixteen foreign banks are invited to establish trading operations in Australia. The first foreign bank begins operations in the last quarter.
	Electronic funds transfer at point of sale is introduced.
	Capital gains tax (CGT) is introduced. Pre-1985 assets are exempt.
	Negative gearing restrictions come into effect.
1986	The first award based superannuation schemes are established.
	The cessation of double tax on company dividends is announced. Imputation is introduced.
	Interest rate ceilings are removed on owner-occupied housing loans.

1987	The dividend imputation system takes effect from mid-year.
	The Australian Stock Exchange (ASX) commences operations and amalgamates state exchanges.
	Negative gearing restrictions are removed.
	World stock markets crash.
	The late-1980s house price boom begins.
1988	An issues paper *Towards a National Retirement Incomes Policy* (The Cass Report) recommends establishing superannuation as an integral component of the retirement income system.
	The RBA introduces consolidated risk-weighted capital requirements for banks, consistent with Bank for International Settlements' proposals. Housing assets held by banks are "risk weighted" at 50 per cent.
	Perth based merchant bank Rothwells collapses.
1989	The Reserve Bank first adopts interest rate targeting. Official interest rates reach 17 per cent.
	The late-1980s house price boom ends
1990	The Commonwealth Government announces the 'six pillars' policy banning mergers between the six largest domestic banks.
	Pyramid Building Society collapses.
1991	Commonwealth Bank shares are offered to the public for the first time and it acquires the State Bank of Victoria.
	The Martin Parliamentary Committee recommends a feasibility study of direct payments system access for NBFIs and the establishment of a high-value electronic payments system.
	Australia experiences a deep recession.
1992	Authorised foreign banks are allowed to operate branches in Australia, but not to accept retail deposits. Limits on the number of new banks that can be established are removed.
	The first mortgage originator, 'Aussie Home Loans', commences operations.
	The Australian Payments Clearing Association (APSC) is established.
1993	The Commonwealth Government Banking Policy Statement is announced, including changes to the interest withholding tax arrangements and a call for monitoring credit card interest rates and fees.
	The Australian Bankers' Association releases a code of banking practice to be monitored by the APSC.
	Reserve Bank begins to articulate a 2-3 per cent medium term inflation target.

1995	The government adopts a "five pillars" banking merger policy, allowing Westpac to acquire Challenge Bank.
	Advance Bank purchases the State Bank of South Australia.
1996	The Financial System Inquiry (Wallis Committee) is announced.
	Commonwealth Bank shares are offered to the public for the second time.
	The government signs an agreement with the Reserve Bank for an explicit 2-3 per cent CPI target on average over the business cycle.
	Banks remove the 1 percentage point differential between investor and owner-occupier housing loans.
	The late-1990s/early-2000s house price boom begins.
1997	St George Bank merges with Advance Bank.
	Banks, building societies, credit unions and life companies are allowed to provide retirement savings accounts.
1999	CGT discounting is introduced while averaging and indexation concessions are abolished.
2000	The New Tax System is introduced, with a goods and services tax (GST) at 10 per cent, the removal of several indirect taxes and substantial personal income tax cuts.
	The residential construction industry enters a post- GST slump.
	The first home owners' scheme (FHOS) is introduced.
	Established house price growth accelerates markedly.
2001	Global stock markets deteriorate after September 11 and a world economic slowdown begins.
	The additional FHOS is introduced.
2002	The additional FHOS phased out.
2004	The late-1990s/early-2000s house price boom ends.

Source: Financial System Inquiry Final Report 1997; Reserve Bank

Appendix C: Data

Descriptive statistics

Variable	*Mean*	*Std dev*	*Variable*	*Mean*	*Std dev*
		1972(3) to 2006(2)			
rhp	0.7681	0.2726	Δrhp	0.0075	0.0218
nhp	4.7695	0.7964	Δnhp	0.0221	0.0214
Li	-2.3268	0.2879	ΔLi	0.0005	0.0460
r	0.0423	0.0400	Δp	0.0147	0.0112
ecm	-13.988	0.5563	$\Delta\Delta p$	7.9823e-006	0.0070
y	-9.9496	0.1136	Δy	0.0034	0.0171
WA	66.802	1.0074	Δs	0.0038	0.1017
$DSrisk$	-0.0251	0.0344	$\Delta dem1$	-0.0265	0.1956
$intsup$	-0.0002	0.0334	$\Delta dem2$	0.2278	0.1842
$infvol$	0.0155	0.0135	Δpop	0.0129	0.0020
$CCI^* \times Li$	-1.3178	11.663	$FHOS$	0.4497	1.0836
$CCI^* \times r$	0.2131	0.7746	$(\Delta rhp_{t-1})^3$	1.8575e-005	7.2202e-005
Lue	1.8766	0.3493	ΔLue	0.0054	0.0657

Unit root tests

ADF tests suggest that the following variables are I(1) for both sample periods: real (rhp) and nominal (nhp) house prices, ecm, real (r) and log nominal (Li) interest rates, inflation (Δp), share prices (s), non-property income per capita (y), and interaction variables ($CCI^* \times Li$ and $CCI^* \times r$). The cubic of lagged quarterly real house prices ($(\Delta rhp_{t-1})^3$), $DSrisk$, change in inflation ($\Delta\Delta p$), interest rate surprise ($intsup$), inflation volatility ($infvol$) and $FHOS$ are all I(0).

Demographic variables were problematic since interpolated annual data do not lend themselves to unit root testing. Unit root tests are instead conducted on the annual series although the power of the tests are quite weak with only 36 annual observations (and less after differencing). This presents a quandary for the modeller. The solved-out life-cycle consumption model applied to aggregate data indicates that age demographics may be an important long run driver of house prices through their influence on the marginal propensities to consume out of income and wealth[68]. Yet WA appears, in a weak test, to be I(2) in level terms. Differencing yields an I(1) variable but information about age proportions is lost. WA combines with I(1) variables to provide a stable and economically meaningful long run solution with an I(0) residual implying cointegration. On this basis, concerns about the order of integration for demographic variables are set aside. $\Delta dem1$ and $\Delta dem2$ also appear to be I(I), while Δpop was I(0).

[68] As illustrated in Muellbauer and Lattimore (1995).

Unit root tests : variables in levels

	1972(3)	to 2006(2)		1979(1)	to 2006(2)	
Variable	**Lags (s)**	**t-adf stat**	**Order**	**Lags (s)**	**t-adf stat**	**Order**
rhp	1	1.028	I(1)	1	0.441	I(1)
nhp	1	-1.238	I(1)	1	-1.111	I(1)
Li	3	-1.816	I(1)	2	-1.652	I(1)
r	0	-1.848	I(1)	0	-2.021	I(1)
s	0	-0.745	I(1)	0	-1.287	I(1)
$DSrisk$	2	-3.744**	I(0)	2	-3.683**	I(0)
$intsup$	0	-10.50**	I(0)	0	-8.340**	I(0)
$infvol$	0	-4.728**	I(0)	0	-5.622**	I(0)
$CCI^* \times Li$	1	-1.433	I(1)	1	-1.310	I(1)
$CCI^* \times r$	2	-2.289	I(1)	2	-2.083	I(1)
Lue	1	-3.617*	I(1)	2	-2.866	I(1)
ecm	0	-2.373	I(1)	0	-2.503	I(1)
y	1	-1.289	I(1)	1	-1.345	I(1)

Unit root tests : variables in differences

	1972(3)	to 2006(2)		1979(1)	to 2006(2)	
Variable	**Lags (s)**	**t-adf stat**	**Order**	**Lags (s)**	**t-adf stat**	**Order**
Δrhp	0	-6.909**	I(0)	0	-6.526**	I(0)
Δnhp	1	-5.001**	I(0)	1	-6.292**	I(0)
ΔLi	1	-5.453**	I(0)	1	-3.907**	I(0)
Δs	0	-11.76**	I(0)	0	-11.49**	I(0)
$(\Delta rhp_{t-1})^3$	1	-6.584**	I(0)	1	-6.108**	I(0)
ΔLue	0	-6.546**	I(0)	2	-4.157**	I(0)
Δecm	0	-13.83**	I(0)	0	-12.66**	I(0)
Δy	0	-14.96**	I(0)	0	-14.09**	I(0)
Δp	1	-2.506	I(I)	2	-2.112	I(1)
$\Delta\Delta p$	2	-11.57**	I(0)	1	-12.72**	I(0)

Unit root tests : interpolated variables
(unit root tests are conducted on annual data)

	1976	to 2006	
Variable	**Lags (s)**	**t-adf stat**	**Order**
WA	1	-2.106	I(2)
ΔWA	0	-1.510	I(1)
$\Delta dem1$	0	-1.895	I(1)
$\Delta dem2$	1	–2.014	I(1)
	1972	**to 2006**	
Δpop	0	-14.18**	I(0)

Other variables

	2000(1)	to 2006(2)	
Variable	**Lags (s)**	**t-adf stat**	**Order**
$FHOS$	1	-4.201**	I(0)

House price model – variable construction and sources

Variable	Full Name	Construction	Source	Frequency	Start date
nhp	Nominal house price index	ln HP HP splices together: BIS: SQ59-JQ78 REA: SQ78 – MQ86 ABS(old): SQ86-DQ01 ABS(new): MQ02-	ABS 6416 REIA BIS Shapnel	Quarterly	
rhp	Real house price index	ln HP – ln p			
y	Real non-property income per capita	NPY - ln p - ln pop (see Appendix D)	ABS 5206-14	Quarterly	SQ 1959
nks	Real dwelling net capital stock per capita	Ln real dwelling net capital stock – ln pop	ABS 5204-69	Annual	Jun 1960
r	Real interest rate (four quarter moving average)	ma4(i/100 – d4p)			
Li	Log nominal interest rate	Log nominal standard variable bank mortgage interest rate	RBA F05	Monthly (use qtr average)	Jan 1959
p	Price level	Log household consumption implicit price deflator	ABS 5206-08	Quarterly	SQ 1959
infvol	Inflation volatility	abs(d4 p(t) – d4 p(t-4))			
DSrisk	Downside risk dummy	= ROR if ROR<0 = 0 if ROR>0 ROR = D4 nhp(t-1) +0.02 – i(t)/100			
Lue	Unemployment rate	ln ue	Datastream (OECD Main Economic Indicators)	Quarterly	Aug 1966
s	Real share prices	Log All Ordinaries Index - p	Datastream (OECD Main Economic Indicators)	Monthly (use end-month)	Jan 1960
NG	Impulse dummy for restricted negative gearing deductions				SQ1985 – SQ1987
FHOS	Dummy for introduction of first home owner's grant	ma4 (Nominal value of grant / median house price value) (Median house price based on SQ04 point estimate from REIA Market Facts, then extrapolated and back-casted using Dnhp)		SQ04 REIA Market Facts	SQ2000
WA	Proportion of the population of working age (15-64yrs)	number of persons aged 15-64 / total est resident population	ABS 3201-09	Annual (interpolated using a cubic spline in PcGive)	Jun 1971

pop	Estimated resident population	ln pop. Cubic spline is used to interpolate and smooth series.	ABS 3101 ABS 3105	Pre-1989(3): ABS 3105 Historical Population Series (annual) Post-1989(3): ABS 3101 Estimated resident population (quarterly)	1901
Dem1	Proportion of the population aged 22-34 years "Household formation age"	number of persons aged 22-34 / total est resident population	ABS 3201-09	Annual (use a cubic spline in PcGive to interpolate quarterly)	Jun 1971
Dem2	Proportion of the population aged 35-64 years "Investor age"	number of persons aged 35-64 / total est resident population	ABS 3201-09	Annual (use a cubic spline in PcGive to interpolate quarterly)	Jun 1971