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Forecasting UK house prices: a time varying coefficient approach

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Abstract

Previous studies of UK house prices, developed from the demand and supply ofhousing or from the asset market approach have been poor in terms of robustness and ex-post forecasting ability. The UK housing market has suffered a number of structural changes, particularly since the early 1980s with substantial house price increases, financial market deregulation and the removal of mortgage market constraints through competition. Consequently, models which assume that the underlying data-generating process is stable and apply constant parameter techniques tend to suffer in terms of parameter instability. This article uses the Time Varying Coefficient (TVC) methodology where the underlying data-generating process in the UK housing market is treated as unstable. The estimation results of the TVC regression of UK house prices is compared with those obtained from three alternative constant parameter regressions. Comparisons of forecasting performance suggest the TVC regression out-performs forecasts from an Error Correction Mechanism (ECM), Vector Autoregressive (VAR) and an Autoregressive Time Series regression. © 1997 Elsevier Science B.V.

JEL classification: C5; E3

Keywords: UK house prices; Time Varying Coefficient models; Kalman filter

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1. Introduction

Since W.W.II there has been a dramatic increase in the proportion of wealth held by the personal sector in terms of owner-occupied housing. The number of owner-occupied dwellings has increased dramatically, as has the proportion of owner-occupiers. UK owner-occupied housing accounted for 40% of the total net worth of the personal sector in 1990; this is in contrast to 20% in the early 1960s.[1] The UK has one of the highest owner-occupation rates in the world and one of the lowest levels of private renting. In 1991, 68% of households were owner-occupiers, whereas it was a mere 10% in 1914, increasing more rapidly since World War II.[2] The period 1981–1989 saw a rapid growth in the number of home-owners from 11.9 million to 15 million, and the number of mortgage holders grew from 6.2 million to 9.1 million households.[3] The average age of first-time buyers is lower in the UK.[4] The UK also has one of the highest ratios of mortgage debt to household income. Maclennan and Gibb (1993) suggest that ease of obtaining mortgage finance, and high ratio of loans to property purchase price are contributing factors.

Research since the early 1980s examines the wider spectrum of the impact of housing on the economy as a whole. House price movements are important to the economy in terms of the effects on the UK general price level and its effects on consumer expenditure. Fig. 1 plots the log of real house prices and the log of real

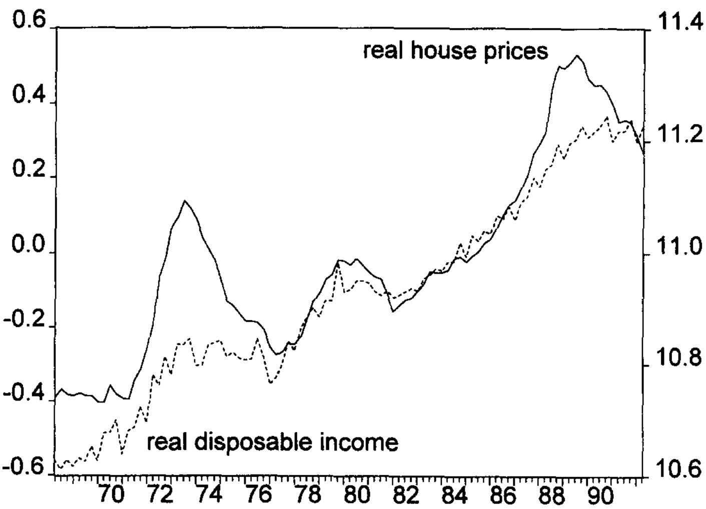

Fig. 1. Real house prices and real disposable income.

[1] Miles (1994), p. 4.
[2] Miles (1994), p. 40.
[3] Maclennan and Gibb (1993), p. 194.
[4] Two-thirds of 25–29 year olds are owner-occupiers.

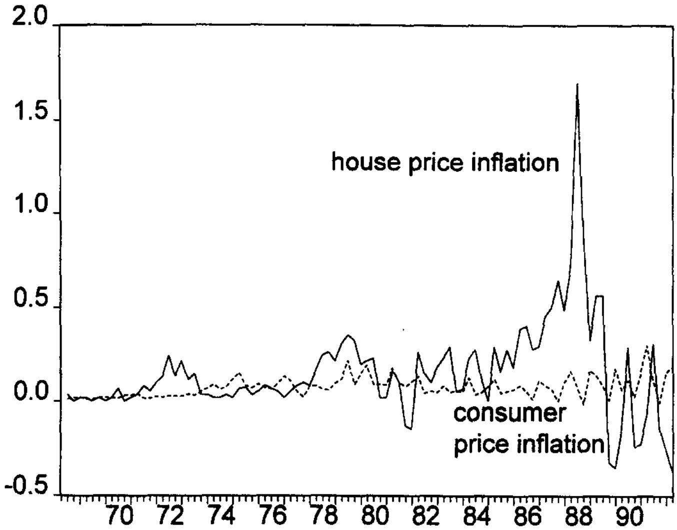

Fig. 2. House price and consumer price inflation.

personal disposable income for the period 1968:Q2–1992:Q2 at 1985 prices.[5] The figure clearly shows the house price boom of the early 1970s, early 1980s and the late 1980s. House price levels rose beyond consumer disposable incomes in the periods 1971:Q3–1976:Q2, 1978:Q4–1981:Q3 and 1986:Q1 to the early 1990s. As indicated in Fig. 2 house price inflation has been more volatile than the general rate of inflation, outstripping consumer price inflation for the periods 1971:Q1–1973:Q4, 1977:Q1–1980:Q4 and 1982:Q2-1989:Q2. Fig. 3 shows the annual rates of inflation of the house price and income series. In boom periods house prices increased rapidly to levels greater than the increases in real personal disposable incomes. Real personal disposable income levels then fell to a lesser extent than the fall in real house prices. Possible causes of these booms included incomes inflation, financial deregulation, demographic factors Mankiw and Weil (1988), inelastic supply and expectations in the housing market Meen (1990). Holmans (1990) considered the abrupt end of the house price booms of the 1970s and 1980s to be due to high interest rates.

Previous studies of UK house prices have been poor in terms of robustness and ex-post forecasting ability. Early UK housing models such as Whitehead (1974), Hadjimatheou (1976), Mayes (1979) and Hendry (1984) were developed in terms of demand and supply equations in which house prices were determined by the demand for housing. Estimated regressions using 1950s and 1960s data were then extended to predict the housing market in the 1970s with very poor results. Whitehead, Hadjimatheou and Mayes failed to forecast the sudden house price boom of 1972–1973 and had problems of parameter instability in their models.

[5]The series is deflated by the CPI since housing is a durable good which provides a flow of consumer services. It also avoids any cross-effects from the mortgage interest rates included in the RPI.

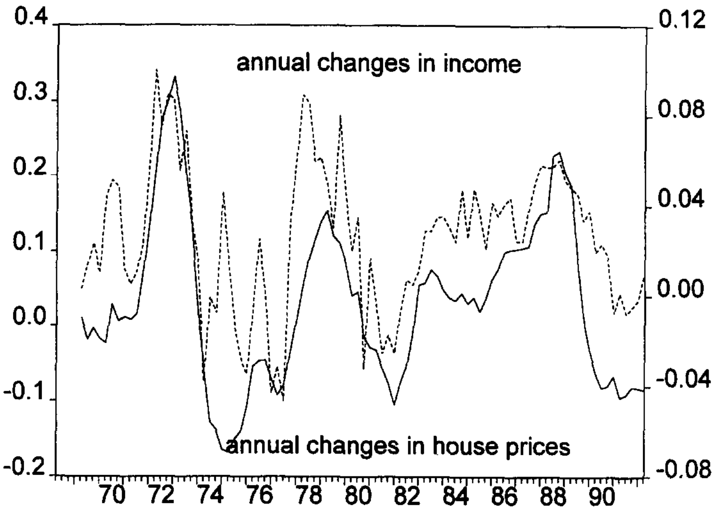

Fig. 3. Annual house price and incomes inflation.

The general dissatisfaction with these demand and supply econometric models prompted the application of an asset market approach to the housing market, see, for example, Docherty and Van Order (1992) and Poterba (1984). Buckley and Ermisch (1982), Meen (1990), Milne (1991) and Breedon and Joyce (1993) develop different equation specifications of UK house prices to improve on the performance of previous models.

Nellis and Longbottom (1981), Buckley and Ermisch (1982) and Meen (1990) re-estimate previous equations of the UK housing market and generally find the regression coefficients change in both magnitude and sign. Estimation over different sample periods often results in coefficient instability implying that the models are probably mis-specified. All of these models assume that the underlying data-generating process is stable and apply constant parameter techniques. The coefficient instability is probably due to structural shifts in the underlying data-generating process. Structural change is said to occur if an economic relationship or process changes over time. The change in the relationship is identified by a change in one or more of the parameter values in the regression. The UK housing market has suffered a number of structural changes, particularly since the early 1980s with substantial house price increases, financial market deregulation and the removal of mortgage market constraints through competition. In classical regression analysis if the point of structural change is known, e.g. periods of war or the oil price shocks, the information is incorporated into the model using dummy variables. They can capture discrete changes in the parameters through time but a model with many shocks to the system requires a large number of dummy variables. Often in economics, the occurrence and effects of structural changes are unknown and the information is unobservable. Coefficient instability in the model is assumed to be rectified by respecification until a stable 'true' model is obtained.

The problem of coefficient instability in the models could be a reflection of an economic system which is itself unstable. The instability may arise because of exogenous shocks to the system, for example, institutional changes, changes in government of differing political persuasion. A more appropriate and parsimonious approach to the representation of an unstable economic system is to build a model using a methodology which takes account of the structural instability. Time Varying Coefficient (TVC) modelling is such a methodology.

Engle and Watson (1987) suggest three reasons for using TVC models in economic modelling. Firstly, the Lucas (1976) critique provides a behavioural motivation for parameter variation. According to Lucas, economic agents adjust not only their behaviour in response to new policies, but also their estimates of the economic model considered relevant to previous policies. Secondly, changes in the unobservable components of economic variables such as expectations and permanent income will cause structural change in the DGP. To the extent that these variables cannot be measured satisfactorily by the inclusion of proxy variables in the model, the parameter changes caused by their variation may be simulated by time series representations (AR, MA and ARMA) of the parameters (Harvey, 1993), and observable economic variables (normally termed as *drivers*) may be used to enhance the model specifications. Finally, model mis-specification is another source of Time Varying Coefficients since it is generally not possible to develop a perfect specification of an economic DGP. The non-white noise residuals from the mis-specified model can be partly explained by the changing coefficient values in the TVC model.

In the housing market exogenous shocks such as substantial house price increases, financial market deregulation and the removal of mortgage market constraints through competition could account for much of the coefficient instability in previous studies. This paper makes the assumption that the housing market is structurally unstable and applies the TVC approach. Forecasts of UK house prices are generated based upon the asset market approach which is outlined in Section 2. Section 3 develops a TVC model of UK house prices and the estimation results are given in Section 4. Section 4 also compares the estimation results from classical constant coefficient models of UK house prices. Section 5 compares the forecasting performances of the models and conclusions are given in Section 6.

2. The user cost of owner-occupied housing

A house is not just an asset in the household's investment portfolio, it is also a consumer durable good which provides a service to the household. The value of the service to the marginal consumer is the marginal cost of that service. Since the marginal cost to the consumer is assumed equal to the market price a measure of this user cost enables the estimation of a price of owner-occupied housing.

In this paper the price for housing is modelled in terms of the user cost of owner-occupied housing. The asset market approach of Buckley and Ermisch (1982), Meen (1990) and Breedon and Joyce (1993) is used to determine owner-occupied house prices.

The household is assumed to solve a time-separable consumer utility maximisation problem of two goods: housing services (where the flow of housing services is assumed directly proportional to the stock of houses) and a composite non-durable consumption good. The consumer is assumed to maximise utility, subject to a budget constraint and technical constraints. It is also assumed there is no rental sector for housing and that there are perfect capital markets.

Breedon and Joyce (1993) derive the following expression for the marginal rate of substitution between housing and the composite good:

$$\frac{U_h}{U_c} = P_h[(i(1-t) - \pi_c) - \pi_h^e + (\delta + \kappa + \tau)] \tag{1}$$

where $P_h = P_h^*/P_c^*$ is the real house price where P_h^* is the nominal price of housing and P_c^* is the nominal price of all other goods, i is the interest rate (lending and borrowing rates are assumed equal), t is the marginal rate of income tax, π_c is the inflation rate, π_h^e is the expected real capital gains on housing, δ is the real rate of depreciation including repairs and maintenance, κ is property taxes and τ is transactions costs.

Credit market constraints are approximated by the ratio of the shadow price of the rationing constraint λ, to the marginal utility of the consumption good U_c. In the capital market equilibrium the real rental price of housing R_t must equal the real user cost. Therefore in capital market equilibrium R_t is the price which clears the market for housing services and is also the real asset price P_h. Incorporating this information into Eq. (1) gives:

$$R_t = P_h[(i(1-t) - \pi_c) - \pi_h^e + \lambda/U_c + (\delta + \kappa + \tau)] \tag{2}$$

where R_t is considered to be determined by the demand and supply of housing services. Since housing services are difficult to measure R_t is an unobservable. R_t is assumed to be determined by permanent income, a demographic variable and stock of dwellings. Consequently the market clearing rental price can be measured by the demand for housing, the supply of housing and the stock of housing. The equilibrium condition in the capital market Eq. (2) can be shown in logarithmic form as:

$$\ln P_h = \ln R_t - \ln[(i(1-t) - \pi_c) - \pi_h^e + \lambda/U_c + (\delta + \kappa + \tau)] \tag{3}$$

The real house prices Eq. (3) is then expressed as a function of permanent income, a demographic variable, the stock of dwellings and the real user cost of housing:

$$\ln P_h = f[\ln Y, \ln \mathrm{DEM}, \ln H, \ln[(i(1-t) - \pi_c) - \pi_h^e + \lambda/U_c + (\delta + \kappa + \tau)]] \tag{4}$$

3. The TVC specification of house prices

The TVC specification of house prices equation takes the form:

$$\ln P_{ht} = \beta_0 + \beta_1 \ln Y_t + \beta_2 \ln \mathrm{DEM}_t + \beta_3 Q3\mathrm{DUM}_t + \beta_4 \mathrm{DUM88}_t + \beta_{5t} \ln \mathrm{USERCX}_t + \beta_{6t} \mathrm{NUPHE}_t + u_t \quad (5)$$

$$\beta_{5t} = \beta_{5t-1} + \gamma_1 \ln Y_t + \epsilon_{5t} \quad (6.1\text{–}6.2)$$

$$\beta_{6t} = \beta_{6t-1} + \gamma_2 \mathrm{MIRATE}_t + \epsilon_{6t}$$

where u_t and ϵ_t are normally distributed error terms with mean zero and constant variances. Milne (1991) notes model instability after the second quarter of 1988 which may bedue to the effects of the removal of the double mortgage interest rate relief announced in the 1988 Budget, hence the dummy variable DUM88 is included; Q3DUM is a seasonal dummy. The stock of owner-occupied dwellings is dropped from the specification on the grounds that it is not significant in the regression estimations. The real user cost of housing is split into two components, nominal user cost (USERCX) and the expected gains on housing (NUPHE) and estimated as separate variables. Equation (4) specifies the log of real user cost of housing which involves negative values when expectations outweigh the costs of housing consequently a logarithmic series cannot be obtained. However, logarithms may be obtained for the nominal user cost series. The problem of 'tilting' in the costs of housing indicates nominal user costs should be used.

Equations (5) and (6) are known as the measurement and transition equations, respectively, together they form a State Space Model. The transition equations explain how the TVC β_{it} (for $i = 5,6$) evolves through time. The coefficient of the nominal user cost variable, β_{5t}, is assumed to follow a random walk process with changes in income as a driver variable. The propensity on changes in the user cost of housing is the accumulation of the previous coefficients plus a fixed proportion of the current income change. The coefficient on the expected capital gains on housing, β_{6t}, is assumed to follow a random walk process which is driven by mortgage interest rate changes. Expected capital gains are formulated assuming adaptive expectations. The mortgage interest rate is assumed to play an indirect role in determining the expectations therefore it is modelled in terms of driving the coefficient on expectations rather than the expectations themselves.

The transition equation is specified such that the coefficient is assumed to follow a random walk process through time. Engle and Watson (1987) find that 'for many data sets the simple random walk process... performs well' and consider the random walk process to be an appropriate specification when there are shifts in the policy regime. The user cost of housing depends largely upon Government policy and legislation, hence any policy changes will change the coefficient on this variable. A measure of depreciation is also included in the user cost of housing which is sensitive to economic conditions. The expected capital gains (losses) on housing is an unobservable which tend to cause model instability, assuming time varying coefficients accounts for any errors in the expectations variable. It is therefore assumed that the expected house price inflation and the nominal user cost of housing are modelled with time varying coefficients.

Equations (5) and (6) are estimated using a TVC estimation technique which employs the Kalman Filter. Engle and Watson (1987) state that in a state space form the '... Kalman filter [is] a useful device for recursively solving the model and that the flexibility of the state space model would be particularly important for applications in which issues such as errors in variables, temporal aggregation, missing data, or temporal instability [are] important'.

To enable estimation of varying coefficient vectors of the user cost of housing and the expected capital gains on housing more information 'a priori' is required. Harvey and Peters (1990) suggest a number of procedures of defining the initial values of the transition coefficients and covariance matrix. Depending on the properties of the state vector β_t, where $\beta_t = (\beta_{5t}, \beta_{6t})$, two procedures are normally used. Firstly the Kalman filter can be initialised with the mean and covariance matrix of the unconditional distribution of β_t when β_t is stationary. Secondly, when β_t is non-stationary, i.e. β_t follows random walk or other types of non-stationary processes, the Kalman filter has to be initialised using a method called *diffuse priors*. This procedure assigns very large initial value to the covariance matrix while the initial values of the time varying coefficients are arbitrarily chosen. In this paper the values of the time varying coefficients are constrained to 1 since a random walk process is assumed for both of the transition equations. The starting value of the co-variance matrix, $\mathbf{P}_0$, is then set to equal kI (where k is a large but finite number and I is a 2×2 identity matrix). After the initial values of the time varying coefficients and the covariance matrix are determined, the EM algorithm of Watson and Engle (1985) is applied to estimate Eqs. 5 and 6. The time varying coefficients and the covariance matrix of the transition equations are computed by applying a fixed interval smoothing method. This requires a forward and a backward pass through the data. The forward pass is simply the Kalman filter and the backward pass is called Kalman smoother. For detailed explanations of the EM algorithm, see Watson and Engle (1983).

4. Empirical results

4.1. The data

Quarterly data for the period 1968:Q2–1992:Q2 is collected on house prices, personal disposable incomes, a demographic variable, and the nominal user cost of housing. The data sources are given in Appendix A. The demographic variable is only available with annual observations and therefore an interpolation procedure is applied to obtain quarterly observations. The data is tested for unit roots using the Dickey Fuller (DF) and the Augmented Dickey Fuller (ADF) tests. The results are given in Appendix B. Expected capital gains on housing (NUPHE) and the loan to

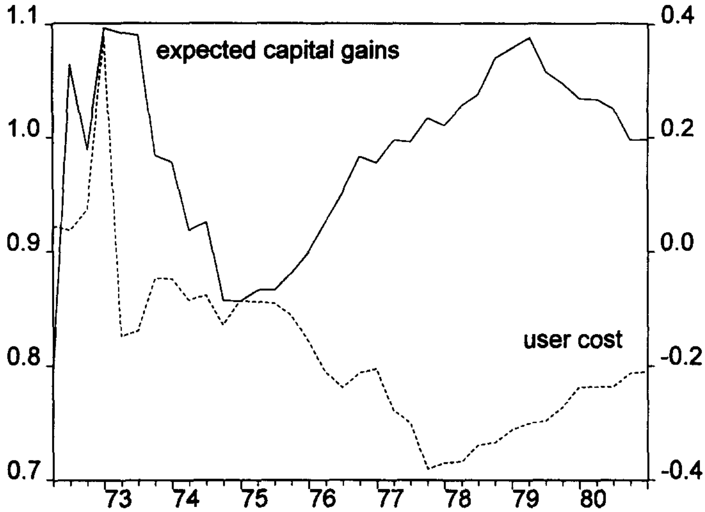

Fig. 4. Recursively estimated coefficients for the period 1968:Q2–1981:Q1.

value ratio for first-time buyers (LOANTVAL) are found to be $I(0)$ variables[6]. All other variables are treated as $I(1)$ variables.

4.2. Results of the recursive least squares estimation procedure

Recursive Least Squares allows OLS to be repeated as the sample period is extended. If the constant parameter model (CPM) is specified correctly then we would expect the coefficient estimates to converge to a constant value as the sample size increases. Recursive Least Squares is applied to the fixed coefficient specification of Eq. (5). Figs. 4 and 5 show the estimated coefficients on the user cost of housing and capital gains on housing for the sub-sample periods 1968:Q2–1981:Q1 and 1981:Q2–1992:Q2. The recursively estimated coefficients indicate structural instability in modelling UK house prices using Eq. (5).

4.3. Results of the time varying parameter estimation

In this section a TVC model of UK house prices is estimated. A constant coefficient Error Correction Model (ECM) is also constructed along with a Vector Autoregressive (VAR) and a time series model for comparison purposes. The explanations given to the constant parameter models is kept to a minimum in this paper.

To enable estimation of the coefficient vectors of the user cost of housing and the expected capital gains on housing more information is required. The initial

[6]The loan–value ratio for first time buyers is included as a proxy for restrictions placed on credit in the housing market.

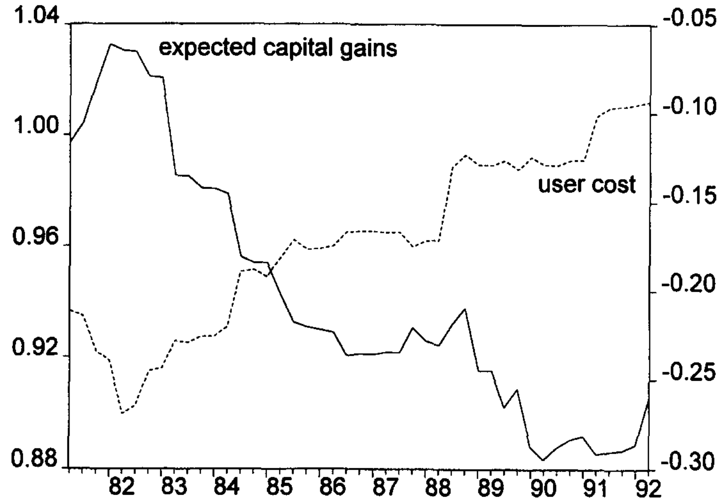

Fig. 5. Recursively estimated coefficients for the period 1981:Q2–1992:Q2.

values of the vector mean and covariance are placed into the Kalman filter based on the method explained in the previous section. The estimation results of the measurement Eq. (5) and the transition Eqs. (6.1–6.2) are given in Eqs. (7) and (8.1–8.2), respectively, where the standard errors are in parenthesis.[7] The estimation period is 1968:Q3–1989:Q2. The period 1989:Q3–1992:Q2 (12 observations) is reserved for forecasting. The TVC model is also estimated where the time varying coefficients are assumed to follow a simple random walk with no drivers which produced good forecasts. However, the inclusion of drivers in the transition equation improves the forecasting performance of the TVC models over the simple random walk specification.

Figs. 6 and 7 plots the estimated TVCs of nominal user cost and expected capital gains on housing, respectively. The coefficient of the user cost shows substantial variations which is consistently increasing. As income changes, an even smaller proportion of the nominal user cost of housing contributes to changes in house prices. The propensity on the user cost is reducing in value and remains negative for most of the estimation period. The plot appears to increase rapidly during the earlier house price booms, however the boom of 1988 seems to not have such a significant increasing effect on the time varying coefficient value.

The time varying coefficient of the expected capital gains also indicates an unstable structure in the housing market. The mortgage interest rate driver variable is assumed to play an indirect role in determining expected capital gains on housing. An increase in the mortgage interest rate will lead to a reduction in the propensity of house price inflation. When mortgage interest rates rise (falls)

[7]Estimation is carried out using Forecast Master which involves Expectations Maximisation and Newton–Raphson numerical optimisation procedures.

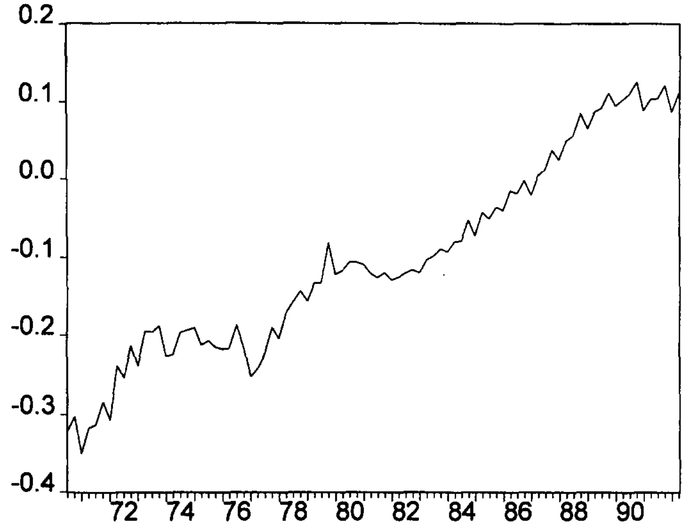

Fig. 6. User cost time varying coefficients.

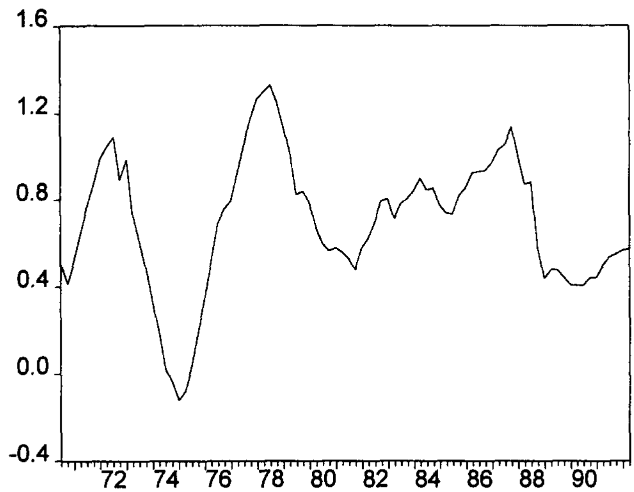

Fig. 7. Expected capital gains time varying coefficients.

this has a dampening (uplifting) effect on the contribution of expected house price inflation on house price changes. The propensity on capital gains is generally increasing during the house price boom periods and falling when house prices are falling. The story told in these Figures is consistent with the results of the recursive least squares shown in Figs. 4 and 5.

Measurement equation regression results:

$$\begin{aligned}\Delta \mathrm{URHP}_t = & -\underset{(4.9954)}{2.5655} + \underset{(0.0824)}{0.1009}\Delta \mathrm{ULRPDI}_t + \underset{(9.248)}{21.66}\Delta \mathrm{POP25T}_t \\ & + \underset{(0.0054)}{0.0172}\mathrm{Q3DUM}_t + \underset{(0.0210)}{0.0236}\mathrm{DUM88}_t + \beta_{5t}\Delta \mathrm{LUSERCX}_t \\ & + \beta_{6t}\mathrm{NUPHE}_t\end{aligned} \tag{7}$$

Transition equations regression results:

$$\begin{aligned}\beta_{5t} &= \beta_{5t-1} + 0.7846\Delta \mathrm{ULRPDI}_t \\ \beta_{6t} &= \beta_{6t-1} - 3.6759\Delta \mathrm{MIRATE}_t \\ \hat{\sigma}^2_{\epsilon 5} &= 2.0257 \times 10^{-6} \\ \hat{\sigma}^2_{\epsilon 6} &= 5.1602 \times 10^{-2}\end{aligned} \tag{8}$$

$R^2 = 0.42$; $DWd = 2.06$; $S.E. = 0.0286$; *Log likelihood* $= 248.21$

4.4. Results of the constant parameter estimation

A constant parameter regression is applied using the Cointegration approach of Johansen (1988) and Johansen and Juselius (1990). The estimates of the short-run dynamic equation are given in Table 1 and the long-run cointegration results are given in Table 2. NUPHEDAT(−1) is the lagged residuals from the cointegration equation. The CUSUMSQ test and the Chow (1960) breakpoint and forecast statistics are rejected indicating the CPM has a problem with unstable coefficients. The Watson–Davies test indicates that the user cost variable and the expected house price inflation should have a time varying parameter specification.[8]

4.5. Results of the vector auto-regression (VAR) and time series estimations

A number of VAR and time series model specifications are investigated. The VAR using 4 lags and the AR(8) are found to be the best in terms of R bar squared, the Akaike Information Criterion (AIC), the Schwarz Criterion (SC) and the forecasts obtained. The performance of the forecasts are considered in detail in the next section.

5. Forecasting results

5.1. Fixed horizon forecasts

The fixed horizon ex-post forecasts from each of the model specifications are

[8] Watson and Engle (1985) tests the null hypothesis that the estimated coefficient from the OLS procedure is fixed against the alternative that it follows an AR(1) process through time.

Table 1
Short-run constant parameter ECM model[a]

Variable	Coefficient	S.E.	t-Statistic	P
C	−1.181090	0.433931	−2.721841	0.0085
DULRPDI	0.600046	0.116463	5.152226	0.0000
DULRPDI(−1)	0.343592	0.108759	3.159204	0.0025
DULRPDI(−3)	0.218131	0.094205	2.315505	0.0240
DULNWLTH1(−2)	0.083330	0.039284	2.121192	0.0380
DLUSERCX	−0.120224	0.054658	−2.199592	0.0317
NUPHE	0.413966	0.166187	2.490964	0.0155
NUPHE(−1)	0.261210	0.141147	1.850624	0.0691
LOANTVAL	0.002097	0.000558	3.754548	0.0004
DUM88	0.032607	0.011435	2.851547	0.0060
NUPHEDAT(−1)	−0.079601	0.033772	−2.357004	0.0217
R^2	0.806854	Mean-dependent variable		0.011991
Adjusted R^2	0.774663	S.D.-dependent variable		0.035410
S.E. of regression	0.016809	Akaike info criterion		−8.030165
ΣR^2	0.016952	Schwartz criterion		−7.679609
Log likelihood	195.326200	F-statistic		25.06454
Durbin–Watson statistic	1.962829	Prob (F-statistic)		0.000000
Chow Breakpoint Test: 1983:2				
F-statistic	2.113270	Probability		0.040234
Log likelihood	24.614410	Probability		0.006126
Chow Forecast Test: forecast from 1986:2 to 1989:2				
F-statistic	1.855623	Probability		0.060936
Log likelihood	28.909310	Probability		0.006743

[a] Dependent Variable is DURHP (sample: 1971:4–1989:2).

Table 2
Long run cointegration model[a]

Variable	Vector	Normalized vector
URHP	−2.8704	−1.0000
ULRPDI	11.1507	3.8847
POP25T	57.2315	19.9386
LUSERCX	−0.4899	−0.1707
LOCC	−9.8466	−3.4304

[a] Dependent variable is URHP. Johansen Cointegration on the sample: 1971:3–1992:2. Maximum lag in VAR = 4. Additional $I(0)$ variables NUPHE.

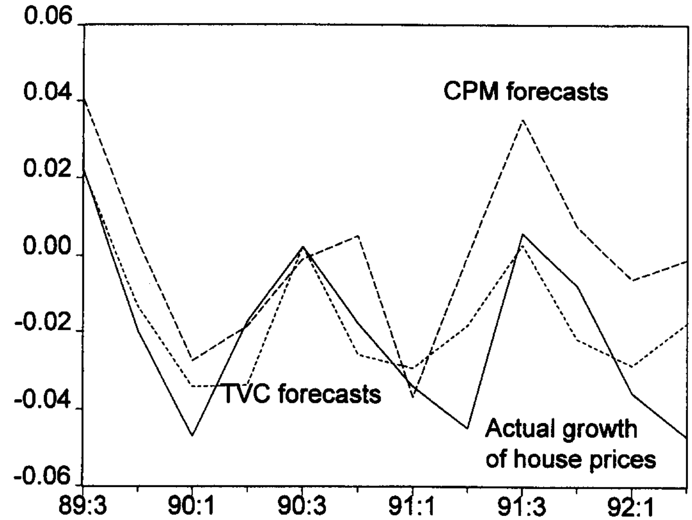

Fig. 8. Forecasting performance.

given in Figs. 8–10 for the period 1989:Q3–92:Q2. Fig. 8 plots the actual growth in real house prices, the TVC forecasts and the forecasts from the constant parameter regression model (Tables 1 and 2). Figs. 9 and 10 show the forecasts of the VAR(4) and AR(8) regressions, respectively with the actual growth in real house prices and the TVC forecasts. The forecasting performances of all four models are compared numerically in terms of error measures in Table 3. The Mean Absolute Forecasting Error (MAFE), Mean Absolute Percentage Error (MAPE), Root Mean Squared Forecasting Error (RMSFE) and the Theil (1985) inequality coefficient (U) are compared for the forecast period 1989:Q3–1992:Q2.[9] Bold typescript indicates the best forecasting model for that statistic. The MAFE, MAPFE and the RMSFE support the visual results in Figs. 8–10. The TVC out forecasts all the other models specifications. Prediction of the current slump in UK house prices has proven difficult, with the overprediction of prices and the failure to predict the length of the slump. The TVC model would appear to perform well up to 1992:Q1 but fails to predict the downturn in 1992:Q2, however the ECM and the time series also fail to predict 1992:Q2.

5.2. Rolling horizon forecasts

The fixed horizon forecasts are limited in that they assume the forecasts

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[9] Theil (1985) inequality coefficient $U = \dfrac{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(Y_t^F - Y_t^A)^2}}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(Y_t^F)^2} + \sqrt{\frac{1}{T}\sum_{t=1}^{T}(Y_t^A)^2}}$

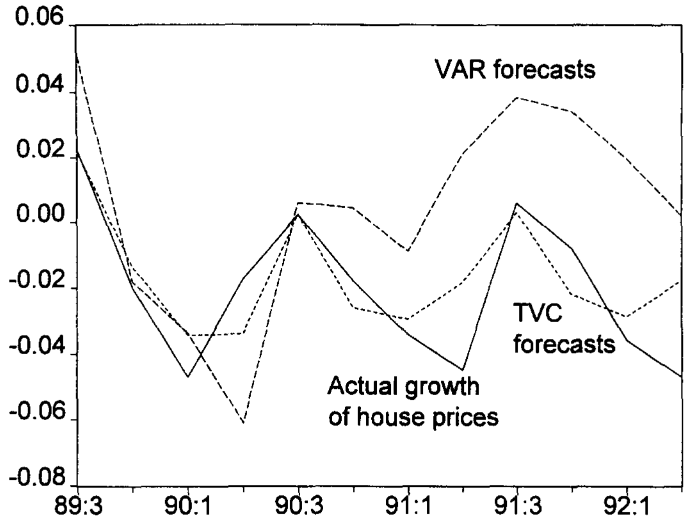

Fig. 9. Forecasting performance.

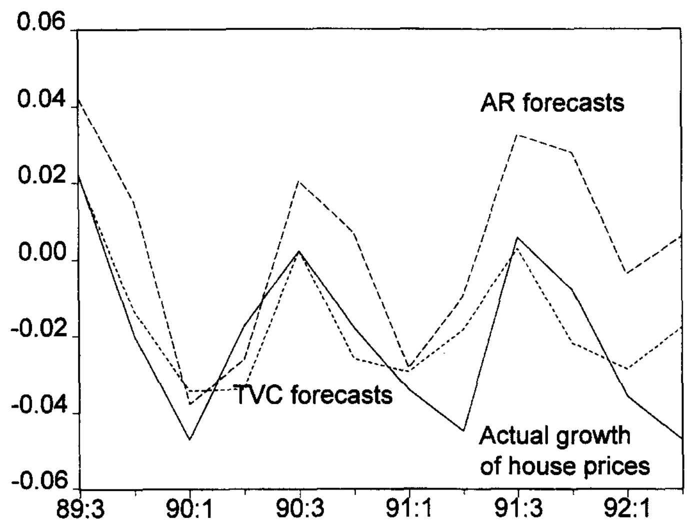

Fig. 10. Forecasting performance.

originate from one data point, in this case 1989:Q3. It is considered that a more rigorous test of the forecasting performance can be obtained through using multiple data points (see Fildes, 1989, 1992). A rolling regression technique is applied to each of the model specifications to obtain multi horizon forecasts and error measures for comparison purposes. N period ahead forecast errors are obtained for each model where N falls from 12 to 1 step ahead forecasts. Tables 4–6 give the results for the Mean Square Forecast Error (MSFE), Root Mean

Table 3
Comparison of fixed horizon forecasts

Model	MAFE	MAPFE	RMSFE	Theil *U*
TVC	**0.010727**	**49.09577**	**0.014058**	**0.265829**
CPM	0.021423	126.2732	0.025709	0.504351
VAR(4)	0.032021	189.8924	0.037351	0.617949
AR(8)	0.016307	85.14349	0.020780	0.367739

Table 4
Comparison of short-run rolling horizon forecasts

Measure	Model	1-lead	2-lead	3-lead	4-lead
MSFE	AR(8)	0.000449	0.000657	0.000641	0.000804
	TVC	**0.000241**	**0.000249**	**0.000259**	**0.000260**
	CPM	0.000488	0.000543	0.000492	0.000640
	VAR	0.000950	0.001047	0.001417	0.001707
RMSPFE	AR(8)	1.011529	1.538264	2.101501	1.931120
	TVC	**0.989755**	**0.744250**	**0.649537**	**0.668311**
	CPM	1.492025	1.697638	0.840742	1.927937
	VAR	1.830615	1.870658	2.532085	2.768077
Theil *U*	AR(8)	0.379969	0.477808	0.474273	0.581918
	TVC	**0.297098**	**0.298644**	**0.295294**	**0.317299**
	CPM	0.430455	0.475770	0.465633	0.534996
	VAR	0.522855	0.581556	0.632815	0.721628

Square Percentage Forecast Error (RMSPFE) and the Theil (1985) inequality coefficient (U). Bold typescript indicates the best model for that period. The results indicate that the TVC regression out-performs the selected constant parameter regressions for the whole of the rolling forecast period.

6. Conclusions

The UK housing market has suffered from a number of structural changes and shocks to the system, with substantial house price rises in the early 1970s, early 1980s and the late 1980s. Financial deregulation particularly in the mortgage lending market and the role of expectations have contributed significantly to the structural instability of UK house prices. Previous studies have re-specified the house price model in the light of new information to internalise these exogenous shocks. This study assumes that the economic system is unstable and a more

Table 5
Comparison of medium run rolling horizon forecasts

Measure	Model	5-lead	6-lead	7-lead	8-lead
MSFE	AR(8)	0.001360	0.001587	0.001747	0.002082
	TVC	**0.000281**	**0.000292**	**0.000325**	**0.000385**
	CPM	0.000801	0.000922	0.000806	0.001189
	VAR	0.001949	0.002276	0.002576	0.002955
RMSPFE	AR(8)	3.672705	2.317806	2.496597	2.661694
	TVC	**0.658038**	**0.666456**	**0.783264**	**0.909650**
	CPM	2.089611	2.158469	2.295225	2.537866
	VAR	3.012422	3.297906	3.469878	3.749825
Theil *U*	AR(8)	0.702507	0.758971	0.741553	0.832295
	TVC	**0.337977**	**0.320371**	**0.330507**	**0.370851**
	CPM	0.589366	0.593143	0.506990	0.689776
	VAR	0.844820	0.845837	0.846778	0.879355

Table 6
Comparison of long-run rolling horizon forecasts

Measure	Model	9-lead	10-lead	11-lead	12-lead
MSFE	AR(8)	0.002282	0.002730	0.002271	0.002801
	TVC	**0.000287**	**0.000365**	**0.000449**	**0.000848**
	CPM	0.001024	0.001114	0.001563	0.002106
	VAR	0.002404	0.002836	0.003202	0.002403
RMSPFE	AR(8)	3.484092	2.836187	1.093231	1.125587
	TVC	**0.985627**	**1.097764**	**0.459332**	**0.619311**
	CPM	2.845767	1.351557	0.921802	0.975925
	VAR	4.058288	3.294136	1.395944	1.042641
Theil *U*	AR(8)	0.862404	0.928401	0.936649	0.99999
	TVC	**0.338951**	**0.330470**	**0.322023**	**0.448552**
	CPM	0.660305	0.841234	0.854881	0.952982
	VAR	0.832881	0.903318	0.983082	0.99908

appropriate and parsimonious methodology of TVC is adopted. A TVC model is constructed and estimated using the Kalman filter. Both static and dynamic forecasts are generated from this model and the results suggest that the TVC specification outperforms the alternative constant parameter specifications of house prices.

It has been suggested by some researchers that most of the models developed in the literature have failed to predict the 1992 housing price downturn. Further study is planned to apply the TVC specification with extended data to examine the model's forecasting performance beyond 1992.

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Appendix A

Data and their sources

1. CPI, Consumer Price Index at 1985 prices from Economic Trends.
2. HP, House prices is the UK mix-adjusted house price index at 1985 prices for all dwellings which is published in Housing and Construction Statistics by the Department of the Environment.
3. URHP, Real house prices is HP deflated by the CPI.
4. POP25T, A demographic variable, population aged over 25 expressed as a proportion of total population, collected from the Monthly Digest of Statistics.
5. MIRATE, The mortgage interest rate collected from Financial Statistics.
6. NUPHE, Expected capital gains on housing is formed using adaptive expectations. The fitted values of an AR(8) process of nominal house prices.
7. ULRPDI, Real personal disposable incomes deflated by the CPI from Economic Trends.
8. LUSERCX, The nominal user cost of housing from Breedon and Joyce (1993).
9. LOCC, Stock of owner-occupied dwellings from Housing and Construction Statistics.
10. LOANTVAL, Loan to value ratio for first-time buyers from Housing and Construction Statistics.
11. ULNRWLTH, Stock of total financial assets from Meen (1990).

Seasonally unadjusted quarterly data for the period 1968:Q2–1992:Q2. All variables are expressed in logarithmic format with the exceptions of the demographic variable and the mortgage interest rate.

Appendix B

Unit root test results

Variable	Statistic	Critical value[a] at 5% level	Test information[b]
URHP	−2.751930	−3.4576	ADF(2)
DURHP	−4.415205	−3.4571	DF
ULRPDI	−2.522663	−3.4576	ADF(2)
DULRPDI	−4.076854	−3.4586	ADF(3)
POP25 T	−2.739051	−3.4571	ADF(1)
POP25 T	−1.914092	−3.4576	ADF(1)
LUSERCX	−2.879925	−3.4571	ADF(1)
DLUSERCX	−5.321889	−3.4576	ADF(1)
NUPHE	−3.866257	−3.4614	DF
UCPI	−2.874063	−3.4586	ADF(4)
DUCPI	−6.878168	−3.4576	ADF(1)
MIRATE	−2.768462	−3.4571	ADF(1)
DMIRATE	−9.592609	−3.4571	DF
ULNRWLTH	−1.586829	−3.4566	DF
DULNRWLTH	−11.76601	−3.4571	DF
LOCC	−1.478097	−3.4576	ADF(2)
DLOCC	−1.471185	−3.4581	ADF(2)
LOANTVAL	−3.264088	−3.4566	DF

[a]MacKinnon critical values for rejection of hypothesis of an unit root.
[b]A constant and a time trend are included in each test, with the exception of the test on LOANTVAL. As in Breedon and Joyce (1993) the DF test on LOANTVAL included a constant and a dummy variable to allow for a deterministic shift in 1981:Q1.

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