Explaining the bubble: House prices, user-cost and credit conditions in Ireland, 1975-2012

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Abstract The Great Recession starting in 2007 has refocused attention on the importance of understanding housing markets dynamics as contributors to macroeconomic fluctuations. A typically omitted variable in analyses of housing prices is credit conditions. This paper examines the case of Ireland, where an extreme housing market cycle saw prices increase four-fold in the decade to 2007, before falling by more than 50% by 2012. Using a quarterly dataset from 1980 to 2012, it estimates an error-correction model that reveals the long-run relationship between house prices and fundamentals. Those fundamentals include the ratio of income to the stock of housing, the ratio of persons to households, user and transaction costs, and credit conditions, as measured by the ratio of mortgage credit to deposits. While the earlier phase of Ireland's house price boom was a product of many factors, growth between 2001 and 2007 was due almost entirely to an easing of credit conditions. Using new data on LTVs for first-time buyers, an error correction model of the price-rent ratio in Ireland is presented for the first time, covering the period 2000-2012. This indicates that credit conditions were, along with the real rate of interest, key to determining equilibrium in the housing market. Normalization of expectations in relation to housing can be expected to generate some upward pressure on prices in coming years, but may be counteracted by a normalization of credit conditions.

Keywords: Housing markets; credit conditions; housing bubble; Ireland.

JEL Classification Numbers: E32; E44; E51; G12; G21; R21; R31.

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1 Introduction

The OECD housing bubble and crash of the 1990s and 2000s has reminded economists of the importance of housing in modern developed economies. It is typically the single most important class of consumption good, making up for example 32% of the U.S. urban CPI basket, and is also the most prevalent investment asset, comprising 54% of US household wealth (Luckett 2001). Unsurprisingly, there is strong evidence of the link between housing and broader economic outcomes, not just for recent economic history (Davis & Heathcote 2005, Leamer 2007) but the entire postwar era (e.g. Holly & Jones 1997) and indeed even predating the Industrial Revolution (Eichholtz et al. 2012, O'Rourke & Polak 1991).

The recent housing bubble and crash cycle has been particularly acute in Ireland. The period from the mid-1990s to 2007 was one of very strong economic growth in Ireland, initially export-led but in later years fuelled by readily available cheap credit and an unprecedented building boom. From 2007, the economic downturn was severe. Nominal GNP fell from €163bn in 2007 to €128bn in 2011, while government finances deteriorated sharply, with a fiscal deficit of 10% of output by 2010. Unemployment rose from below 5% in 2007 to almost 15% by 2011, while large inward migration flows changed to emigration. Central to the dramatic change in Ireland's economic fortunes was the end of a domestic real estate bubble, which had seen nominal house prices rise four-fold in the decade to 2007. By late 2012, prices had fallen by more than half.

The case of Ireland exemplifies the links between housing and other aspects of the economy, including financial stability, the labour market, government finances, and public service provision. Research examining its housing crash, however, remains scarce. This paper uses a quarterly dataset to examine the long-run relationship and short-run dynamics that governed house prices in Ireland from the mid-1970s until 2012. Credit conditions are increasingly acknowledged as an omitted variable in many existing models of house prices. Thus, in addition to metrics of income, housing stock, demographics and user cost, it includes a readily available measure of credit conditions, the ratio of mortgage credit to household deposits. Using new data on the typical loan-to-value for Irish first-time buyers, it also develops the first model of the price-rent ratio in Ireland, covering the period 2000-2012.

The paper is structured as follows. Sections 2 and 3 outline briefly the economic theory behind models of house prices and the existing literature on the relationship between credit conditions and housing prices and on the Irish housing market. Section 4 provides details on the data used in this analysis. Section 5 outlines the empirical results of an error-correction framework applied to an inverted demand model of the Irish housing market, while Section 6 applies an equivalent framework to the ratio of income to housing stock and outlines the cointegration properties between the two. Section 7 presents a model of the price-rent ratio in Ireland from 2000 to 2012, while Section 8 decomposes Irish house price growth since the 1970s and assesses the policy implications of the analysis presented here. Section 9 concludes.

2 Theory

There are two main methods with which house prices are modeled over time. The first is the inverted demand approach, which draws on basic consumer theory and the fixed nature of housing supply in the short run. The second, drawing more on financial theory, is the price-rent ratio approach. As both forms of model are employed in this analysis, both are described below.

2.1 Inverted Demand

Theoretically, demand for a good depends on its prices, the income of consumers and other demand shifters. Applied to housing, suppose that in any given period t, the quantity of housing demanded, h_t, can be approximated linearly by:

$$ln(h_t) = -\alpha ln(hp_t) + \beta ln(y_t) + z_t$$

where hp_t refers to the real housing price, y_t to (real) household income and z_t to demand shifters, as discussed below. As the supply of housing is fixed in the short run, the demand function can be inverted, giving:

$$ln(hp_t) = (\beta ln(y_t) - ln(h_t) + z_t)/\alpha$$

Where the income elasticity of demand, β, is one, this simplifies further, with house prices being determined by the log income per house ($\frac{y}{h}$)and other demand shifters, z.

Demand shifters may include demographics, user costs and credit conditions. Demographics, for example the proportion of the population of household-forming age (typically 25-34 year-olds), may have an impact on house prices, *ceteris paribus*. Other demographic variables that may capture similar effects include net migration or the ratio of persons to households.

As discussed in more detail below, the user cost, uc_t, reflects the asset nature of housing. Measures of the user cost typically include the interest rate, reflecting capital and opportunity costs, any depreciation and maintenance and any transaction or taxation costs. From this is subtracted any expected capital gain: the faster house prices are expected to rise, the less the anticipated cost of owning a house. Theory also suggests that a risk premium term should be included in user cost: everything else being equal, if market participants believe there to be risk associated with current market conditions, this will depress demand and thus prices.

Income, housing stock, user costs and demographics are typically included in inverted demand models. Credit conditions, however, have until recently been omitted, often because such conditions are hard to measure. Theoretically, however, everything else being equal, at a given interest rate, house prices will be higher if banks are more prepared to lend, i.e. if credit conditions are more favourable. This can be thought of as a relaxation of credit rationing, or a fall in shadow price of credit (see Meen 1990). In practical terms, one may think of this as either secular financial

liberalization (as occurred in many OECD economies in the generation to 2007) or cyclical appetite among financial institutions for mortgage assets. Credit conditions can be captured by proxies, such as the average or maximum loan-to-value offered to first-time buyers (see, for example, Duca et al. 2011*a*) or alternatively can be estimated using latent variables (e.g. Muellbauer & Williams 2011).

2.2 Price-to-rent Ratio

An alternative approach for establishing the equilibrium level of housing prices is related to the concept of financial arbitrage (Poterba 1984). In an equilibrating market, housing prices will reflect the discounted future stream of rents: $hp_t = rent_t/\rho_t$, where ρ_t represents a discount rate. Where discount rates match interest rates r_t, and where housing is subject to costs of depreciation and maintenance (δ_t), costs of transaction and taxation (τ_t), and expected capital gains (κ_t), this means that the ratio of housing prices to rents (hpr_t) depends on the user cost[1]:

$$hpr_t = 1/(r_t + \delta_t + \tau_t - \kappa_t)$$

In log formulation, and allowing for flexibility in relation to the relative importance with which the various factors affect the ratio:

$$ln(hpr_t) = \beta_0 + \beta_1 r_t + \beta_2 \delta_t + \beta_3 \tau_t + \beta_4 \kappa_t$$

where the expectation is that β_1, β_2 and β_3 are negative and β_4 is positive (greater expected capital gains push up house prices). As mentioned above, a risk premium term, π_t, should be included in user cost, while tax relief on mortgage interest will also affect the net cost of capital.

Two other factors should affect the equilibrium ratio of prices to rents in the housing market. Firstly, as outlined in Kim (2008), if a house provides a different level of rental service to an owner-occupier than to a tenant, and houses are rented out reflecting this "rental efficiency", then the ratio of prices to rents will be positively related to rates of home ownership, θ_t. Put another way, the dividend on housing (the rent-price ratio) will be lower when home ownership is greater, due to the different level of service derived from housing by owner occupiers.

Secondly, as with the inverted demand approach, credit conditions affect the equilibrium ratio of prices to rents. Empirically, where uc_t refers to the user cost term described above, the log form allows the estimation of the long-run relationship between the various factors:

$$ln(hpr)_t = \beta_0 + \beta_1 r_t + \beta_2 \delta_t + \beta_3 \tau_t + \beta_4 \kappa_t + \beta_5 CCI_t + \beta_6 \theta_t + \beta_7 \pi_t$$

where CCI is specified such that an increase reflects an easing of credit conditions; thus the

[1] This is typically thought of in annual terms. For example, market participants may use a rule such as: "what multiple of annual rent is this property worth?" Equivalently, one could consider the ratio of rents to house prices as being the percentage dividend on housing as an asset.

expectation is that β_4, β_5 and β_6 are positive, with all other coefficients (apart from the intercept) negative.

3 Literature

3.1 Credit Conditions & House Prices

The link between housing market outcomes, deposits and credit is well established. For the U.S., Jaffee et al. (1979) stressed the importance of the availability of credit, as well as its cost, and document some research on its importance in determining post-war cycles in housing and construction. They also include in their model fundamentals such as the population aged 25-34 and the "headship rate", or ratio of persons to households. For the availability of credit, their model uses the flow of deposits into thrift institutions and the flow of mortgage credit from federal agencies (both relative to house prices).

The availability of credit – also described in the literature as mortgage rationing – affects prices by acting as a shadow price on the credit constraint. This affects both real house prices and the ratio of prices to rent; for more on the early literature on this, see Meen (1990). Whereas Meen estimated mortgage rationing through the percentage increase in mortgages advanced, Dicks (1990) used loan-to-value (LTV) information for the housing market. More recently, Fernandez-Corugedo & Muellbauer (2006) developed a credit conditions index for the UK over the period 1976-2001. This is done by using quarterly microdata from the Survey of Mortgage Lenders on LTV and loan-to-income (LTI) ratios for first-time buyers, in particular combining data on the proportion of high LTV and LTI loans with aggregate information on debt to give ten quarterly series. A single index is then calculated by controlling for economic and demographic influences.

Where such rich micro-data is not available, reduced-form proxies have been used as alternatives. Duca et al. (2011*a*,*b*) use American Housing Survey information on the average LTV for first-time buyers in the U.S., for the period 1979-2007, to capture credit conditions. Doing so, they find that the inclusion of credit conditions notably improves models of house price, giving better model fits, reasonable speeds of adjustment, and stable long-run relationships with sensible and more precisely estimated income and user cost coefficients, both for the pre-2002 sample and for the whole period. An alternative approach is taken in Muellbauer & Williams (2011), which models large, unobserved structural changes in the macroeconomy using a latent interactive variable equation system. This involves using smoothed step dummies, informed by knowledge of the specific institutional environment – in this case Australia – to form a spline function.[2]

[2]This is similar in spirit to work such as Barrell & Philip Davis (2007), whose research uses indicator variables informed by OECD research to measure the effects of financial liberalization on consumption.

3.2 Ireland's Property Market

Broadly speaking, there have been four phases of applied research on the Irish housing market, with the principal work summarized in Table 1. The first dates from the late 1970s and early 1980s, in response to the publication of official housing price statistics in the 1970s. Very little research on the market was then undertaken until the late 1990s, when a number of papers attempted to understand the long-run fundamentals determining house prices, in order to assess the probability of a bubble in the housing market at that time. A similar phenomenon occurred around 2004-2005, as there was growing concern again that house prices were over-valued. Since the crash, a number of papers – led by economists at the Central Bank of Ireland – have undertaken analyses of the housing market, to shed light on where house prices should be and whether they have over-corrected.

Early 1980s Official quarterly bulletins relating to the Irish housing market started around 1970 and by the late 1970s, the first econometric research on the market was emerging (see, for example, Kenneally & McCarthy 1982). While it is not proposed to examine this early literature in detail, the details of one paper are useful motivation for this research. Using a partially mix-adjusted quarterly dataset of new house prices from 1971 to 1980, Thom (1983) outlined a model where the change in house prices is positively related to excess demand. Six demand shifters were included in the analysis: income (proxied by higher-frequency industrial production data); demographic factors (the ratio of marriages to private sector completions); user-cost (as measured by the net real rate of interest, less the anticipated change in house prices); credit conditions (described presently); and two other credit market factors, the mortgage repayment in real terms and the elasticity of the present value of the stream of mortgage repayments with respect to the discount rate.

Similar to the measure used here, credit conditions are measured using the growth rate in building society share and deposit liabilities; this measure performed statistically better than alternatives such as average loan-to-value or total mortgage approvals. While not an error correction model, as no lagged level is included, all variables are statistically signifcant at 5% with the expected sign. The implied long-run equation suggested a cofficient on income of 1.68 and on mortgage availability of 0.69.

Late 1990s A number of studies of the Irish housing market appeared between 1998 and 2001, concurrent with a major review of policy in relation to the housing market, known as the Bacon Report. These were typically inverted demand models, using annual data from the 1970s. A summary of four of these, Harmon & Hogan (2000), Kenny (1999), Murphy (1998), Murphy & Brereton (2001), is given in Table 1. The most comprehensive, by Murphy & Brereton (2001), suggests that the long-run equation for real house prices was unstable towards the end of the sample (1997-9), suggesting that demand was higher than predicted, a possible indicator of bubble conditions.

Mid-2000s Between 2003 and 2006, a number of studies of Irish housing prices were undertaken, as there were renewed concerns, particularly among international organisations, that the Irish housing market exhibited bubble conditions. In particular, two key metrics – the price-income and price-rent ratios – had risen steadily from 1996 onwards. Table 1 lists seven: IMF (2003), McQuinn (2004), Murphy (2005), Rae & van den Noord (2006), Roche (2004), Stevenson (2003). This includes papers by the IMF, the OECD and papers commissioned by the Central Bank of Ireland and Ireland's National Competitiveness Council. Two further papers, McQuinn & O'Reilly (2008), Stevenson (2008), also date from this period, with the later date of publication reflecting the peer-review process.

None of these includes a continuous measure of credit conditions or financial liberalization and some suffer from other issues. For example, analysis by IMF (2003) includes no measure of housing stock, while the preferred specifications in Stevenson (2003) and Roche (2004) are ad-hoc in nature. While McQuinn (2004) uses solid theoretical foundations, the inclusion of the average mortage term is problematic, and the model has a very low long-run coefficient on income (less than 0.2) and slow speed of adjustment (0.14).

Both Murphy (2005) and Rae & van den Noord (2006) use inverted demand error-correction models (ECM), although both impose an error correction term using first-stage OLS results. Murphy (2005) includes dummy variables for financial liberalization and the results indicate rapid adjustment to equilibrium prices, although the cofficient on income is less than on housing stock. Rae & van den Noord (2006) use quarterly data in an ECM framework, and the results (for prices of second-hand houses at least) indicate rapid adjustment (speed of adjustment, SOA, of 0.34) and a similar magnitude of coefficients on income and housing stock (roughly 1.7).

Post-crash Since the crash, there has been a growing body of work examining the determinants of Irish house prices. Of interest for this analysis is work by Addison-Smyth et al. (2009), who present a two-equation system of average mortgage levels and house prices that builds on McQuinn & O'Reilly (2008). Analysis by McQuinn & O'Reilly (2008), on the price of new dwellings, uses a specific form of borrowing capacity, that is effectively a restriction on how income and interest rates affect prices. Addison-Smyth et al. (2009) extend this, before undertaking a supplementary specification including the "funding rate", the ratio of the outstanding level of mortgage lending to total domestic deposits. This is found to have considerable power in explaining average mortgage levels over the period and a plot of fundamental house prices including this factor matches price developments more closely than the more restricted model of mortgage levels.[3]

Two technical papers by economists at the Central Bank of Ireland have recently attempted to understand fundamental house price levels and their likely future path in the post-crash era.

[3]McQuinn & O'Reilly (2008) include the average loan-to-value reported by the DOE – see Section 4.10 – in robustness checks but this does not improve the fit of their model, which has a very slow speed of adjustment (close to 0.05).

Kennedy & McQuinn (2011) uses the model in Addison-Smyth et al. (2009), extending the sample to 2010Q4 and using improved house price information from 1996. They do not report their econometric results in detail, however. Similarly, an overview of house prices in 2011 using four different specifications, all based on the inverted demand approach and including the Addison-Smyth et al. (2009) funding-rate specification, suggests that house prices in mid-2011 were below their fundamentals, by between 12% and 26% (Kennedy & McQuinn 2012).

User cost It is worth noting that there has been only a limited interest in the user-cost of Irish housing and the authors are unaware of any existing price-rent models of the Irish housing market. Research by Barham (2004) found that user cost associated with owning housing in the Irish market was negative for large parts of the period from 1976 on, principally due to the favourable tax treatment afforded owner-occupancy (including the lack of an annual property tax, any capital gains tax on principal private residences, and generous mortgage interest relief, grants and subsidies). More recently, Browne et al. (2013) have updated this analysis, finding that the user cost is dominated by expected capital gain, where this is measured with the annual gain over the last four years.

Author	Period	Method	Fundamentals	Finding/Comment
Kenneally & McCarthy (1982)	1969IV-1976III	Quasi-inverted D; 6-eq'n system	Y, S, r_r, demog, q_mort, rhp_1	Levels not logs, lack of statistical significance; unsuccessful inclusion of credit rationing
Thom (1983)	1971I-1980IV	Inverted D; quasi-ECM	Y, S, r_r, demog, CCI, repayment, T	T as described in text; coeff on Y 1.68, coeff on CCI 0.69
Murphy (1998)	1974-1997	Inverted D	Y, S, r_r, pop2534, dY	Coeffs on Y, r 1.4 and -0.35 respectively: both low compared to other countries
Kenny (1999)	1975I-1997I	Inverted D; VECM	Y, S, r_n	Unit elasticities imposed; Y measured by agg GNP (no demographics)
Harmon & Hogan (2000)	1972-1999	Inverted D	Y, S, r_n, pop2534	Only Y significant; prices in 2000 above LR prediction
Murphy & Brereton (2001)	1974-1999	Inverted D	Y, S, r_r, pop2534, dY	LR equation unstable in period 1997-9; demand higher than predicted
IMF (2003)	1976-2002	Inverted D; ECM	Y, r_r, pop2534	1976-97 model suggests 50% overvalued in 2002; no stock measure; SOA=0.31
Stevenson (2003)	1978-2001	Ad hoc, based on inverted D	Y, S, r_r, pop, conf, empl, rhp_1	Interpretation unclear; model without lagged DV performs poorly
Roche (2004)	1979I-2003I	Regime-switching; ad hoc	Y, r_r, av_mort, migr, c_build, c_land	Good fit, but likely due to endogeneity issues (incl of land values)
McQuinn (2004)	1980I-2002IV	Inverted D; ECM in 3-eq system	Y, S, r_r, av_mort, migr, uc	User cost term dropped; LR coefficient on income very low (<0.2), SOA<0.14
Murphy (2005)	1974-2004	Inverted D; two-stage ECM	Y, S, uc, r_r, pop2534	Lower coeff on Y than S; dummies for financial liberalization; SOA=0.44
OECD (2006)	1977I-2004I	Inverted D; two-stage ECM	Y, S, r, pop2534	2nd-hand: coeff on Y and S similar (1.69, -1.68), SOA=0.34; new: only Y, S included
Stevenson (2008)	1978I-2003I	Inverted D; two-stage ECM	Y, S, r_r, pop2534	Large LR coeffs on Y (3.3), S (11); SOA= 0.08 (t-stat of 2); 18% overvaluation by 2003
McQuinn & O'Reilly (2008)	1980I-2005IV	Inverted D; two-stage ECM	Y + r_n (specific functional form), S	LR coeff on Y,r term 0.8; SOA=0.05; report that LTV when included not significant
Addison et al (2009)	1982IV-2009I	Inverted D; 2-eq system ECM	Y + r_n (specific functional form), S	SOA=0.17; coeff on joint Y,r term close to 1
Kennedy & McQuinn (2011)	1982I-2010IV	Inverted D; 2-eq system ECM	Y + r_n (specific functional form), S	Detailed results not reported; DOE price data replaced with hedonic price data post-1996
Kennedy & McQuinn (2012)	1980I-2011III	Inverted D; 4 variants	Y, S, r_r, pop / Y+r_n, S (as above)	Detailed results not reported; prices estimated at 12-26% below fundamental levels
Browne et al (2013)	1980I-2012IV	User cost	N/A	Real user cost of capital negative 1980-4 and 1998-2008

Table 1: *Overview of literature on Irish housing market; Notes: (1) SOA refers to ECM speed of adjustment; (2) specific data series vary significantly between studies; (3) regressors are denoted as follows: Y is income (dY change in income); S is housing stock; r_r and r_n real and nominal rates of mortgage interest; pop is population, pop2534 the population aged 25-34 (demog refers to an alternative measure of demographics); CCI is a credit conditions index; q_mort is quantity of mortgages; rhp_1 is the lagged dependent variable; uc is user cost (as distinct from interest rate); c_build and c_land refer to cost indices for building and land.*

4 Data

This section outlines the data used in the analysis of Ireland's housing market. In addition to discussions of the price and rent data, there are sections reflecting each of the fundamentals outlined in Section 2: income, housing stock, demographics, interest rates, expected capital gain, transaction costs and credit conditions.

4.1 House Prices

The quality of information on trends in Irish housing prices over the period analysed is mixed. Nonetheless, it possible to connect up two sources, the Residential Property Price Index by Ireland's Central Statistics Office (CSO, 2005-2012) and the ESRI index (1996-2010, based on mortgages issued by the PTSB bank) to generate a hedonic index of Irish housing prices from 1996 until the end of the sample.[4]

For the period prior to 1996, however, the only information is a raw average of transaction prices (as reflected by mortgage transactions), provided by the Department of the Environment from the 1970s. Quarterly information for all dwellings (both new and second-hand) is available from 1978Q1, while information on new dwellings is provided quarterly from 1975Q1. There is information on housing prices in Ireland published by the Department of the Environment from 1950 to 1975, but it is affected by changing periodicity (annual from 1965 and 5-yearly prior to this), geographic coverage (Dublin-only, prior to 1968) and scope (alternating between all properties, new dwellings, and new and second-hand separately).

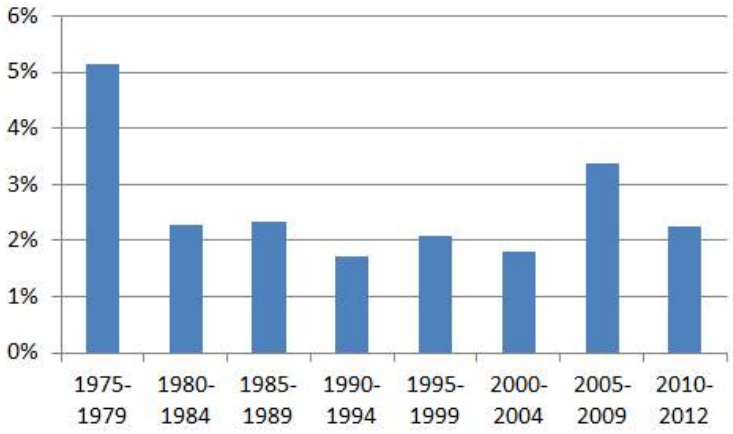
Inflation Conversion from nominal to real house prices is done using the Consumer Price Index (CPI), excluding mortgage interest. This is available from 1975Q4 on. (For any analysis prior to this, the CPI ex-mortgage interest is extended backwards using quarterly changes in the full CPI.) Using the information on house prices and general price levels, this yields two key variables: $ln(rhp)$ and $dln(rhp)$, the log and change in log of real house prices.

Extending back to 1975 In Section 5, the principal analysis is undertaken on the period 1980-2012. As explained above, quarterly data on prices of new dwellings do exist for the period 1975-1978; however, as is shown in Figure 1, there is significantly greater volatility in the quarterly change in real house prices in this earlier period. The standard deviation in the quarterly change in real house prices for 1975-9 was over 5%, more than twice the average standard deviation for other intervals shown. This may result from economic factors – the late 1970s saw high inflation which ultimately saw Ireland break its peg with sterling – or due to data issues, as mean prices refer before 1978 solely to new dwellings. Regardless, the greater volatility during the late 1970s

[4]Where a level of house prices is needed, for example comparing actual and fitted values, the Census-weighted average price from the 2012Q4 Daft.ie Report was used.

affects the precision with which the long-run equation can be estimated, thus a model spanning the entire 1975-2012 period is presented as a supplement to the main analysis.

Figure 1: *Standard deviation in quarterly real house price changes, 1975-2012*

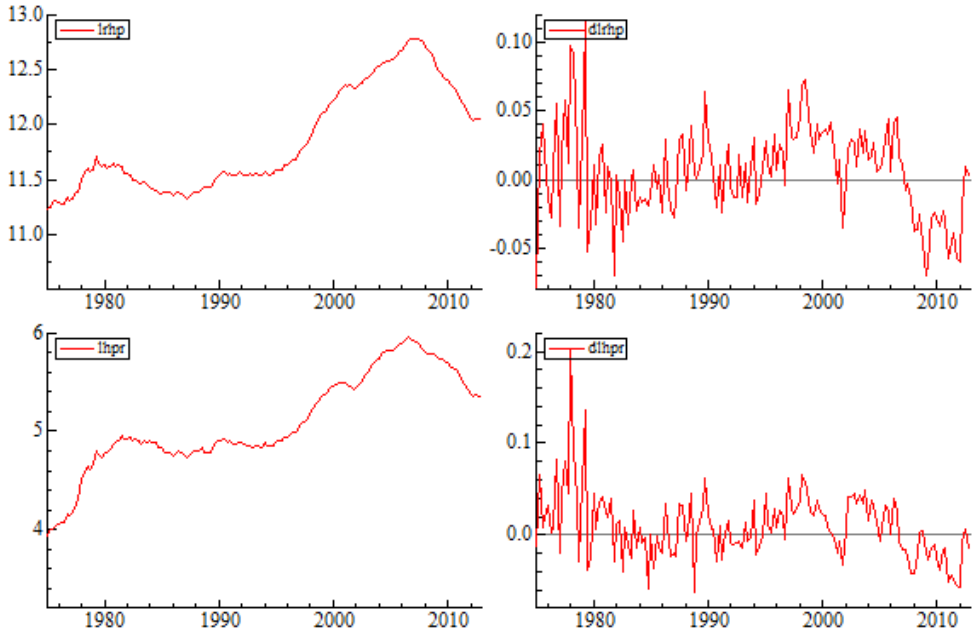


4.2 Rents

Information on rents, needed to calculate the price-rent ratio, is from the CSO. While an alternative, mix-adjusted series is available for the period 2002-2012, to investigate the ratio prior to this date, CSO information – typically gathered via a small survey of landlords and lettings agents – is needed. This is available on a quarterly basis, as part of the Consumer Price Index, from 1947 on. As with prices, these indices are converted to levels using the Census-weighted average rent according to daft.ie in 2012Q4 and, where necessary, nominal rents are converted to real rents using the CPI excluding mortgage interest. Using series for house prices and rents gives: $ln(hpr)$ and $dln(hpr)$, the log and change in log of the house price to rent ratio, hpr. The various dependent variables are shown in Figure 2.

Private renting in Ireland Between 1961 and 1991, the proportion of people renting in Ireland halved to 18%, led initially by falling numbers in private rented dwellings and then by those renting from local government; see Figure 5. The fraction of renters rose to 26% in between 2002 and 2011, due to private renting, as the proportion privately renting almost doubled from 11% to 19% in that period. The rapid decline in renting, particularly in the 1970s and 1980s, was associated with a halving in real rents between 1973 and 1983. Coupled with this, there were significant reforms of the private rented sector in Ireland in the late 1990s and early 2000s. This is discussed in more detail in Section 7 on the price-rent ratio.

Figure 2: *Plot of dependent variables, 1975-2012*



4.3 Income

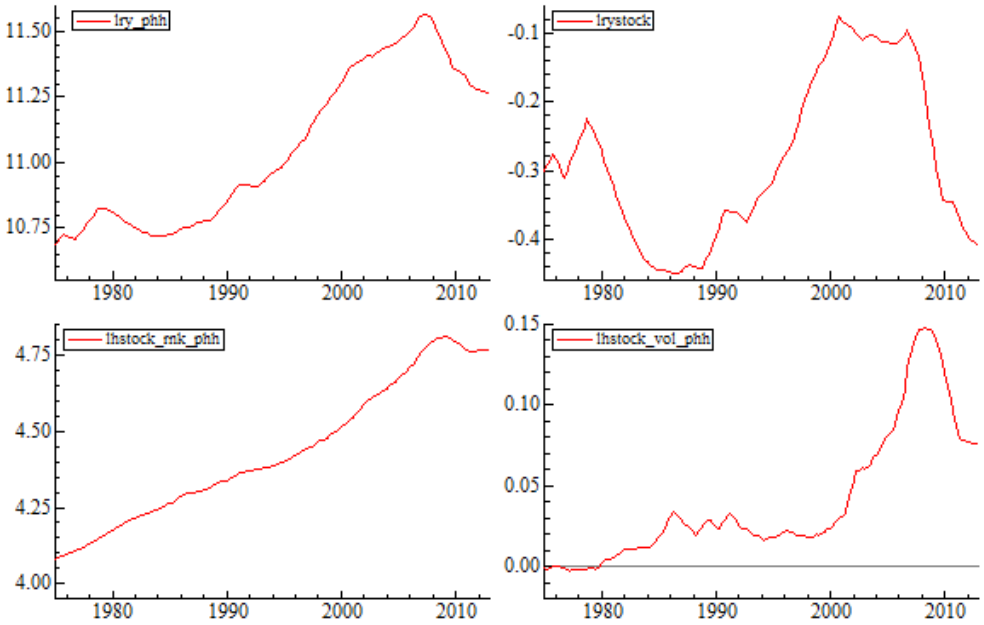
Information is available annually from the AMECO database for the period 1960-2012 on per capita real and nominal gross national disposable income (GNDI). As this includes non-labour sources of income, and is after-tax, this is preferred to alternatives such as nominal compensation per employee, which is available on an annual basis, or quarterly earnings data, which is only available (through the CSO) from the 1980s on. Annual information on disposable income per capita is converted into quarterly information using interpolation such that the annualized Q4 figure matches the end-of-year statistic in the AMECO database, giving $ln(ry)$ and $dln(ry)$, log and delta-log of real income per capita or per household (depending on the specification).

As outlined below, per-household series are preferred to per-capita series, due to their stationarity properties, with the decline in persons per household captured separately; see Section 4.6. Similarly, the ratio of income to housing stock, in log form, is used frequently. Figure 3 plots income per household, the income-housing stock ratio, and the value and volume of housing stock per household, all in logs, for the period 1975-2012.

4.4 Housing Stock

Ireland's housing stock can be measured in either units (number of dwellings) or value (in constant-price euro). The latter has the advantage of capturing any changes in the size and mix of housing (e.g. a greater proportion of apartments over time, or counter-cyclical improvements to housing

Figure 3: *Plot of regressors: income and housing stock, 1975-2012*



due to negative equity and thus a lack of mobility). For this reason, the real net capital stock in dwellings was used. This is available on an annual basis as part of the CSO National Accounts from 1985 on. For the period preceding this, real gross fixed capital formation in dwellings was used, together with the depreciation rate implied by the National Accounts, to give net fixed capital formation. This rate was estimated from difference between gross and net formation for the period after 1985. For the decade 1986-1995, the rate was a constant 1.66%, so this rate was applied to figures prior to 1985.

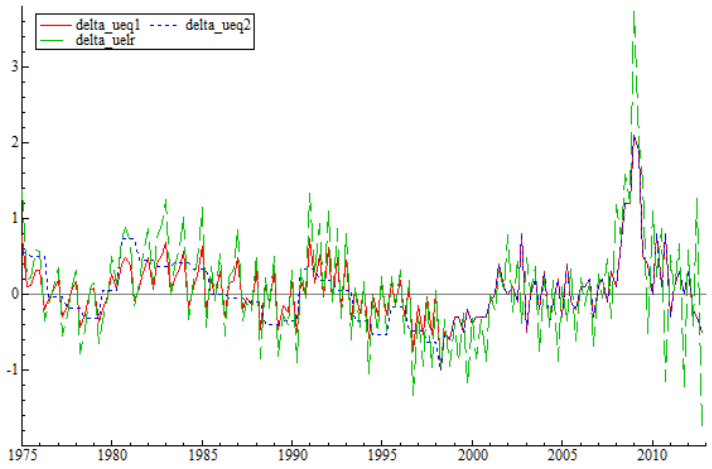
Combined with the series on real income, the series on the value of housing stock gives $ln(y/stock)$, the log of the ratio of income (per capita or per household) to the stock of housing, measured in 2012€. To give an idea of the scale of this variable, in late 2012, per-household income was measured at €78,000, while per-household housing stock was valued at €117,000, giving a ratio of income to stock of 0.67.

4.5 Unemployment

While the bulk of labour market effects will be captured by disposable income, included in certain specifications of the dynamic modelling of changes in real house prices and the price-rent ratio are measures of unemployment. For the period 1998Q1 to 2012Q4, the (seasonally adjusted) unemployment rate is taken from Ireland's Quarterly National Household Survey (QNHS), administered by the CSO, which is Ireland's official unemployment rate. The series is extended to the 1970s using

the percentage change in the Live Register, a monthly indicator of those in receipt of unemployment benefits. An alternative is to use a four-quarter moving average of the annual unemployment rate provided by AMECO (ultimately also from the CSO). However, as shown in Figure 4, for dynamics, this results in the same change in unemployment rate in each quarter of a year. Conversely, the Live Register series may be subject to seasonal swings, although this can be examined empirically.

Figure 4: *Plot of regressors: change in unemployment, 1975-2012*



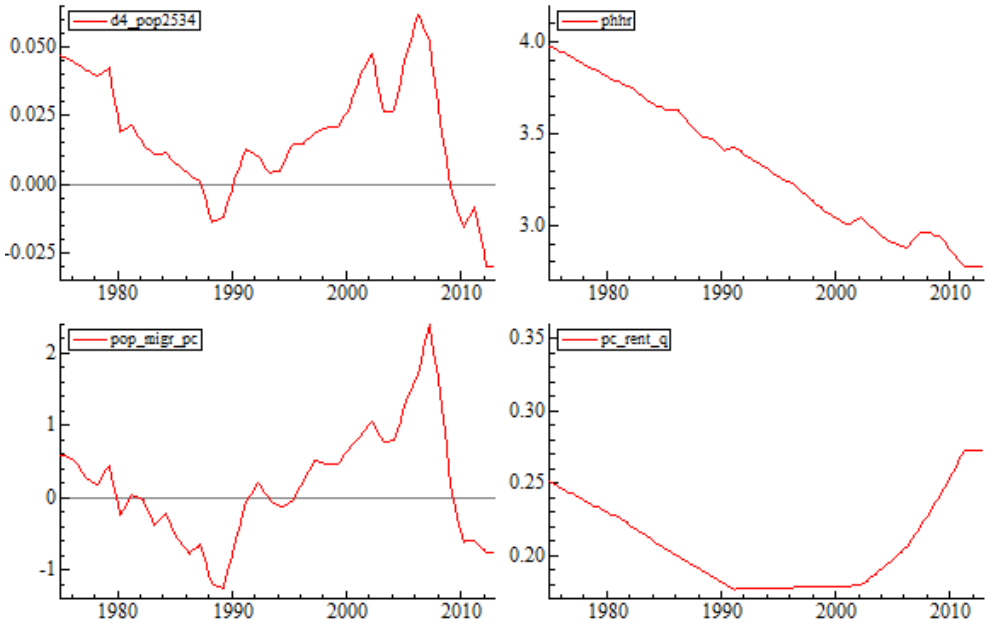
4.6 Demographics

Three potential series of demographics are included in the dataset. The first is the proportion of the population aged between 25 and 34, typically regarded as the "home-buying cohort". This is available from annual data published by the CSO and is interpolated into quarterly data. As outlined in Section 4.11, $ln(pop_{2534})$ is I(2), so any long-run solution will involve the delta-log form, $dln(pop_{2534})$. The second demographic series is net migration, which again is measured annually by the CSO and can be expressed as a percentage of the total population.

Lastly, and new to studies of the Irish housing market, is the ratio of persons to households, *phhr*. Everything else equal, a smaller number of persons in the average household is associated with a higher level of demand, as the same population is spread across a greater number of dwellings. The number of households is available at typically five-year Censal intervals, while the total population is available on an annual basis. Interpolating the number of households between Census years gives annual and quarterly series for the person to household ratio, *phhr*.

Plots of four demographic variables are given in Figure 5: the change in population aged 25-34 (in logs); the person-to-household ratio; the net migration rate (in percent); and the percentage renting (a quarterly interpolation; discussed in more detail in Section 7).

Figure 5: *Plot of regressors: demographics, 1975-2012*



4.7 Interest Rates

Mortgage market interest rates are taken from official sources. For the period from 2003, the quarterly average of the annual percentage rate of charge (APRC) reported by the ECB is used. For the period 1975-2002, the data is the CSO "representative Building Society mortgage rate". These are variable rates, as these represent the vast majority of mortgages in Ireland; according to Kennedy & McIndoe-Calder (2011), just 15% of the loan-book of the four major Irish lending institutions at the end of 2010 was based on fixed-rate mortgages, most of which will revert to variable rates after a certain period.

The series form the gross nominal mortgage rate rm^{GN}, where rm stands for mortgage rate (as opposed to deposit rate or some combination), G for gross and N for nominal. The net nominal mortgage rate, rm^{NN}, is calculated by deducting the marginal rate of mortgage interest relief. For the period 1975-1992, the marginal tax rate for first-time-buyers is lower than the top marginal rate. This is typically lower by one band and is based on average salaries at the time; see Figure 12 in the appendix for more details.

Opportunity cost Technically, if a downpayment of θP is required, where P is the house price, the opportunity cost for a first-time buyer is not given solely by rm. Rather it is given by a weighted average of $\theta rd + (1-\theta)rm$, where rd represents the (after-tax) rate of return on alternative investments. Using typical deposit rates for rd, a series giving this overall rate of interest is available,

using crude information on loan-to-value as discussed below, for θ. In this case, information on $rd^N N$, the net nominal interest rate on deposits, comes from the Central Bank of Ireland (the gross rate) and the Revenue Commissioners (on the rate of tax applied to interest, DIRT).

4.8 Expected Capital Gain

Gross interest rates are only part of the cost of home ownership. An offsetting component of user cost is the expected capital gain: if interest costs are 5% per year but nominal house prices are expected to grow by 10% per year, assuming no other costs to ownership, the real user cost would be perceived as negative. Unfortunately, there are no consistent data on expected capital gains in residential housing for the whole period under analysis. Two separate surveys exist, one by ESRI-IIB for the period 2003-2007 and another by daft.ie from 2012 on.

Based on the top-level findings of both these surveys, one cannot reject a null hypothesis of adaptive expectations, i.e. that housing market participants look at the recent history of the market as their best guide regarding the future direction of prices. For example, in early 2007, a year when nominal house prices were at best stable, participants expected strong price growth, as had been the case in recent years. Similarly, in early 2012, consumers expected prices to fall 10%, the average rate over the previous four years; prices actually fell by 4% in 2012.

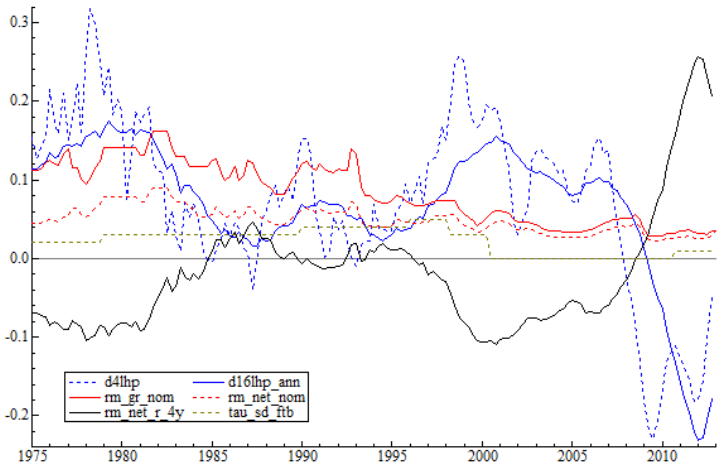
The existing literature suggests that for other countries, the four-year average and one-year rates of change in nominal house prices often perform well as measures of expected capital gains based on adaptive or extrapolative expectations (Muellbauer 2012). Depending on the specification, either or both are used here in explaining real house prices and the price-rent ratio, as explained below. This is denoted in the suffix to the net interest rate, where rm^{NR4} indicates an interest rate net of expected capital gains, based on four-year appreciation.

Figure 6 plots on one chart changes in house prices over 1- and 4-years (blue lines; annualized), the gross and net nominal interest rates (red lines), and the principal measure of net user cost, based on deducting four-year house price inflation from the net nominal rate (black line). Also included in this plot is the stamp duty rate that applied to first-time buyers at prevailing house prices (denoted tau_sd_ftb).

4.9 Other Costs

Typically, a major cost of owner-occupancy is annual property taxation. However, unusually for developed countries, Ireland had no annual property tax on the typical property for almost all the period under analysis. Recurring property taxes were abolished in 1978 and only reinstituted in 2013. The only exception was a property tax that applied during the period 1983-1996, where certain valuation and income thresholds applied that would not be relevant to the typical first-time buyer (roughly speaking, where both house values and incomes were twice the average). Instead, property taxes took the form of stamp duties, i.e. transaction taxes. The percentage rate that

Figure 6: *Plot of regressors: user-cost, 1975-2012*



applied was subject to certain bands, but for a first-time buyer of a house of average value, the rate varied during the period from 5% in the late 1990s to 0% throughout most of the 2000s. This is denoted τ^{SD}. There were also first-time buyer grants and subsidies available from 1977 to 2002.

Maintenance & transaction costs It is possible to use the CSO Household Budget Survey 2010 to estimate the amount spent on maintenance; based on spending and housing prices in 2010, households spend on average about 0.5% of the value of their dwelling on maintenance. However, setting a fixed proportional cost of maintenance means that this does not vary over the period and thus is irrelevant for a dynamic model of changes in house prices over time. Likewise, based on costs prevailing in early 2013, the (one-off, rather than annualized) financial costs of moving were set at 5%, and as research on the housing market suggests that psychological costs of moving are at least as large as financial costs, these were also set at 5% (Bayer et al. 2011). However, as these do not vary, by construction, they too can play no role in explaining house price changes if the model is linear in user cost. A more detailed understanding of these costs and how they vary over time is a topic worthy of further research.

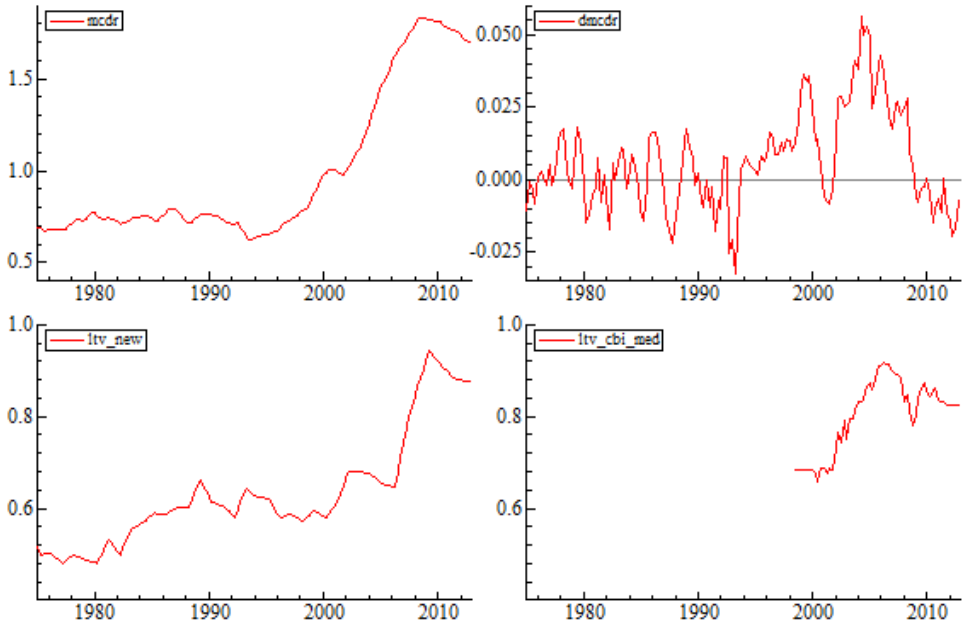
Risk premium It is very likely that prospective first-time buyers have some assessment of how risky a purchase would be in their mind. Nonetheless, research understanding the risk premium associated with owner-occupancy is in its infancy – although Sinai & Souleles (2005) use a model where owner-occupancy is itself a hedge against rent risk. Crucially, the risk premium is likely to be time-varying. Two *ad-hoc* formulations of the risk premium were included in candidate models: the first uses a discounted average of the absolute value of changes in prices over the last four years; the second uses the standard deviation of the last four annual changes in house prices. Neither features as an economically or statistically significant variable.

4.10 Credit Conditions

The final fundamental in the housing market – often an omitted variable – is credit conditions. Like the risk premium discussed above, this is often excluded as it is viewed as tough to measure. The Global Financial Crisis and subsequent Great Recession, however, are a powerful reminder of the importance of including some measure of credit conditions, when trying to understand housing price trends.

For Ireland, for the period under consideration, credit conditions are measured using the ratio of mortgage credit to domestic deposits. As mentioned in Section 2.1, credit conditions may vary with trends in financial liberalization or due to cyclical appetite among financial institutions for mortgage assets; i.e. they may be due to technology or preferences. Both will be reflected in the ratio of credit to deposits. In the case of Irish financial institutions, it is particularly important that whatever measure of credit conditions is used, it reflects the increasing reliance after entry into the eurozone on bond financing of mortages. The ratio of credit to deposits was below 80% for the entire pre-Eurozone period but more than doubled to 180% by 2007.

Figure 7: *Plot of regressors: credit conditions, 1975-2012*



For the period 2003-2012, Central Bank of Ireland data on the oustanding amounts (including securitized loans) of loans for house purchase were used, as were total deposits from Irish private households. This series was extended back to the 1970s using quarterly data from the IMF *International Financial Statistics* on demand and other deposits, and on domestic credit.[5] The series

[5]Series breaks in 1976, 1982 and 1995 were, by necessity, ignored; growth in the relevant series was for that quarter

displays some quarter-on-quarter volatility that may not reflect the more slowly-moving nature of credit conditions, so a four-quarter moving average was taken; this series is denoted *mcdr*, i.e. the mortgage credit-deposit ratio.

Loan-to-value Some existing studies investigating the role of non-price credit conditions have used the loan-to-value ratio faced by the marginal first-time buyer (Duca et al. 2011*a*). Aggregate statistics on the volume of lending and the average house price, collected by the Department of the Environment (DOE) do yield a figure that can be interpreted as the average loan-to-value for property purchases in a given year (and thus used to give θ described above). However, this is not the same as the marginal LTV ratio and may be skewed by positive equity during periods of rising prices. A new loan-level Central Bank of Ireland (CBI) dataset, detailed in Kennedy & McIndoe-Calder (2011) and Lyons (2013), can be used to calculate the mean and median loan-to-value for first-time buyers across four Irish-owned financial institutions (all subsequently recapitalized by the Irish state), for the period 2000-2011. The series is based on over 100,000 loans on the books of the four institutions as at end-2011.

Figure 7 plots the estimated ratio of mortgage credit to deposits, the change in that ratio (used in dynamics), the estimated series for loan-to-value on new dwellings and the CBI series on median loan-to-value for first-time buyers, from 2000 on. What is striking is how the DOE loan-to-value series peaks after the bubble. The average loan-to-value on new dwellings in mid-2006 was 65%, when both prices and the CBI series on LTC peaked, but nearly 95% at the turn of 2010. Overall, it is clear from the series that the DOE data do not capture accurately the timing of peak in loan-to-value and its subsequent fall. Thus, where the focus of analysis is a period longer than 2000-2012, the ratio of credit to deposits will be used, instead of DOE data on loan-to-value. An overview of all data is presented in Table 2.

4.11 Stationarity properties

Table 3 outlines the results of augmented Dickey-Fuller tests for a unit root, across all the major variables. Results are shown for the deltas of each variable, thus highlighting whether any series are I(2), thus potentially biasing analysis including such variables in a long-run solution with I(1) series. For all variables in Table 3, the sample is 1980I-2012IV, with the 1%, 5% and 10% critical values of -3.48, -2.88 and -2.57 denoted by three, two and one stars respectively.

Using a 10% significance level, it is possible to conclude that in delta form, almost all the variables are stationary, including *dlrhp*, *dlhs_ph*, *dlyhs*, *dmcdr*, *drm_net*, *dphhr* and *due*. Failure to reject the null of a unit root occurs for income per household (*dlry_ph*) and the population aged 25-34, (*d4p2534*). These are explored in more detail in Table 15 in the Appendix. This table presents strong evidence in favour of using the per-household formulation of income and housing

set to zero.

Indicator	Source	Period	Orig. Frequency
House prices	DoE	1975-1996	Quarterly
	ESRI-PTSB	1996-2005	Monthly
	CSO	2005-2012	Monthly
Rents	CSO	1975-2012	Monthly
Consumer prices	CSO	1975-2012	Monthly
Income	AMECO	1975-2012	Annual
Unemployment rate	QNHS	1998-2012	Quarterly
	AMECO	1975-1998	Annual
Live Register	CSO	1975-2012	Monthly
Stock capital in dwellings	CSO	1975-2012	Annual
Housing stock (volume)	DOE	1975-2012	Annual
Mortgage rates	ECB	2003-2012	Monthly
	CSO	1975-2002	Monthly
Deposit rates	CBI	1975-2012	Monthly
DIRT rates	RevComm	1986-2012	Monthly
Stamp duty rates	RevComm	1975-2012	Monthly
MIR rate	RevComm, Barham	1975-2012	Monthly
Grants & subsidies	Barham	1975-2012	Annual
Mortgage credit	CBI	2003-2012	Monthly
Household deposits	CBI	2003-2012	Monthly
Private sector credit	IFS	1975-2003	Quarterly
Private deposits	IFS	1975-2003	Quarterly
Average LTV	DoE	1975-2012	Annual
Median LTV	CBI	2000-2012	Monthly
Maintenance	CSO HBS	2011	Parameter
Moving costs	Author calculations	2013	Parameter

Table 2: *Overview of dataset*

stock (suffix *_ph*), instead of the per-capita series (*_ph*), with no rejection of the null hypothesis of a unit root at any conventional significance level for either income per capita or housing stock per capita.

Thus, it is clear that per-capita series for income and housing stock are I(2). Are the per-household series I(2) or I(1)? Results for the 1975-2012 sample for both, denoted by the suffix † in Table 15, suggest that the lack of statistical significance at the 5% or 1% levels for income and stock per household relate more to the power of the test than to the underlying data series. One means of overcoming any uncertainty about the stationarity of changes in income and stock is to use their ratio: at the 10% level for the 1980-2012 series, and at the 1% for the 1975-2012 series, the null of a unit root can be rejected.

5 Inverted Demand Model

In modelling changes in real house prices, there are two sets of factors that may be relevant. The first is long-run fundamentals, including income, housing stock, credit conditions, demographics, and user and transaction costs. The second set of factors is short-run dynamics. While it less clear from theory which dynamics are most likely to matter, six potential factors are suggested from existing research: lagged changes in real house prices (autoregression); changes in inflation (do changes in real house prices stem from the numerator or the denominator?); changes in the nominal mortgage interest rate (cash-flow concerns); changes in credit conditions; changes in unemployment; and changes in net migration.

It is unclear what particular dynamics might apply to any of these factors – contemporaneous changes might be most important or conversely they may only matter at a lag of up to four quarters. While the following specification is clearly over-parameterized, with almost 40 parameters to be estimated from just over 130 observations, it offers a useful starting point for analysis:

$$dln(rhp_t) = \beta_0 + \sum_{j=1}^{k}\sum_{s=0}^{4} \beta_{js}\delta x_{j,t-s} + \beta_{k+1}(ln(rhp_{t-1}) - \alpha_1 ln(y/stock_{t-1}) - \alpha_2 phhr_{t-1} - \alpha_3 ln(pop2534_{t-1}) - \alpha_4 mcdr_{t-1} - \alpha_5 rm^{NR4}_{t-1} - \alpha_6 \tau^{SD}_{t-1}) \quad (1)$$

where $mcdr$ is the ratio of mortgage credit to household deposits, τ^{SD} the rate of stamp duty applicable to first-time buyers at average prices, and rm^{NR4} refers to the after-tax rate of mortgage interest less the annualized 4-year rate of house price inflation. The j subscript represents the following k dynamics: $dln(rhp)_{t-s}$), dr^{NN}_{t-s}, $dmcdr_{t-s}$, due_{t-s}, $infl_{t-s}$, and $migr_{t-s}$. Full regression output is given in Table 12 in Appendix B. A long-run solution is immediately apparent from this model (one that excludes *lpop*2534), but it is also clear that most of the dynamics are not statistically significant.

Table 3: *ADF unit root tests*

Var	D-lag	t-adf		beta Y_1	sigma	t-DY_lag	t-prob	AIC	F-prob
dlrhp	3	-2.908	**	0.775	0.021	1.044	0.298	-7.657	
	2	-2.735	*	0.795	0.021	-3.829	0	-7.664	0.298
	1	-4.063	***	0.698	0.022	-2.893	0.005	-7.57	0.001
	0	-5.691	***	0.607	0.023			-7.523	0
dlry_ph	3	-2.389		0.909	0.005	0.496	0.621	-10.73	
	2	-2.344		0.913	0.005	-0.082	0.935	-10.74	0.621
	1	-2.427		0.912	0.005	0.511	0.611	-10.76	0.881
	0	-2.379		0.916	0.005			-10.77	0.916
dlhs_ph	3		-2.734*	0.879	0.002	0.353	0.725	-12.54	
	2	-2.739	*	0.883	0.002	0.783	0.435	-12.56	0.725
	1	-2.632	*	0.891	0.002	0.141	0.888	-12.57	0.694
	0	-2.687	*	0.892	0.002			-12.58	0.861
dlyhs	3	-2.619	*	0.887	0.005	0.04	0.968	-10.76	
	2	-2.689	*	0.887	0.004	0.521	0.603	-10.78	0.968
	1	-2.646	*	0.892	0.004	-0.156	0.877	-10.79	0.874
	0	-2.764	*	0.891	0.004			-10.81	0.961
dmcdr	3	-2.975	**	0.857	0.009	-0.347	0.729	-9.466	
	2	-3.225	**	0.852	0.009	1	0.319	-9.48	0.729
	1	-3.067	**	0.865	0.009	1.037	0.302	-9.488	0.575
	0	-2.896	**	0.877	0.009			-9.494	0.538
drm_net	3	-3.156	**	0.689	0.008	1.116	0.267	-9.526	
	2	-2.959	**	0.72	0.008	-3.618	0	-9.532	0.267
	1	-4.751	***	0.574	0.009	-0.871	0.386	-9.449	0.001
	0	-6.088	***	0.534	0.009			-9.459	0.002
dphhr	3	-4.963	***	0.67	0.005	1.92	0.057	-10.57	
	2	-4.529	***	0.719	0.005	1.632	0.105	-10.55	0.057
	1	-4.198	***	0.756	0.005	1.411	0.161	-10.55	0.044
	0	-3.939	***	0.783	0.005			-10.55	0.042
due	3	-3.635	***	0.707	0.044	3.056	0.003	-6.231	
	2	-2.882	*	0.768	0.045	-1.662	0.099	-6.175	0.003
	1	-3.517	***	0.728	0.045	-5.01	0	-6.169	0.003
	0	-6.206	***	0.541	0.049			-6.006	0
d4p2534	3	-1.82		0.985	0.002	-0.921	0.359	-12.76	
	2	-2.091		0.984	0.002	-0.486	0.628	-12.77	0.359
	1	-2.309		0.983	0.002	17.08	0	-12.79	0.583
	0	0.4483		1.006	0.003			-11.62	0

It is possible to iteratively develop increasingly parsimonious models by examining the p-values, and using a rule of thumb p-values of below 0.10 as a guide to potential statistical significance. For example, excluding all dynamic terms in inflation and migration (due to high p-values) still leaves none of the nominal mortgage rate terms significant (at a cut-off of 10%) nor any unemployment lags after the first (the fit of the model, as measured by its standard error, improves substantially, from 0.017 to 0.0165). Excluding these terms – and the fourth lag for *dmcdr* – suggests that neither second nor third lags of *dlrhp*, nor the contemporaneous value of *dmcdr*, is statistically significant. Parimsony suggests omitting the second and third lags of *dmcdr*. Dropping the population aged 25-34, which is significant in none of the specifications, leaves a model with the following specification[6]:

$$\begin{aligned} dln(rhp_t) = \beta_0 + \beta_1 dln(rhp_{t-1}) + \beta_2 dln(rhp_{t-4}) + \beta_3 dmcdr_{t-1} + \beta_4 due_t + \beta_5 due_{t-1} \\ + \beta_6 (ln(rhp_{t-1}) - \alpha_1 ln(y/stock_{t-1}) - \alpha_2 phhr_{t-1} \\ - \alpha_3 ln(pop2534_{t-1}) - \alpha_4 mcdr_{t-1} - \alpha_5 rm_{t-1}^{NR4} - \alpha_6 \tau_{t-1}^{SD}) \end{aligned} \quad (2)$$

A model with the fourth lag of $dln(rhp)$ is strongly preferred to one without (sigma rises from 0.01673 to 0.01762 without this term), while similarly a model with the one-quarter lag in unemployment included is preferred to one with just contemporaneous changes in unemployment (sigma rises from 0.01673 to 0.01702).

Regression output for this model is shown in Table 4, while actual and fitted values are plotted in Figure 13 in Appendix D. As noted above, the sigma for the regression is 0.01673, with the none of six core tests of model specification indicating a rejection of the null hypothesis. For the period from 1980 to 2012, this model explains over two thirds of the changes in real house prices seen ($R^2 = 0.696$), with all variables strongly statistically significant (particularly fundamentals) and all with the sign suggested by theory.

5.1 Short-run dynamics

The model suggests that for the 33-year period under analysis, there were four elements that mattered for short-run house price dynamics, independent of forces pushing prices back towards their equilibrium level. The first is changes in real house prices in the previous quarter, an element of momentum in house prices. Every one percentage point (pp) increase in prices in the previous quarter was associated with a 0.16pp increase in the current period. The second is the change in real house prices a year ago. Here, the relationship is negative: a percentage point increase in prices in the same quarter a year ago was associated with a 0.26pp decrease in the current period. Everything else being equal, large house price gains in particular quarter in one year were associated with price falls a year later.

[6]The same equation results from the use of Autometrics software that algorithmically develops a parsimonious model by omitting based on statistical significance, once the long-run variables are included.

Table 4: *Model of dlrhp with parsimonious dynamics, 1980-2012*

	Coeff		S.E.	t-stat	p-value
Constant	4.0786	***	0.6618	6.16	0.000
log rhp ($ln(rhp_{t-1})$)	-0.3137	***	0.0522	-6.01	0.000
log y/stock ($ln(y/stock_{t-1})$)	0.3952	***	0.0777	5.08	0.000
person:HH ($phhr_{t-1}$)	-0.1222	***	0.0222	-5.49	0.000
credit:deposit ($mcdr_{t-1}$)	0.1743	***	0.0345	5.05	0.000
user cost (rm_{t-1}^{NR4})	-0.4812	***	0.0915	-5.26	0.000
stamp duty (τ_{t-1}^{SD})	-0.4757	**	0.2118	-2.25	0.0265
$dlrhp_{t-1}$	0.1661	**	0.0791	2.1	0.0378
$dlrhp_{t-4}$	-0.256	***	0.0681	-3.76	0.0003
$delta\_ue$	-0.0162	***	0.0044	-3.67	0.0004
$delta\_ue_{t-1}$	-0.0104	**	0.0046	-2.29	0.024
$dmcdr_{t-1}$	0.3097	**	0.1209	2.56	0.0117

The other two factors reflect conditions in the mortgage and labour markets. A percentage point increase in the ratio of mortgage credit to deposits in the previous quarter was associated with a increase of 0.31pp in the current period. Lastly, there was a negative relationship between unemployment and changes in house prices in the short-run, an effect that lasted two quarters: a one-percentage point increase in the unemployment rate in a given quarter was associated with a fall in house prices of roughly 1.6% in the same period and 1% in the following period.

5.2 Long-run equation

The model presents a clear long-run relationship that determines house prices over this period and indicates that there was fast adjustment to this equilibrium in the Irish housing market. The coefficient on $lrhp_{t-1}$ of -0.314 implies that almost one third of the gap between actual and equilibrium house prices was corrected every quarter. Compared to similar studies for other economies, this represents rapid adjustment, possibly reflecting Ireland's nature as a small, relatively homogeneous economy.

This coefficient can also be used to reveal the underlying long-run relationship between real house prices and their determinants. For the period under analysis, there are five fundamental factors that affected the equilibrium level of house prices. The long-run relationship suggested by the analysis is as follows, where Ψ represents the intercept term (unobservable in the error correction form):

$$ln(rhp_t) = \Psi + 1.26ln(y/stock_t) - 0.39phhr_t + 0.56mcdr_t - 1.53rm_t^{NR4} - 1.52\tau_t^{SD} \qquad (3)$$

Income-stock ratio The model suggests a strong positive long-run relationship between real house prices and the ratio of household income to the stock of residential housing. The coefficient

of just over 1.26 implies that price responds more than proportionately to changes in income and to housing supply. An increase in real income of 10% (relative to the stock of housing) is associated with a 12.6% increase in the real price of housing. The same coefficient can be interpreted as the absolute value of the inverse of the price elasticity with respect to supply; i.e. an increase in the real value of the housing stock of 10% is associated with a fall in real house prices of 8% (-1/1.26).

Person-household ratio The results indicate a clear relationship between real housing prices in Ireland and the average number of persons per household. The negative coefficient in the long-run relationship of -0.389 can be interpreted as follows: between 1980 and 2012, the average number of people per household fell by one (from 3.79 to 2.78). This increase in effective demand per head of population was associated with a 39% increase in real house prices, controlling for other factors. Breaking the income per house restriction and including per-person or per-household income and stock separately and omitting average household size leads to omitted variable bias, in particular an upward bias on the income coefficient on this interpretation.[7]

Credit-deposit ratio Credit conditions, as measured by the ratio of the stock of mortgages to the stock of deposits, have a long-run impact on house prices, as well as a short-run impact. The coefficient of roughly 0.56 on the credit conditions term in the long-run equation indicates that an increase of ten percentage points in the ratio of mortgage credit to deposits was associated with an increase in real house prices of 5.6%. Ireland's credit-deposit ratio increased by 100 percentage points in the decade to 2007. This model suggests that this was associated with an increase in equilibrium level of real house prices of 56%.

Real interest rates The user cost for housing – as measured by the difference between nominal rates after tax reliefs and the expected capital gain based on the last four years – represent a drag on housing prices. The coefficient of -1.53 indicates that an increase in user cost of 1 percentage point is associated with a decrease in equilibrium real house prices of 1.53%. The user cost measured in this way increased by 30 percentage points (roughly speaking, from -10% to +20%) between 2006 and 2012. This was associated with a fall in equilibrium prices of 45%.

Stamp duty The final factor suggested by the error correction model as important for the long-run level of house prices is the rate of stamp duty applying to first-time buyer purchases. The

[7]It is like that average household size has some endogenous elements; in the long run, affordability and credit conditions may have an effect on household size. However, there will also be a large demographic component, including longer life spans, more widows, later marriages and more divorces, that will be mostly exogenous and, if excluded, caught up by the income coefficient. Here, omitting *phhr* from the model reduces the speed of adjustment to 10% and doubles the implied long-run coefficient on the ratio of income to housing stock from 1.26 to 2.57. The fit of such a model is substantially worse: the sigma of the regression increases from 0.01673 to 0.01864 and the R^2 reduces from almost 70% to 61.9%. This can be partially remedied by including per-capita income and housing stock separately; see Section 5.3 for more details.

coefficient of close to -1.5 on indicates that a decrease in the rate of stamp duty applying to first-time buyers of one percentage point was associated with a 1.5% increase in real housing prices. This more-than-proportionate response indicates that down-payment constraints for first-time buyers were important in the housing market, in the period under analysis. Nonetheless, the small number of changes to the stamp duty rate applicable to first-time buyers means that caution should be exercised in relying on this result.

5.3 Robustness & Sensitivity

A number of choices were made in the construction of the dataset, each of which may impact the results presented. Two tables in Appendix C outline a number of robustness and sensitivity checks. Coefficients and p-values are presented for variables, along with two measures of model fit (sigma and R^2) and also whether any of six standard tests were failed: AR 1-5, ARCH 1-4, Normality, Hetero, Hetero-X, and RESET23. Also presented, in Figure 16, are recursive estimates of the parameters associated with the long-run variables. It is clear that there are no statistically significant changes in any of the coefficients, although there is small shift in a number of the coefficients between 2002 and 2004.

The first table takes the various fundamentals and explores alternatives for each. An extra fundamental is added, the log of the population aged 25-34, which has almost no impact on the results, as the coefficient on the variable is close to zero. For credit conditions, instead of the ratio of credit to deposits, the estimated average loan-to-value for new dwellings is used. Perhaps reflecting the weakness of this data series, the inclusion of this variable effectively destroys the long-run relationship.[8] The fit of the model is as close to a specification with only dynamics (first column in Table 14 as to the preferred specification.

Five other specifications are included in Table 13, including splitting out income and stock (which reveals coefficients of similar magnitudes), using per-capita instead of per-household measures of income and stock (replacing the stock of housing measured in value with a series on the number of dwellings, using a weighted rate of interest (across both mortgages and deposits), including a measure of grants for first-time buyers (relative to value), and an alternative measure of quarterly unemployment, based on interpolated official annual unemployment rates instead of changes in unemployment implied by Live Register data. None of these changes has a meaningful effect on the long-run equation, but have worse fit than the specification outlined above.

The second table explores functional form, particularly for the three ratios included in the fundamental long-run equaton. The log of the ratio of income to housing stock was used in the principal specification, while the level of the two other ratios – mortgage credit to deposits, and persons to households – was used. In principle, one might think that as income and housing stock

[8] In house price booms, repeat buyers have higher net equity stakes from past appreciation and so can reduce their LTV; hence, average LTV series that include purchasers other than first-time buyers will be a very misleading indicator of credit availability.

are both euro amounts, relativities matter more than levels, while for the credit-deposit ratio, ten percentage points of deposits lent out at the margin is roughly equivalent at different starting points. Table 14 investigates the importance of this, using different combinations of logs and levels for the three ratios.

While the overall fit of the model does not change greatly across all five specifications, it appears from the fit and test results that the level of the credit to deposit ratio is a better measure of credit conditions than the log, particularly in relation to dynamic effects. A specification where all three ratios (income/stock, credit/deposits, and persons/households) are included in logs suggests the following long-run house price elasticities: 1.15 for the income (relative to stock), 0.64 for the mortgage-deposit ratio, and -1.57 for the ratio of persons to households.

5.4 Modelling from 1975

As outlined in Section 4.1, quarterly data are available from 1975, although house prices changes in the 1975-9 period are substantially more volatile than during the subsequent 33-year period and for most of the period refer only to new dwellings. The core specification for the period 1980-2012 was applied to the dataset running from 1975Q2 on. The results are presented in Table 5, while the actual and fitted values of *dlrhp* are shown in Figure 14 in Appendix D.

The zig-zag nature of changes in real house prices in the late 1970s affects the autoregressive properties and thus the overall fit of the model (the R^2 is 51% compared to 70% for the model from 1980 on). The estimated income and credit conditions effects are smaller for the model from 1975 than from 1980 (such that the 1980 coefficient is well outside the 95% confidence interval). The effect of real interest rates and the person-household ratio, however, are larger in absolute size, while the stamp duty effect is not significant.[9]

The substantially different results and fit for the 1970s suggests that a structural break in the Irish housing market around 1980. One candidate is the end of the parity peg between the Irish pound and sterling in early 1979, although it is left to future research – with data extending further back and of a higher quality – to examine the nature of the break and the model that preceded it.

6 Income, supply and cointegration

The analysis undertaken in Section 5 shows a clear long-run relationship between real house prices and a range of fundamentals, including user cost, the ratio of income to housing stock, the ratio of persons to households and the ratio of mortgage credit to household deposits. However, housing supply and indeed household income may not be exogenous to the system. When house prices rise, this should increase profitability in the construction sector and may stimulate a supply-side

[9] Using Autometrics on this longer sample, with extended dynamics and including *lpop*2534 suggests outlier dummies for 1978I and 1979II-III (the latter marking the Irish punts break with sterling parity). The additional demographic variable is statistically significant ($p = 0.022$) with an implied long-run coefficient of 1.25.

Table 5: *Model of dlrhp extended back to 1975*

	Coeff		S.E.	t-stat	p-value
Constant	2.2556	***	0.4695	4.8	0.000
log rhp ($ln(rhp_{t-1})$)	-0.1646	***	0.0349	-4.72	0.000
log y/stock ($ln(y/stock_{t-1})$)	0.1637	***	0.0515	3.18	0.0018
person:HH ($phhr_{t-1}$)	-0.099	***	0.0249	-3.97	0.0001
credit:deposit ($mcdr_{t-1}$)	0.0751	***	0.0261	2.88	0.0046
user cost (rm_{t-1}^{NR4})	-0.3205	***	0.106	-3.02	0.003
stamp duty (τ_{t-1}^{SD})	-0.1766		0.2495	-0.71	0.4802
$dlrhp_{t-1}$	0.0739		0.0789	0.94	0.3509
$dlrhp_{t-4}$	-0.0378		0.0758	-0.5	0.6185
$delta\_ue$	-0.0175	***	0.0059	-2.97	0.0036
$delta\_ue_{t-1}$	-0.0093		0.006	-1.55	0.1241
$dmcdr_{t-1}$	0.2982	*	0.1662	1.79	0.0749

response. Similarly, a rise in house prices may bring about an increase in household income, particularly in sectors related to housing such as construction, banking, real estate, various retail services and even public administration.

6.1 Model of income and stock

A priori, one would expect the following factors to bring about an increase in completions and thus in housing stock, *ceteris paribus*: a rise in house prices or incomes or a fall in any major cost (labour, materials, land or capital). Also, an outward shift in demand, e.g. through demographics, would be expected to elicit a supply-side response. Lastly, both planning conditions and credit conditions may matter, such that everything else being equal, it will be easier to get projects approved and funded at one time than at another.

Table 6 outlines an error-correction model for the per-household stock housing (in real net capital terms), over the sample 1980-2012. Where a long-run equation emerges, one with a speed of adjustment of about 10% per year, the income effect is negative, rather than positive, while user-cost – capturing capital costs – is positively associated with housing supply, albeit in a statistically insignificant way. Some effects do have the expected sign: higher house prices are associated with greater housing stock, as are smaller families (lower *phhr*) and favourable demographics (growth in the 25-34 population), while an index of construction costs (labour and materials) is negative associated with housing stock.

The inclusion of credit conditions does not improve the fit of the model however, nor does the inclusion of a rudimentary measure of planning conditions, the proportion of apartments among all units for which planning permission was granted. In addition, land costs are not explicitly captured. Thus, there is reason to think that the coefficients on income, user-cost and house prices may be biased due to omitted variables. For this reason, and also to overcome any concerns about

Table 6: *ECM model of dlhstock*

	Coeff	S.E.	t-stat	p-value
Constant	0.288	0.074	3.87	0
lhstock_phh_t-1	-0.023	0.006	-3.7	0
lrhp_t-1	0.011	0.003	4.18	0
lry_phh_t-1	-0.023	0.007	-3.06	0.003
phhr_t-1	-0.016	0.005	-3.55	0.001
rm_net_r_4y_t-1	0.01	0.007	1.44	0.154
d4_pop2534_t-1	0.07	0.021	3.3	0.001
bui_cost_t-1	-0.005	0.003	-1.76	0.081
Seasonal	0.001	0	1.94	0.054
dlhstock_rnk_phh_t-1	0.702	0.062	11.3	0
dd4_pop2534_t-1	-0.109	0.07	-1.55	0.124

stationarity outlined in Section 4.11, an error-correction model of the ratio of income to housing supply is presented instead.

Due to the likely presence of many variables in both income and stock equations, expectations a priori are not clear. Both income and supply would be expected to rise with smaller families (↑ phhr), growing population at family-forming age (↑ d4pop2534), falling unemployment (↓ ue), higher house prices (↑ rhp), lower user-cost (↓ rm) and expanding credit (↑ mcdr, ↑ dmcdr). Supply would also be expected to rise with income. The level in euro of the ratio of household income to housing stock is presented in Figure 8. It is relatively stable in the long run, but is low for much of the 1980s and high for much of the 2000s.

Figure 8: *Level of household income to housing stock, 1980-2012*

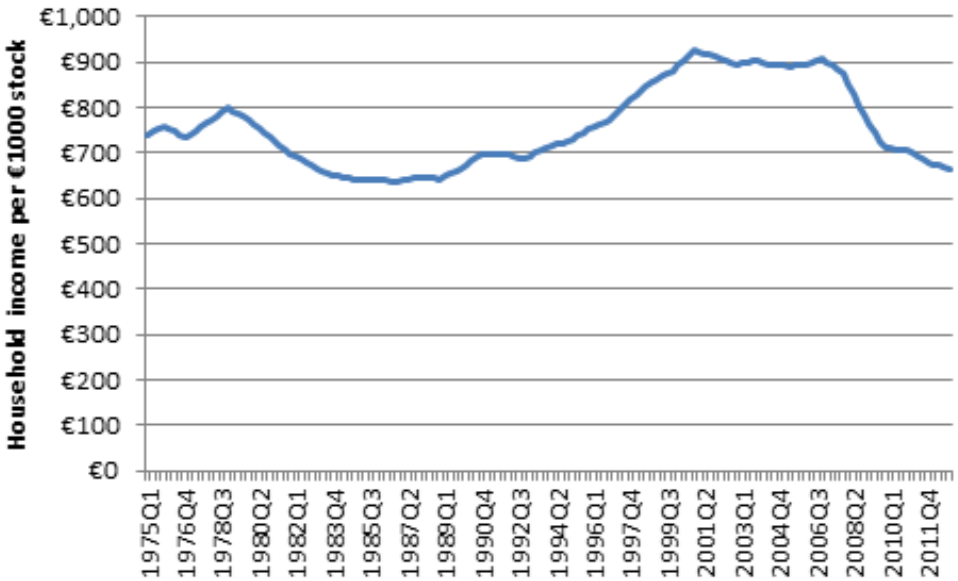


Table 7: *ECM model of dlyhstock*

	Coeff	S.E.	t-stat	p-value
dlrystock_t-1	0.685	0.061	11.2	0
Constant	0.245	0.147	1.66	0.099
lrystock_t-1	-0.129	0.033	-3.95	0
lrhp_t-1	-0.01	0.011	-0.891	0.375
rm_net_r4y_t-1	-0.049	0.024	-2.08	0.04
phhr_t-1	-0.043	0.009	-4.7	0
d4_pop2534_t-1	0.142	0.052	2.74	0.007
ue_q_t-1	-0.196	0.055	-3.56	0.001
mcdr_t-1	-0.011	0.008	-1.32	0.19
bwdir_t-1	0.006	0.006	0.987	0.326

An error-correction model of the log ratio of income to stock is presented in Table 7. A long-run equation emerges, with a quarterly speed of adjustment of 13%, similar in speed to a model of income alone (not shown). User cost is associated with lower income-to-stock, suggesting its effect on income is proportionately greater than its effect on stock. The ratio of income to stock is positively associated with lower unemployment, a growing population aged 25-34 and smaller household size. Other effects are not statistically significant. The implied long-run equation is:

$$lrystock = 1.9 - 0.078lrhp - 0.38usercost - 0.33phhr - 1.52ue + 1.1d4pop2534$$

6.2 Cointegrating relationship

Summarising the two error-correction models suggests the two relationships described in sign terms in Table 8. While there are no sign disagreements, the factors that are relevant for the two relationships are sufficiently different to suggest at least two cointegrating vectors between the three endogenous variables: *lrhp*, *lyhstock* and *rm_net*. Indeed, Johansen tests suggest more than two cointegrating vectors. This section analyses both the two- and three-cointegrating vector cases.

The unrestricted VAR is presented in Table 16. For the house price and income/stock regressions, they produce results similar in size and statistical significance to the long-run equations implied by the error-correction models. User-cost is very highly autocorrelated – unsurprising given its construction – but is also related in a statistically significant way to house prices, the person-household ratio and unemployment (all positively).

A Johansen test suggests that there are three cointegrating vectors (CIVs) – the trace test value for rank 2 is 23.6, so the null of two vector is statistically rejected. (This is not dependent on lag length, as allowing a second lag across the unrestricted VAR produces almost identical results for the Johansen test.) Imposing restrictions on the three diagonals ($lrhp = -1$, $lrystock = -1$ and $rm\_net\_r4y = -1$, with a negative value so that other coefficients can be intrepreted in a

Table 8: *Overview of long-run relationships implied by ECMs*

Vars	rhp	ystock	Group
rhp	///	-	Endogenous
rystock	+	///	Endogenous
rm_net	-	-	Endogenous
phhr	-	-	Demographics
d4pop2534	0	+	Demographics
mcdr	+	0	Conditions
dmcdr	+	0	Conditions
stampduty	-	0	Conditions
ue	0	-	Labour mkt
delta_ue	-	0	Labour mkt

Table 9: *Beta and alpha values; 3 CIV case with restrictions*

Type	Variable	S.E.	t-stat	p-value
beta	lrhp	-1	-0.715	-0.789
	lrystock	1.263	-1	-1.624
	rm_net_r_4y	-1.404	3.878	-1
	phhr_t-1	-0.409	0.410	-0.993
	d4_pop2534_t-1		1.554	3.225
	ue_q_t-1		-13.688	-4.466
	delta_ueq1_t-1	-0.037		-0.084
	mcdr_t-1	0.520		0.014
	dmcdr_t-1	1.285		0.576
	tau_sd_ftb_t-1	-1.900		0.592
alpha	lrhp	0.27	0.003	0.032
	(se)	(0.037)	(0.009)	(0.019)
	lrystock	-0.004	-0.011	0.065
	(se)	(0.011)	(0.003)	(0.005)
	rm_net_r_4y	-0.001	-0.015	-0.035
	(se)	(0.017)	(0.004)	(0.008)

straightforward manner) as well as zero restrictions for the six instances of variables without a statistically significant relationship with price and income/stock respectively (as per Table 8) gives the β-vectors and α speeds of adjustment/loading weights outlined in Table 9.

The first vector clearly reflects the house price relationship, with prices positively related to the income/stock ratio and the level and change in credit conditions and negatively related to user-cost, stamp duty, changes in unemployment and the ratio of persons to households. Furthermore, the matrix of loading weights suggests that only house prices respond to this vector, suggesting weak exogeneity of other variables. The other vectors, however, are much more difficult to interpret economically, due to coefficients with an unexpectedly large sign (such as unemployment in what would be the income/stock ratio vector).

Alternatively, while the statistical tests might suggest three inter-relationships, economic theory

Table 10: *Beta and alpha values; 2 CIV case with restrictions*

Type	Variable	S.E.	t-stat	p-value
beta	lrhp	-1	-0.457	
	(se)		(0.037)	
	lrystock	1.294	-1	
	(se)	(0.206)		
	rm_net_r_4y	-1.463	-0.765	
	(se)	(0.293)	(0.188)	
	phhr_t-1	-0.407	-0.68	
	(se)	(0.072)	(0.045)	
	d4_pop2534_t-1		2.162	
	(se)		(0.592)	
	ue_q_t-1		-1.692	
	(se)		(0.382)	
	delta_ueq1_t-1	-0.062		
	(se)	(0.018)		
	mcdr_t-1	0.522		
	(se)	(0.043)		
	dmcdr_t-1	1.383		
	(se)	(0.507)		
	tau_sd_ftb_t-1	-1.73		
	(se)	(0.77)		
alpha	lrhp	0.251	0.047	
	(se)	(0.022)	(0.025)	
	lrystock	0.036	0.089	
	(se)	(0.006)	(0.007)	
	rm_net_r_4y	-0.042	-0.036	
	(se)	(0.011)	(0.012)	

implies relationships for house prices and the income-stock ratio, with user-cost effectively a random walk once the other relationships are controlled for. A two-CIV system is presented in Table 10, including all beta and alpha values and their standard errors. As with the three-CIV case, zero restrictions are imposed for those variables shown through the error-correction framework not to have a statistically significant long-run impact on a particular series.

All beta-coefficients are statistically significant. The first vector can be interpreted as a house price vector, with real house prices responding almost identically in the 2-CIV case as in the 3-CIV case outlined above. The second vector is similar to the ECM model of the income-stock ratio, although while all signs are the same, the absolute size of the coefficients – in particular house prices – is larger. All alpha loading weights are also statistically significant, suggesting rich interactions between house prices, the income-stock ratio and user-cost. Prices and income/stock respond as in error correction, with speeds of 25% and 9% to their own vector and 4% to the other vector respectively. User-cost has positive loading weights for both vectors.

Summary There is inconclusive evidence regarding the cointegration properties of the house price vector with other related economic variables. Unit root tests show that all variables are of the same order of integration, particularly if the ratio of income to stock is used. Statistical Johansen tests suggest more than two cointegrating vectors between the variables, but only the price vector – to which other variables are weakly exogenous – makes economic sense. Theory suggests just two vectors – one for prices and one for the income/supply ratio. The vectors returned match those from the ECM framework but the loading weights suggest a much richer set of interactions between house prices, income, supply and user cost. Disentangling the various relationship may require a measure of land costs and of planning conditions.

7 House Price-to-Rent Model

As outlined in Section 4.2, the scale and nature of the private rented sector in Ireland has changed substantially over the period 1975-2012. The first decade or so represents a one-off downward shift in the real cost of renting in Ireland, while the second decade witnessed continued falls in the total proportion renting. This, combined with reforms of the private rented sector in the late 1990s, mean that there is little evidence of any error correction in the price-rent ratio for the period as a whole.

Taking the period 2000-2012, however, during which there was a relatively well-developed private rented sector nationwide, there is strong evidence of an error-correction relationship in the house price-rent ratio. In explaining changes in the ratio of house prices to rents (*dlhpr*), three dynamic terms are included: the lagged value of *dlhpr*, capturing any memory; the contemporaneous change in rents, capturing the extent to which changes in the ratio reflect changes in the denominator; and the contemporaneous change in credit conditions. The long-run equilibrium relationship includes the following fundamentals: the rate of interest (either nominal, and thus expected capital gains terms would also be required, or real) and credit conditions.

Two other terms may matter for the ratio of prices to rents. Firstly, it may be the case that, in comparing mortgage payments with equivalent rents, non-linearities exist. Thus, where a combined real rates of interest term is included, the log of the nominal net interest rate can be included to capture any such effects. Second, as suggested by Kim (2008), the percentage of renters may be inversely related to price-rent ratio in equilibrium, reflecting the differential return from real estate derived by owner-occupiers compared to tenants and landlords.[10]

Two different measures of credit conditions are used. The first is, as with the inverted demand model, the ratio of credit to deposits. Secondly, given the timeframe covered, it is possible to use Central Bank of Ireland (CBI) data on the median loan-to-value for first-time buyers from 2000 on. This may give a more direct measure of changing credit conditions, particularly later in the period

[10] A limitation to use of this variable is its interpolated nature and thus the failure to reject the null of the annual change in the percentage renting being I(1).

Table 11: *Modelling changes in the price-rent ratio (dlhpr), 2000-2012*

	MCDR		MCDR (non-lin)		MCDR (%rent)		LTV		LTV (non-lin)		LTV (%rent)	
	Coeff	p-value	Coeff	p-value	Coeff	p-value	Coeff	p-value	Coeff	p-value	Coeff	p-value
Constant	1.296	0.000	1.333	0.000	1.766	0.000	0.732	0.000	0.731	0.000	0.751	0.000
$lhpr_{t-1}$	-0.249	0.001	-0.255	0.000	-0.305	0.000	-0.177	0.000	-0.175	0.000	-0.185	0.000
cci_{t-1}	0.131	0.007	0.134	0.005	0.219	0.000	0.361	0.000	0.36	0.000	0.362	0.000
rm_{t-1}^{NN}	-3.001	0.000					-1.036	0.04				
$d16lhp\_ann_{t-1}$	0.343	0.002					0.211	0.000				
$d4lhp_{t-1}$	0.24	0.001					0.126	0.004				
rrm_{t-1}^{NN41}			-0.581	0.000	-0.409	0.013			-0.34	0.000	-0.402	0.012
$l(rm_{t-1}^{NN})$			-0.078	0.000	-0.081	0.000			-0.024	0.122	-0.026	0.116
pc_rent_{t-1}					-1.244	0.025					0.175	0.667
$dlhpr_{t-1}$	0.21	0.099	0.228	0.058	0.29	0.015	0.192	0.109	0.186	0.105	0.174	0.141
$dlrent$	-0.707	0.000	-0.685	0.000	-0.519	0.001	-0.72	0.000	-0.741	0.000	-0.782	0.000
$dcci$	0.389	0.057	0.466	0.014	0.458	0.012	0.257	0.016	0.261	0.012	0.271	0.012
sigma	0.01377		0.01372		0.01307		0.01287		0.0127		0.01283	
R2	0.819		0.816		0.837		0.842		0.842		0.843	
Test failures	Hetero		None		None		None		None		None	

when the stock of debt was high and static, due to bubble-era lending. Thus, the sample for the price-rent model is 2000Q1-2012Q4, less any terms lost to dynamics.[11]

Results for three specifications are presented in Table 11, for both measures of credit conditions. The first separately includes the net nominal interest rate, and 1- and 4-year (annualized) house price inflation to reflect extrapolative expectations. For both measures of credit conditions, the results show an order of magnitude difference between the interest rate and expectations terms, suggesting non-linearities are important. Thus, the second specification includes one term for the real net rate of interest, with a weight of 0.6 on 4-year inflation and 0.4 on 1-year (as suggested by their relative coefficients), as well as the log of the net nominal interest rate. In both cases, this improves the fit of the model, although in the *ltv* specification, the coefficient on the log rate is at best marginally significant. The final specification adds the percentage in rented accommodation. For the specification using *mcdr*, this term is significant. However, for the specification using *ltv* to measure credit conditions, this variable is not statistically significant and indeed has the wrong sign. It also worsens the fit of the model.

The models explain between 80% and 85% of variation observed in changes in the price-rent ratio. The speed of adjustment implied by the coefficient on the lagged level of the price-rent ratio is between 25% and 30% for models using *mcdr* and roughly 18% for models using *ltv*. Across all three specifications, however, the fit of the model using loan-to-value information was substantively better than the fit using the credit-to-deposit ratio (as measured by sigma). Thus, while the ratio of mortgage credit to deposits is a good proxy for credit conditions, it does not perform as well in explaining changes in the price-rent ratio as the loan-to-value for the typical first-time buyer.

[11] The CBI dataset only runs to 2011Q4. To utilize 2012 data, the median first-time buyer LTV was set at 82.5%, the level observed in 2011Q4. The median LTV was relatively stable in 2011, averaging 83.2%. As this is an equilibrium term, excluding these points does not have a significant impact on the results, although it does have a meaningful impact on sample size.

The specification using the median loan-to-value for first-time buyers is thus chosen to estimate the long-run relationship; actual and fitted values are plotted in Figure 15. It suggests one important dynamic relationship also: the coefficient on the contemporaneous change in the loan-to-value of 0.26 is statistically significant and implies that as credit conditions are being loosened, the price-rent ratio rises beyond just what is suggested by the long-run coefficient. The implied long-run relationship from this model is as follows, where Φ represents the unobserved intercept term:

$$ln(hpr_t) = \Phi + 2.05ltv_t - 1.94rm_t^{RN*} - 0.13ln(rm_t^{NN}) \tag{4}$$

Credit conditions Credit conditions have a long-run impact on the price-rent ratio, with the coefficient of 2.05 indicating that an increase of ten percentage points in the loan-to-value of the typical first-time buyer was associated with an increase in ratio of prices to rents of 20.5%. Assuming static rents, this translates into a 20.5% increase in house prices. Put another way, suppose average house prices are €170,000 and the average monthly rent is €800; thus the average gross yield (annual rent relative to prices) is 5.6%. An increase in the LTV by 10pp is associated with a fall in the yield from 5.6% to 5.2% in equilibrium. (There would also be a dynamic effect on the price-rent ratio, as outlined above, in this example of 2.6%, pushing the yield down to 5.0%.)[12]

Real interest rates Real interest rates for housing – as measured by the difference between nominal rates after tax reliefs and the expected capital gain (based on 4-year and 1-year inflation) – are associated with a lower price-rent ratio, as expected. The coefficient of 1.94 indicates that an increase in real interest rates of 1 percentage point is associated with an increase in equilibrium price-rent ratio of 1.94%. This is somewhat larger than the coefficient in the inverted demand model (1.53) and suggests that a relationship between interest rates and inflation to a much greater degree than between interest rates and rents.

Nominal interest rates In addition to real interest rates for housing, the nominal rate may also matter, although its statistical significance is marginal (potentially a product of the small sample size). A 10% reduction in the nominal after-tax mortgage rate is associated with a 1.3% rise in the price-rent ratio. This may reflect the cash-flow constraints and the direct choice faced by would-be first-time buyers of a particular rent or nominal net mortgage payment.

Robustness & Sensitivity Overall, these results are sensitive to series chosen, due to the small period for which the model is computed. Nonetheless, largely similar results are obtained if an

[12] Duca et al. (2011*a*) use the log form of the loan-to-value for first-time buyers and report a long-run elasticity of prices with respect to LTV of 1.4. Here, a model with level of LTV/downpayment ($\sigma = 0.01270$) has better fit than one with log LTV ($\sigma = 0.01282$), and also performs better than one with log down-payment, which will have different non-linearities ($\sigma = 0.01278$). For reference, the implied long-run elasticity of prices with respect to LTV for Ireland 2000-2012 was roughly 1.6, compared to 1.4 in the case of the USA, 1980-2007.)

alternate series for rents (from property website daft.ie) is used for the period 2002-2012. Adding other dynamics does not improve model fit, while using loan-to-income information contained in the same CBI data is not preferred. Using the DOE series on LTVs for new dwellings results in a significantly poorer model fit, with neither house price appreciation term statistically significant and the nominal rate only marginally significant.

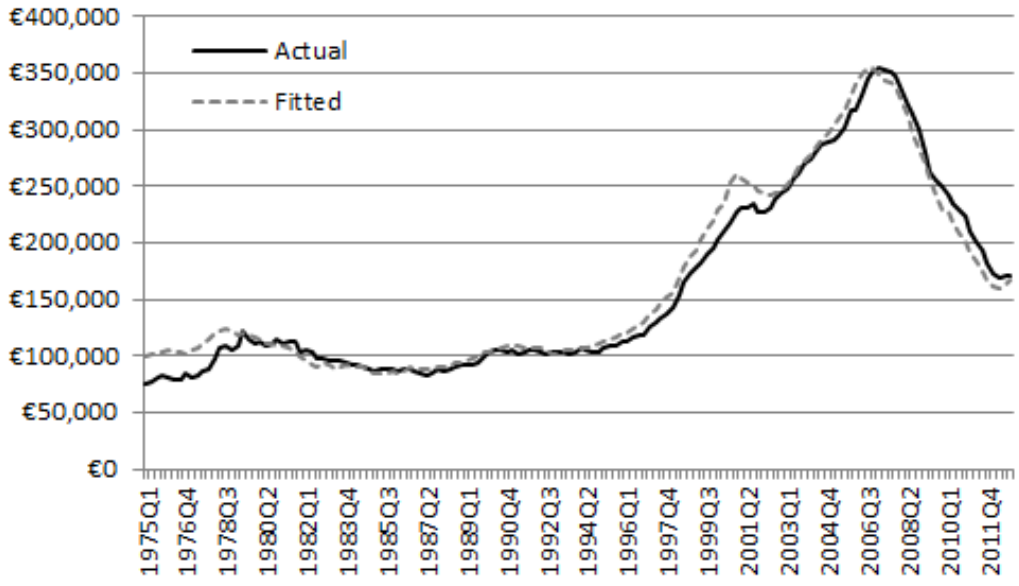
8 Decomposition & Analysis

This section decomposes real house price growth in each of six phases from 1975 to 2012 into changes due to the various fundamentals. It also uses the information contained in the inverted demand model to comment on likely future pressures on Irish house prices.

8.1 Decomposing Irish house price growth

As can be seen in Figure 9, there were roughly six phases in the Irish housing market between 1975 and 2012. The first was from 1975 (the start of quarterly information) until 1979:Q2, during which real house prices rose 60%, or almost 12% on an annualized basis. The second finished in 1987:Q2, and between 1979 and 1987, real house prices fell by 32% (or almost 5% on an annualized basis). Between 1987:Q2 and 1995:Q3, real house prices rose by 31%, or 3.3% per year on average.

Figure 9: *Actual and fitted real house prices, national average, 1975-2012*



The fourth phase, the period between 1995:Q3 and 2001:Q3, saw the strongest growth, as real house prices rose by 117%, or 13.7% per year on average. Between 2001:Q3 and 2007:Q1, when real house prices peaked, there were further growth of 52%, or just under 8% on an annualized

basis. The final phase is from 2007:Q1 to 2012:Q4 (the end of the time series), during which house prices fell by 52%, or an annual average rate of 12%. Figure 9 also shows that there is no deviation of actual house prices from their long-run determinants, although it should be noted that these "fundamentals" include unrealistic extrapolative expectations and potentially unsustainable levels of mortgage credit relative to household deposits.

Figure 10: *Annual house price growth attributed to fundamentals, by market phase, 1975-2012*

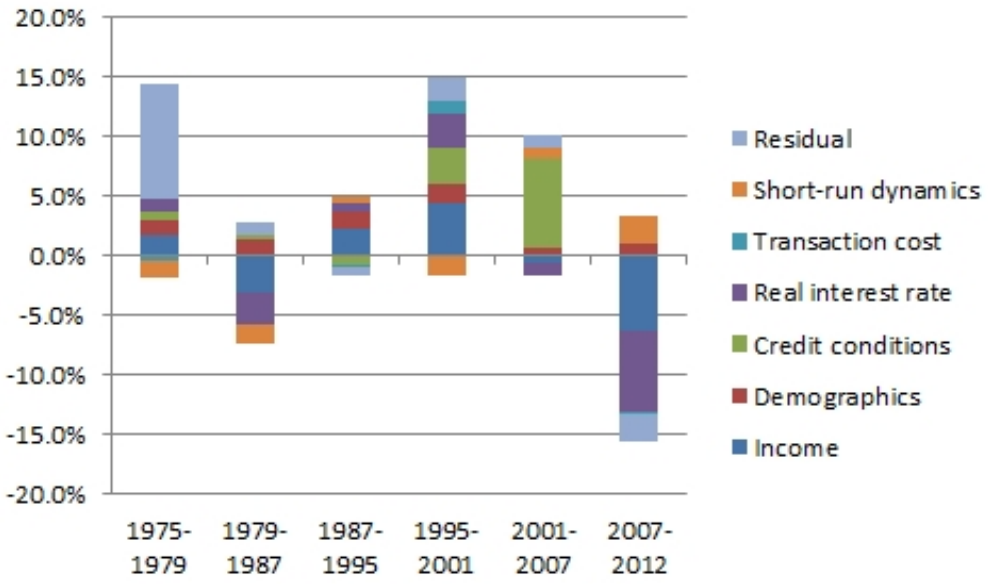


Figure 10 uses the long-run equilibrium relationship for the period 1980-2012 to decompose Irish house price growth in each of these six phases into growth driven by each of the five fundamental factors, as well as a proportion not explained by the long-run component of the model, which can be broken into dynamic and residual factors. The percentage rates of change in real house prices are annualized and thus comparable across periods.

Aside from the sheer volatility of house price growth in Ireland during the period as a whole, two things are striking about the figure. The first is the large proportion of house price growth in the 1970s not explained by the long-run component of the model. The second is the nature of house price growth between 2001 and 2007. Unlike the preceding period, where house price growth appears to have been driven by a mix of factors, including income growth (relative to the stock of housing) and demographics, growth in real house prices from 2001 to 2007 was almost entirely driven by credit conditions. Most of the remainder of the growth in house prices during this period is either due to short-run dynamics or else is a residual that may be considered a pure bubble effect. Dynamics and the residual offset a falling ratio of income to housing stock, due to Ireland's extraordinary building boom, and a higher real interest rate (reflecting slower house price growth overall).

8.2 Future pressures on Irish house prices

The end of 2012 saw the end of mortgage-interest relief available to first-time buyers. Based on prevailing interest rates at end-2012, this is the equivalent of a 0.07 percentage point increase in the interest rate. According to the long-run coefficient on interest rates, this could be expected to push equilibrium real house prices down by 1.1%, if the model pertaining to the generation to 2012 were to hold in coming years.

Similarly, the local property tax – levied at 0.18% of the value of a property – may be thought of in present value terms as the equivalent of an increase in stamp duty, although this assumes away any deposit constraints associated with stamp duty. Assuming a discount rate of 5% per annum and a seven-year horizon for households, this could be expected to lower equilibrium house prices by 1.7%. It should be noted, however, that it is likely the effect of stamp duty was through down-payment constraints, while it is also worth stating that the long-run effect of stamp duty is not precisely estimated, due to the small number of changes to it during the period analysed.

A final tax issue is one brought up by Browne et al. (2013), namely the preferential tax treatment of capital gains associated with owner-occupancy. Given the significance of expected capital gains in the long-run equation of fundamentals determining Irish house prices, it is clear that were a tax liability to apply for realised capital gains, this would have the ability to dampen somewhat the extrapolative nature of the Irish housing market. If the rate of 33% were to apply to principal private residences, this would clearly have an impact on the user cost calculation of Irish housing market participants.

Related to this, the likely presence of extrapolative expectations suggests that the user cost associated with housing in Ireland in late 2012 was very high: the real rate of interest in housing is estimated at over 20% for late 2012. At some point, this will fall, as the average rate of change in real house prices goes to zero. If house prices were stable between 2012 and 2016, this alone would represent an improvement in the user cost of 18 percentage points. Such an improvement in expectations would – according to the model presented – be associated with an increase in real house prices of more than 25% – which of course would feed in itself into house price expectations.

Lastly, there is the issue of credit conditions. As measured, credit conditions is a linear combination of the level and change in the credit-deposit ratio. While the coefficient on the change term is nearly twice as large as that on the level, the scale of the level of roughly two orders of magnitude larger (for example, between 2000 and 2007, the average value of $mcdr$ was 1.4, while for $dmcdr$ it was 0.026). Thus, as measured, credit conditions remained in late 2012 quite loose by historical standards: the linear combination of $mcdr + 1.78dmcr$ stood at 1.69 in late 2012, down from 1.87 in 2007 but well above the pre-2000 average of 0.74. If a measure that gives greater weight to stocks than flows proves too sticky to capture marginal credit conditions, the typical loan-to-value (as highlighted by the model of the price-rent ratio) may be a better indicator in the future. Nonetheless, the question of how Irish banks will fund their loan books in the future – in

particular the balance between internal deposits and external financing – is relevant for the future path of Irish house prices.

8.3 Could the bubble have been prevented?

The long-run equation presented in this research can be used to estimate alternative scenarios for house prices. Three are presented in Figure 11, alongside nominal house prices during the period 1980-2012. As outlined in Section 6.2, rich relationships may exist between house prices and its determinants, so the scenarios presented here are done so as thought experiments, rather than predicted counterfactuals.

The first, Scenario 1, estimates house prices where the real user cost is adjusted to include a Capital Gains Tax of 33% on principal primary residences.[13] This line closely matches actual house prices, although it is worth noting that both the bubble and the crash are slightly attenuated. At the margins, therefore, this is evidence to suggest that a tax on profit from homeownership may have smoothened the housing market cycle.

However, even with a tax on gains, the bulk of the housing bubble and crash would likely still have occurred. Scenario 2 presents estimated house prices in a situation where macro-prudential policy restricted the ratio of mortgage credit to deposits of 80%.[14] This policy measure would have prevented Irish banks from engaging in any substantial bond-financing of mortgages upon entry into the eurozone. There is a noticeable impact on the run-up of house prices between 1995 and 2007. The increase in prices in Scenario 2 is 180%, just over half the increase actually seen (350%).

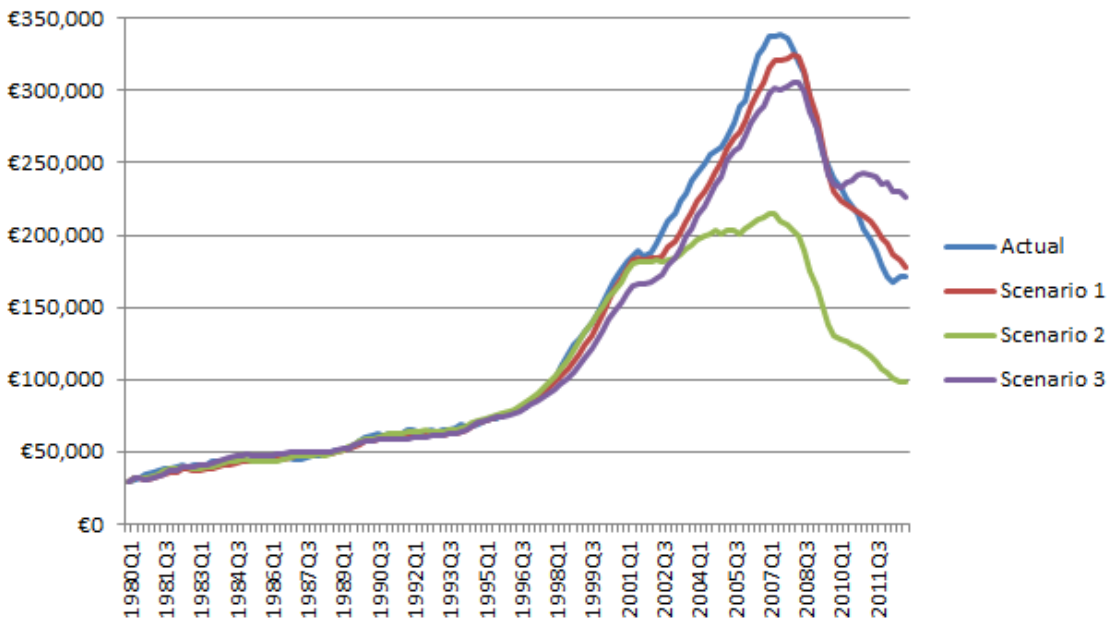
The fall from the peak in Scenario 2 is substantial, though. This indicates that while credit conditions were key to driving up prices, they have not played a significant role in the crash. The final scenario, Scenario 3, replaces one simplistic calculation of expectations – whatever happened in recent years is the best guide to the near future – with another: the empirical evidence is that in the long run, house price increases match but rarely exceed inflation. That is, user cost is calculated as net interest rates minus average consumer price inflation over the last four years, instead of net interest rates minus average house price inflation. As can be seen in Figure 11, this has a far greater impact on prices falls than preceding price rises. Whereas prices are estimated to still have increased by a factor of four, the fall from the peak is 26%, rather than 50%.

Thus, the evidence from the bubble and crash in Ireland is that both macro-prudential regulation of mortgage products and ensuring consumer expectations are well-educated are important tools in the policymakers fight against destructive housing market cycles.

[13] For the purposes of simulation, the tax is assumed to have been introduced in 1980:Q1. No further feedback, for example through diminished down-payments, is included.

[14] A more likely policy would be a cap on loans-to-value, as was implemented in Hong Kong. Given the lack of a long-running series on loan-to-value, however, this is not possible here. Nonetheless, the ratio of credit to deposits can be thought of as similar to a system-wide loan-to-value.

Figure 11: *Actual and scenario house prices, national average, 1980-2012*



9 Conclusion

This paper has examined the housing market in Ireland from the mid-1970s until 2012, with a particular focus on the bubble that peaked in 2007 and the crash that followed. Following a growing literature that focuses on the role of credit conditions, a readily available measure of credit conditions was included, the ratio of mortgage credit to deposits, one with both early and more recent antecedents in the Irish housing market literature, which proved highly significant in both inverted demand and price-rent models of the Irish housing market.

The error-correction model developed for the Irish housing for the period 1980-2012 found that there were four principal fundamentals that determined the long-run equilibrium level of real house prices: the ratio of income to the housing stock, the ratio of persons to households, the ratio of mortgage credit to deposits, and the user cost, as measured by difference between net nominal mortgage interest rates and the annualized 4-year rate of house price inflation. In addition, it seems likely that the rate of stamp duty was important for the level of house prices, while other factors mattered for short-run changes in house prices, in particular conditions in the labour and mortgage markets.

For much of the early period analysed, the rental market in Ireland was in secular decline. From the mid-1990s, though, the proportion in rented accommodation started to grow, and there is significant evidence of an error-correction relationship in the price-rent ratio for the period 2000-2012. The long-run relationship between prices and rents is more parsimonious than for prices alone, with the user cost and credit conditions the most important factors. Here, user cost is the

net interest rate less a combination of 1-year and 4-year inflation, with potential non-linearities applying in relation to the nominal rate of interest. Credit conditions were measured in two ways: firstly, the ratio of credit to deposits, as above, and secondly, using a new dataset of typical loan-to-value rates for first-time buyers from 2000 on. While both measures capture significant variation in the sample, the LTV measure performs better, reflecting the importance of including the change in the credit-deposit ratio, as well as the level.

In both models, credit conditions matter, both for the long-run solution and for short-run dynamics. An increase in the credit-deposit ratio of 10 percentage points was associated with a 5.6% increase in equilibrium house prices but also a 1.7% short-run effect in the following quarter. Similarly, an increase of ten percentage points in the typical first-time buyer LTV was associated with an increase in the long-run price-rent ratio of 20.5%, as well as a short-run effect of 2.6%. This suggests that previous studies of the Irish housing market have suffered from omitted variable bias, attempting to model prices but without accounting for credit conditions.

Indeed, a decomposition of Irish house price growth from 1975 to 2012 into its various phases highlights the importance of credit conditions in the last phase of Ireland's bubble. Whereas house price growth between 1995 and 2001 was a combination of factors, including rising income relative to housing stock, lower real interest rates, demographics and credit conditions, during the 2001-2007 period, looser credit conditions were responsible for 7.5 percentage points of growth per annum on average, at a time when annual growth was 7.9%. While incomes were rising during this period, the housing stock rose faster, to the extent that the ratio of income to stock was actually a drag on prices during this time.

The demographic variable included in the inverted demand model – the ratio of persons to households – is one rarely commented on in the recent literature, but it is a largely common-sense variable: a population of 4 million with four to a house will demand fewer houses and occupy less land than a population with three to a house. Previous studies, not just for Ireland, that focus solely on income (relative to supply) may be overstating the effect, if part of the effect is actually a greater spread of the population. With an ageing population and smaller family units, it is likely that this variable will continue to put upward pressure on prices over the coming decade, even if income pressures are weak.

Of note in both models, but in particular in the inverted demand approach, is the speed with which real house prices in Ireland during this period adjusted to a new equilibrium. The principal specification suggests that almost one third of the gap between actual and equilibrium prices was closed every quarter. In this sense, Ireland's bubble was not an irrational bubble in the housing market, marked by prices deviating significantly from fundamentals. Rather, the analysis here suggests that Ireland's bubble was one step further up: it was the "fundamentals" themselves – in particular credit conditions and expectations – that had deviated from sustainable levels. However, given the extrapolative nature of expectations of capital gains, one should not regard

expectations as a true fundamental: they are ultimately driven by all the shocks that drive house prices. The extrapolative nature of these expectations generates a natural mechanism for house price to overshoot on both upside and downside. How policy can prevent this recurring, for example tracking expectations with regular surveys to warn about future problems, should be an active topic of future research and policy analysis.

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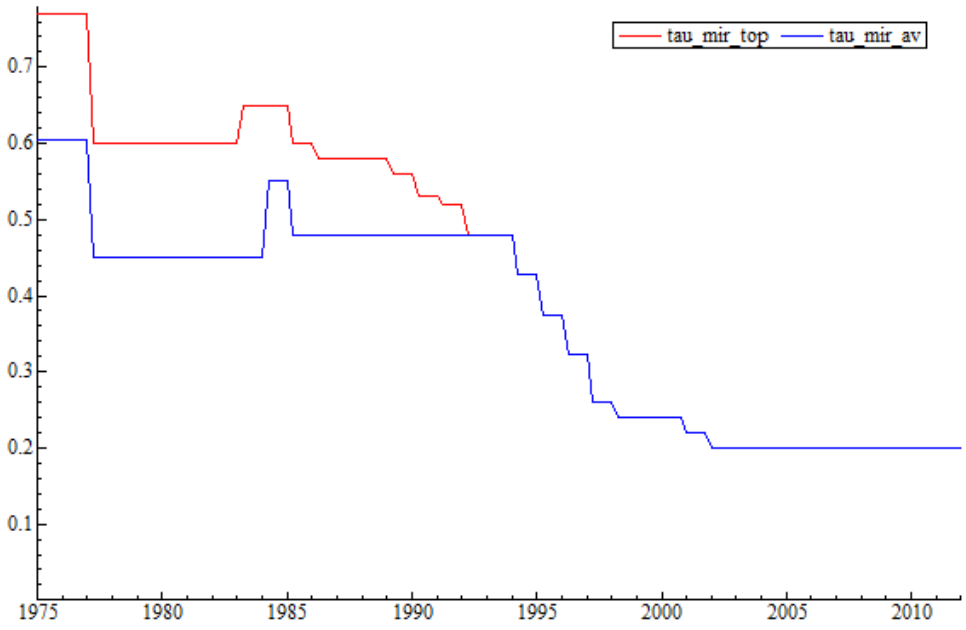
A Mortgage Interest Relief

In Section 4.7, reference was made to mortgage interest relief, through which owner-occupiers received an income tax rebate. This relief was at the marginal rate for earners, and subject to ceilings to time limits at different points. For the purposes of this study, as the relief applied for more than five years throughout the sample, and the ceilings were not binding for those buying at average prices, the key variable in determining the net mortgage rate was the marginal rate of income tax paid. Figure 12 shows the full marginal rate and the marginal rate that would have applied at the average industrial wage, using data from AMECO on nominal average compensation per employee. Mortgage interest relief did not apply in the Irish market from January 2013.

Figure 12: *Rate of mortgage interest relief, marginal and average wage, 1975-2012*



B Regression Output

Table 12 details the regression output, including coefficients and associated standard errors, t-statistics and p-values, for the model with full dynamics outlined in Section 5. As is outlined in the text, the long-run solution is clear, while few of the dynamic terms are statistically significant.

C Robustness & sensitivity analysis

Tables 13 and 14 show the coefficients and associated p-values for a number of specifications designed to check the robustness of the results outlined in Section 5.3. The first table examines alternative data series for a range of fundamentals, while the second table shows results for different functional specifications of the three core fundamental ratios: income to supply, mortgages to deposits, and

Table 12: *Model 1: dlrhp with full potential dynamics, 1980-2012*

	Coeff		S.E.	t-stat	p-value
Constant	3.9627	***	1.377	2.88	0.0049
lrhp_1	-0.3058	***	0.0811	-3.77	0.0003
lrystock_phh_1	0.3859	***	0.1071	3.6	0.0005
phhr_1	-0.1148	**	0.0562	-2.04	0.0438
mcdr_1	0.1654	***	0.0552	3	0.0035
rm_net_r_4y_1	-0.4387	***	0.1542	-2.85	0.0054
tau_sd_ftb_1	-0.4941		0.3285	-1.5	0.1359
dlrhp_1	0.264	***	0.0993	2.66	0.0092
dlrhp_2	-0.1323		0.1061	-1.25	0.2154
dlrhp_3	0.1427		0.0934	1.53	0.1301
dlrhp_4	-0.2514	***	0.0924	-2.72	0.0078
infl_cpi_ex	-0.2574		0.1984	-1.3	0.1975
infl_cpi_ex_1	0.3451		0.2481	1.39	0.1675
infl_cpi_ex_2	-0.0824		0.2548	-0.32	0.7471
infl_cpi_ex_3	-0.2635		0.2461	-1.07	0.2872
infl_cpi_ex_4	0.2342		0.1794	1.31	0.1949
pop_migr_pc	1.4425		3.006	0.48	0.6325
pop_migr_pc_1	-1.0089		5.848	-0.17	0.8634
pop_migr_pc_2	0.4902		6.09	0.08	0.936
pop_migr_pc_3	-4.0599		5.667	-0.72	0.4755
pop_migr_pc_4	3.5081		2.996	1.17	0.2445
delta_ueq1	-0.0193	***	0.0056	-3.42	0.0009
delta_ueq1_1	-0.0098		0.0059	-1.66	0.1003
delta_ueq1_2	0.0057		0.0059	0.97	0.3363
delta_ueq1_3	-0.0003		0.0059	-0.05	0.9565
delta_ueq1_4	0.0021		0.0052	0.4	0.6883
dmcdr	-0.0223		0.2365	-0.09	0.9251
dmcdr_1	0.4768	*	0.2678	1.78	0.0781
dmcdr_2	-0.415		0.2826	-1.47	0.1452
dmcdr_3	0.4506		0.287	1.57	0.1197
dmcdr_4	-0.2027		0.2336	-0.87	0.3877
lpop_2534_1	0.0007		0.1692	0	0.9965
drm_net_nom	0.2153		0.4498	0.48	0.6333
drm_net_nom_1	-0.2963		0.4466	-0.66	0.5087
drm_net_nom_2	0.8682	*	0.4655	1.87	0.0653
drm_net_nom_3	-0.3328		0.4382	-0.76	0.4495
drm_net_nom_4	0.7072		0.4484	1.58	0.1181

persons to households. The final rows of each table show measures of model fit and also whether the model failed any of six core tests. Commentary on these results is given in Section 5.3.

Table 13: *Robustness analysis of inverted demand model: alternative fundamentals*

	Original		25-34 pop		LTV		Income, stock		Per cap y, stock		Stock (volume)		Weighted r		Grants		Annual unemp	
	Coeff	p	Coeff	p	Coeff	p	Coeff	p	Coeff	p	Coeff	p	Coeff	p	Coeff	p	Coeff	p
Constant	4.079	0	3.94	0	0.943	0.001	0.628	0.332	0.431	0.091	-0.477	0.402	3.614	0	3.93	0	3.94	0
lrhp_1	-0.314	0	-0.324	0	-0.06	0.004	-0.339	0	-0.344	0	-0.343	0	-0.284	0	-0.303	0	-0.306	0
lrystock_1	0.395	0	0.405	0	0.073	0.309							0.395	0	0.376	0	0.418	0
phhr_1	-0.122	0	-0.119	0	-0.059	0.022	-0.071	0.099	0	0	0.02	0.539	-0.086	0	-0.113	0	-0.106	0
mcdr_1	0.174	0	0.17	0	-0.023	0.714	0.167	0	0.161	0	0.157	0	0.163	0	0.165	0	0.171	0
rm_nr4_1	-0.481	0	-0.496	0	-0.146	0.037	-0.491	0	-0.495	0	-0.555	0	-0.411	0	-0.465	0	-0.435	0
tau_sd_1	-0.476	0.027	-0.476	0.027	-0.158	0.478	-0.53	0.015	-0.532	0.014	-0.485	0.026	-0.438	0.041	-0.468	0.029	-0.499	0.024
lpop2534_1			0.041	0.678														
lry_1	0	0	0	0	0	0	0.435	0	0.442	0	0.394	0						
lrstock_1	0	0	0	0	0	0	-0.302	0.004	-0.262	0.001	-0.349	0.016						
gtv_1															-0.094	0.266		
dlrhp_1	0.166	0.038	0.17	0.036	0.111	0.211	0.175	0.029	0.18	0.023	0.187	0.022	0.142	0.081	0.159	0.048	0.204	0.013
dlrhp_4	-0.256	0	-0.251	0.001	-0.202	0.007	-0.249	0	-0.243	0	-0.222	0.001	-0.272	0	-0.256	0	-0.256	0
dueq1	-0.016	0	-0.016	0	-0.017	0.001	-0.018	0	-0.018	0	-0.019	0	-0.017	0	-0.016	0	-0.014	0.014
dueq1_1	-0.01	0.024	-0.011	0.022	-0.011	0.03	-0.012	0.012	-0.012	0.007	-0.014	0.004	-0.011	0.023	-0.011	0.021	-0.006	0.295
dmcdr_1	0.31	0.012	0.301	0.016	0.331	0.016	0.298	0.015	0.296	0.015	0.314	0.012	0.302	0.015	0.345	0.007	0.302	0.021
sigma	0.01673		0.01679		0.01841		0.01666		0.0166		0.01686		0.01684		0.01671		0.01725	
R2	0.696		0.696		0.631		0.701		0.7		0.694		0.691		0.699		0.676	
Test failures	None		None		AR1-5		None		None		None		None		None		None	

Table 14: *Robustness analysis of inverted demand model: logs vs. levels for ratios*

	No LR		Original		Log MCDR		Log PHHR		All logs		All levels	
	Coeff	p	Coeff	p	Coeff	p	Coeff	p	Coeff	p	Coeff	p
Constant	0.003	0.133	4.079	0	2.388	0	4.158	0	2.461	0	3.274	0
lrhp_1			-0.314	0	-0.223	0	-0.312	0	-0.221	0	-0.288	0
lrystock_1			0.395	0	0.264	0	0.38	0	0.253	0	0.487	0
phhr_1			-0.122	0	-0.1	0	-0.426	0	-0.345	0	-0.114	0
mcdr_1			0.174	0	0.148	0	0.168	0	0.142	0	0.163	0
rm_nr4_1			-0.481	0	-0.403	0	-0.495	0	-0.411	0	-0.45	0
tau_sd_1			-0.476	0.027	0.005	0.983	-0.449	0.036	0.015	0.943	-0.247	0.223
dlrhp_1	0.3	0.001	0.166	0.038	0.139	0.088	0.169	0.035	0.144	0.08	0.155	0.053
dlrhp_4	-0.045	0.541	-0.256	0	-0.252	0.001	-0.25	0	-0.246	0.001	-0.258	0
dueq1	-0.02	0	-0.016	0	-0.016	0.001	-0.016	0.001	-0.015	0.001	-0.015	0.001
dueq1_1	-0.015	0.003	-0.01	0.024	-0.011	0.017	-0.01	0.027	-0.011	0.018	-0.01	0.034
dmcdr_1	0.314	0.006	0.31	0.012	0.16	0.161	0.316	0.011	0.162	0.157	0.288	0.02
sigma	0.02045		0.01673		0.01724		0.01681		0.01733		0.01688	
R2	0.522		0.696		0.677		0.693		0.673		0.69	
Test failures	None		None		AR1-5		None		AR1-5		None	

D Fitted values & Parameter stability

Figures 13 and 14 show the actual and fitted values of the change in real house prices (*dlrhp*) for the model applied to the 1980-2012 period and the same model applied to the 1975-2012 period. Figure 15 shows the actual and fitted values of the change in the house price-to-rent ratio, 2000-2012. Figure 16 shows the recursive estimates of parameters on the long-run variables in the inverted demand specification, starting with a ten-year window (1980-1990). Commentary on all these results is given in the text.

Figure 13: *Actual and fitted values of dlrhp, 1980-2012*

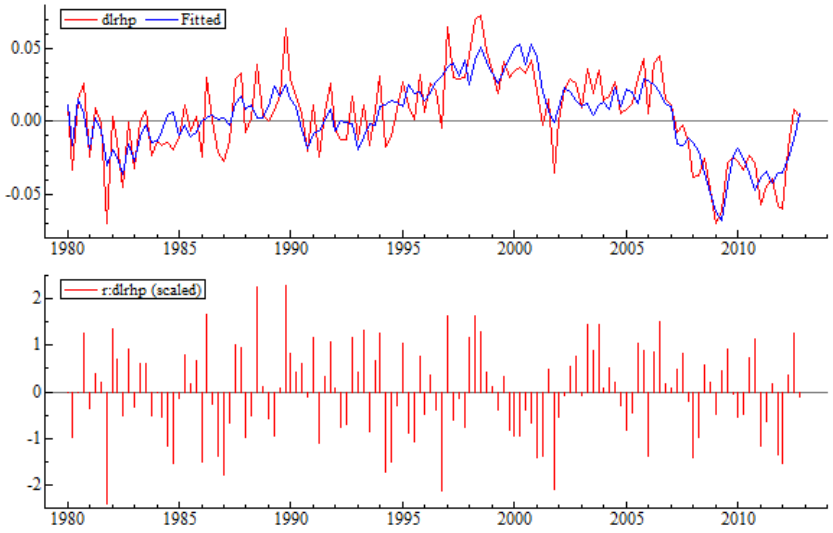


Figure 14: *Actual and fitted values of dlrhp, 1975-2012*

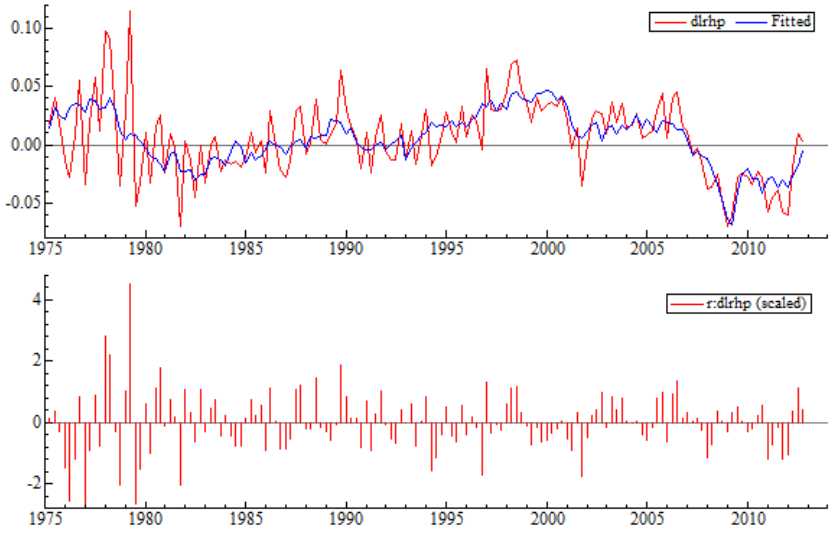


Figure 15: *Actual and fitted values of dlhpr, 2000-2012*

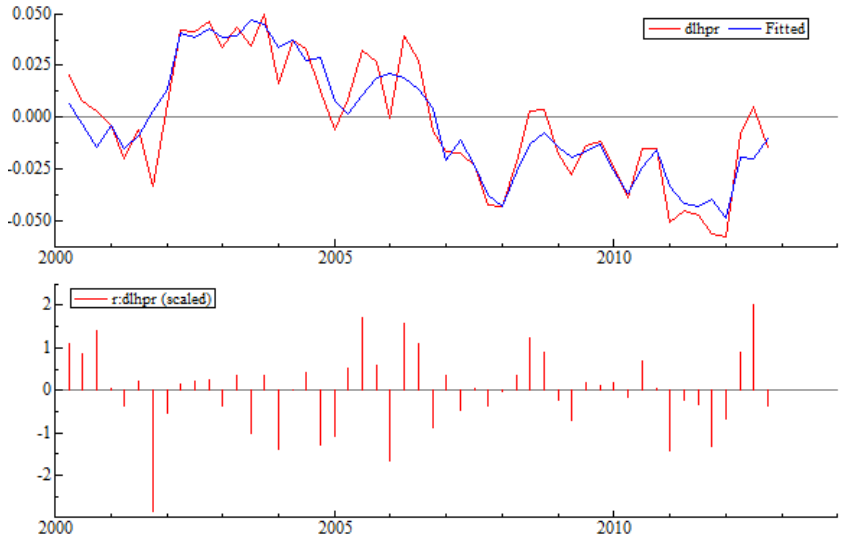


Figure 16: *Recursive estimates of coefficients, inverted demand model, 1990-2012*

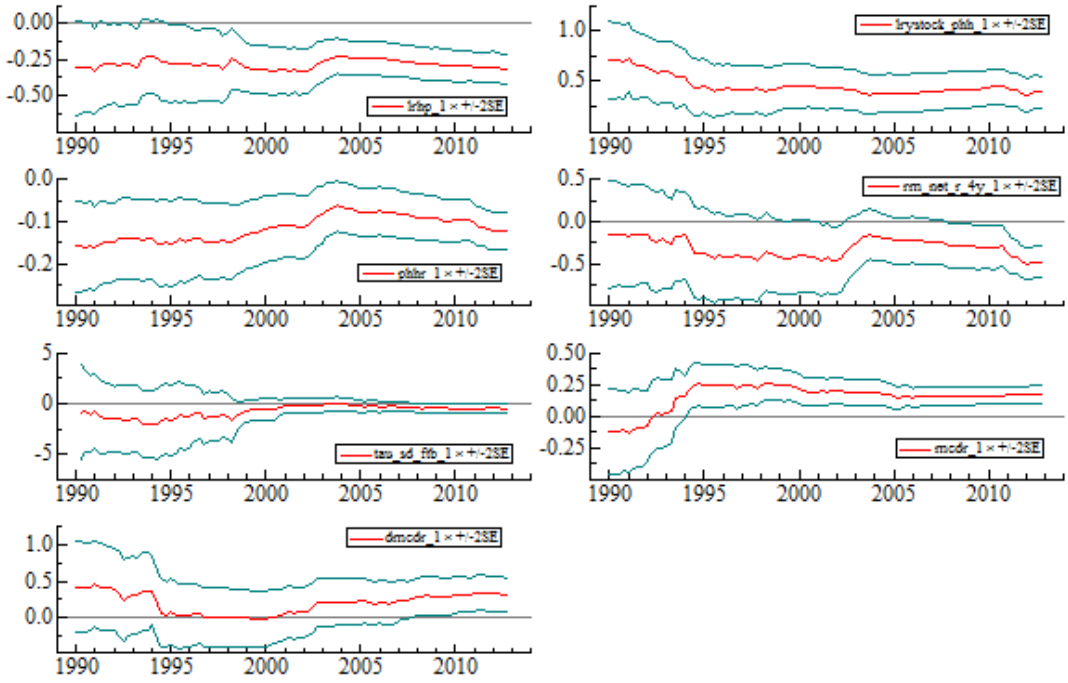


Table 15: *ADF unit root tests: supplementary series*

Var	D-lag	t-adf	beta Y_1	sigma	t-DY_lag	t-prob	AIC	F-prob
dlry_pc	3	-2.286	0.919	0.004	0.471	0.639	-10.87	
	2	-2.243	0.922	0.004	0.453	0.652	-10.89	0.639
	1	-2.204	0.925	0.004	0.436	0.664	-10.9	0.809
	0	-2.167	0.928	0.004			-10.91	0.893
dlhs_pc	3	-0.1197	0.996	0.001	-1.658	0.1	-13.62	
	2	-0.437	0.985	0.001	-3.116	0.002	-13.61	0.1
	1	-1.121	0.96	0.001	-3.272	0.001	-13.55	0.003
	0	-1.912	0.932	0.001			-13.49	0
dlry_phˆ†	3	-3.441**	0.854	0.005	0.814	0.417	-10.45	
	2	-3.347**	0.862	0.005	0.379	0.705	-10.46	0.417
	1	-3.363**	0.866	0.005	0.785	0.434	-10.47	0.669
	0	-3.274**	0.873	0.005			-10.48	0.702
dlhs_phˆ†	3	-2.949**	0.878	0.002	0.392	0.696	-12.67	
	2	-2.950**	0.882	0.002	0.854	0.395	-12.68	0.696
	1	-2.831*	0.89	0.002	0.168	0.867	-12.69	0.646
	0	-2.886**	0.892	0.002			-12.7	0.824
dd4pop2534	3	-4.471***	0.746	0.002	1.551	0.124	-12.76	
	2	-4.170***	0.777	0.002	1.366	0.174	-12.75	0.124
	1	-3.927***	0.8	0.002	1.065	0.289	-12.75	0.121
	0	-3.778***	0.815	0.002			-12.76	0.148
dlyhsˆ†	3	-3.937***	0.812	0.005	0.664	0.508	-10.46	
	2	-3.905***	0.82	0.005	0.972	0.333	-10.47	0.508
	1	-3.783***	0.832	0.005	0.464	0.644	-10.47	0.503
	0	-3.800***	0.837	0.005			-10.49	0.661

E Stationarity & Cointegration

Table 15 presents supplementary augmented Dickey-Fuller tests, as described in the text. Figures 17-18 show plots of the following variables in delta form: log real house prices, log real income per household, log real housing stock per household, log of the income-stock ratio, the credit-deposit ratio, user-cost, the person-household ratio and the change in population aged 25-34. Figures 19 and 20 contrast changes in per household income and housing stock (likely to be stationary) with changes in per capita income and stock, which fail unit root tests at all conventional levels of statisticaly significance. Table 16 shows regression output for the unrestricted 1-lag VAR in real house prices, the log income-stock ratio, and user-cost.

Table 16: *Unrestricted 1-lag VAR in prices, income/stock and user-cost*

	Coeff	S.E.	t-stat	p-value
URF equation for: lrhp				
lrhp_t-1	0.699	0.058	12.1	0.000
lrystock_t-1	0.293	0.172	1.7	0.091
rm_net_r_4y_t-1	-0.407	0.101	-4.03	0.000
phhr_t-1	-0.142	0.032	-4.39	0.000
d4_pop2534_t-1	0.104	0.247	0.42	0.675
ue_q_t-1	-0.18	0.281	-0.64	0.523
delta_ueq1_t-1	-0.013	0.005	-2.74	0.007
mcdr_t-1	0.144	0.04	3.6	0.001
dmcdr_t-1	0.347	0.136	2.55	0.012
tau_sd_ftb_t-1	-0.504	0.244	-2.07	0.041
Constant	4.01	0.725	5.53	0.000
sigma = 0.0187			RSS = 0.0422	
URF equation for: lrystock				
lrhp_t-1	-0.038	0.016	-2.34	0.021
lrystock_t-1	0.899	0.049	18.4	0.000
rm_net_r_4y_t-1	-0.099	0.029	-3.45	0.001
phhr_t-1	-0.067	0.009	-7.32	0.000
d4_pop2534_t-1	0.192	0.07	2.74	0.007
ue_q_t-1	-0.142	0.08	-1.79	0.077
delta_ueq1_t-1	-0.005	0.001	-3.81	0.000
mcdr_t-1	-0.002	0.011	-0.181	0.857
dmcdr_t-1	0.036	0.039	0.942	0.348
tau_sd_ftb_t-1	0.049	0.069	0.708	0.480
Constant	0.656	0.206	3.19	0.002
sigma = 0.0053			RSS = 0.00339	
URF equation for: rm_net_r4y				
lrhp_t-1	0.045	0.026	1.74	0.084
lrystock_t-1	0.064	0.077	0.827	0.410
rm_net_r_4y_t-1	0.991	0.045	21.8	0.000
phhr_t-1	0.031	0.014	2.15	0.033
d4_pop2534_t-1	-0.14	0.111	-1.25	0.212
ue_q_t-1	0.358	0.126	2.83	0.005
delta_ueq1_t-1	0.004	0.002	1.64	0.103
mcdr_t-1	-0.005	0.018	-0.293	0.770
dmcdr_t-1	0.005	0.061	0.088	0.931
tau_sd_ftb_t-1	-0.005	0.11	-0.049	0.961
Constant	-0.651	0.326	-1.99	0.048
sigma = 0.0084			RSS = 0.0085	
log-likelihood = 1323.15			$-\frac{T}{2log}\|\Omega\|$ = 1885.05	
$\|\Omega\|$ = 3.944e-013			$\log\|Y'Y/T\|$ = -12.79	
$R^2(LR) = 1$			$R^2(LM) = 0.9835$	
no. of obs = 132			no. of params = 33	

Figure 17: *Plots of changes in house prices, income and housing stock*

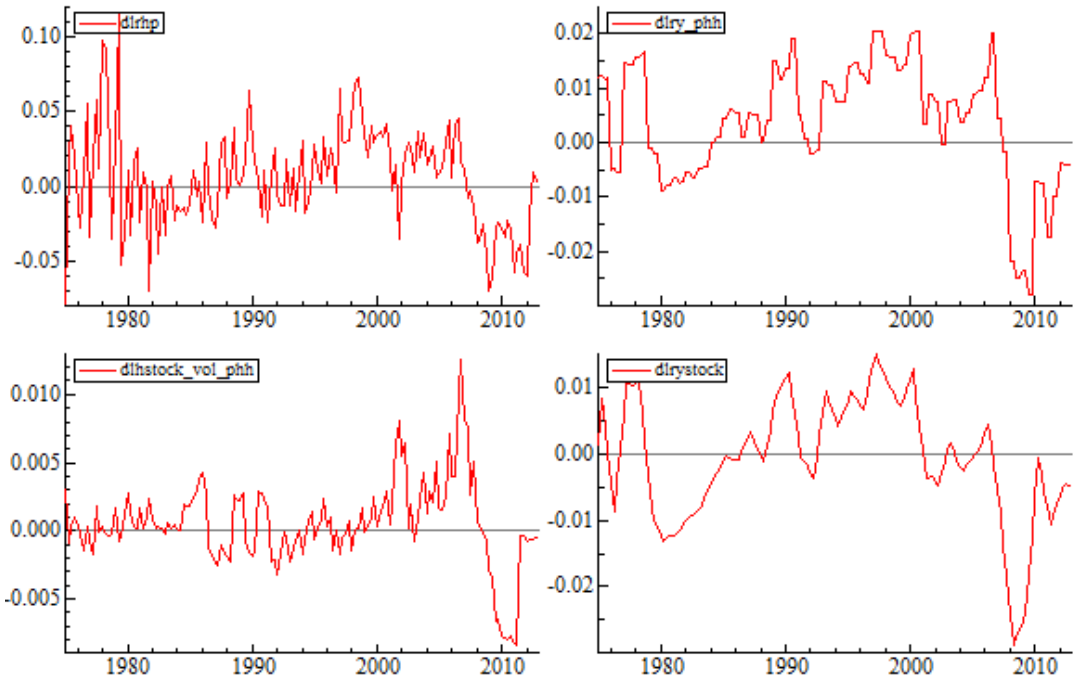


Figure 18: *Plots of changes in other regressors*

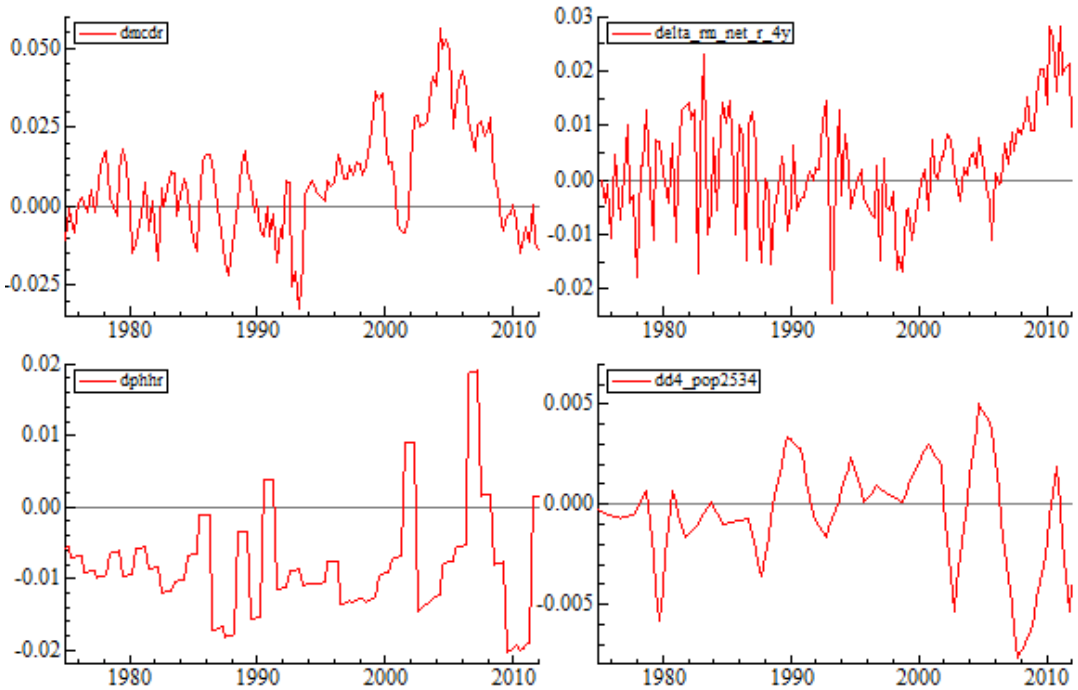


Figure 19: *Plots of changes in per household and per capita income*

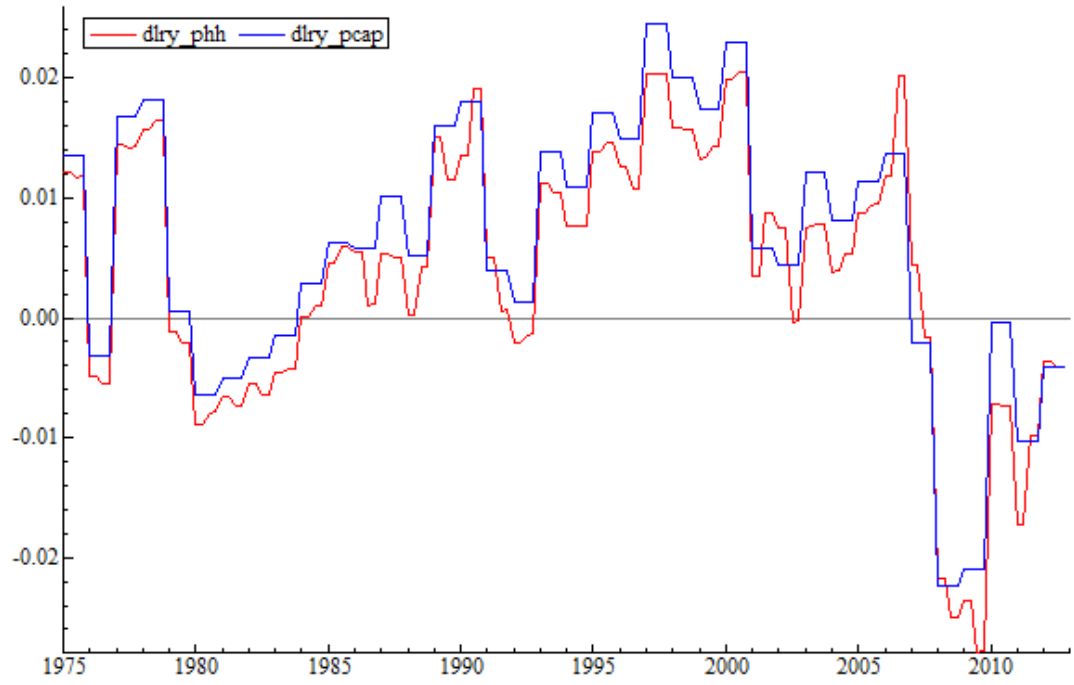


Figure 20: *Plots of changes in per household and per capita housing stock*