Stock of dwellings, house prices and interest rates: an econometric model for the UK

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Abstract

The often volatile behaviour of UK housing stocks is analysed in an annual econometric model. Theory suggests that an increase in house prices leads to a rise in housing stock, whereas an increase in interest rates leads to a decrease in housing stock. This paper develops an econometric model to examine the cyclical activity of stocks of dwellings in the UK. The use of annual data allows us to analyse the period 1964-96. The paper also examines the time series behaviour of housing stocks, house prices and interest rates in the UK market. The evidence presented in this paper supports the predictions of theory. The presence of adjustment costs suggests that the adjustment of housing stocks is inelastic with respect to house prices.

Keywords

Housing stock; interest rates; house prices; unit root tests

Introduction

The empirical investigation of the fluctuations in housing stock results in a fuller understanding of its dynamics and, more importantly, it improves the decision making of developers, investors and policy-makers. Before presenting our model, it is useful to start with a discussion of previous literature.

Muth (1960) argues that the long-run housing supply is highly elastic, but the short-run supply has a lagged adjustment process of actual housing stock toward desired stock. Smith (1969) estimates an equation with lagged stock and current and lagged housing starts as independent variables, explaining the stock of houses. Smith also uses credit-rationing variables in the equations to explain the housing stocks and prices, but the variables were not significant. Maisel (1963) states that credit costs have an important effect on developers' decisions. In the model by Huang (1969), the housing supply is a function of lagged one and two supply, of the expected ratio of housing prices to construction costs, of a short-term interest rate, of vacancies, and of credit availability. In addition, the desired housing stock is taken to be a function of income and of the rent-to-value ratio. Alternatively, Fair (1972) argues that new construction depends upon the expected selling price of the house relative to the expected cost of building the house. This decision in turn depends upon the expected profitability of residential construction relative to the expected profitability of non-residential construction. Muth (1988) argues that a rise in the rate of interest increases the rental value of housing, and, hence, reduces the stock of housing demanded. Muth approximates the housing stocks demanded by a linear function with the rate of interests and a time trend the independent variables. Muth then relates current period house price to lagged price, interest rate, and stock and the current period expected price change. Swan (1984) shows that it is the comparison of changes in house prices to construction costs that leads to adjustments in the housing stock. Swan argues that long-run equilibrium requires that the stock of houses adjust so house prices equal construction costs.

Buying a dwelling is for living as well as for investment. If the buyers are motivated by asset considerations, stocks of dwelling will be sensitive to the changes in interest rates. However, it is possible that households behave somewhat irrationally by paying too much attention to past housing returns and not enough attention to future returns. Maclennan and Tu (1996) suggest that housing trade friction is a function of housing stock in the sense that higher trade friction reduces the number of dwellings traded and the stock adjustments. Meen (1996) argues that the rate of increase of the housing stock is positively related to the real house price and negatively to the existing stock, although no further empirical evidences were provided. Meen finds that new housing construction in the UK does not clear housing markets in the short run, and housing stocks in all regions are very sensitive to changes in interest rates. Changes in the cost price of housing will also alter the steady state asset price of housing. For example, an increase in the cost price due, say, to increased labor costs not offset by advances in productivity, reduces the rate of return on the marginal investment in housing production, thus inducing a reduction in the rate of replacement of the existing stock which, in turn, ultimately reduces the size of the stock and drives up the rental rate on housing services. The rate of return on housing investment then reverts to its initial level, but the rental rate on services and the asset price reaches equilibrium at higher levels. Increased demand for housing services creates a stock disequilibrium and stimulates construction. It is argued that credit availability only alters the speed of adjustment, but not equilibrium stock or equilibrium flow of new housing production (Meltzer, 1974).

This paper reports on a research project that explores links between stock of dwellings, house prices and interest rates in the UK housing market. The study develops a theoretical framework within which the variation in housing stocks can be analysed empirically on the basis of changes in house prices and interest rates. However, econometric models that employ standard estimation methods for determining fluctuations in housing stocks are based on the assumption of stationarity in the underlying data generating process (Muth, 1960; Maisel, 1963; Whitehead, 1971; Burnham, 1972; Huang, 1973). The property of stationarity requires that there is no fundamental change in the structure of the process. However, many macroeconomic time series exhibit non-stationary properties because of the presence of stochastic trend components. As a result, one would expect housing variables such as stock of dwellings and house prices to contain unit roots. Past quantitative research studies typically rely on historical time-series data to estimate the cyclical patterns of housing stocks. These literature appear to have focused little attention on the statistical properties of the housing data.

Thus, a major purpose of this paper is to fill an important gap in the literature associated with practical problems in the estimation of housing stock fluctuations. In the next section, we examine the data series of the stock of dwellings, house prices and interest rates in the UK. In the following section, an econometric model which estimates the impacts of house prices and interest rates on housing stocks, is developed. Empirical results were reported. The last section provides some concluding remarks.

Unit Root Tests

Macroeconomic models require the use of stationary time-series data (Granger and Newbold, 1974; Dickey and Fuller, 1979; Granger, 1981; Harvey, 1989). Under current practice, developing such data requires the observed data series be tested for unit roots. The tests for unit roots are also known as Dickey-Fuller (DF) and augmented Dickey-Fuller (ADF) tests.

In this study, the data were based on annual indices of the stock of dwellings and house prices, and building societies mortgage rates in the UK. All of the data come from the Housing and Construction Statistics, Great Britain. This study employs annual data from 1964 to 1996.

Let K, p and i are the stock of dwellings, house prices and mortgage interest rates respectively. Estimates of the total dwelling stock are made by the Department of the Environment, the Scottish Office and the Welsh Office and are based on data from the Censuses of Population, with adjustments for enumeration errors and for definitional changes. Estimates have been made taking the number of self-contained household spaces in permanent buildings, each of which must by definition correspond to a separate dwelling, and add to that figure an allowance for shared dwellings by assuming that outside Inner London on average 100 "not self-contained" household spaces are equivalent to 25 separate dwellings. The dwelling stock estimate is not very sensitive to the number of household spaces assumed per shared dwelling, since only a very small proportion of dwellings are shared. The house price index (pt) is a weighted average of prices of a standard collection of dwellings. Details of the methods by which the indices are constructed were published in Economic Trends 348, October 1982. K and i are end-year figures.

The three data series were depicted in Figure 1. Table 1 reports the DF and ADF test statistics on the logarithm of the variables in Equations 1-3 omitting minus signs for simplicity. The null hypothesis of unit root for K and p in level form is rejected at all conventional levels of significance when the calculated Dickey-Fuller test statistics associated with α are compared with its critical values, as given in Engle and Granger (1987). Thus, we have shown that stock of dwellings and house price data series are non-stationary in log-level terms. The unit-root tests for the three data series are performed using 0-4 lagged (log) first-difference of the dependent variable. Estimations both with and without the trend term are reported (Table 1). The AD/ADF tests reject the hypothesis of a unit root at all conventional levels of significance, suggesting that K and p are (log) first-difference stationary (i.e., I(1)). Thus, stock of dwellings and house prices are I(1), and interest rates is I(0).

Econometric Model

Even if movements in economic variables provide signals for profitable development opportunities, the time taken to assess these signals and the resilience of the market, draw up plans, select sites, secure finance, search the market to obtain tenders imply that the response of the development industry will be with a delay and developments will be initiated with a lag. Thus, it is expected that changes in economic variables will not have an immediate effect on changes in housing stock. Against this background, we propose the short-run adjustment model:

$$K_t^* - K_{t-1} = \lambda(K_t - K_{t-1}) \qquad (1)$$

Since Kt is stationary in first difference, we taking difference operator to both sides of equation (1),

$$\Delta Kt^* - \Delta Kt\text{-}1 = \lambda(\Delta Kt - \Delta Kt\text{-}1) \qquad (2)$$

Unlike space demand, asset demand (Dt) for housing capital mainly depends upon two parts: house price and interest rate. Following Tse and Webb (2006), housing demand is hypothesized to depend upon the current house prices and the rate-of-interest. Thus, the market clearing price for a given level of vacancy is that which solves,

$$Dt(p, i) = (1 – vt)Kt \qquad (3)$$

where v is the vacancy rate. With a long-run relationship, the desired changes in housing stock are expected to depend upon changes in house prices and level of interest rates, for a given level of natural vacancy rate (vn): $Kt^* = Dt(p, i)/(1 - vn)$. Against this background, the following specification is used,

$$\Delta K_t^* = a_0 + a_1 \Delta p_t + a_2 i_t \qquad (4)$$

Changes in desired housing stock are influenced positively by changes in house prices, and negatively by interest rates. Thus, it is expected that $\alpha 1 > 0$ and $\alpha 2 < 0$. Equations (1) and (2) generate the following reduced form equation:

$$\Delta K_t = b_0 + b_1 \Delta p_t + b_2 i_t + b_3 \Delta K_{t-1} \qquad (5)$$

where $\beta 0 = \alpha 0/\lambda$; $\beta 1 = \alpha 1/\lambda$; $\beta 2 = \alpha 2/\lambda$; $\beta 3 = -(1-\lambda)/\lambda$. Thus, we would expect that $\beta 1 > 0$, $\beta 2 < 0$, and $\beta 3 < 0$ if $0 < \lambda < 1$. Clearly, $\beta 1$ represents price elasticity and $\beta 2$ represents interest-rate elasticity. Equation (3) can be equivalently expressed as

$$\Delta K_t = m + b_1 \sum_{j=0} b_3^{\,j} \Delta p_{t-j} + b_2 \sum_{j=0} b_3^{\,j} i_{t-j} + \ldots. \qquad (6)$$

where $\mu = \beta 0 \Sigma[\beta 3]j$ for $j = 0,1,2,\ldots.$ Hence, the limiting value of μ is $\beta 0/(1-\beta 3)$. Equation (4) shows that the impacts of house prices and interest rates on the changes in the stock of dwellings diminish over time, since $(\beta 3)T$ vanishes as $T \to \infty$.

Table 2 reports the empirical results. The results for equation (3) is represented by OLS2 in which all the estimators are significant and as expected. As we can see, β1 = 0.15 which is less than one, indicating that the housing supply is inelastic with respect to changes in prices. The adjustment parameter λ = 1/(1-β3) is 0.622. The inelastic supply of housing production reduces the speed of adjustment to the new stock equilibrium, reducing the rate of housing production in any period (Pollock, 1973).

In theory, equation (2) cannot be estimated directly, since the actual stock may not equal desired stock; that is, the adjustment coefficient, λ, might not be unity. Let us consider the regression:

$$K^{*} = Xa \qquad (7)$$

Recall equation (2),

$$K^{*} - K_{-1} = l\,(K - K_{-1}) + u \qquad (8)$$

thus,

$$Xa = lK + (1 - l)K_{-1} + u \qquad (9)$$

where X is a matrix of the explanatory variables in the long-run relation (2), K is a column vector of observations on the dependent variable, α is a vector of coefficients, K-1 is a vector of the lagged dependent variable, u is distributed with zero mean and constant variances. It follows that equation (6) satisfies the normal equation:

$$X'X\hat{a} = \hat{l}\,X'K + (1 - \hat{l})\,X'K_{-1} \qquad (10)$$

Since X′K = X′(K-1 + ΔK) = X′(K-1) + X′(ΔK), thus one would expect X′K ≅ X′K-1 when the covariances between ΔK and the explanatory variables are small compared with those between K-1 and the explanatory variables. Therefore, we have from equation (8),

$$X'X\hat{a} \cong X'K \qquad (11)$$

This estimate of α is approximately equal to the coefficients in equation (5), using actual stock (K) as the dependent variable. We thus run equation (5) using the same set of data. As shown in Table 2 (OLS1), this estimate of the coefficients is very close to OLS2, but OLS2 performs better than OLS1.

The adjusted R2 increases greatly from 0.116 in OLS1 to 0.473 in OLS2 and the DW statistic takes a more satisfactory value. Thus it is expected that a lag model as stated in equation (3) captures adequately the adjustment effect of housing stocks.

Instead of using the OLS, the Hildreth-Lu (H_LU) methodology is a grid-search procedures, which choose the value of serial correlation for which the sum-of-squared residuals is minimum. In using the H_LU procedure, we may choose any limits and any spacing arrangement for the grid values (Hildreth and Lu, 1960). As shown in Table 2 (col. 4), the estimators using the H_LU procedure perform quite closely to OLS. Note that this estimate of equation (3) is also very close to the OLS2, indicating that the specification in (3) is robust. In addition, we can employ Durbin-h to test for serial correlation when lagged dependent variables are present (Durbin, 1970):

h-statistics = (1-DW/2)√[n/(1-nVar(β3)], where n is the number of observations and Var(β3) is the estimate of the sampling variance of the estimator for β3. The null hypothesis of zero autocorrelation is not rejected at the 0.01 level.

Instead of using current interest rates, we assume that individuals have extrapolative expectations for interest rates, such that the expected rate of interests imt = (it + it-1)/2. The OLS regression results were reported in Table 3. Again, all the coefficients are significant and have the right signs, but the Adjusted R2 has slightly decreased compared with OLS1 and OLS2.

Alternatively, equation (2) can be expressed as

$$\Delta K_t^* = \hat{l}\, \Delta^2 K_t + \Delta K_{t-1} \qquad (12)$$

which indicates that the desired changes in housing stock at time t depends upon two factors: the change in housing stock at time t-1 and the accelerated change in housing stock at time t. Thus, the adjustment parameter λ can also be viewed as an accelerator. The difference between the desired change and actual change in housing stocks is

$$\Delta K^{*} - \Delta K = (\hat{I} - 1)\Delta^{2} K \qquad (13)$$

The desired change will lag behind actual change if the accelerated change in housing stock is positive. If the flow of housing services is proportional to the stock of dwellings, an increase in the demand for those services opening a gap between the desired and actual stock above. An increase in house prices (interest rates) pushes up (down) the rate of return on residential property relative to the cost of capital, and thereby induces (reduces) investment.

Based on the OLS2 and H_LU models, the desired changes in housing stock are:

OLS2

$$\Delta K_t^{*} = 0.0165 + 0.0938\Delta p_t - 0.00158 i_t \qquad (14)$$

Hildreth-Lu

$$\Delta K_t^{*} = 0.0157 + 0.0929\Delta p_t - 0.00150 i_t \qquad (15)$$

which were depicted in Figure 2 in comparison with the actual change in housing stocks.

As we can see, the specification (5) produced satisfactory results in modelling variations in the stock of dwellings in the UK housing market considered. In order to ensure that misspecification problems do not arise, we use levels of housing stocks instead of changes. Specification (5) can be transformed into

$$K_t = b_0 + b_1 \Delta p_t + b_2 i_t + g_1 K_{t-1} + g_2 K_{t-2} + e_t \qquad (16)$$

where $\gamma1 = 1+\beta3$ and $\gamma2 = -\beta3$, implying that $\gamma1 + \gamma2 = 1$.

Firstly, we run unrestricted OLS. As shown in Table 4, OLS5U and OLS6U report the results when i and im were used respectively. Except for the constant term, all coefficients are significant and have the right signs. The estimators β1, β2, and λ are slightly reduced compared to the results obtained in OLS2 and H_LU. In order to test for $\gamma1 + \gamma2 = 1$, we run restricted OLS. The results were reported in OLS5R and OLS6R (Table 4). The F-tests indicate that equation (16) with the restriction $\gamma1 + \gamma2 = 1$, cannot be rejected at the 0.01 level.

Conclusions

Theoretical work on modelling the housing market has highlighted the impacts of economic factors on the changes in housing stock. As generally expected, our model reveals that house prices and rates of interest play an important part in driving stock of dwellings in the UK housing market. We have shown that cyclical fluctuations in housing stock are strongly influenced by changes in house prices and interest rate movements. However, the growth of the equilibrium stock depends upon the growth of demand for housing services, which is primarily a function of demographics and income levels.

On the demand side, rising income and number of households increase the demand for housing space, which will increase the rate of change of housing stocks. Adjustment to long-run equilibrium takes time, given asset durability. In general, the short-run rate of change of housing stock, given stock disequilibrium, is constrained by profitability of housing development as reflected by changes in house prices; cost of capital or financing as reflected by mortgage interest rates; and developer perceptions of and expectations regarding the stock disequilibrium as reflected by the lags in stock adjustment.

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Table 1. Results of Unit-root Tests

	K	p	i
Level	1.682	1.425	2.002**
First Difference			
No Trend No Constant			
0-lag	6.91***	1.83	5.74***
1-lag	3.50**	2.11	4.32***
2-lags	2.25	1.25	3.96***
3-lags	1.65	1.29	3.54***
4-lags	1.33	0.83	1.48
No Trend + Constant			
0-lag	8.78***	3.01**	5.65***
1-lag	5.08***	3.62***	4.24***
2-lags	3.56***	2.30	3.88***
3-lags	2.77	2.53	3.46**
4-lags	2.27	1.56	1.39
Trend + Constant			
0-lag	9.07***	0.01	5.96***
1-lag	5.48***	3.94**	4.70***
2-lags	4.02**	2.81	4.78***
3-lags	3.33	3.11	4.99***
4-lags	2.93	2.42	2.40
	I(1)	I(1)	I(0)

Notes: ** and *** indicate significant at the 5% and 1% levels. The critical values of DF statistics are: 3.5 with trend and 2.93 without trend, and 4.15 with trend and 3.58 without trend at the 5 and 1% levels of significance respectively.

Table 2. Regression results I

ΔK(t)	OLS1	OLS2	H_LU
Constant	0.02510**	0.02653**	0.02535**
	(1.737)	(2.259)	(2.041)
Δp(t)	0.10068**	0.15078***	0.15015***
	(2.311)	(4.237)	(4.145)
i(t)	-0.00243*	-0.00254**	-0.00243**
	(-1.674)	(-2.200)	(-2.005)
ΔK(t-1)		-0.60842***	-0.61497***
		(-4.435)	(-4.369)
DW statistics	3.171	2.204	2.192
Adjusted R2	0.116	0.473	0.473
λ		0.622	0.619
h-statistics		0.88	0.826

Notes: *; ** and *** indicate significant at the 0.1; 0.05 and 0.01 levels respectively. Figures in parenthesis are *t*-statistics.

Table 3. Regression results II

ΔK(t)	OLS3	OLS4
Constant	0.02561*	0.02979**
	(1.592)	(2.216)
Δp(t)	0.08439**	0.13481***
	(2.045)	(3.985)
im(t)	-0.00234*	-0.00269**
	(-1.518)	(-2.146)
ΔK(t-1)		-0.62443***
		(-4.510)
DW statistics	3.148	2.154
Adjusted R2	0.102	0.469
λ		0.616
h-statistics		0.67

Notes: *; ** and *** indicate significant at the 0.1; 0.05 and 0.01 levels respectively. Figures in parenthesis are *t*-statistics.

Table 4. Regression results III

	OLS5U	OLS5R	OLS6U	OLS6R

K(t)	unrestricted	restricted	unrestricted	restricted
Constant	0.07981 (0.4557)	0.02653	0.03652 (0.1896)	0.02979
Δp(t)	0.14555*** (3.634)	0.15078	0.13428** (3.566)	0.13481
i(t)	-0.00232** (-1.693)	-0.00254	-0.00266* (-1.597)	-0.00269
K(t-1)	0.38131** (2.656)	0.39158	0.37453** (2.598)	0.37557
K(t-2)	0.60656*** (4.343)	0.60842	0.62391*** (4.397)	0.62443
DW statistics	2.196		2.153	
Adjusted R^2	0.965		0.964	
λ	0.6224	0.6217	0.6158	0.6156
F-statistics		0.092974		0.00122

Notes: *; ** and *** indicate significant at the 0.1; 0.05 and 0.01 levels respectively. Figures in parenthesis are *t*-statistics.