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Forecasting house prices

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Abstract

House prices are an important determinant of the OBR's fiscal forecasts. This paper sets out a number of changes to our house price forecasting methodology. Foremost is development of a house price model, based on an inverted demand function for housing services, relating house prices to household income, the supply of houses, the number of households and a housing discount rate. A central finding is that, absent policy effects, distributional issues or income constraints, both house prices and household debt are likely to rise faster than income for some time yet. However, the model alone is unlikely to capture short-term price dynamics fully, particularly when house price inflation is changing rapidly. The model is therefore used in conjunction with near-term indicators, and the OBR's house price forecast is ultimately subject to the judgement of the Budget Responsibility Committee.

JEL references: E510, R210, R310
Keywords: house prices, household debt

I am grateful for comments from Geoff Meen, colleagues at the Office for Budget Responsibility and the OBR's Advisory Panel.

Contents

1 Introduction and summary: forecasting house prices

1.1 In the pre-crisis decade to 2008, the UK housing market was characterised by rapid turnover, prices rising much faster than incomes and strong growth in mortgage finance. The subsequent recession was associated with tighter lending conditions, near-zero growth in mortgage finance, falling prices and a halving of residential property transactions. Five years later, the housing market is now well on the way to recovery. This has helped to reduce the budget deficit, particularly through rising stamp duty receipts. However, considerable uncertainty remains as to how far and how fast house prices – an important fiscal determinant – will rise.

1.2 Up until December 2013, we assumed in our *Economic and fiscal outlooks* that house prices would move in line with the average of external forecasts reported in the Treasury's *Comparison of independent forecasts* over the first two years of the forecast, and grow in line with average earnings thereafter. This had the advantage of being simple and transparent, but the disadvantage that there can be a significant lag between new information becoming available and external forecasts being updated, collated and published.[1] This problem is particularly apparent when house price inflation is changing rapidly, as has been the case over the past year.

1.3 We have therefore made a number of changes to our forecasting methodology. Foremost is the development of a model for house prices, estimated over more than 40 years of data. This provides some useful insights into the underlying drivers of UK house prices. However, market conditions can change rapidly and beyond the short term considerable uncertainty remains over key factors, notably the supply of new homes. Therefore, our new forecasting approach is a combination of short-term indicators, an estimated model and the judgement of the Budget Responsibility Committee.

1.4 This paper describes the model and explains how it fits into the forecasting process, in three stages:

1. **Model structure (Chapter 2)**: we set out the main stages of model development, and the tests and methods used in its configuration, including:
   - the theory behind the model structure, which describes a commonly-used household demand function for housing services;

[1] Another drawback was that external forecasts reference a number of different house price indices, meaning only a subset are directly relevant to the ONS house price series we forecast.

- estimation of a mortgage demand equation, to generate a quantity indicator of credit rationing over time. Given the role of credit in property transactions and the financial crisis, and post-crisis direction of policy toward relaxing credit constraints, this is an important part of the house price equation;

- estimation of a housing discount rate, to connect households' current demand for housing services and the market price for houses. This combines mortgage and non-mortgage housing costs, and proxies for credit rationing and expected capital gains; and

- estimation of the house price model itself, based on real economy indicators of current demand for housing services and the housing discount rate.

2 **Interpretation of the model (Chapter 3)**: we look at the short and long-term price elasticities of the model inputs, and the long-term determinants of the model, identifying some important implications for the long-term path of house prices and household debt.

3 **Model performance and the house price forecast (Chapter 4)**: we look at how well the model performs as a predictive tool. We then set out how we combine the model with other judgements to arrive at our house price forecast.

Summary of main conclusions

1.5 In **Chapter 2** we describe the process of estimating the house price model, centred on a relationship between real house prices and real incomes, housing supply and the discount rate. The final specification is robust to a wide range of static and recursive diagnostic tests. Interpretation of the model coefficients in **Chapter 3** finds that the model implies that house prices will consistently rise faster than income, barring a strong (and historically unprecedented) response from housing supply, leading to a steady rise in household debt relative to income. **Chapter 4** then looks at the model's forecasting performance and concludes that although successful in long-run prediction, it is less well-suited to capturing short-run dynamics. We therefore include short-term leading indicators, and judgement in the medium term, when using the model in the forecast process. **Annexes A, B** and **C** provide additional detail on diagnostic tests, data and references.

2 Model structure

2.1 The house price model is based on a demand function for housing services and a standard, life-cycle model of utility for a representative household. This is a common approach in academic research into house prices. The subsequent estimation process, particularly the estimation of a quantity measure of credit rationing, closely follows the approach used by Geoff Meen of the University of Reading in a number of papers. Specific references are noted in the text below and in detail in Annex C.

The theoretical foundation of the model

2.2 We assume a utility function where utility is derived from a composite consumption good (C), housing services (assumed to be derived directly from the stock of dwellings, *Hs*) and leisure (*L*). Therefore a generic, infinitely-lived household (and existing owner of housing assets) maximises the sum of discounted utility over an infinite horizon (1), subject to a budget constraint (2):

Lifetime utility: $\int_0^\infty e^{-\beta t} U(C_t, Hs_t, L_t)$ (1)

Budget constraint: (2)

$$RPH_t * (dHs_t + \delta Hs_t) + (dGFA_t + \pi_t * GFA_t) + C_t = RY_t + i_t * GFA_t$$

2.3 Where RPH_t is the real purchase price of dwellings; δ the rate of depreciation of housing assets; *d* the difference operator; GFA_t real financial assets; π_t the rate of inflation; RY_t is real, post-tax household disposable income; and i_t is the tax-adjusted market interest rate for an existing owner.[2] From this we can see that net acquisition of financial and non-financial assets, plus consumption, is equal to current income plus income from financial assets.

2.4 Solving the household optimisation problem, maximising utility (1) given (2), leads to the marginal rate of substitution between housing services and consumption goods, or shadow price of housing services, or real user cost of capital (*RUCC*):[3]

$$RUCC = \frac{U_{hs}}{U_c} = RPH_t * (i_t - \pi_t + \delta - \frac{dRPH_t}{RPH_t}) \quad (3)$$

2.5 A major factor in house purchase decisions is access to mortgage finance. Pre-crisis, ready access to credit facilitated house purchases. Post-crisis, the withdrawal of credit availability reduced purchases. Banks tightened loan-to-value (LTV) conditions on mortgage products

[2] δ includes other indirect costs of housing ownership when the model is estimated, such as maintenance, council tax and stamp duty (see Table 2.1).

[3] Full derivation of Equation (3), via dynamic Lagrangian function, is available on request.

due to a perceived rise in credit risk and their own concerns about access to wholesale funds.[4] To reflect the role played by credit we need to add a further constraint to the original optimisation problem, giving an augmented, adjusted *RUCC*:

$$RUCCadj = \frac{U_{hs}}{U_c} = RPH_t * (i_t - \pi_t + \delta - \frac{dRPH_t}{RPH_t} + \lambda_t / U_c) \quad (4)$$

2.6 The term λ_t / U_c is the ratio of the shadow price of the credit supply constraint to the marginal utility of consumption. Effectively, it captures the impact of access to credit on households' purchasing decision for housing services. We can't measure this directly, but we can derive a proxy measure through an estimate of the quantity constraint on mortgage demand (*mrat*). And so λ_t / U_c is referred to as *f(mrat)* from now on.

2.7 We assume that, given the actual supply of housing services is relatively inelastic (i.e. the stock of dwellings changes quite slowly due to net additions from new building, conversions and changes of use, less demolitions), changes in the real rental value per unit of housing (*R*) clears the market for housing services. However, housing also has an asset value, and the asset price (*RPH*) must adjust to establish capital market equilibrium, so that:

$$\frac{R_t}{RPH_t} - \delta + expected\ capital\ gains = i_t; \quad (5)$$

Where:

$$Expected\ capital\ gains = \pi_t + \frac{dRPH_t}{RPH_t} \quad (6)$$

or the expected rise in cash house prices (i.e. unadjusted for general inflation). As explained below, since these expectations are not directly observed, they are proxied via lagged actual house price changes.

2.8 Equation (5) shows that the return on housing assets is equal to the cost of housing finance in equilibrium, and *RUCC* and R_t both equal the marginal rate of substitution between housing and consumption goods. So combining Equation (6) with (5), we now have an equation for real house prices in period t:

$$RPH_t = R_t / (i_t + \delta - expected\ capital\ gains + f(mrat)) \quad (7)$$

2.9 Unfortunately R_t is not directly observable, but we can use a number of real economy variables to approximate it, including real household income, housing supply and demographic variables.[5] This leaves the basic structure of the house price model, in natural logs:

[4] Average LTV ratios for first-time buyers fell from 90 to 80 per cent between 2007 and 2013.

[5] An imputed rent series can be used. This is available in the CPI dataset, and also in the National Accounts, but the two are gathered in different ways and very different in outturn. The National Accounts series is currently under review and is likely to be substantially revised in Blue Book 2015 on current plans.

$$ln(RPH_t) = ln(R_t(RY_t, Hs_t, demographics) - ln(i_t + \delta - expected\ capital\ gains + f(mrat)) \quad (8)$$

The estimation process

2.10 Equation (8) requires a number of inputs. Some are directly observable, others require further estimation. Definitions for the key variables, and the model identifiers used in the rest of the document, are set out in Table 2.1.

Table 2.1: Data inputs and definitions

Variable	Identifier	Definition	Further discussion	Source
RPH_t	*rph*	The 'real' house price. This is *ph* adjusted for changes in the consumer price deflator.	-	ONS; OBR estimates.
	ph	The 'nominal' house price. A mix-adjusted, seasonally adjusted UK house price index.	Paragraph 2.11	ONS; OBR estimates.
i_t	*i1*	The average effective rate for all household mortgages. Net of mortgage interest relief at source (MIRAS) before 2000.	Paragraph 2.13	Bank of England; OBR estimates.
$i_t+\delta$	*i2*	The nominal user cost of mortgage capital. This is *i1* adjusted for depreciation, maintenance, stamp duty and council tax.	Paragraph 2.13	OBR estimates.
RY_t	*ryhh*	Real, seasonally adjusted household disposable income per household.	-	ONS; DCLG; OBR estimates.
	y	Nominal, seasonally adjusted household disposable income.	-	ONS.
Hs_t	*hshh*	Owner-occupied housing stock per household.	-	DCLG; OBR estimates.
	hsval	Value of owner-occupied housing stock.	-	DCLG; ONS; OBR estimates.
demographics	*hh*	Number of households.	Paragraph 2.38	DCLG; OBR estimates.
	m	Stock of mortgage finance.	-	Bank of England.
	wshx	Labour income:total household disposable income (*y*).	Paragraph 2.37	ONS; OBR estimates.
	lvr	Loan-to-value ratio (equal to *m/hsval*).	Paragraph 2.19	Bank of England; OBR estimates.
mrat	*mrat*	The credit rationing component of the housing discount rate.	Paragraph 2.29	OBR estimates.
expected capital gains	*capgains, l.phyoy*	The capital gains component of the housing discount rate.	Paragraph 2.33	OBR estimates.
	discr	The housing discount rate.	Paragraph 2.31	OBR estimates.

Note: Further information on definitions and sources is available in Annex B.

2.11 The measure of house prices used in this model is the ONS house price index, which is based on mortgage completions from the Regulated Mortgage Survey. This only reflects prices from transactions involving debt (but not buy-to-let loans[6]), suggesting that the ONS index is more directly a measure of the price of owner-occupied housing. For this reason we

[6] Council of Mortgage Lenders, "New mortgage market data: key changes and better information".

use owner-occupied housing as a proxy for housing services in the model, rather than the entire housing stock (and statistically, the former has greater explanatory power for ONS house prices than the latter). The resulting house price model is strictly speaking an inverted demand function for owner-occupied housing services.

2.12 The sources column in Table 2.1 also shows that there are three variables in particular that require more work before estimating the price model:

- **the nominal user cost of mortgage capital** (*i2*). While the average mortgage rate is easily obtained, additional tax and benefit adjustments need to be calculated from tax thresholds and allowances (from paragraph 2.13);
- **the credit rationing term**. We use a proximate measure *mrat*, which is the difference between the predictions of a model for demand for mortgage finance (from paragraph 2.16) and actual mortgage supply. The calculation of *mrat* is set out from paragraph 2.29; and
- a relative weighting must be found for the expected capital gains and rationing terms in the housing discount rate (discussed from paragraph 2.31).

The nominal user cost of mortgage capital

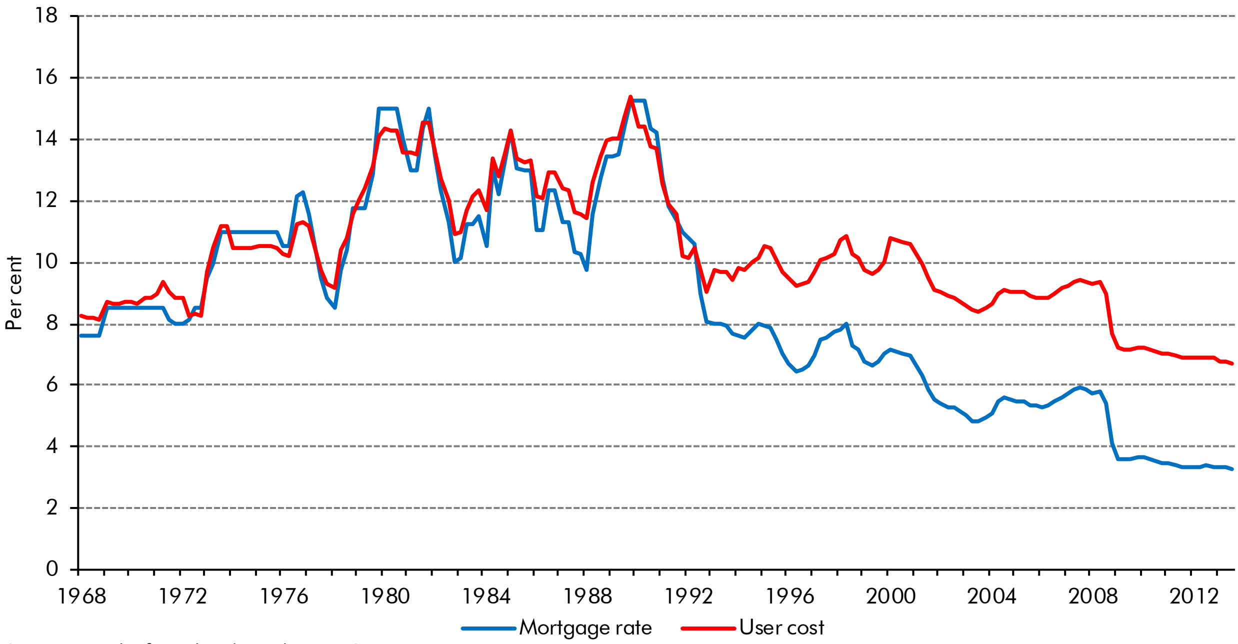
2.13 The nominal user cost of mortgage capital is effectively the full marginal cost of housing ownership. A major element is the direct cost of servicing mortgage debt, for which we use the average for all borrowers (both existing and new) in our model. However, a number of other costs and benefits must also be included. All are applied at the margin (rather than effective, average rates) to reduce endogeneity in subsequent modelling:

- the stamp duty rate, applied at the average house price and prevailing thresholds;
- Mortgage Interest Relief at Source (MIRAS, up to 2000), based on average loan size per house (implied by the total mortgage stock and the total value of owner-occupied homes), the cap on loan size available for relief (never exceeded, on average) and the prevailing tax relief rate;
- council tax rates (and domestic rates prior to 1990), calculated using data from HMRC and average house prices from ONS; and
- maintenance (current running costs) and depreciation (long-term replacement costs), each assumed to be a flat 1 per cent per year.[7]

[7] A proxy for housing depreciation can be derived from National Accounts data for total household fixed capital consumption and the value of their non-financial assets, but this is variable and infrequently updated. Most recent data, for 2011, suggest a depreciation rate (excluding maintenance and repairs) of 1.1 per cent a year, although this has been as high as 1.6 per cent in the mid-90s. A recent paper ("Very long-run discount rates", see Annex C for full reference) suggests a combined 1.5 per cent annual cost for depreciation and maintenance of housing in England and Wales. Our combined 2 per cent assumption, used in all housing market studies by Meen referenced at the end of this paper, is considered reasonably neutral.

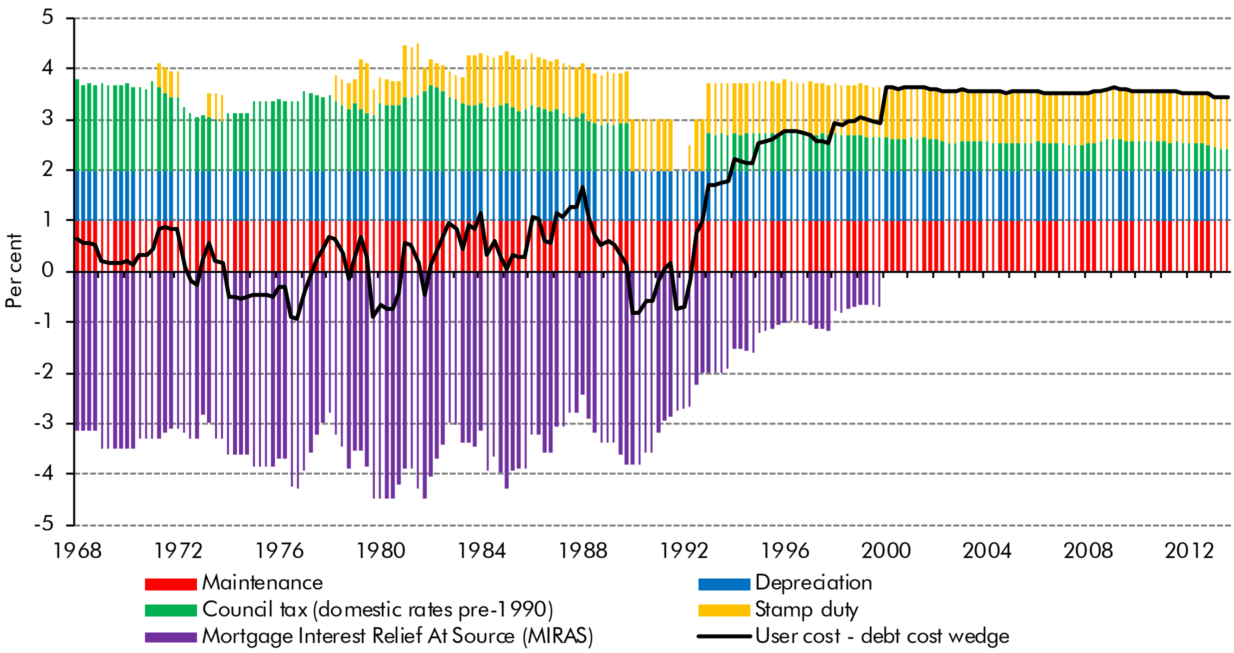
2.14 Chart 2.1 shows the difference between the mortgage rate (direct cost) and the nominal user cost, and Chart 2.2 shows what has driven that difference over the last 40 years.

Chart 2.1: Households' nominal user cost of mortgage capital



Source: Bank of England, Bankstats; OBR estimates

Chart 2.2: Difference between direct and indirect user cost of mortgage capital



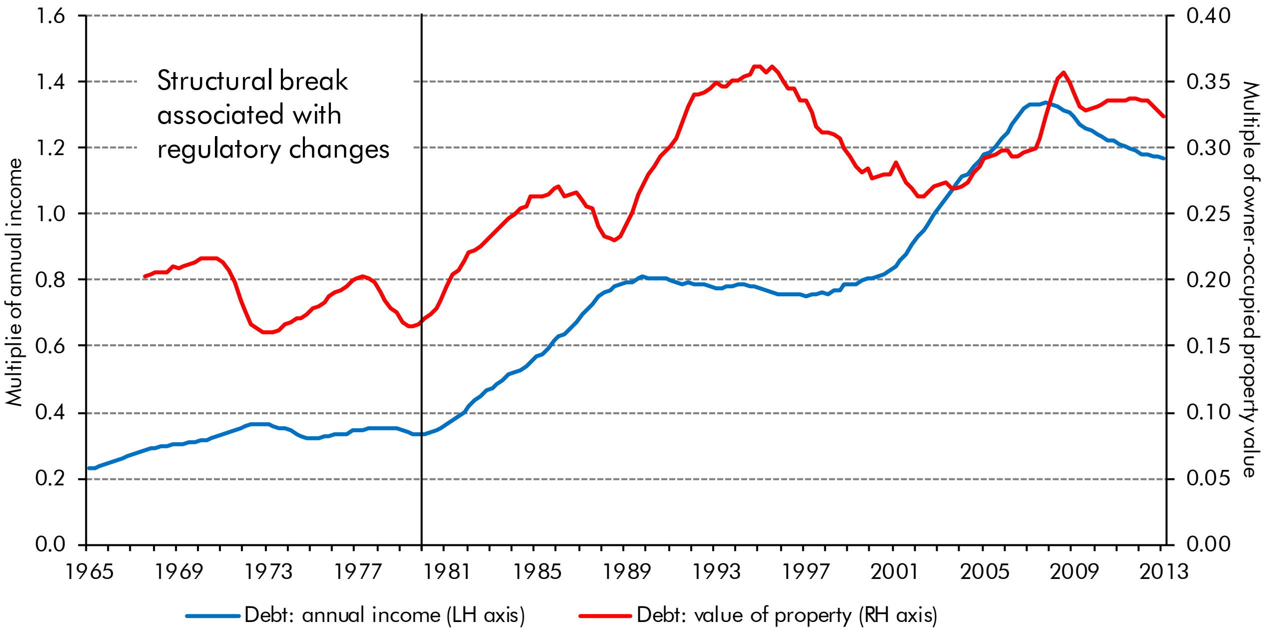
Source: Bank of England, Bankstats; OBR estimates

2.15 While the falling policy and market interest rates of the pre-crisis decade helped bring down household mortgage rates, the actual end-user cost of mortgage capital was more stable. As Chart 2.2 shows, up to the early 1990s, net additional costs (domestic rates, depreciation, maintenance, stamp duty) were largely offset by MIRAS, through which mortgagors were able to claim back debt interest costs at the basic rate of income tax. As the rate of relief was gradually reduced from 1994, and abolished completely in 2000, the marginal benefit of MIRAS diminished and the wedge between average mortgage rates and the user cost of mortgage capital increased. The user cost only fell substantially from 2008, as Bank Rate was cut sharply in response to the financial crisis and mortgage rates followed.

Demand for mortgage finance

2.16 We now estimate a model of demand for mortgage finance, in order to create an indicator for mortgage rationing (i.e. the difference between actual mortgage finance supplied and what we would expect demand to be). We first look for an independent variable with which mortgage finance has a stable long-term relationship. Denominators commonly used (implying a long-run relationship) are disposable income and the value of property.

Chart 2.3: Measures of UK household secured debt



Source: ONS, Economic Accounts; Bank of England, Bankstats; gov.uk

2.17 Both ratios have a significant structural break in 1981. The supply of mortgage debt before then was constrained by much more restrictive banking regulations, which were reduced steadily over the 1970s and substantially in 1980.[8] If we exclude data before 1981, debt:income has a clear rising trend. The loan:value ratio increased substantially in the early 1980s, but does not appear to have a rising trend thereafter. Both exhibit large and long-lived cycles around these trends.

2.18 Both ratios are trend stationary after 1980 (test results in Table A.1), which is important for forecasting, although both return to equilibrium only slowly after a shock. We have chosen

[8] Particularly the 'Corset' (the Supplementary Special Deposit Scheme), which was a form of quantitative control on banks' balance sheets. This imposed penalties on banks whose interest-bearing deposits increased faster than a pre-set limit, and therefore restricted the supply of credit. It was removed in March 1980. The process of financial sector deregulation continued through the 1980s.

the second ratio, debt:value, for estimating our model. Debt:income has a statistically significant deterministic time trend, which suggests that there are other, long-term factors driving the ratio. Without knowing what those factors are, it is difficult to judge if, or how long, they will continue.

2.19 We also consider debt:value to be more consistent with the way the market for housing finance works: it is more likely that secured debt is bound to the value of property, given the use of loan-to-value standards in mortgage products and collateral in banks' risk management. A more accurate benchmark on this basis would be the ratio of debt to the value of the property secured against it – the debt:value ratio we use includes all owner-occupied homes in the denominator, not just those that are mortgaged – but a long time series is not available.

Table 2.2: Mortgage demand equation

Model	1		2	
	D.lxm		D.lxm	
	Coefficient	Prob / T stat	Coefficient	Prob / T stat
DL.lxm	0.692	0.00 / 12.49	0.741	0.00 / 14.44
DL.lxi1	-0.013	0.05 / -1.97	-0.014	0.04 / -2.09
D.lxph	0.089	0.00 / 4.48	0.084	0.00 / 4.16
DL.lxy	0.039	0.22 / 1.24	0.053	0.09 / 1.73
L.lxm	-0.019	0.00 / -4.25		
L.lxhsval	0.018	0.00 / 3.88		
L.lxlvr			-0.019	0.00 / -4.20
dum2	0.007	0.00 / 7.31	0.007	0.00 / 7.53
dum3	0.005	0.00 / 5.10	0.005	0.00 / 4.90
dum1988q4	-0.011	0.02 / -2.35	-0.011	0.02 / -2.45

Note: Further diagnostic test results are shown in Table A.2. A full list of variable identifiers and definitions is available in Table 2.1.

Table 2.3: Additional model identifiers

Identifier	Description
lx	Natural log operator
D, L	Difference, lag operators
dum2, dum3, dum1988q4	Seasonal dummies and the ending of double Mortgage Interest Relief at Source (MIRAS) in 1988

2.20 Table 2.2 shows two specifications for a mortgage demand equation based on the long-term relationship between debt and housing value. Both are estimated on data from 1981q1, given the structural break discussed in paragraph 2.17, and in error correction form, using OLS, with short-term effects from income, prices and mortgage rates. Estimators are significant to 95 per cent confidence in both model specifications, except the coefficient on income growth. Both are also robust to a wide range of diagnostics, set out in greater detail in Annex A, Table A.2.

2.21 Model 1 does not restrict the path of the debt:value ratio, and the ratio of the coefficients on the lagged value and debt terms suggest a long-term elasticity of 0.92 – a gradually declining debt:value ratio. We then impose a unitary relationship in model 2, by using a single loan:value variable (*lxlvr*). The statistical justification for this restriction is mixed (further details are in paragraph A.6) but more conclusively, a one-to-one relationship between debt and property value is neutral in the long run for both banks' appetite for collateral and borrowers' appetite for leverage.

2.22 We have chosen model 2 as the final form for the mortgage demand equation:

$$D.lxm = 0.74*DL.lxm - 0.01*DL.lxi1 + 0.08*D.lxph + 0.05*DL.lxy - 0.02*L.lvr + \text{constant and seasonal dummies} \quad (9)$$

2.23 The adjustment term (or the coefficient on the lag of the loan:value ratio) is highly significant but also quite small. This means that following a shock, the model reverts to the original loan:value ratio gradually, at just 2 per cent a quarter – this is consistent with the very slow stabilisation evident in Chart 2.3 and Table A.1. This seems plausible. A rise in house prices can have an immediate, substantive effect on the denominator of the loan:value ratio, but the numerator will change more gradually. The stock of secured debt grows only as first-time buyers enter the market at new, higher prices, or existing home-owners take on more debt (through equity withdrawal or as they move house), and is therefore relatively inelastic to prices in the short term.

Structural stability and recursive tests

2.24 While the model appears well specified, it is important to look at how stable its structure and predictive power have been over the years, to check our current estimates are time-consistent. We use recursive tests to do this, which run successive estimations on an expanding set of observations.

2.25 First, we can use recursive estimates of key coefficients, such as the lag terms in an error-correction model. The blue line in Chart 2.4 shows what the coefficient on the loan to value ratio would have been if model 2 was estimated with data only up to that point in time. This shows how stable the relationship between the independent and dependent variables is, and how robust the model specification is to sample selection.

2.26 Second, we can use recursive estimates of the model's average error, relative to actual data, to see if there has been a structural break in forecasting performance. Chart 2.5 shows cumulative recursive residuals for model 2. This is the cumulative forecast error for every extra data point added to the sample. If there's a significant break in forecasting performance, the cumulative error moves outside the confidence intervals.

Chart 2.4: Coefficient on lagged loan:value ratio, recursive estimation

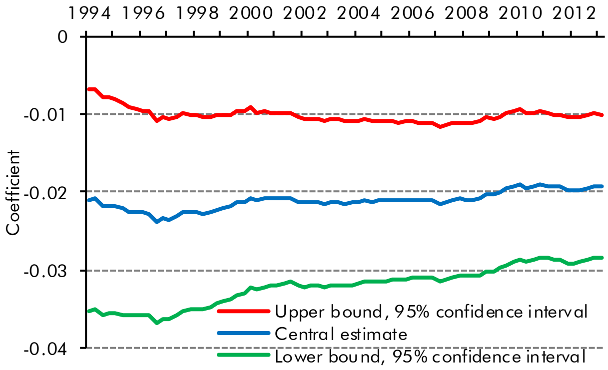
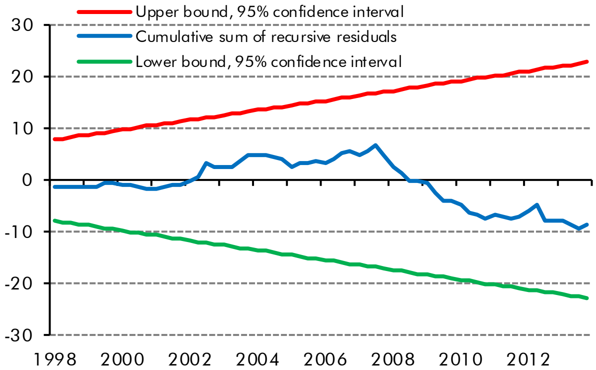


Chart 2.5: Cumulative recursive residuals, mortgage demand equation



Coefficients

2.27 Chart 2.4 shows how the coefficient on the loan:value ratio (the adjustment term) evolves over time, within a 95 per cent confidence interval. It never moves beyond the confidence interval over the past 20 years. So if we had estimated the model 20 years ago, the coefficient would still have been acceptable now, within a 95 per cent confidence interval. This confirms the current form of the model and its interpretation: there is a significant relationship between secured debt and housing value, but it takes a while to assert itself over short-term factors, like house prices, income and changes in the mortgage interest rate.

Residuals

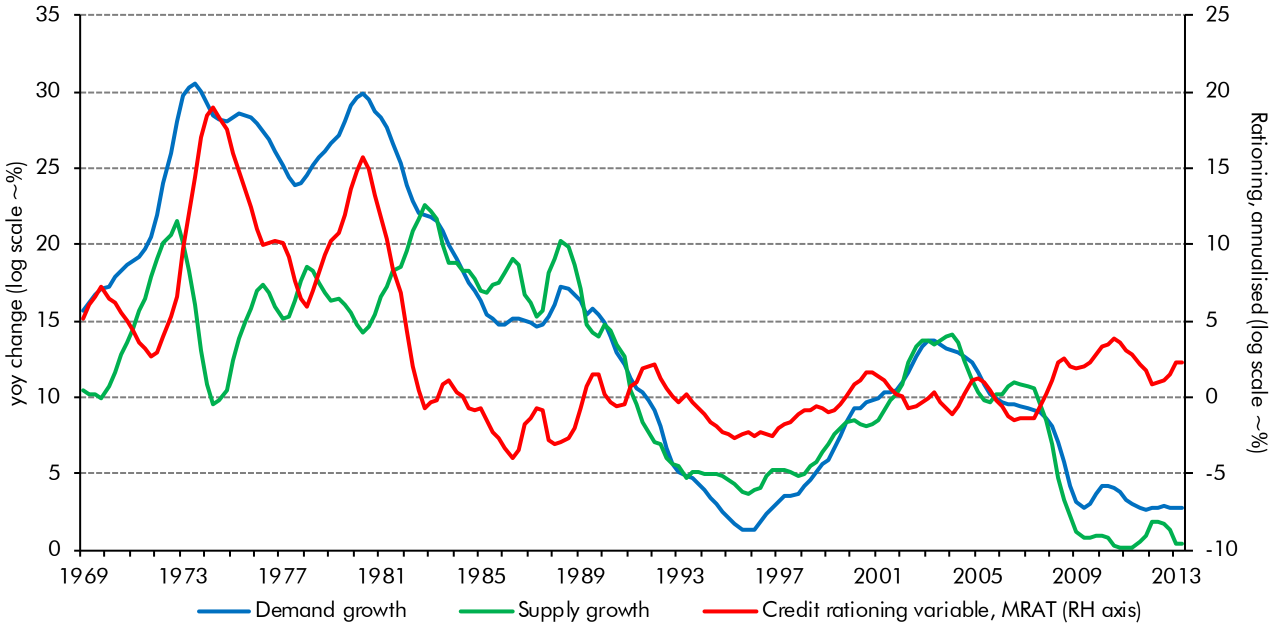
2.28 Chart 2.5 shows some sign of a break near 2008, as might be expected given the financial crisis, although this is not significant at the 95 per cent level. In the context of a longer testing period this break does look more pronounced (see Chart A.3), but further analysis shows that any change in the model's performance over that period is statistically insignificant (further details of tests in paragraph A.7). This shows that the model specification is robust to sample selection: the structure used in model 2 gives a consistent forecasting performance over time.

Credit rationing

2.29 Using the equation in Table 2.2, we can calculate an approximate measure for the effect of credit constraints. Chart 2.6 compares the observed growth in household finance (the red line, 'supply') and the expected growth (the blue line, 'demand'). 'Demand' is the growth of housing finance predicted by the model, given only an initial stock (from 1968). The green line, the credit rationing variable (*mrat*) is the difference between the two. It is stationary around 0 after 1980, with a strong convergence term,[9] reflecting the stationarity of the model error and test results in Table A.2. This means that historically, when demand has diverged from supply, the resulting 'rationing' gap has not persisted for long.

2.30 Although the mortgage demand model was only estimated on data from 1981, we assume the same demand characteristics hold before then. The result is a much higher level of rationing before 1981, but this is consistent with the assumption that regulation of banking services before that point meant the amount of mortgage finance provided did not reflect demand. Chart 2.6 also shows an increase in credit rationing since 2008, consistent with empirical evidence of non-quantity indicators (such as first-time buyer LTVs), which persists to date.

Chart 2.6: Credit rationing indicator, *mrat*



Source: ONS, Economic Accounts; Bank of England, Bankstats; gov.uk; OBR estimates

The housing discount rate and the house price model

2.31 Of the three components of the housing discount rate, the nominal user cost of mortgage finance is directly observed, and taken as given, but the other two – mortgage rationing and expected capital gains – are unobserved and we use approximate indicators. We therefore need to work out their relative weights. We do this by estimating an error correction form of Equation (8), with a disaggregated housing discount rate (Equation (10) below):

Real house price = f (real disposable income per household, housing stock per household, wage share in disposable income, user cost of mortgage capital, expected capital gains, mortgage rationing) (10)

[9] An Augmented Dickey Fuller test with four lags produces a test statistic of -5, compared to a 1% critical value of -3.5. The coefficient on the lag term is-0.3; 70% of a disturbance from equilibrium in one period is recovered a year later.

2.32 The results are shown in Table 2.4 as model 1. All coefficients are significant to the 95 per cent confidence level and the model is robust to a range of diagnostic tests. An extended table with diagnostics is available in Annex A, Table A.3.

2.33 The relative weights for expected capital gain (*phyoy*, the lag of annual nominal price growth), mortgage rationing (*mrat*, as above) and the nominal user cost of mortgage finance (*i2*, as calculated from paragraph 2.13) are calculated using the coefficients in Table 2.4. A weight of 0.29 on the capital gains term, within the housing discount rate, is less than that in the theoretical specification, Equation (8) (where it has a unit weight). This could be due to measurement error – we use lagged annual house price growth as a proxy for expected capital gains, but other measures can be used.[10] However, Chart 2.7 shows that this weight is quite stable over time, and that at no point would a unit weight be statistically significant. This implies that nominal interest rates affect housing demand, as well as real rates.[11] This has implications for the long-run responsiveness of the forecast to consumer price inflation, noted in Chapter 3. The weight on rationing is also stable (Chart 2.8).

Chart 2.7: Capital gains weight in the housing discount rate

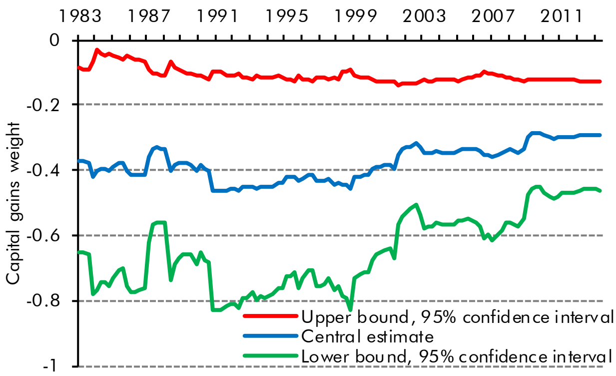
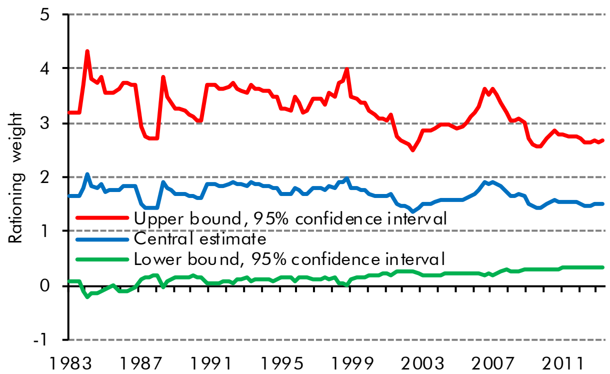


Chart 2.8: Rationing weight in the housing discount rate



Note: Confidence intervals above are calculated with variance and covariance of the estimators used in the capital gains and rationing weights (i.e. the capital gains weight is the ratio of the coefficients on *l.phyoy* and *i2* in model 1, Table 2.4), using the delta method.

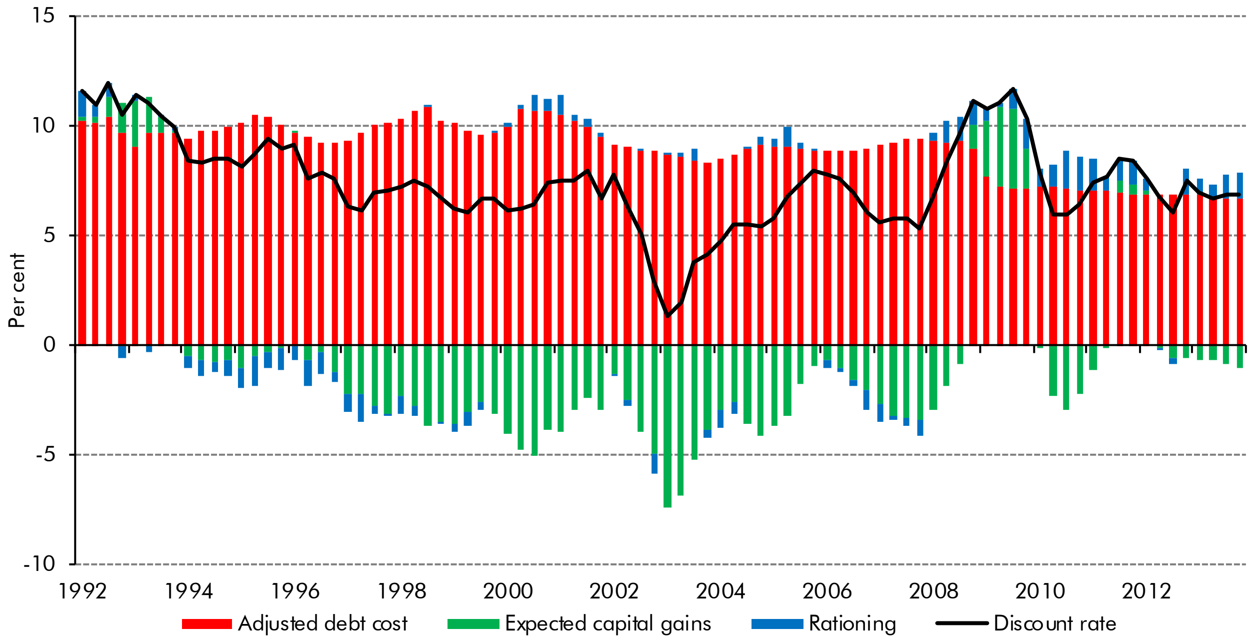
2.34 Together these are combined as a real, household housing discount rate (*discr*):

$$discr = i2 - 0.29*L.phyoy + 1.51*L.mrat \qquad (11)$$

[10] Duca, Muellbaeur and Murphy (2009) use lagged, four-year annual average house price growth for a US house price model.

[11] Often attributed to a front-end loading effect: lower nominal interest rates enable households to finance a given level of borrowing more easily, allowing them to afford a larger up-front sum.

Chart 2.9: Contributions to households' housing discount rate



Source: Bank of England, Bankstats; OBR estimates

2.35 Chart 2.9 shows the housing discount rate and its components over the past 20 years. It is clear that the rationing component is currently playing a significant role – despite strong house price growth, the stock of secured debt is growing very little – but the strength of current house price growth is generating an offsetting benefit through rising expectations of capital gains.

The house price model, final specification

2.36 Model 1, introduced in paragraph 2.32, is the unrestricted form of the house price model. We now restrict model 1 by introducing a single discount rate, as Equation (11), in place of its components – the estimation results are shown as model 2 in Table 2.4. The diagnostics (shown in detail in Table A.3) are again strong, with no loss of performance due to the extra restrictions. The coefficients on lagged housing supply and income variables are unchanged, although the speed of adjustment does increase slightly, as the coefficient on the lag price term, *l.lxrph*, falls from -0.108 to -0.112.

Table 2.4: Three different specifications of the house price model

Model	1		2		3	
	D.lxrph		D.lxrph		D.lxrph	
	Coefficient	Prob / T stat	Coefficient	Prob / T stat	Coefficient	Prob / T stat
D.lxryhh	0.306	0.00 / 4.12	0.317	0.00 / 4.28	0.361	0.00 / 4.71
D.i2	-0.006	0.03 / 2.17				
DL.phyoy	0.003	0.00 / 6.02				
D.discr			-0.007	0.00 / 7.33		
D.lxdiscr					-0.051	0.00 / -7.89
L.lxrph	-0.108	0.00 / 7.12	-0.112	0.00 / 7.46	-0.112	0.00 / -7.11
L.lxryhh	0.298	0.00 / 6.28	0.308	0.00 / 6.45	0.304	0.00 / 6.07
L.lxhshh	-0.123	0.04 / 2.06	-0.123	0.00 / 3.58	-0.115	0.00 / -3.22
L.discr			-0.006	0.00 / 16.16		
L.lxdiscr					-0.042	0.00 / 12.25
L.i2	-0.006	0.00 / 3.46				
L2.phyoy	0.002	0.00 / 0.78				
L2.mrat	-0.009	0.00 / 5.96				
L.lxwshx	0.272	0.00 / 3.83	0.246	0.00 / 3.54	0.185	0.01 / 2.53
L.duma	0.066	0.04 / 2.13	0.054	0.08 / 1.77	0.030	0.35 / 0.94
dum1988q3	0.076	0.00 / 4.88	0.073	0.00 / 4.78	0.077	0.00 / 4.82
_cons	-0.073	0.33 / 0.98	-0.071	0.11 / -1.59	-0.028	0.55 / -0.60

Note: Further diagnostic tests results are shown in Table A.3. A full list of variables and identifiers is given in Table 2.1.

Table 2.5: Additional model identifiers

Identifier	Description
lx	Natural log operator
D, L	Difference, lag operator
duma	Intercept dummy, matching introduction of wshx in 1990
dum1988q3	Dummy for the ending of double Mortgage Interest Relief at Source in 1988

2.37 An additional 'wage share' variable (*wshx*) is introduced from 1990, together with an intercept dummy (*duma*) to capture a structural shift in demand for housing, attributed to a shift in income distribution after the labour market reforms of the 1980s.[12] Without this variable the strength of the convergence term is much reduced and model performance suffers (although all but the mortgage rate variable remain significant, and other diagnostics are still acceptable). But the long-term, partial elasticity between income and prices remains at around 2.6 – very similar to the model with the wage share variable.

2.38 The use of the number of households in the model, as a scalar for some of the independent variables, does suggest possible endogeneity. The rate of new household formation is affected by a number of factors, including the cost of housing and demographic factors. However, there is strong persistence in the stock of existing households. If an individual is already in a separate household, he or she will usually stay as a separate household.[13] This implies that affordability issues, connected to house prices, are likely to affect the stock of households and the house price forecast (via the income and housing stock terms in model 2 above) quite slowly – at least over our normal five year forecast period.

2.39 A further possible criticism of both models 1 and 2 is the use of unlogged values for the discount rate, while all other regressors are in logs.[14] Model 3 shows that re-estimating using a log version of '*discr*', '*lxdiscr*', does not affect the coefficients on the main long-run components of the model: income, housing supply and the lagged-price term. However, other diagnostics do deteriorate more significantly (Table A.3 gives full details), so we choose model 2.

Structural stability and recursive tests

2.40 As for the mortgage demand Equation (9), and with the methods described from paragraph 2.24, we use recursive tests to check the structure and predictive performance of the model over time.

[12] Suggested in Meen and Andrew, 1998, "On the aggregate labour market implications of labour market change".
[13] Meen and Andrew, 2008, "Planning for Housing in the Post-Barker Era: Affordability, Household Formation and Tenure Choice".
[14] This can cause heteroskedasticity in the error term and bias estimators: Meen, 2001, "Modelling Spatial Housing Markets: Theory, Analysis, and Policy".

Chart 2.10: Coefficient on lag price term, recursive estimation, house price model

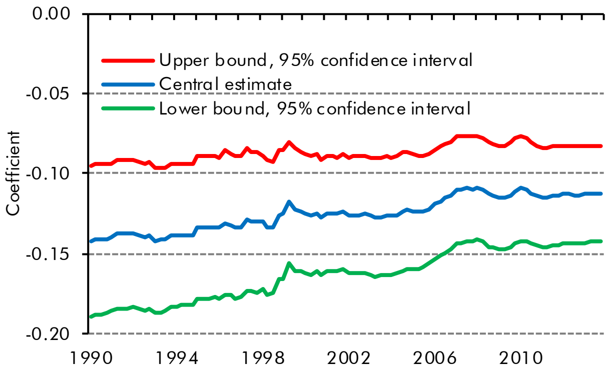
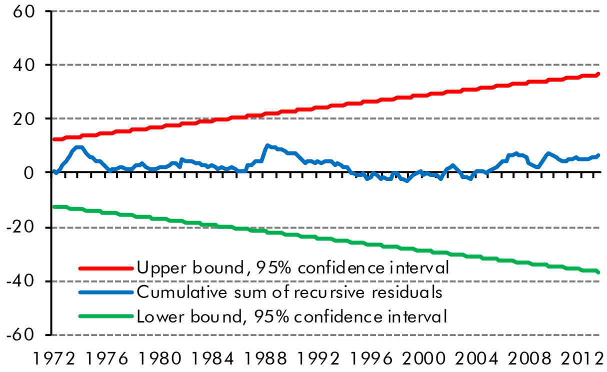


Chart 2.11: Cumulative recursive residuals, house price model



Coefficients

2.41 The coefficients on the lagged terms, which are the dimensions of the long-run relationship driving the model, are stable. Chart 2.10 shows the coefficient on the lagged price term – the speed of adjustment of prices back to equilibrium after a shock – over the past 25 years (see paragraph 2.25 for method). The coefficient does increase gradually, rising from about -0.14 to its current value of -0.11, suggesting that convergence has been getting slower – it currently takes about six quarters to recover half the gap between trend and the last observation. But this chart shows that the current estimate of the adjustment term would not have been rejected if the equation had been estimated at any point in the past 25 years.

Residuals

2.42 Chart 2.11 shows cumulative recursive residuals over the testable period (using the same method described in paragraph 2.26), which remain well within a 95 per cent confidence interval throughout. This means that the model's predictive performance remains stable and without statistically significant deterioration over the full period of observation.

Conclusions

2.43 The estimation process results in three models/identities:

$$D.lxm = 0.74*DL.lxm - 0.01*DL.lxi1 + 0.08*D.lxph + 0.05*DL.lxy - 0.02*L.lvr + constant \text{ and seasonal dummies} \quad (12)$$

2.44 Equation (12) forecasts the growth in mortgage debt, based on short-term dynamics from lagged debt growth, income growth and interest rate changes and contemporaneous price growth, and a long-term, unit relationship between debt and housing value. This is model 2 in Table 2.2.

$$discr = i2 - 0.29*l.phyoy + 1.51*l.mrat \quad (13)$$

2.45 Equation (13) combines the adjusted mortgage rate (*i2*) with a proxy for expected capital gains (*l.phyoy)* and a proxy for credit rationing (*l.mrat*) into a single housing discount rate (*discr*).

*D.lxrph = 0.317*D.lxryhh – 0.007*D.discr – 0.112*L.lxrph + 0.308*lxryhh – 0.123*lxhshh – 0.006*discr + 0.246*lxwshx + constant, dummies* (14)

2.46 Equation (14) shows the full house price model: growth in real house prices is a function of growth in real income, change in the housing discount rate, and a long-term relationship between prices, incomes, housing stock, wage share and discount rate. This is model 2 in Table 2.4.

3 Interpretation of the model

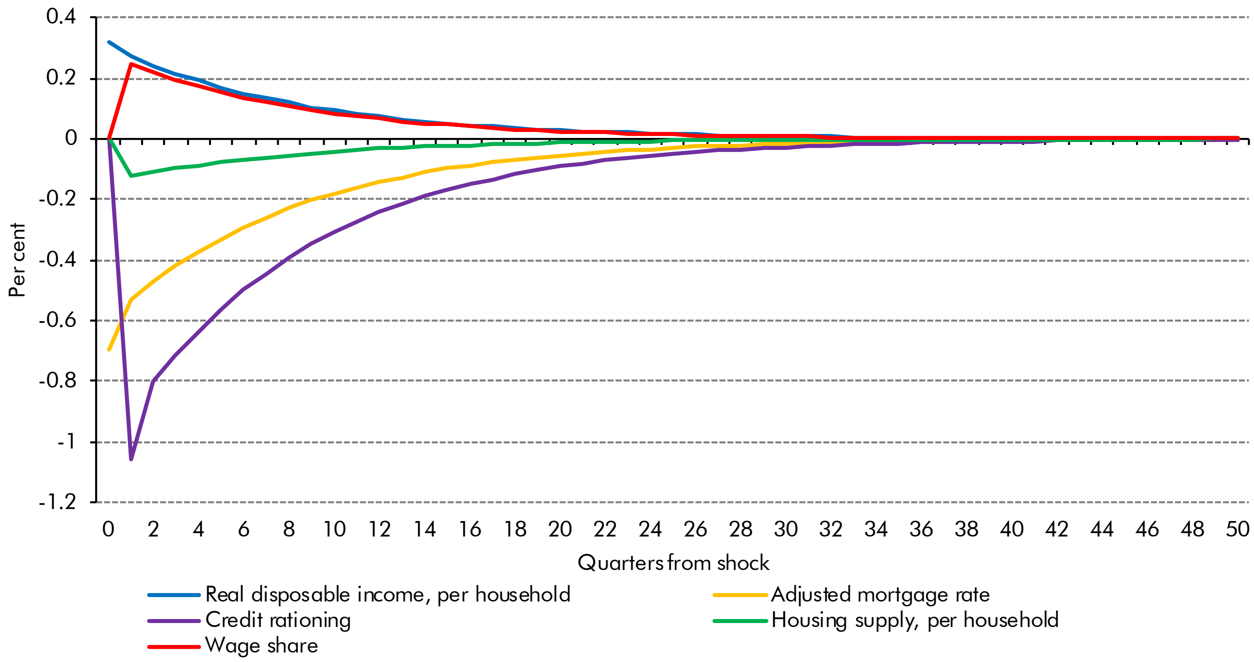
3.1 Having specified the model's structure and estimated coefficients, we can see what they imply for the dynamics of house prices in the short and long run with respect to each descriptive variable. We then look at two more general characteristics: the behaviour of the model with respect to household income and consumer price inflation.

3.2 Charts 3.1 and 3.2 show the cumulative impact of a 1 per cent (or percentage point, in the case of unlogged variables such as rationing and adjusted mortgage rate) shock to the main independent variables on the real house price.

3.3 Chart 3.1 shows the effect of a temporary shock (introduced in one period and removed in the next) given the full house price model Equation (14). As expected, none of the variables have a permanent effect on real house prices. For example: a 1 per cent increase in the rationing variable – a 1 per cent rise in the demand growth predicted by the mortgage finance model relative to the supply of mortgage debt – leads to a 1 per cent fall in house prices in the following period (the rationing term enters the model through the housing discount rate, with a lag). The effect fades gradually, given the adjustment term on lagged prices and despite mortgage supply subsequently growing in line with demand (i.e. zero further rationing). 90 per cent of the shock has dissipated in five years' time.

3.4 The impact of the rationing term might provide us with a useful starting point for estimating the implications for house prices of some possible macroprudential policies. These could affect the risk capital requirements of mortgage lending, and, assuming sufficient demand, the quantity of credit supplied. Where a new policy led to higher/lower growth in the stock of household secured debt (for example, by relaxing/tightening LTV requirements on first-time buyers) the model suggests the impact on prices would be as described in paragraph 3.3, although most likely in a more gradual way. In the absence of historic UK precedent, it is difficult to allocate a specific credit supply response to policy innovations. But the model does offer insights on a possible transmission mechanism by which the house price forecast might be affected.

Chart 3.1: Response of house prices to a short-term shock

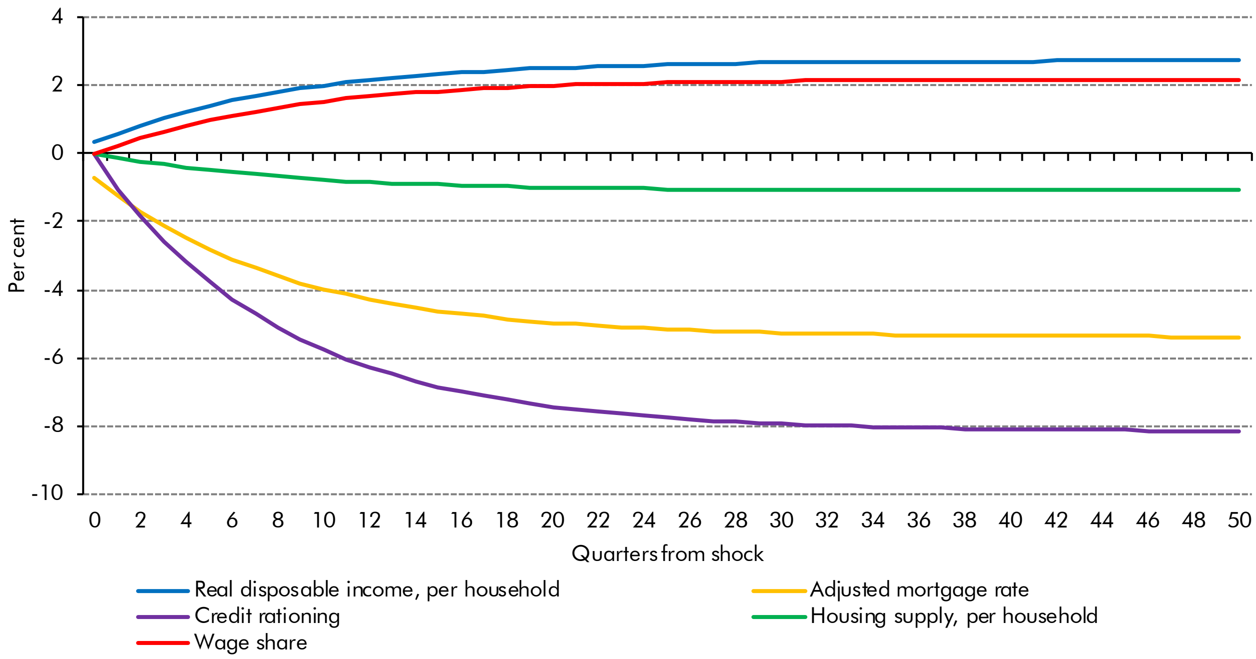


3.5 Chart 3.2 shows the long-run dynamics, reflecting the relationship between the level terms in Equation (14):

$$lxrph = 2.74*lxryhh - 1.09*lxhshh + 2.19*lxwshx - 0.054*discr \quad (15)$$

3.6 Equation (15) shows the partial elasticities of house prices to: income per household (*lxryhh*), owner-occupied housing supply per household (*lxhshh*); the wage share variable (*lxwshx*); and the housing discount rate (*discr*). So a 1 per cent, sustained increase in income per household causes a 2.7 per cent increase in house prices. The coefficient on the discount rate term is more complicated, as the variable is unlogged, but can be approximately interpreted by multiplying by 100. On this basis, a 1 percentage point, permanent increase in the mortgage rate would lead to a 5.4 per cent decrease in house prices. The most significant effect would be a persistent 1 per cent increase in the mortgage rationing variable – but this does not seem a plausible scenario since it would require the actual growth in mortgage debt to be 1 per cent a quarter slower than expected demand in perpetuity, and a very rapid rise in the ratio of debt to housing value.

Chart 3.2: Response of house prices to sustained shock



3.7 Table 3.1 shows the partial elasticities on income and housing supply in Equation (15) relative to other UK studies using aggregate data. It should be noted that the inclusion of demographic factors (scaling the income and housing stock variables) and differences in specification complicate direct comparisons.

Table 3.1: UK house price elasticities from the literature

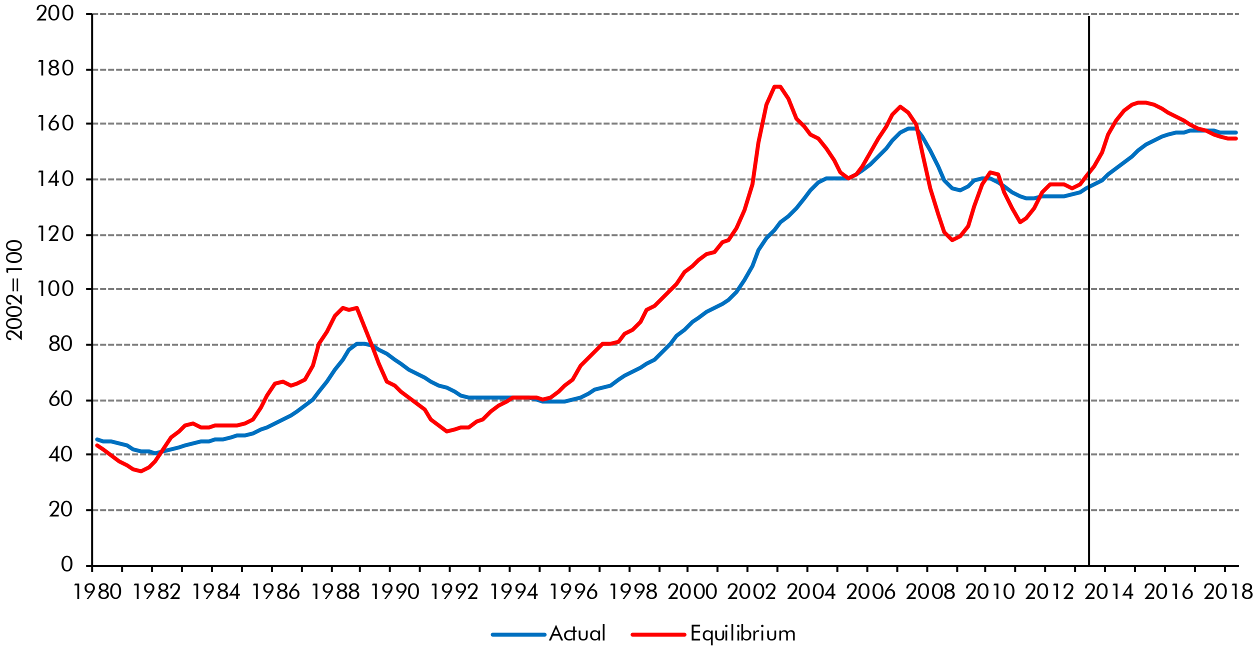
Study	Income elasticity	Supply elasticity	Last data point used
[per household]			
This model	2.7	-1.1	2013 q4
Meen (2013)	2.8	-1.7	2009 q4
[per capita]			
Muellbauer/ Murphy (1997)	2.6	-2.2	1994
Cameron/ Muellbauer/ Murphy (2006)	1.6	-1.6	2003
[unscaled]			
This model, re-estimated without number of households	2.3	-1.2	2013 q4
OECD (2011)	2.9	-2.1	2010 q1
Meen (2009)	2.1	-1.5	2007 q2

Note: See section 7 for full references

3.8 The elasticity of house prices to income is consistent with the literature, but the elasticity of prices to supply is low. This may be due to mis-measurement of supply in the model. As explained in paragraph 2.11, we use the owner-occupied housing stock for the variable *hshh*. However, there has been rapid expansion of the supply of buy-to-let rental property in recent years, which may be an increasingly close substitute for owner-occupation.

3.9 The prediction of Equation (15) can be plotted against observed prices to show how the two interact (Chart 3.3): when the 'equilibrium' line rises above 'actual', the underlying determinants of the model imply future price rises, to close the gap at a rate dictated by the adjustment term (the coefficient on the lagged price term in Table 2.5 is -0.11 – so roughly half the gap is closed every 6 quarters, barring a further shock).

Chart 3.3: Long-term dynamics of the house price model vs actual data



Note: Both lines show rolling annual average real house price levels

3.10 Chart 3.3 demonstrates the model's outlook for real house prices beyond the estimation period (up to 2013 q4), given some assumptions for the independent variables.[15] Chart 3.3 does not match our March 2014 house price forecast: it uses a neutral assumption for housing supply, with housebuilding matching household formation and no change in the owner occupation rate, and shows the model's prediction over the full 5-year period. We reverted to house price growth in line with average earnings in our March 2014 forecast after two years (see paragraph 4.6 for explanation).

3.11 On this basis, the model suggests little overvaluation relative to the house price determinants it includes. Given current interest rates, rationing, previous house price rises, income and house supply, prices are near where the model predicts. The lines diverge over 2014 as faster nominal house price growth drives down the discount rate, implying further upward pressure on prices in the future. But by mid-2015, the rate of nominal house price growth in the model peaks. At the same time, the average mortgage rate begins to rise and the recovery in real income growth slows. Together, these factors lead to a rapid rise in the

[15] Mortgage rates, incomes and the consumption deflator (general price inflation as used in the model) rise in line with the March 2014 forecast; house building keeps pace with the number of households; and household formation matches DCLG projections.

housing discount rate, more than the mortgage rate alone would suggest, and a steady deceleration of predicted house price growth.

3.12 Using some long-run assumptions for real income growth (2.2 per cent a year, including growth in the number of households of 1 per cent a year) and housing supply (keeping pace with the number of households), and assuming the housing discount rate and wage share variable are stationary, the model predicts around 3.3 per cent real house price growth a year in steady state. In addition, assuming consumer price inflation in line with the Bank of England's 2 per cent target implies 5.3 per cent a year nominal house price growth in steady state.

House prices, income and debt

3.13 A key observation from the model is that, on average, house prices rise faster than incomes. This is a common finding in house price studies, as the income elasticities in Table 3.1 show. We can further demonstrate this by re-ordering Equation (15) into a long-run demand function for housing services:

$$lxhshh = 2.51*lxryhh - 0.92*lxrph + 2.01*lxwshx - 0.05*discr \qquad (16)$$

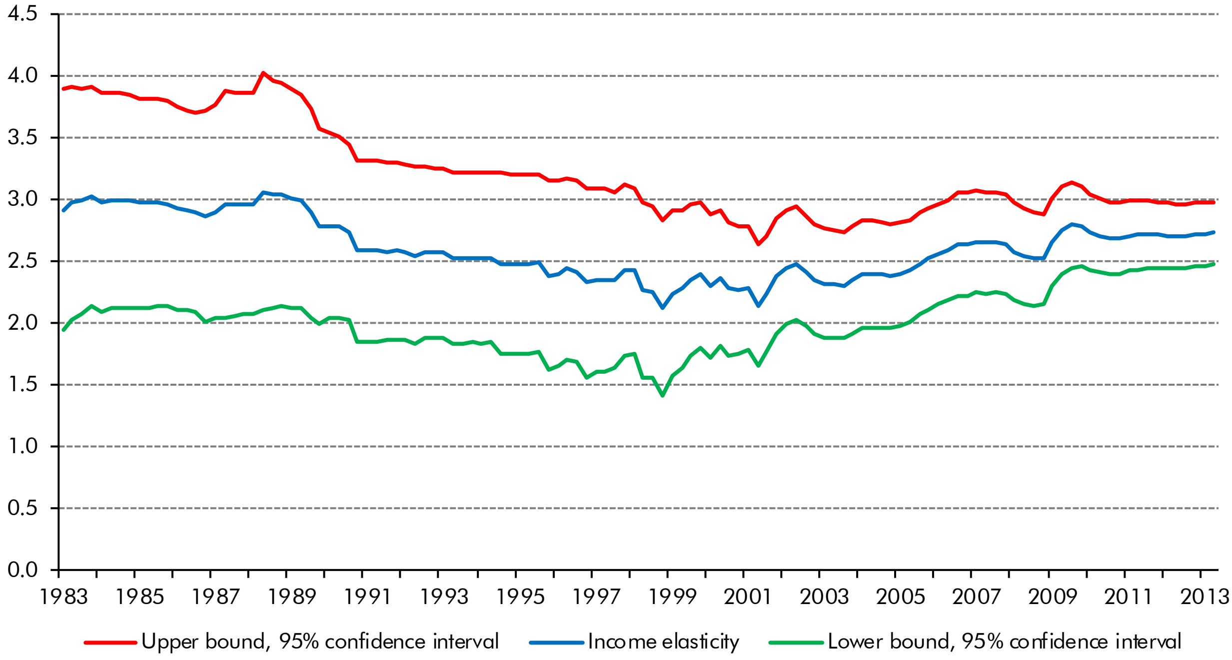
3.14 This shows that the income elasticity of demand for housing services (2.51) is greater than the price elasticity (-0.92). So even if the supply of housing keeps pace with the number of households, and the left-hand term in Equation (16) is a constant, any growth in the income variable (*lxryhh*) must be matched by faster growth in prices (*lxrph*) to keep the equation in balance.

3.15 The demand elasticities in Equation (16) are high relative to the literature – around 1.4 and -0.5 are more common – because of the weak impact of supply on prices, discussed in paragraph 3.8. However, the price-income elasticity remains within the range of comparators and is quantitatively much more important in the determination of house prices: average growth of per household real incomes between 1992 and 2007 was around 0.6 per cent; average growth of per household owner-occupied housing stock over the same period was 0.04 per cent.[16]

3.16 Chart 3.4 shows how stable estimates of the price elasticity of household income have been using this model specification. The upper and lower lines are a 95 per cent confidence interval around the central estimate. The lower band remains well above 1 throughout. This means that an income-price elasticity of 1 would have been rejected by the data at any point in the past 30 years of observations.

[16] So with the same growth rate over the forecast period, a more standard supply-price elasticity of -2 (consistent with an income-demand elasticity of around 1.4 and price elasticity of -0.5) would produce only 0.16 per cent less price growth per year.

Chart 3.4: Recursive price elasticity to income with confidence interval



Note: Confidence intervals above are calculated with variance and covariance of the estimators used in income elasticity (the coefficients on *l.rph and l.ryhh* in model 2, Table 2.4), using the delta method.

3.17 Combined with the model for mortgage demand (Equation (10)), which anchors secured debt growth to the value of the housing stock, and the assumptions in paragraph 3.12, this means that secured debt will also rise faster than income.

3.18 Then, assuming both house price and debt models operate from steady state, secured household debt:income would rise by around 2.1 per cent per year. And assuming other unsecured household debt remains a fixed share of household income, total household debt:income would rise from its current level of around 140 per cent to its pre-financial crisis peak of 170 per cent by 2024.

3.19 The model makes no allowance for income constraints – eventually, debt servicing costs would rise above income, given a constantly rising debt:income ratio (in 2142, using these assumptions). However, assuming mortgage rates rise gradually, in line with current market expectations for Bank Rate, and stabilise at a spread of around 1.1 percentage points above Bank Rate of 5 per cent, average debt-servicing costs do not return to their pre-crisis (mid-2008) peak of 10.8 per cent of income until around 2026.

3.20 The model does not incorporate future policy action. In the Bank of England's June 2014 Financial Stability Report (FSR) two recommendations were made by the Financial Policy Committee: for guidance to lenders on the interest rate stress tests used in assessing mortgage affordability; and for the regulatory authorities to introduce limits to the share of very high loan to income mortgages in new lending. Both could limit the rate of growth of household debt although, as the FSR notes, they are not expected to have a material impact on mortgage lending and housing transactions in the near term. These new measures are intended to provide insurance against the possibility that the housing market turns out to be stronger than expected and are unlikely to be binding to our central five-year house price forecast, given current conditions.[17]

3.21 However, barring policy interventions and distributional issues (for borrowers' affordability and lenders' risk management), and renewed disruption to the banking system, it is both possible and likely for household debt to rise faster than income for some while yet.

House prices and inflation

3.22 By including a separate term for expected nominal capital gains in the discount rate, with a weight of less than one, the model's forecast for real house prices can be non-neutral to consumer price inflation shocks. Decomposing the discount rate in Equation (15) produces:

$$lxrph = 2.74*lxryhh - 1.09*lxhshh + 2.19*lxwshx - 0.054*(i2 - 0.29*(l.real\ house\ price\ growth + l.inflation) + 1.51.mrat) \quad (17)$$

3.23 If we assume that *lxryhh*, *lxhshh, mrat* and *lxwshx* (real income, housing stock, wages share, rationing) are inflation-neutral, this leaves:

$$d(lxrph)/d(l.inflation) = -0.054*(d(i2)/d(l.inflation) - 0.29) \quad (18)$$

3.24 So, the impact on the model's forecast for real house prices of a change in the previous quarter's inflation rate depends on: the elasticity of the adjusted interest rate to changes in the previous period's inflation; the weight on the capital gains term in the discount rate; and the coefficient on the discount rate.

3.25 The short-term elasticity of the adjusted interest rate to an inflation shock is not obvious. While Bank Rate may react to an inflation shock, the degree of transmission into average mortgage rates could be limited, in the short term. Currently, only a sixth of all mortgage contracts are linked directly to Bank Rate,[18] another half to banks' own internally-set standard variable rates and the remaining third to fixed-rate deals.

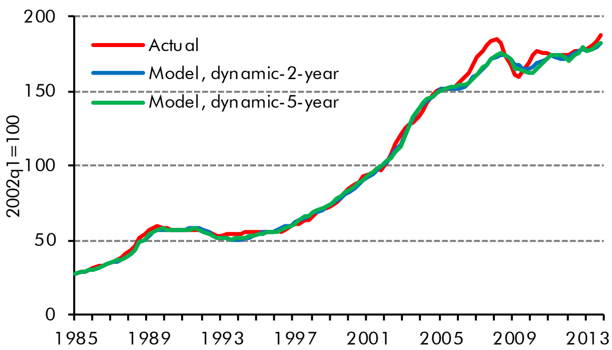
3.26 Mechanically, in the long term, if we assume that a 1 percentage point shock to inflation leads to a full 1 percentage point rise in average mortgage rates, there is a rise in the real housing discount rate of 0.71 (given the 0.29 weight on the capital gains term) and the model predicts a fall in real house prices of 3.8 per cent. However, in reality, it is highly unlikely that such a rise in inflation would be sustained. And in practice, the short- and long-run sensitivities of the real house price forecast to changes in inflation are impossible to isolate from other forecast judgements that enter the model more directly, such as household income growth and mortgage interest rates.

[17] One of the recommendations limits the share of new mortgage lending to borrowers at over 4.5 times income to 15 per cent. This share currently stands at less than 10 per cent, in aggregate. We also note that, based on the Bank of England/NMG Survey for 2013, average mortgage debt:income is around 2.9.
[18] Based on Bank of England NMG Survey, 2013.

4 Model performance and the forecast

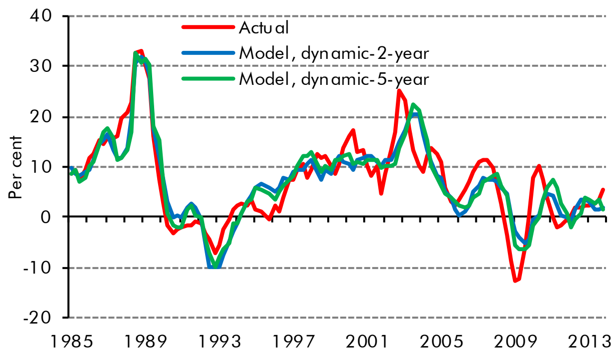
4.1 Charts 4.1 and 4.2 show model simulations of house price levels and growth over the past 30 years. The 'dynamic-5-year' green lines show what the model would have predicted given only price data up to five years before the prediction (the capital gains and credit rationing terms of the discount rate are also driven by predicted price growth). Chart 4.1 shows that in the long term the model predicts price levels well, but is slow to catch up with periods of rapid acceleration or deceleration. However, Chart 4.2 shows that the model is less successful at predicting the short-run dynamics of house prices, particularly in the period from 2005 to 2010, with peaks and troughs of predicted growth rates often lagging the data by around 4 quarters.

Chart 4.1: Simulation, price levels



Source: ONS; OBR estimates

Chart 4.2: Simulation, price growth



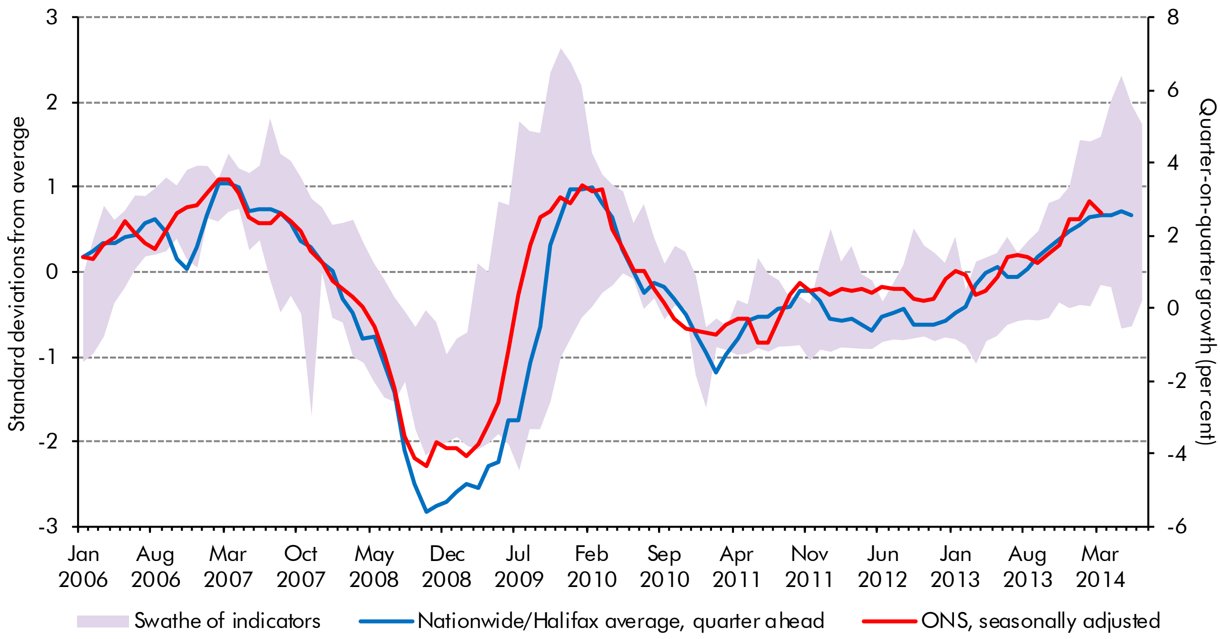
Source: ONS; OBR estimates

4.2 This is a common problem with house price models – it is difficult to capture the change in price growth when the market is moving rapidly. However, we can take steps to mitigate this: first, by limiting the forecast period of the model; and second, by incorporating the latest leading indicators into the first quarter of the forecast.

4.3 The charts above also show a 2-year ahead dynamic forecast: each point on the blue lines is the model's prediction given the previous 8 quarters' price predictions and actual data before that. Therefore, the model is allowed to correct itself for actual price data with a 2-year lag. The resulting forecast matches the data more closely, particularly on price growth, although still with a lag of 2 to 3 quarters. By limiting the model's prediction to just two years ahead, we improve the dynamic performance of the model.

4.4 To reduce the lag between the model's dynamic prediction and actual data even further, we use a range of short-term indicators for the first quarter of the forecast. Chart 4.3 compares a swathe of indicators (such as RICS measures of price expectations, market capacity, stock levels), standardised for mean and variance, to actual price growth.

Chart 4.3: Annual house price growth and range of short-term indicators



Source: RICS; Rightmove; Nationwide; Halifax; ONS; OBR estimates

4.5 Chart 4.3 also shows a simple average of the Nationwide and Halifax price indices, which are collected at mortgage approval stage (and therefore 1 to 2 months ahead of completion prices,[19] as recorded in the ONS series we forecast). However, short-term indicators do not predict short-term price growth perfectly, as the chart shows, and we also apply near-term judgement with respect to broader market conditions.

4.6 Our 5-year house price forecast is therefore now informed by a number of elements, including near-term indicators and the model, where previously we used the consensus of external forecasters. To date, we have also converged on average earnings for house price growth after two years of the forecast, given the medium-term uncertainties around some model inputs and the model's relatively poor performance in capturing short-term dynamics after that point. But more importantly, since no model-based approach can be perfect, the house price forecast, like all aspects of our economy and fiscal forecasts, is ultimately subject to the Budget Responsibility Committee's judgement. We will keep these models and forecasting approaches under review to ensure they remain appropriate to our task of forecasting the public finances, to assess the Government's performance against its fiscal targets and the sustainability of the public finances more generally.

[19] Bank of England: "The measurement of house prices", Quarterly Bulletin Spring 2003.

A Diagnostic tests

Mortgage demand model

Table A.1 Unit root tests, UK household secured debt ratios

	Debt:income	Debt:value
Lag term	-0.021 (p-stat:0.00)	-0.023 (p-stat:0.01)
ADF test statistic	-4.335	-2.865
Critical value (5%)	-3.446	-2.888
Trend term	0.0001 (p-stat:0.00)	#N/A
Constant	0.0859	0.1063

Note: Sample used 1981q1 to 2013q4. Variables tested are in logs.

A.2 Table A.1 describes the trend characteristics of the ratio of household secured debt to income and to owner-occupied housing value, using an Augmented Dickey Fuller test with four lag terms (lag selection based on correlograms). In both cases, the null hypothesis of a unit root is rejected with more than 95 per cent confidence – they do not follow a random walk.

A.3 The debt:income ratio is tested against the null hypothesis of a random walk with a deterministic time trend, and the debt:value ratio against a random walk with a non-zero drift term (the constant in Table A.1 is assumed to be non-zero). The decision to test with a trend or a drift term is based on visual assessment (debt:income shows a clearer upward trend than debt:value in Chart 2.3).[20]

[20] Using a strategy suggested in Elder and Kennedy, "Testing for unit roots: what should students be taught".

Table A.2 Mortgage demand equations, full diagnostics

Model	1		2	
	D.lxm		D.lxm	
	Coefficient	Prob / T stat	Coefficient	Prob / T stat
DL.lxm	0.692	0.00 / 12.49	0.741	0.00 / 14.44
DL.lxi1	-0.013	0.05 / -1.97	-0.014	0.04 / -2.09
D.lxph	0.089	0.00 / 4.48	0.084	0.00 / 4.16
DL.lxy	0.039	0.22 / 1.24	0.053	0.09 / 1.73
L.lxm	-0.019	0.00 / -4.25		
L.lxhsval	0.018	0.00 / 3.88		
L.lxlvr			-0.019	0.00 / -4.20
dum2	0.007	0.00 / 7.31	0.007	0.00 / 7.53
dum3	0.005	0.00 / 5.10	0.005	0.00 / 4.90
dum1988q4	-0.011	0.02 / -2.35	-0.011	0.02 / -2.45
		Prob / stat		Prob / stat
Adj R2		0.932		0.930
RMSE		0.004		0.004
Reset	F(3,119)	0.26 / 1.34	F(3,120)	0.79 / 0.35
Breusch-Godfrey (serial correlation)	X2	(1 lag) 0.04 / 4.04 (2 lag) 0.02 / 8.26		(1 lag) 0.04 / 4.24 (2 lag) 0.02 / 7.60
White test (homoscedasticity)	X2	0.56 / 49.83		0.30 / 46.33
Normality	adj X2	0.00 / 14.69		0.00 / 11.12
ADF, cointegration	lags(4)	0.00 / -6.22		0.00 / -5.87
Akaike criterion		-1053.9		-1050.7
F-test of restriction		0		0.03 / 4.88
ARCH LM test	X2	0.00 / 23.01		0.00 / 24.81

Diagnostics

A.4 All terms in model 2, the preferred specification, are significant to at least 95 per cent confidence, except the income term (to 90 per cent confidence). The residuals are stationary (the Augmented Dickey Fuller test shows a statistic of -5.9 vs a 1 per cent critical value of -3.5), and this is consistent with the results in Table A.1. Further diagnostics show that the errors are homoscedastic (White test),[21] and the model is well specified (RESET test). The

[21] Given Guass-Markov assumptions, which include homoscedasticity, OLS will produce the best linear unbiased estimators of the coefficients.

result for normality is weak, particularly for kurtosis, but a simple plot of residuals (Charts A.1 and A.2) shows that this is not a major problem, and driven by only a few outliers. The (Breusch-Godfrey) test for serial correlation is also quite weak, although this will only reduce the efficiency of the equation and not bias the estimators. This can indicate mis-specification, but the strength of the RESET test makes this unlikely. Serial correlation can be reduced substantially by adding a fourth lag of the dependent variable, with little impact on the estimators.

Chart A.2: Distribution of errors, mortgage demand equation

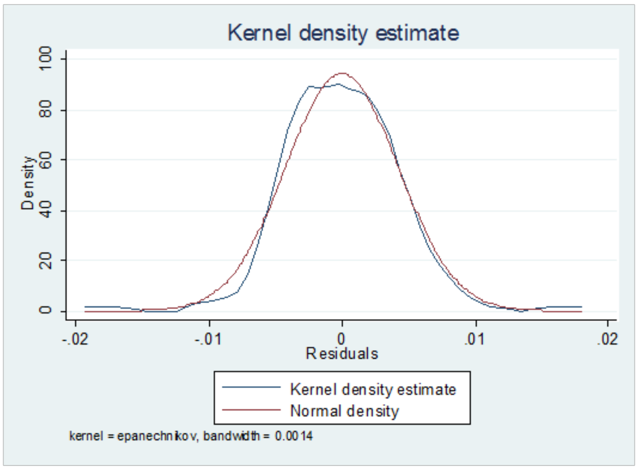
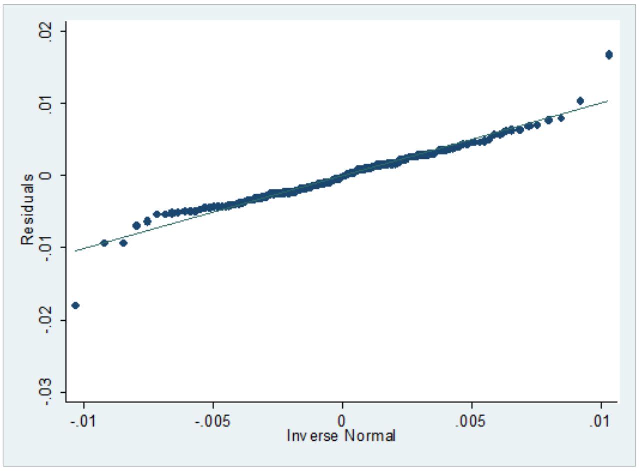


Chart A.3: Distribution of errors, mortgage demand equation 2, normality



A.5 A further weakness is the LM test for autoregressive conditional heteroskedasticity (ARCH) – indicating serial correlation in the variance of the errors, which may distort other diagnostic tests. But a further estimation adjusting for ARCH produces very similar coefficients, with a slightly stronger adjustment term (-0.021 compared to -0.019 above) and a weaker and less significant coefficient on income growth.

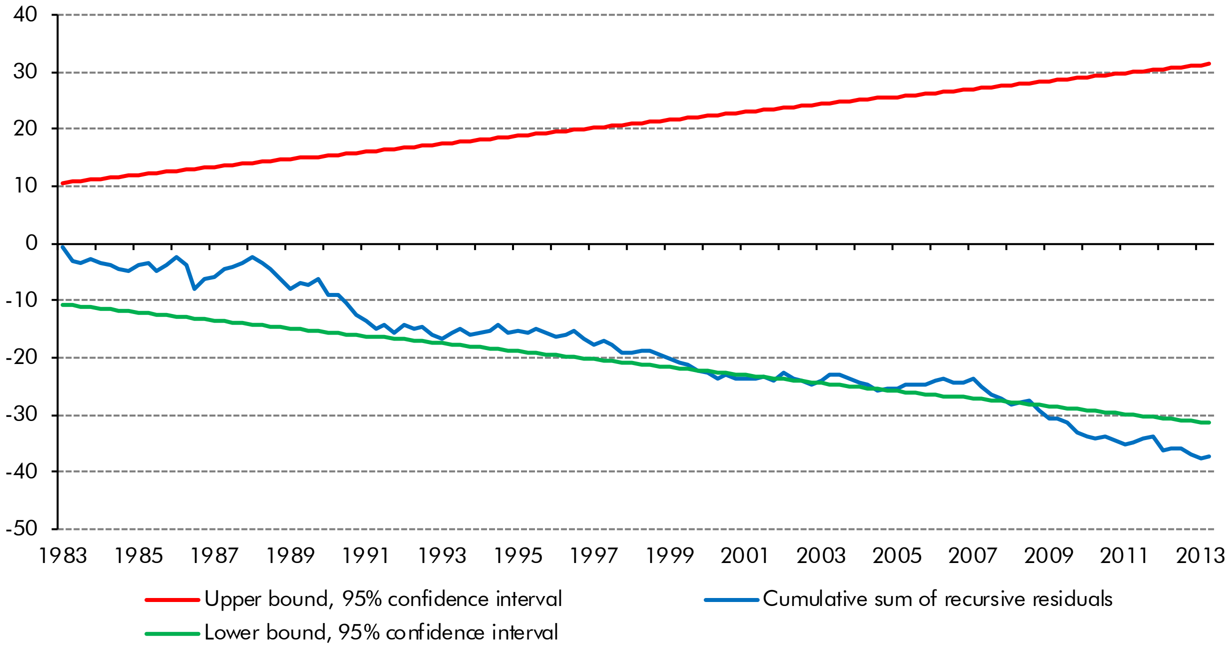
Restrictions

A.6 The statistical justification for the restriction imposed on the debt:value ratio in model 2 is mixed: it does affect the predictive power of the model (according to an incremental F-test,[22] reported at the bottom of Table A.2) and reduces goodness of fit marginally (according to Akaike criterion, also in Table A.2); but a Wald test cannot reject the hypothesis of a unit relationship between the two variables at the 5 per cent level.[23] The theoretical justification is more compelling, as set out in paragraph 2.19.

[22] Comparing models 1 and 2 generates a test statistic of 4.88 ((RSS[c]-RSS[uc])/1)/(RSS[uc]/(132-10)), compared to 5 per cent critical value of 3.92 and 1 per cent critical value of 6.85; so the null hypothesis that the fit is the same between the two specifications is rejected.
[23] A test of coefficients (l.lxm/l.lxhsval = -1) produces an F-stat of 3.26, vs a 5 per cent critical value of 3.92.

Recursive tests

Chart A.4: Mortgage demand model 2, recursive residuals, full sample



A.7 Chart A.3 shows cumulative recursive residuals over the available data. This is the cumulative forecast error for every extra data point added to the sample (starting from observation 9,[24] 1982 q4, to 2013 q4). There is some sign of a break around 2008 (the blue line, the cumulative sum of recursive residuals, crosses the green, the lower band of the 95 per cent confidence interval), but this is partly because of an earlier, partial break in the early 1990s.

A.8 A Chow forecast test gives a statistic of 0.87 for a break in 2009q1, much lower than an F-distribution critical value of 1.48 for 10 per cent confidence[25] – so we can't reject the null hypothesis that the additional forecast errors post-2009q1 are insignificant. This shows that any change in the model's performance over that period is statistically insignificant. Chart 2.5 shows the same recursive test over a smaller period, and again shows the 2008 break, but this time it falls well within the 95 per cent confidence interval.

[24] Number of coefficients + 1 = 9

[25] Test stat = ((RSS[full] – RSS[2009q1])/T2)/(RSS[2009q1]/(T1-k), where T1 = 113, T2 = 19 and k = 8.

House price model

Table A.3 House price model, 3 specifications

Model	1		2		3	
	D.lxrph		D.lxrph		D.lxrph	
	Coefficient	Prob / T stat	Coefficient	Prob / T stat	Coefficient	Prob / T stat
D.lxryhh	0.306	0.00 / 4.12	0.317	0.00 / 4.28	0.361	0.00 / 4.71
D.i2	-0.006	0.03 / 2.17				
DL.phyoy	0.003	0.00 / 6.02				
D.discr			-0.007	0.00 / 7.33		
D.lxdiscr					-0.051	0.00 / -7.89
L.lxrph	-0.108	0.00 / 7.12	-0.112	0.00 / 7.46	-0.112	0.00 / -7.11
L.lxryhh	0.298	0.00 / 6.28	0.308	0.00 / 6.45	0.304	0.00 / 6.07
L.lxhshh	-0.123	0.04 / 2.06	-0.123	0.00 / 3.58	-0.115	0.00 / -3.22
L.discr			-0.006	0.00 / 16.16		
L.lxdiscr					-0.042	0.00 / 12.25
L.i2	-0.006	0.00 / 3.46				
L2.phyoy	0.002	0.00 / 0.78				
L2.mrat	-0.009	0.00 / 5.96				
L.lxwshx	0.272	0.00 / 3.83	0.246	0.00 / 3.54	0.185	0.01 / 2.53
L.duma	0.066	0.04 / 2.13	0.054	0.08 / 1.77	0.030	0.35 / 0.94
dum1988q3	0.076	0.00 / 4.88	0.073	0.00 / 4.78	0.077	0.00 / 4.82
_cons	-0.073	0.33 / 0.98	-0.071	0.11 / -1.59	-0.028	0.55 / -0.60
		Prob / stat		Prob / stat		Prob / stat
Adj R2		0.705		0.702		0.657
RMSE		0.015		0.015		0.016
Reset	F(3,161)	0.27 / 1.23		0.75 / 0.41		0.00 / 6.10
Breusch-Godfrey (serial correlation)	X2	(1 lag) 0.11 / 2.59 (2 lag) 0.05 / 5.83		(1 lag) 0.11 / 2.55 (2 lag) 0.10 / 4.70		(1 lag) 0.00 / 16.7 (2 lag) 0.00 / 17.4
White test (homoscedasticity)	X2	0.20 / 87.84		0.01 / 70.40		0.00 / 94.20
ARCH LM test (serial hetero-scedasticity)	X2	0.60 / 0.28		0.63 / 0.24		0.01 / 7.52
Normality	adj X2	0.56 / 1.17		0.63 / 0.91		0.00 / 12.28
ADF, cointegration	lags(4)	0.00 / -6.50		0.00 / -7.08		0.00 / -5.47
Akaike criterion		-975.1		-975.6		-939.9

Diagnostics

A.9 The diagnostic test results are strong for both models 1 and 2, with no loss of performance due to the extra restrictions in model 2: RESET tests suggests robust specification; the ADF (Augmented Dickey Fuller) tests show that the independent variables form a stationary combination, and the residuals are stationary; and the null hypothesis of no serial correlation is not rejected (Breusch-Godfrey test). The White test shows that the null of homoscedasticity is rejected, but this can be resolved by restricting the estimation period to post-1980 with little impact on the estimators.[26]

A.10 All forms of the house price model are estimated using OLS. Given Guass-Markov theorem, this should produce the best linear, unbiased estimators (BLUE) of the coefficients. The conditions for this to be true – that the errors are uncorrelated and homoscedastic – are confirmed by tests for serial correlation and homoscedasticity for both unrestricted and restricted forms of the house price model, as in Table A.3 and discussed in paragraph A.9.

[26] Model 2 estimated from 1981q1 produces a White statistic of 53 and p-stat of 0.19 (the null of homoscedasticity cannot be rejected). The price-income elasticity (the ratio of the coefficients on real prices and housing supply) remains at 2.7.

B Variable descriptions and sources

Identifier	Definition	Source
rph	The 'real' house price. This is ph adjusted for changes in the national accounts seasonally adjusted consumer price deflator.	ONS, House Price Index, Economic Accounts; OBR estimates.
ph	The 'nominal' house price. A mix-adjusted, seasonally adjusted UK house price index. We apply an X12 ARIMA process to the longer, non-seasonally adjusted time series, which is available from 1968.	ONS, House Price Index; OBR estimates.
i1	The average effective rate for all household mortgages. Net of mortgage interest relief at source (MIRAS) before 2000. The marginal MIRAS benefit is based on historic data of average debt size, house prices, MIRAS thresholds and tax relief rates.	Bank of England, Bankstats; OBR estimates.
i2	The nominal user cost of mortgage capital. This is *i1* adjusted for depreciation, maintenance, stamp duty and council tax. Historic stamp duty and council tax rates are calculated from HMRC data and ONS house prices.	Bank of England, Bankstats; OBR estimates
ryhh	Real, seasonally adjusted household disposable income from the National Accounts, divided by the number of households (*hh* , below).	ONS, Economic Accounts; DCLG, gov.uk, table 401; OBR estimates.
y	Nominal, seasonally adjusted household disposable income from the National Accounts.	ONS, Economic Accounts.
hshh	The number of owner-occupied dwellings (*hs*) divided by the number of households (*hh*).	DCLG, gov.uk, tables 101, 401; OBR estimates.
hsval	The value of owner-occupied housing, derived from the number of owner-occupied dwellings (*hs*) and the house price index (*ph*).	ONS, House Price Index; DCLG, gov.uk, table 101; OBR estimates.
hh	The number of households, interpolated from annual DCLG data using Denton method.	DCLG, gov.uk, table 401; OBR estimates.
hs	The number of owner-occupied dwellings, interpolated from annual DCLG data using Denton method.	DCLG, gov.uk, table 101; OBR estimates.
m	The stock of mortgage finance lent to UK households by deposit-taking monetary financial institutions (banks and building societies).	Bank of England, Bankstats.
wshx	Labour income as a share of total household disposable income, from the National Accounts.	ONS, Economic Accounts; OBR estimates.
lvr	The ratio of household secured debt to the value of owner-occupied homes (equal to *m/hsval*).	Bank of England, Bankstats; ONS, House Price Index; DCLG, gov.uk, table 101; OBR estimates.

Note: all variables are quarterly and for the UK as a whole

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