

# House Prices and Housing Investment in Sweden and the United Kingdom.

Econometric Analysis for the period 1970 – 1998

By

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## Abstract

We estimate quarterly dynamic housing demand and investment supply models for Sweden and the UK for the sample period 1970-1998, using an Error Correction Method (ECM). To facilitate comparisons of results between Sweden and the UK we model both countries identically with approximately almost the similar type of exogenous variables. The long run income elasticities for Sweden and the UK are constrained to be 1.0 respectively. The long runs semi-elasticity for interest rates are 2.1 and 0.9 for Sweden and the UK. The speed of adjustment on the demand side is 0.12 and 0.23 while on the supply side is 0.06 and 0.48 for Sweden respectively the UK. Granger causality tests indicate that income Granger causes house prices for Sweden, while for the UK there is also a feedback from house prices to income. House prices Granger cause financial wealth for Sweden, while for the UK it's vice versa. House prices cause household debt for Sweden, while for UK there is a feedback from debt. Interest rates Granger cause house prices for the UK and Sweden. In both countries Tobin's q Granger cause housing investment. Generally the diagnostic tests indicate that the model specifications were satisfactory to the unknown data generating process.

**Keywords:** House prices, Housing investment, Tobins' q, Error Correction, Cointegration, long run and elasticities, Granger- causality, forecasting ability.

## Acknowledgements.

The authors are grateful for the provision of UK data from Pam Seaton, James Bell, Peter Westaway, Kanak Patel, and Geoff Meen. Valuable suggestions from Jan Alsterlind, John Quigley, Hans-Martin Krolzig, Kari Takala, K.W. Chau, Peter Englund, Parameswar Nandakumar, Alfred Kanis, Gunnar Rosenquist, Rune Wigren, Thomas Lindh, and Bengt Turner. We also thank Mats Wilhelmsson's comments in the role of the dicussant at my final seminar held at Uppsala University on the 27/09/02. Niklas Ahlgren and Jukka Nyblom valuable comments on this paper. We also thank Roland Andersson, Bosse Söderberg Kicki Björklund from the Insitute of Infra Structure at the Royal Institute of Technology for participating in the seminar held on 11/09/2002. In addition we thank Ingemar Hanson, Johnny Nilsson, Johan Linden, Göran Hjelm, Åsa Johnansson, Mikel Apel, Tomas Lindström, Mårten Löf and Henrik Braconier who were the participants at the seminar held at N.I.E.R. on 3/10/02. In particular I thank Birgit Kaur for the sensible suggestions while making the figures for this paper. Tommy Persson and Hans-Roland Johnsson have always been around moral supporting. The two anonymous referees, Piyush Tiwari and Daniel Baron of the Review of Urban and Regional Development studies. Data is available on request for replication studies.

This paper has also been published in Review of Urban & Regional Development studies (RURDS), Vol. 14, No.2 July 2002. For details visit [blackwellpub.com/online](http://blackwellpub.com/online).

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## 1. Introduction

The importance of housing for the wider economy, the financial system, labour market, and construction industry justifies this study. Besides house prices been a national obsession their developments are been scrutinised in the United Kingdom and Europe as advanced indicators of demand pressure. The correlation of the growth of real house prices and output gap is associated with strong economic expansion. In addition monetary policy by central banks take into account the demand pressures in order to target the inflation rate.

The major econometric models both of the UK and the Swedish economy do now incorporate housing wealth along with financial wealth in their consumption functions, see Davidson, Hendry, Srba and Yeo (1978) and Hendry (1981) for the UK; Berg et al. (1995), Kanis et al. (1993), and Barot (1995) for Sweden. This makes it all the more important to have an econometric model which increases our understanding of the determinants of house prices and of effects on house prices of both fiscal and monetary policies. We refrain from the policy aspects, (see Barot 2001), and put the main focus of the paper on econometric modelling of house prices and investment for owner-occupied homes both in the UK and Sweden.

Case et al. (2001) study examines consumer behaviour at the USA State level from 1982 to 1999. It found that the wealth effect from housing wealth was both statistically significant and twice as large as the stock market effect. On average a 10% rise in house prices resulted in a rise in consumption of roughly 0.6% whereas a 10% increase in stock market wealth pushed up consumption up only by 0.3%. For the USA the marginal propensity to consume is about 0.04 out of stock wealth and some what higher out of housing wealth. (see Boone et al. (1998)).

When the study examined data for 14 countries, including USA, they found an even larger wealth effect from housing-increased consumption roughly 1.3% from a 10% rise in housing wealth-with no discernible equity wealth effect at all. Greenspan, (1999, 2001), investigated in his study the relationship between consumption and wealth for 16 OECD countries using panel data techniques. Their results indicate both types of wealth are statistically significant in the long as well as the short run. Similar results are found for Sweden (see Kanis et al. (1993) and Barot (1995)). The empirical results indicate that asset prices have become increasingly important in the transmission of domestic and global business cycles (see I.M.F. study April 2002). This makes it all so important to understand the determinants of house prices.

According to Meen (2001), the UK national housing models for owner occupied homes have broken down due to the structural changes after 1990 which has resulted into that the parameters of house price equations have been particularly volatile compared with other aggregate time series relationships.

The main objective of this paper is two folds. The primary objective is to investigate the degree of similarities and differences in private owner-occupied housing markets for Sweden and the UK. The owner-occupier rate in Britain stands at 68% but only 40% in Sweden. In order to facilitate comparisons between the countries we use approximately the same type of exogenous variables modelling house prices and housing investment. We compare the short and the long-term point estimates, elasticities and the error correction speed of adjustment coefficients. Both the countries under scrutinisation are modelled using a stock-flow model in order to examine if the nature of housing market is fundamentally different between Sweden and the UK. This in turn would imply that a single theory of housing growth could not apply internationally to cases, which are so different from each other. In addition, long-run trends in real house prices differ across countries and therefore it is important to investigate why these differences occur.

The secondary objective is to investigate if changes in house prices can be predicted? There is a common belief that share and house prices follow random walks. The questions to be explored are as follows: (1) Can the private owner-occupied markets in Sweden and the UK be explained within the theoretical framework of stock-flow model? (2) Is there a good house price and investment model in the sense that these structural models beat their auto-regressive counterparts? (3) Can these models be used for forecasting? The contribution of this study is in its extensive country comparison that has not been carried out in earlier studies.

This study is structured in the following sections: Section 2 presents a review of earlier studies. In section 3 the theoretical considerations for modelling the real house prices in Sweden and the UK are outlined. Section 4 describes the data used in this study. Section 5 deals with the ECM methodology applied in this study. Section 6 presents the empirical results on house prices and investment functions for Sweden and the UK. Section 7 presents the forecasting evaluations of Sweden and the UK models. A comparison with naive auto-regressive alternatives is carried out. Section 8 presents the Granger causality test between the determinants of house prices. Section 9 concludes. Appendix 1 presents the results from unit root tests of integration and cointegration. In Appendix 2, we present data and data sources for Sweden and the UK.

## 2. Review of earlier studies

Since the seminal work by Hendry (1984) there has emerged a flora of empirical macro estimates house price functions. Fluctuations in house prices have been analysed in terms of an inverted demand function for houses, conditional on last period's housing stock. In the short term, the housing stock is taken as fixed. In the long term it evolves as new construction, conversion and rehabilitation of the older stock takes place. Tobins (1969)  $q$  investment theory is often adopted in order to model the long-term changes in the housing stock.

House prices are commonly derived as a reduced form from separate housing demand and supply equations. The UK studies in this category are those by Mayes (1979), Nellis and Longbottom (1981), Bradley (1981), Hendry (1984), Meen (1990), Westway and Pain (1996), Chen and Patel (1996), and finally Muellbauer et al. (1997) and Kapparova and White (2001). The US studies in this tradition are the studies of Malpezzi (1999) and Meese and Wallace (1997). For Asian studies see Tse (1999) and Chen and Patel (1998). Similar ECM models of house prices in other countries are for example, Barot and Takala (1998) and Ahlgren (1999) for Finland.

For details of specifications and estimates from different studies see Meen (1990)<sup>1</sup>. Pain and Westway's derive their house price equation from the marginal rate of substitution condition relating the consumption goods and housing services in an intertemporal optimising model. It should be pointed out that their model differs from previous work since they condition the demand side equation on consumption than income (i.e. consumption is used as a proxy for income).

Jaffee (1994) studies the determinants of Swedish house prices using the stock-flow model. Heiborn (1994), analyses how the quantity of housing demand can be explained by the size of different age cohorts. Her study indicates that there is a positive effect of demographic demand on house prices. Another study on Sweden is by Hort (1997) using a dynamic capital asset market model in which an ECM estimates real house prices as a function of total income, user and construction costs. Barot (2001), models Swedish house prices using a simple demand and supply econometric model and finds similar to Hort that Swedish house prices can be traced back to demand and supply conditions. In addition Barot illustrates that the Swedish model can be used for both short and medium-term forecasting.

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1. Meen (1990) on p. 11 presents results and estimates of Nellis and Longbottom, Bradley, Hendry and finally an autoregressive model.

More recently, the investment debate has focused on the issue of whether Tobin's  $q$  is a sufficient variable in order to explain housing investment. Tax policies and interest rates have been additional variables used to model various "Tobin  $q$ " measures. According to Feldsten (1982), the general failure of "Tobin  $q$ " models has resulted into new challenging approaches. Feldsten makes use of reduced form equations and obtains separate strong influences for both the output (GDP) and capital cost measures (including the tax policies).

### 3. Theoretical considerations

#### 3.1. The long run demand side

A stock-flow model of the real estate sector serves as the theoretical basis<sup>2</sup> for the fundamental determinants of real estate construction and prices. The term stock refers to the outstanding stock of structures, for which demand and supply interact to determine asset prices. The term flow refers to the rate of new construction, which is determined by profit potential as measured by the rate of asset prices to construction costs (Tobin's  $q$ ). This type of stock-flow models in macroeconomics studies of the housing market are motivated by a concern with business cycles and forecasting. The long-run demand for the stock of housing services can be written as:

$$\frac{H^D}{Y} = f\left(\frac{PH}{P}, (R * (1 - M) - \left(\frac{\Delta P}{P}\right)), \frac{WF}{Y}, \frac{DE}{Y}\right) \quad (1)$$

(-)
(-)
(+)
(+)

Where,  $H^D$  denotes the demand for housing services (stock),  $Y$  is disposable income,  $M$  is the marginal tax rate on interest deductions,  $PH / P$  is the real house price,  $PH$  is the nominal house price index and  $P$  is the consumption deflator,  $DE$  is the household debt,  $WF$  is the household financial wealth,  $R * (1 - M) - \Delta P/P$  is the after tax, after inflation, long-run government bond rate and inflation ( $\Delta P/P$ ) is defined as the annual change in  $P$ . Solving (1) for house prices, we get the inverted demand function:

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2. For theoretical derivations see Meen (2001).

$$\frac{PH}{P} = g \left( \frac{H^D}{Y}, (R^*(1-M) - \frac{\Delta P}{P}), \frac{WF}{Y}, \frac{DE}{Y} \right) \quad (2)$$

(-)
(-)
(+)
(+)

The anticipated signs of the partial derivatives are indicated below the equations. The house price function is expressed in ratio form to highlight the long-term features of a steady state. This means that all ratios are constant if numerator and denominator expand at the same constant rate (of growth, inflation)<sup>3</sup>. The long-run relationship to be tested is log linear. In the error correction equation real house prices depend negatively on real interest rates and the housing stock income ratio, and positively on the financial wealth / income ratio and the debt / income ratio. Higher income raises prices by reducing the stock. For example a rise in income first boosts demand and thereby raises prices where stock is initially given. The debt and wealth ratios have a net positive effect. On long run, when real housing prices begin to diverge from their long run relationship, the three ratios with the level of interest rate act in the error correcting mechanisms driving house prices and stock towards equilibrium.

The short-term dynamics on the demand side for Sweden are represented by the following variables: the yearly change in the long term interest rate, the unemployment rate, household debt, rental stock, and the yearly changes in total population. The short-run dynamics on the demand side for the UK are similar with the addition of the yearly changes in disposable income and the inflation rate. The interest rates for the UK are not after tax interest rates.

### 3.2. The long run supply side

Much of the work on the supply side of housing has not paid particular attention to the stock in existing private owner-occupied homes. The macroeconomic literature has usually assumed that the supply in the short-run is perfectly inelastic and all increases in supply come from new construction. The full analysis requires not only the supply side decision, but also the demand side with household preferences. The UK tradition in modelling the supply side is

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3. In the steady state equation (2) all the ratios are constant provided the numerator and denominator for each ratio grows at constant rate. If housing stock, financial wealth, and debt and income all grow at the same rate (g), all ratios including real house price are steady state stable (all relevant variables all grow at an identical rate). The economic justification of a model like (2) is because many economic theories suggest long-run proportionality e.g. the quantity theory of money and life cycle hypothesis. ECM is consistent with static equilibrium. By equilibrium here we mean no inherent tendency to change.

modelling new construction (i.e. housing starts). Contrary to the UK tradition we adapt a slightly different approach. We model the UK housing investment using the same Tobin's  $q$  model as corresponding to Sweden.

Applying Tobin's  $q$  theory to the housing market, construction activity is determined by the profit incentive represented by the ratio of the asset prices of existing structures, to the cost of new construction. Average  $q$  is defined here as an index of market price ( $PH$ ) to the construction price index ( $PB$ ) :

$$q = \frac{PH}{PB}$$

In long-equilibrium, the value of Tobin's  $q$  converges to  $1$ , implying that asset prices converge towards construction costs, but in the short run  $q$  may vary from  $1$ . In equilibrium, investment equals depreciation of the capital stock (if net investment is zero), see Jaffee (1994), or adjusted for a constant growth rate. The augmented Tobin's model of housing investment incorporating the interest rate can be written as:

$$\frac{IH}{H} = h(q, r) \quad (3)$$

(+)

(-)

Where  $IH$  is housing investment and  $r$  the interest rate reflecting the cost of financing investments.  $H$  is the capital stock of housing and it acts as a scalar in (3).

$$\text{In the long-run } H^D = H = H^S \quad (4)$$

On the supply side, i.e. investment rises above its long run relationship (in response to the price deviation), Tobin's  $q$  ( $PH/PB$ ) act as an error correcting mechanism driving housing investment towards equilibrium. The two mechanisms thus interact. A higher interest rate depresses both the supply and demand. The Tobin's  $q$  model treats old and new housing as



perfect substitutes<sup>4</sup>. However in applied work, particularly when using micro data one should correct for the different characteristics of these groups. Equations (2) and (3) are the basic demand and supply equations respectively. Finally, the housing stock evolves over time with investment through the perpetual inventory relation as specified in (5).

$$H^S = IH + (1 - \delta) * H_{[-1]} \quad (5)$$

Where  $H$  is the housing stock in hand and  $\delta$  is the rate of depreciation of the stock ( $H$ ). Equation (2) and (3) are estimated separately and a reduced form can be derived by the identity (4).

#### 4. Data

According to Hendry (1993) there exists a data generating process (DGP), which produces and measures economic data. This data are assumed to be generated by a process of immense generality and complexity. The economist and the econometrician seeks to model the main features of the data generating process in a simplified representation based on the observable data and related to prior economic theory. We for simplification purposes assume that the underlying unknown DGP for the housing market is correctly measured.

The data for both Sweden and the UK are in quarterly frequency and cover the sample period 1970q1–1998q4. The advantages of using quarterly data in contrast to semi-annual and yearly data is the number of observations which provide us with larger number of degrees of freedom to conduct testing and draw inference. The housing demand in international studies is reflected by a range of variables and they are as follows for Sweden: real house prices, real personal disposable income, personal sector financial wealth, household total debt, consumer expenditure deflator, interest rates, the unemployment rate, the total population, user cost and the 1991 year tax reform dummy. For the UK we use the same type of variables with the exception of the number of owner-occupied dwellings instead of housing stock, mortgages outstanding instead of total household debt. Statistics UK does not calculate housing stock using the perpetual inventory relation, as is the case for Sweden. It would have been plausible in order to facilitate a fair comparison to have the housing stock for the UK in pounds.

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4. This assumption implies that one is led to focus on the total supply of housing units at every given point of time.

Analogously for Sweden a time series for outstanding mortgage debt does not exist for the earlier period of the study. It's only recently that Statistics Sweden, in the Financial Accounts 1995-1999 (FM 11 SM 0001) has started publishing this series. The consequences of these weaknesses are that the earlier studies for the UK report income elasticities above unity. To avoid this problem we impose unitary income elasticity for both the countries by estimating the long run part of the demand side in ratio form. The unitary elasticities are tested by adding log income (lagged one year) in the dynamic counterpart to (2). Similarly a high coefficient on outstanding mortgage debt for the UK is estimated for the short-term part of the model. A detailed description of the sources of data is given in Appendix 2.

## 5. Econometric methodology<sup>5</sup>

Error correction models link equations formulated in levels and with those formulated in differences of the original variables. The levels represent the long run while the differences the short-term dynamics. ECM implies testing for integration and cointegration. An important issue in econometrics is the need to integrate short-run dynamics with long-run equilibrium. The analysis of short-run dynamics is often done by first eliminating trends in the variables usually by differencing. Explicit attention is paid in this study to the time series properties of the housing data set to form a meaningful model. Thus unit root and cointegration tests are performed.

### 5.1. Integration

A series, which is, itself non-stationary, but which is stationary after first differencing is defined as been integrated of order one  $I(1)$ . Therefore as a preliminary step to cointegration analysis, the order of integration of the housing model data set is to be tested. Several procedures are available (see Dolado et al. (1990), for a survey). Augmented Dickey-Fuller (ADF) integration test is employed to the log level of the respective variables. Tests for unit roots are performed on the Swedish/UK housing data set employing equation (6) using  $I$  up to 9 lags.

$$\Delta y_t = \alpha + \gamma t + \delta y_{t-1} + \beta \Delta y_{t-1} + \dots + \beta_s \Delta y_{t-s} + \varepsilon_t \quad (6)$$

where  $y_t$  is the relevant time series and  $\varepsilon_t$  is the residual,  $t$  is a linear deterministic time trend and  $s$  is the lag length. One can choose whether to include a constant or constant and trend, and the lag length.

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5. See Alogkouisa and Smith (1991) for details.

The null and the alternative hypothesis are  $H_0: \beta = 1$ , and  $\gamma = 0$  in (6) and  $H_1: |\beta| < 1$ . The results of the ADF test indicate that the variables are stationary after first-differencing. We conclude that all the variables are integrated of order one. The results are presented in Table A1, in Appendix 1.

## [TABLE A1 ]

### 5.2. Co-integration

The primary objective of cointegration analysis is to uncover the long-run relationships between non-stationary variables under consideration. The basic idea of cointegration is that individual economic time series wander considerably, but certain linear combinations of the series do not move too far apart from each other. Economic forces tend to bring them into line, e.g., as hypothesised by some economic theory. Engle and Granger (EG), (1997), developed the theory of cointegration. Economic theory tells us that two variables should be cointegrated, and a statistical test for cointegration is a test for the theory. There is a flora of tests for co-integration. Co-integration results, using the well-known Johansen and Juselius (1990) procedure, are presented in Table A2 and Table A3 for Sweden and Table A4 and Table A5 for the UK in Appendix 1. Both a deterministic trend, constant and four to eight lags are included when carrying out the test. We identify four cointegrating relationships, two for each country representing the demand and supply sides respectively. If there is only one co-integration relationship, it may be easier to interpret it as a long-run relationship. It should be noted that the Johansen method, estimates a VAR model and first determines the number of cointegrating vectors. This approach is in particular a-theoretical. Cointegration is a purely statistical concept and the cointegrating vectors need not have any economic meaning. That is why Johansen (see Johansen (1994)) distinguishes between three concept of identification:

(i) generic identification which is related to a linear statistical model. (ii) empirical identification which is related to the estimated parameter values. (iii) economic identification which is related to the economic interpretability of the estimated coefficients of an empirically identified structure. We follow the (iii) aspect in this study.

The long run on the demand and supply sides are based on equations (2) and (3). The critical values for these tests are found in Johansen and Juselius (1990). The appropriate table depends on the role of the intercept and trend in the model. The VAR test has been carried out

in PCFIML<sup>6</sup>. The existence of cointegrating vectors implies Granger-causality. The causality analysis in Section 8 is an added feature to reconfirm that our stock-flow model is correct.

**[TABLE A2 AND TABLE A3 ]**

**[TABLE A4 AND TABLE A5 ]**

### 5.3. Estimation

As the variables are found to be integrated and cointegrated an error correction model can be formulated. An unrestricted autoregressive distributed lag model (ADL) is finally estimated for the respective countries. This model is then solved numerically for the static long run and reparameterized into ECM form. The ECM here estimates the long-run parameters and the short-run dynamics jointly. The general model on the demand side for both the countries is over-parameterised with lags for both house prices, income, wealth and a broad set explanatory variable (both the nominal and real interest rates, household debt, population, unemployment, inflation rate, financial net wealth, household debt, housing stock, rental stock, seasonal dummies and finally the ECM term). Similarly the general model on the supply side is over-parameterised with lags for investment<sup>7</sup>, Tobins  $q$ , GDP, and interest rates.

We do not estimate Vector Error Correction Model (VECM) because in general, cointegrating vectors are obtained from the reduced form of a VAR system where all the variables are assumed to be jointly endogenous. Consequently, they cannot be interpreted as representing structural equations because, in general, there is no way to go from reduced form back to the structure<sup>8</sup>. However in a multivariate VAR, it could be possible to give the so-called structural interpretation by imposing identifying restrictions on the reduced-form parameters. Nevertheless we do not estimate a VAR. In our single equation framework we do impose the unitary income elasticity restriction from the theory.

The quarterly models are estimated using the fourth difference as it removes much of the seasonality in the time series and also as an aid for interpreting and forecasting short term developments in annual terms. In addition fourth differencing reduces the impact of any level shifts in seasonality (or intercepts) to transient four-quarter blips, and reduces trend shifts to

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6. See Doornik and Hendry (1997).

7. One begins in the general to specific methodology with an over parameterised model. An overparameterized model is defined as a model, which contains more lags than are expected to be necessary. The model is then reduced in scale by a sequence of statistical tests. The final derived model is the specific model.

8. See Rao p.17 (1994).

level shifts<sup>9</sup>. The models are estimated using the fourth difference and can be interpreted in the dependent variable as the yearly change in house prices is explained by the yearly changes in a broad set of variables (representing the short term dynamics) and the variables in log levels representing the long-run variables.

## 6. Presentation of results

### 6.1. The demand side Sweden and UK

To facilitate comparisons of results between the Swedish and the UK dwelling markets, the estimated specific model, equation (2) including the short-run dynamics using the general to specific approach, is reported in Table 1. For both countries the standard error of the regression is approximately 2% and 95% of the total variance in the annual log change in real house prices is accounted for. Equation (2) has a clear economic interpretation. The signs of all of the long and short-run dynamic variables are in agreement with prior theoretical expectations and significant. The empirical significant of lagged behaviour is a feature of estimated house price equations. The inclusion of lags in the house price equation is motivated on the bases of down payment constraints, housing market search, expectation formations and finally construction delays. Interesting to note is that in both Sweden and the UK has the same lag structures that are significant, however there are some marginal differences in the magnitude of the coefficients.

The elasticities for change in the population, the important demographic variable is quite high for both Sweden and the UK. Demographics incorporated in the change in population definitely have a strong effect on house prices both for Sweden and the UK. The short-run elasticity for income and debt for the UK is 0.4 and 0.7. The annual change in mortgage debt has a larger elasticity for UK than Sweden. This is due to the fact that for the UK in contrast to Sweden we use outstanding mortgage debt. In the UK both the level and the change in unemployment are significant. While for Sweden the employment rate is significant only in the short-run dynamics. The unemployment variable reflects uncertainty<sup>10</sup>. Hence the speed of adjustment is approximately two times faster in the UK than Sweden. Earlier UK studies had the adjustment coefficient between 12% - 17% , (see Meen) for the sample period 1964-1987. The signs of the entire long and the short-run dynamics are in agreement with prior theoretical expectations and significant.

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9. See Clements and Hendry (1997).

10. See Barot (1995).

Table 1. The demand side results [1970 – 1998]  $D^4 \ln(\text{PH}/\text{P}) =$ 

<b>Regressors</b>	<b>Coeff.</b>	<b>T-Stat.</b>	<b>Regressors</b>	<b>Coeff.</b>	<b>T-Stat.</b>
<b>Sweden)</b>			<b>(UK)</b>		
Constant	0.25	3.17	Constant	0.57	1.71
<b>Short-run</b>			<b>Short-run</b>		
$D^4 \ln(\text{PH}/\text{P})_{[-1]}$	0.80	10.94	$D^4 \ln(\text{PH}/\text{P})_{[-1]}$	0.78	13.76
$D^4 \ln(\text{PH}/\text{P})_{[-4]}$	-0.45	4.73	$D^4 \ln(\text{PH}/\text{P})_{[-4]}$	-0.30	3.22
$D^4 \ln(\text{PH}/\text{P})_{[-5]}$	0.23	2.53	$D^4 \ln(\text{PH}/\text{P})_{[-5]}$	0.19	2.41
$D^4 \ln(\text{POP})_{[-5]}$	3.63	2.78	$D^4 \ln(\text{POP})_{[-1]}$	6.92	1.82
$D^4 (\text{RG})$	-0.47	3.17	$D^4(\text{RB})$	-0.27	1.79
91TR	-0.02	2.47	$D^4(\ln \text{RY})_{[-1]}$	0.41	3.99
$D^4(\ln \text{E})$	0.47	1.90	$D^4(\ln \text{UNP})$	-0.06	2.86
$D^4(\ln \text{HF})_{[-1]}$	-0.67	3.70	$D^4(\ln \text{HS})_{[-1]}$	-	-
$D^4(\ln \text{DE})$	0.20	2.39	$D^4(\ln \text{RL})$	0.75	6.90
<b>Long-run</b>			<b>Long-run</b>		
$D^4(\ln \text{P})$	-	-	$D^4(\ln \text{P})$	0.87	4.91
$\ln (\text{PH}/\text{P})_{[-4]}$	-0.12	4.18	$\ln (\text{PH}/\text{P})_{[-4]}$	-0.23	6.16
$\ln (\text{H}/\text{Y})_{[-4]}$	-0.30	4.56	$\ln (\text{HS}/\text{RY})_{[-4]}$	-0.30	2.18
$\ln (\text{WF}/\text{Y})_{[-4]}$	0.05	3.14	$\ln (\text{RW}/\text{RY})_{[-4]}$	0.04	2.32
$\ln (\text{DE}/\text{Y})_{[-4]}$	0.19	4.13	$\ln (\text{RL}/\text{RY})_{[-4]}$	0.07	1.82
$\text{RG}_{[-4]}*(1-\text{M})-\ln(\Delta\text{P}/\text{P})$	-0.26	2.13	$\text{RB}_{[-4]} - \ln(\Delta\text{P}/\text{P})$	-0.20	1.95
$\ln(\text{E})_{[-4]}$	-	-	$\ln (\text{UNP})_{[-4]}$	-0.03	1.96
Q2	0.00	0.11	q2	-0.00	0.49
Q3	0.00	0.39	q3	0.00	0.45
Q4	-0.02	1.74	q4	0.00	0.08
$R^2$	0.95		$R^2$	0.97	
R- Bar	0.94		R- Bar	0.97	
Std Err	0.02		Std Err	0.02	
D.W.	2.05		D.W.	2.08	
<b>Diagnostics</b>		<b>Critical Values</b>	<b>Diagnostics</b>		<b>Critical Values</b>
Normality	4.95	5.99	Normality	<b>29.1</b>	5.99
ARCH	2.97	9.49	ARCH	0.56	9.49
RESET	0.81	3.18	RESET	1.27	3.18
LM (1)	0.31	3.84	LM (1)	0.32	0.69
LM (2)	0.28	5.99	LM (2)	2.62	0.93
LM (4)	9.14	9.49	LM (4)	9.00	9.49

**Note:** The operator  $D^j$  stands for a j-period difference, with  $D = D^1$  for simplicity, and  $L(x) = \log(x)$  for short. Thus  $D^j L(x) = \log(x/x-j)$  is a j-period difference in logs. For quarterly data  $j = 4$  in the dependent variable.  $D^4 L(x)$  are the annual rates of change.  $D(D^4(X))$  is the change in an annual rate of change. Normality test is violated for the UK.

As expected the error correction term is negative and significant. The adjustment coefficient for the level of real house prices ( $PH/P$ ) indicates that in case of departure from equilibrium, 12% of the shock is corrected within one year for Sweden and 23% for the UK. Both the changes in the nominal interest rates in the short term and the real interest rate in the long term effect house prices in both the countries. The change in the long interest rate has a semi-elasticity of  $-0.5$  for Sweden and  $-0.3$  for the UK in the short term. The long interest rate has a semi-elasticity of 2.1%, i.e. one percentage point increase in long after tax rate would decrease the real house prices by 2.1% for Sweden while for the UK the long run semi-elasticity for the real building interest is 0.9%.

Wealth effects are triggered by changes in interest rates. The interest rate channel works in the following way. Given some degrees of price stickiness, an increase in nominal interest rates, translate in the real interest rate and the user cost of capital (see Federal Reserve Bank of New York (2002)). Indeed most of the UK studies of house price determinants use nominal and not real interest rates. However we find that both the nominal (in the dynamics) and the real interest rate (in the long-term) works as well for both Sweden and the UK.

Inflation causes owner-occupied housing less affordable i.e. the relative price of housing is rising. We get this effect for the short run for the UK. Since the nominal interest rate enters the house price equation for both the countries, this is also the term for the inflation level. Increased inflation changes the time profile of real mortgage payments. Because expectations of rising inflation increase the nominal rate of interest, higher anticipated inflation raises both the mortgage cost and forgone interest cost of homeowner equity. In this study, however interest rates are used as a proxy for debt amortisation. Sweden has stronger effects from interest rates, financial wealth and debt than the UK. In addition households paying back mortgage debt are directly influenced by changes in nominal interest rates.

The solved long-run estimated equations (2) on the demand side excluding short run dynamics for Sweden and the UK can be written as:

$$\ln \frac{PH}{P} = 2.1 - 2.4 * \ln \frac{H}{Y} + 1.5 * \ln \frac{DE}{Y} - 2.1 * (RG * (1 - M) - \ln \frac{\Delta P}{P}) + 0.4 * \ln \frac{WF}{Y} \quad (7)$$

$$\ln \frac{PH}{P} = 2.5 - 1.3 * \ln \frac{HS}{RY} + 0.3 * \ln \frac{RU}{RY} - 0.9 * (RBSI - \ln \frac{\Delta P}{P}) + 0.2 * \ln \frac{RW}{RY} - 0.13 * \ln UNP \quad (8)$$

The long run elasticity for financial net wealth is  $0.4$  for Sweden and  $0.2$  for the UK. The long run elasticity for household debt is  $1.5$  for Sweden and  $0.3$  for the UK. The differences in the debt elasticities are mainly due to the differences in the utilisation of the household debt series for Sweden respective the UK.

Using gross financial wealth instead of net implies that that we would capture simultaneously the financial assets and liabilities of the households in the estimated coefficients, while when it is decomposed as done in this study, we have two different coefficients for the respective components (net worth and indebtedness). In the household balance sheet, net financial wealth plays an important role in the purchase of new homes, as household has to make a down payment of about 25% percent of the purchase price of owner-occupied homes in Sweden. Usually increases in debt are considered to be an indicator of consumer optimism and strong demand. People buy houses with debt financing to a large extent, which tells us that real house prices and debt could be positively correlated.

On the other hand an increase in indebtedness or a drop in holdings of financial assets would raise the risk of financial distress, thus prompting the consumer to shift his demand away from durables and housing thus reducing house prices. This is the solvency aspect to debt from which we refrain from in this study. In 1991 (91TR), “The Tax reform of the Century” was implemented in Sweden. One of the main goals was to reduce the distortions in housing. The 91TR effected the user costs for owner occupied homes and hence made it more expensive for private homeowners.

The income elasticity of housing demand happens to be one of the most important parameters in housing economics. Table 2 presents some estimates of both income and price elasticities from different UK and Swedish studies. The long-run demand sides have been estimated in ratio forms, which implies unitary income elasticity for both the countries. The unitary elasticities were tested by adding log income (lagged one year) in the dynamic counterpart to (2) in estimation and testing whether its elasticity is zero. We find no compelling reason either in the Swedish and UK literature to reject the unitary income elasticities. For the sake of comparisons we present earlier UK and Swedish studies and their estimates of income and price elasticities where no restrictions have been imposed. In the UK literature estimates are in the range of  $1.0$  to  $1.4$ . An elasticity in excess of unity is bound to lead to problems in macro models when the consumption function is related to housing wealth and house prices.



Hence any shock to house prices can generate large explosive multiplier effects to aggregate consumption.

**Table 2. Income and Price elasticities of housing demand**

UK	Income	Price	Sweden	Income	Price
Meen (1996)	1.4	-0.4	Englund	0.4	-0.3-0.4
Muellbauer&Murphy	1.3	-0.5	Hort	1.0	
Westway & Pain	2.0	-0.5	Barot & Yang	1.0	-0.50
Barot & Yang	1.0	-0.8			

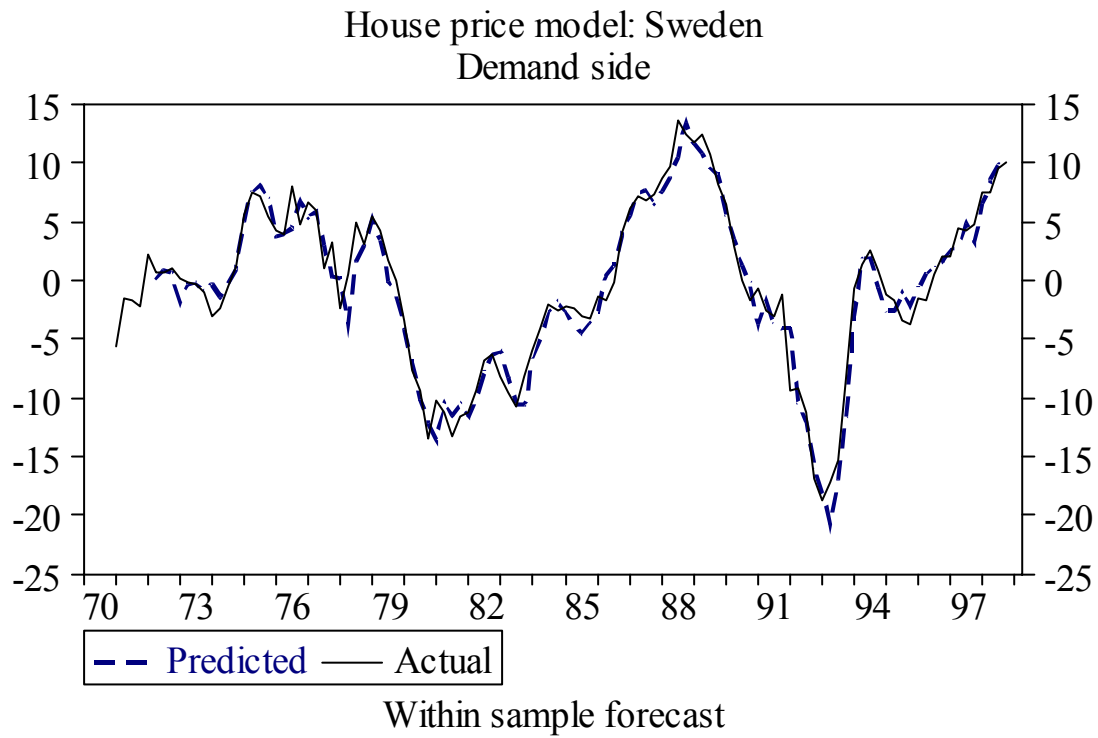
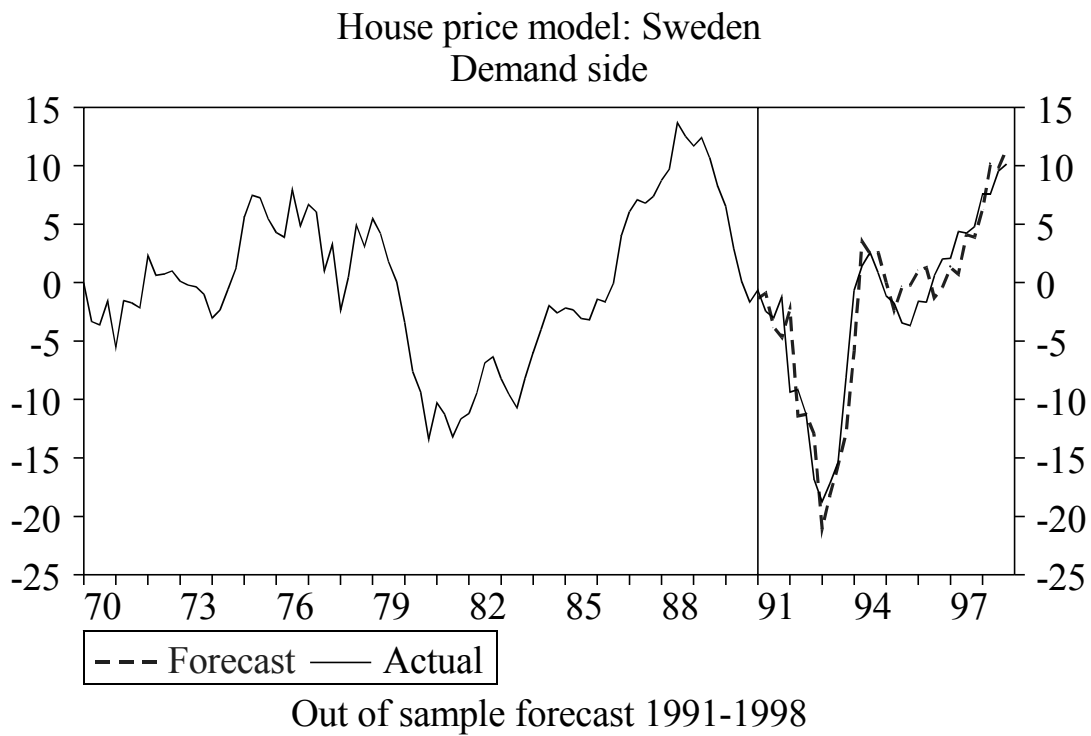
**Note:** See Meen (1998). Solving the long-run steady state equations for the respective countries in anti-logs one gets for both Sweden and UK unitary income elasticities.

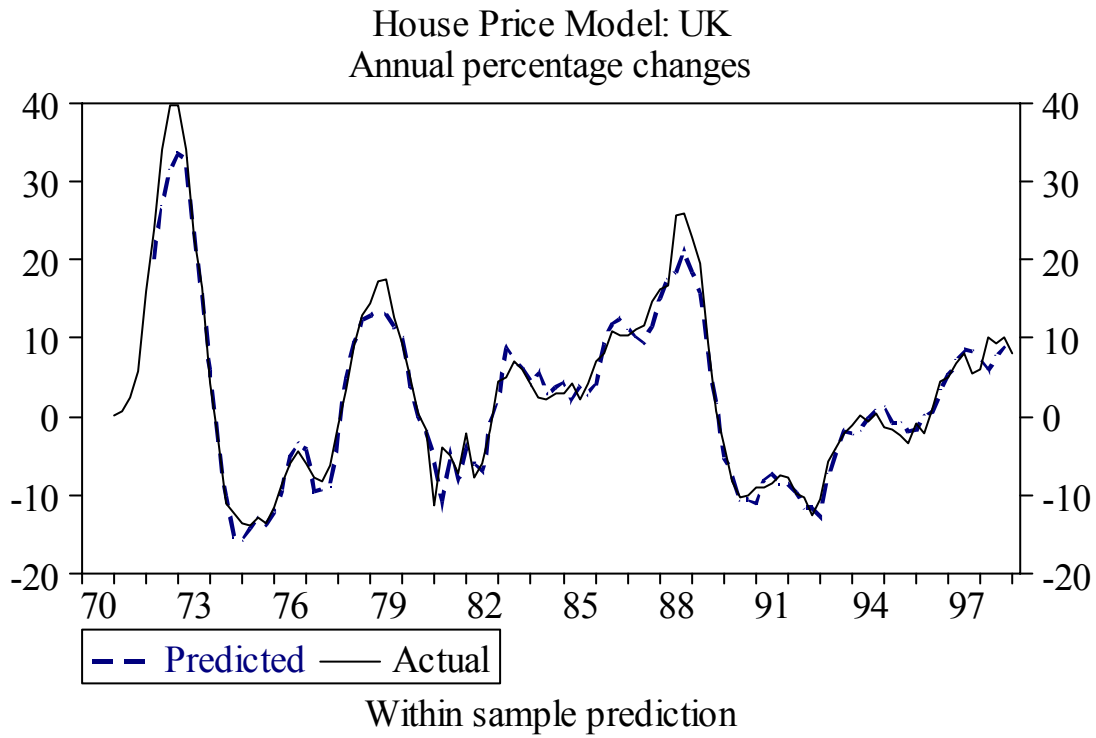
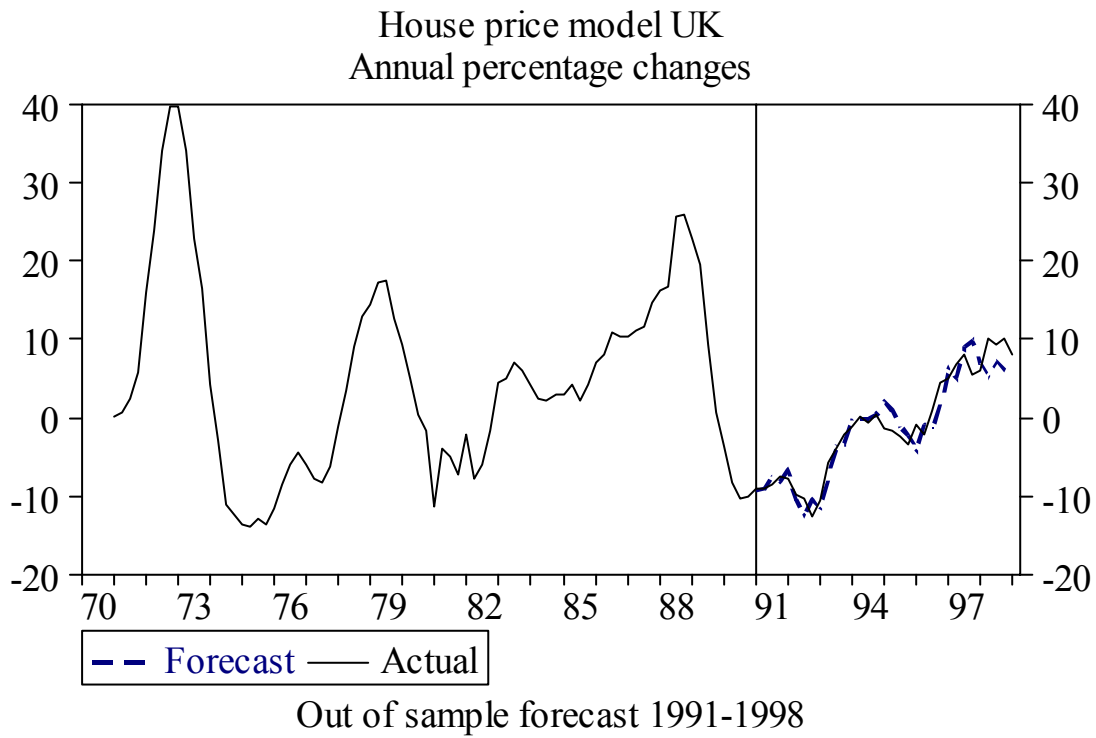
Hence we find justification of imposing unitary income elasticities from the underlying theory. Given that the ratios of the long-term part of the model are constant, the housing stock is proportional to income. The long-run steady state equations (7) and (8) can be solved out for the stock income ratios in anti-logs. This gives us a value of *0.05* for Sweden and *0.19* for the UK. In logs it comes down to approximately *1.0* and *1.2* for Sweden respectively the UK.

The model tracks the size and the direction of changes in house prices for owner-occupied homes for both Sweden and the UK fairly well (see Figure 1 and Figure 3). The out of sample forecasts for the period 1991-1998 are impressive indicating that house prices are predictable (see Figure 2 and Figure 4). The model picks up quite well the turning points, recessions and recoveries in Sweden and UK for the sample period.

## 6.2. The supply side Sweden and the UK

The estimated dynamic housing investment function for Sweden and the corresponding one for the UK, where we model housing investment as a function of Tobin's *q* using a dynamic version of equation (3) are reported in Table 3. The standard errors of the regression are 8% for Sweden and 9% for the UK, and 82% of the total variance in the annual change in housing investment for Sweden and 54% for the UK is accounted for, thus indicating poorer fit than for the house price equations, though this may be characteristic for supply sides, i.e. investment functions. The signs of most of the short run dynamics and long run are in agreement with prior theoretical expectations. The short run *q* for the UK has an elasticity of *0.4* which is stronger than for Sweden. The nominal interest rate matters for the supply side for the UK but not for Sweden. The interest rate reflects the cost of borrowing in order to

**Figure 1. Sweden: Demand side****Figure 2. Sweden: Demand side**

**Figure 3. UK: Demand side****Figure 4. UK : Demand side**

**Table 3. The supply side results [1970 – 1998]  $D^4 \ln(IH) =$** 

<b>Regressors (Sweden)</b>	<b>Coeff.</b>	<b>T-Stat.</b>	<b>Regressors (UK)</b>	<b>Coeff.</b>	<b>T-Stat.</b>
Constant	0.21	0.40	Constant	4.11	5.98
<b>Short-run</b>			<b>Short-run</b>		
$D^4 \ln(IH)_{[-1]}$	0.86	14.59	$D^4 \ln(IH)_{[-1]}$	0.32	3.97
$D^4 \ln(IH)_{[-4]}$	-0.36	3.53	$D^4 \ln(IH)_{[-2]}$		
$D^4 \ln(IH)_{[-5]}$	0.39	4.09	$D^4 \ln(IH)_{[-3]}$	0.13	1.63
$D^4(\ln(PH/PB))$	0.16	1.21	$D^4 \ln(PH/BH)$	0.35	3.14
$D^4 \ln(GDP)$	0.73	1.73	$D^4 \ln(GDP)$	0.04	1.66
<b>Long-run</b>			<b>Long-run</b>		
$\ln(IH/H)_{[-4]}$	-0.06	2.43	$\ln(IH)_{[-4]}$	-0.48	5.83
$\ln(PH/PB)_{[-4]}$	0.16	1.91	$\ln(PH/BH)_{[-4]}$	0.22	3.61
			$AMIH_{[-4]}$	-1.28	4.33
Q2	-0.01	0.64	q2	0.04	1.55
Q3	-0.02	0.82	q3	0.04	1.71
Q4	-0.00	0.41	q4	0.05	2.09
$R^2$	0.82		$R^2$	0.54	
R- Bar	0.80		R- Bar	0.50	
Std Err	0.08		Std Err	0.09	
D.W.	2.03		D.W.	1.97	
<b>Diagnostics</b>		<b>Critical values</b>	<b>Diagnostics</b>		<b>Critical values</b>
Normality	3.68	5.99	Normality	0.43	5.99
ARCH	1.06	9.49	ARCH	0.94	9.49
RESET	1.98	3.18	RESET	0.90	3.18
LM (1)	0.47	3.84	LM (1)	2.20	3.84
LM (2)	0.53	5.99	LM (2)	4.88	5.99
LM (3)	3.02	9.49	LM (4)	5.86	9.49

**Note:** From the diagnostic statistics, the residual of the estimated equation appears to be white noise. The Breusch (1978) and Godfrey (1978) Lagrange multiplier test statistic for autocorrelation has been applied. ARCH is Engle (1982) test for heteroscedasticity. Normality refers to the Jarque and Bera (1980) test for normality of residuals, with a correction of degrees of freedom. RESET is Ramsey's (1969) test for correct specification. Standard deviations for the change in investment are 17% for Sweden and 12% for the UK.

finance housing investment. One percentage point increase in the London clearing banks base rate would decrease housing investment by 2.7 percentage points.

The solved long-run equation on the supply side excluding the short run dynamics for Sweden and the UK can be written as:

$$\ln \frac{IH}{H} = 3.7 + 2.8 * \ln \frac{PH}{PB} \quad (9)$$

$$\ln IH = 8.8 + 0.5 * \ln \frac{PH}{BH} - 2.7 * AMIH \quad (10)$$

The Tobins q is significant for the UK on the short run but not for Sweden while for the long run it's significant for both the countries. The solved out long run Tobin's q model for Sweden is more plausible with respect to its steady state properties. The error correction coefficient and the speed of adjustment for Sweden is *0.06* while for the UK its *0.48* which is eight times faster. The interpretation is that when housing investment begins to diverge from its long-run equilibrium value Tobins q will error correct it i.e. (6% - 48% of the error is corrected within a year) for Sweden respectively UK. The speed of adjustment is much faster for the UK mainly due to slightly different specification for the long-run part of the model. The UK model is however richer as we get significant effects from the interest rate, which is the cost of financing the investment.

With respect to residual diagnostics both the Swedish and the UK model clear all the residual based tests. However the steady state properties of supply side for the UK are not plausible as investment in the long run should grow proportionally to the housing stock (at constant growth rates).

The evolution of the q indicator for the majority of the OECD countries indicates that there is a fairly close contemporaneous association between movements in the price / cost ratio and private residential investment. The results from OECD study by Girouard and Blöndal (2001) indicates that over the period of their study 1980 – 1999, the correlation coefficient is above *0.5*.

On the supply side of the market, adjustment of the stock of dwellings is also generally held to be quite slow. Over the very short run, since the level of housing completion is small relative to the total stock of housing, it is argued that the supply of housing is completely fixed. Against this, over the medium to long run, building firms in the construction industry will make their production decision based on the expected profitability of house building activity. Over the medium to long run, therefore, the supply of dwellings is thought to be quite, although not perfectly elastic.

For housing investment functions which are hard to econometrically model, the Swedish model in particular in contrast to the UK tracks the size and the direction of changes in housing investment exceptionally well (see Figure 5 and Figure 6 for Sweden). However both the within sample prediction and out of sample forecast are poorer for the UK (see Figure 7 and Figure 8).

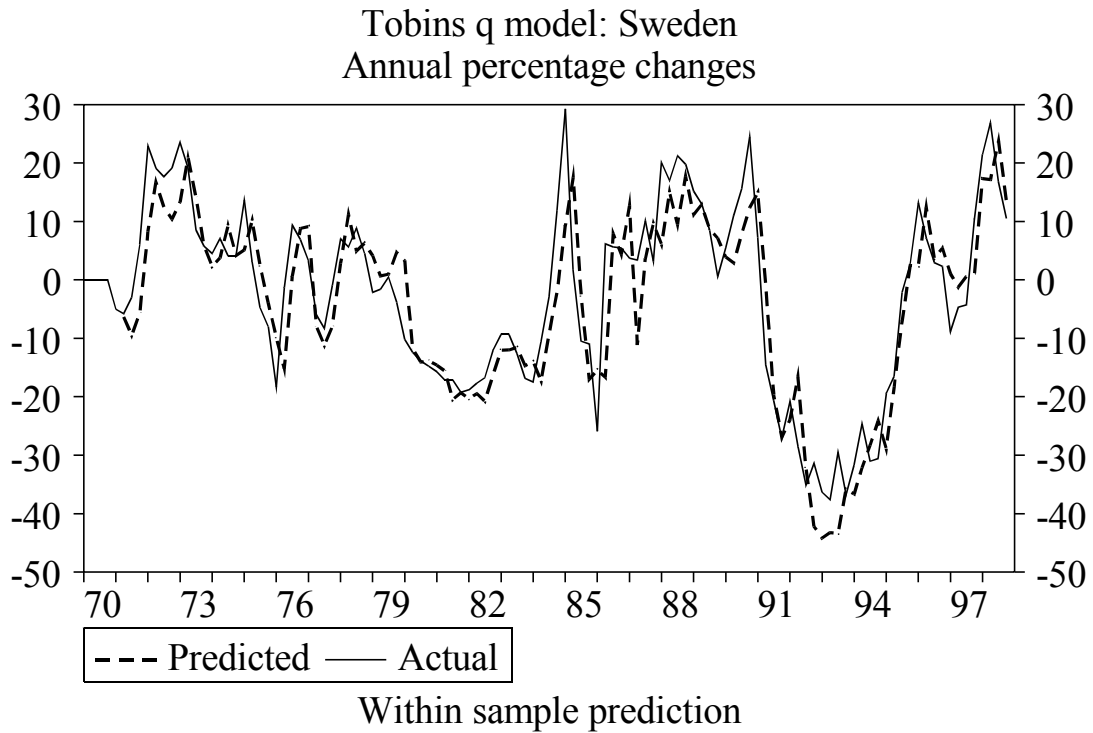
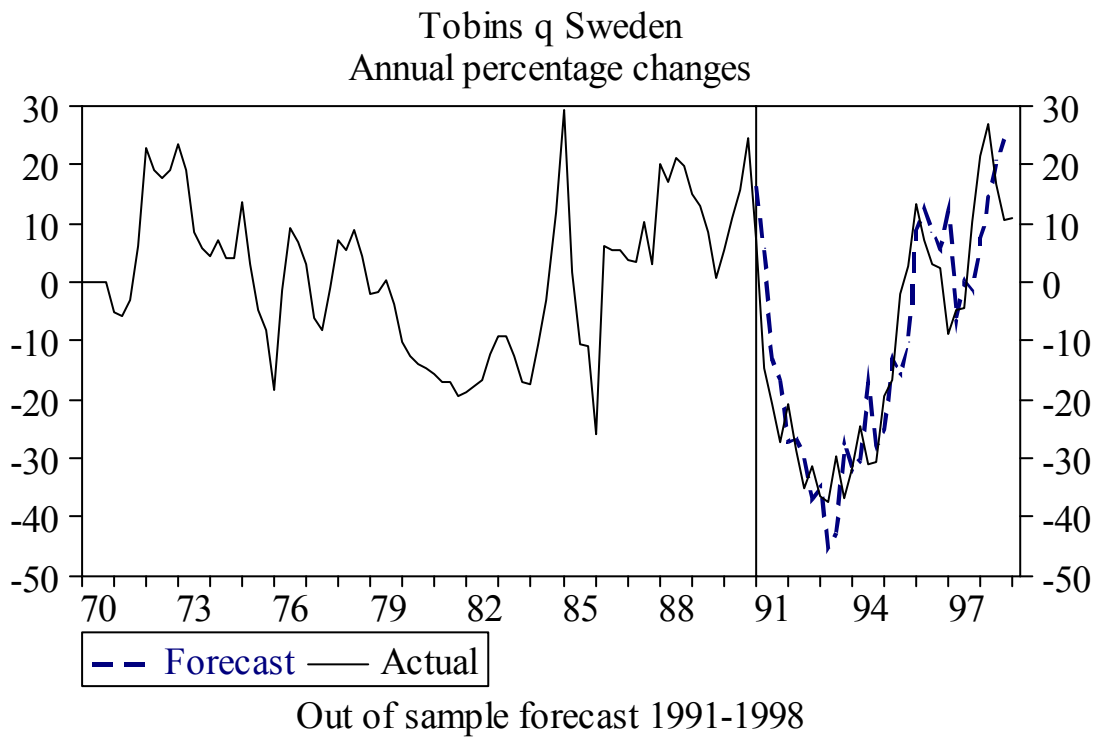
## 7. Forecasting ability

The Swedish and the UK models will be evaluated from a forecasting point of view. In order to do this in a realistic manner, we perform ex-ante (out of sample) forecasts for the period 1991-1998 using data for 1970-1990. There are several commonly used measures of forecasting accuracy: the Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Theil's Inequality Coefficient (Theil U index), the Mean Absolute Proportional Error (MAPE), and finally the Mean Percentage Error (MPE). Our basic econometric models the demand and supply sides for the respective countries, and a naive autoregressive (AR) model will be evaluated with respect with to some of this forecasting statistics. The *naive autoregressive* models has been estimated with the following specifications for the demand respective the supply sides:

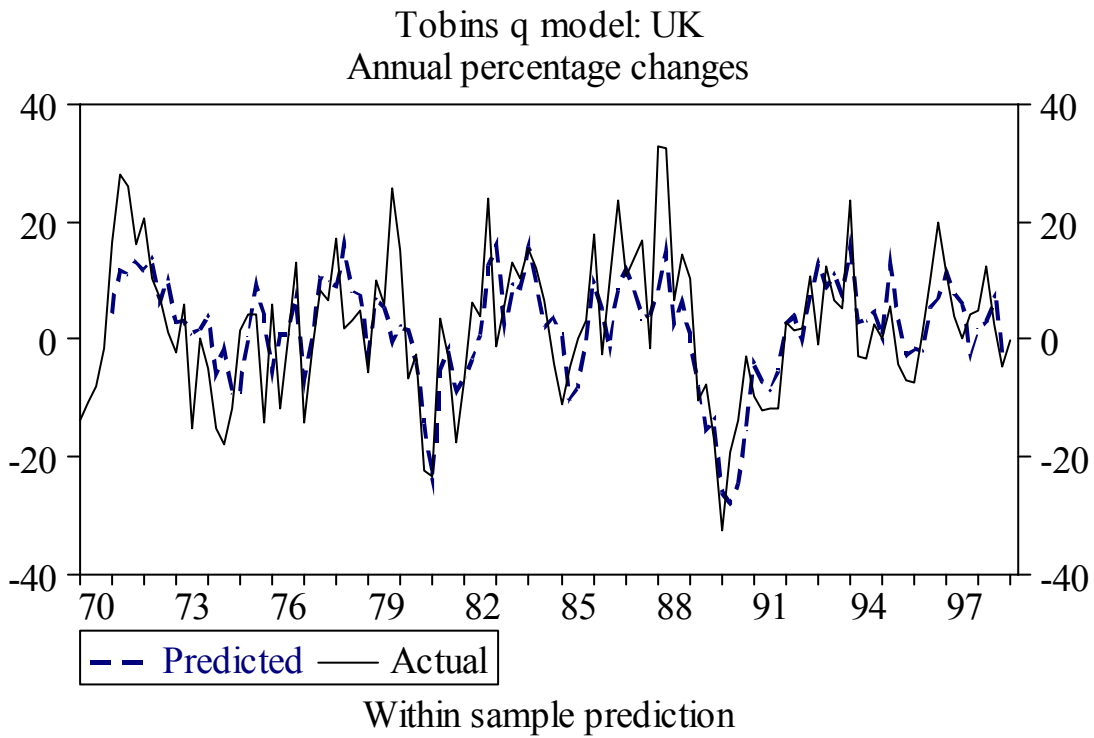
$$D^4 \ln\left(\frac{PH}{P}\right) = g\left(D^4 \ln\left(\frac{PH}{P}\right)_{[-1]}, D^4 \ln\left(\frac{PH}{P}\right)_{[-2]}, DREG, TREND, 91TR\right) \quad (11)$$

$$D^4 \ln(IH) = g\left(D^4 \ln(IH)_{[-1]}, D^4 \ln(IH)_{[-2]}, DREG, TREND, 91TR\right) \quad (12)$$

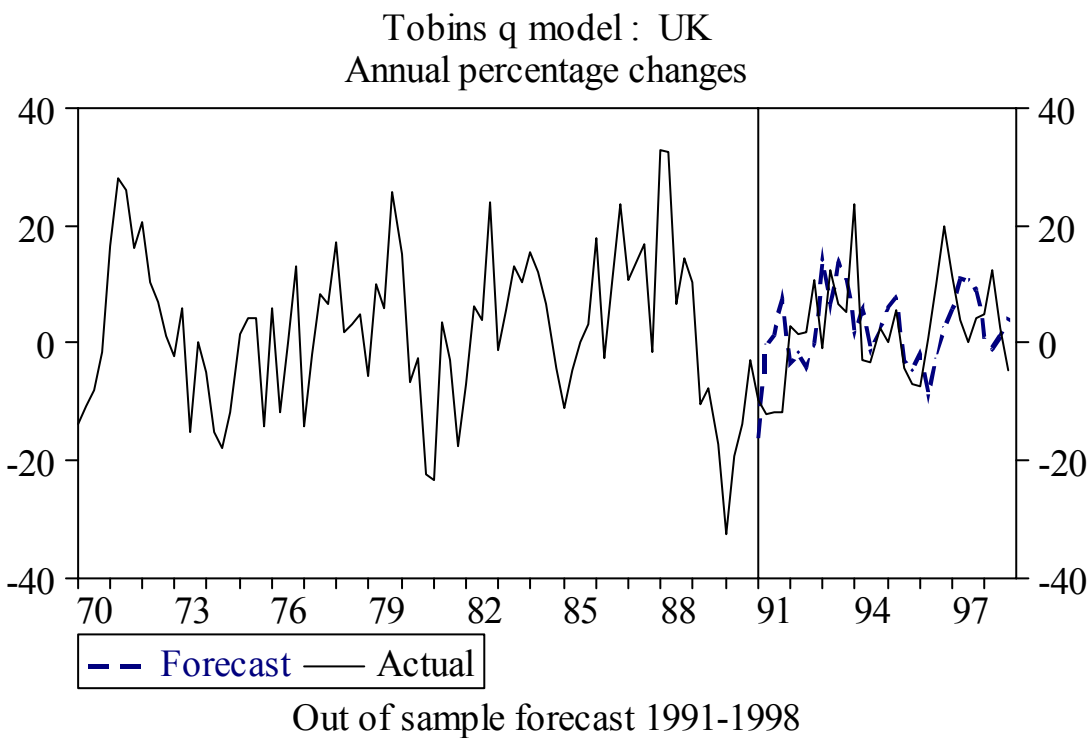
where  $f$  and  $g$  are linear in its arguments.  $D^4 \ln(PH/P)$  is the annual change in real house prices.

**Figure 5. Sweden: Supply side****Figure 6. Sweden: Supply side**

**Figure 7. UK: Supply side**



**Figure 8. UK: Supply side**





Results on the out of sample forecasting accuracy are presented in Table 4 and Table 5. We conclude that for both Sweden and the UK structural models forecasting accuracy is better than the naive auto-regressive counterparts.

**Table 4. Forecasting accuracy housing prices (1991 - 1998)**

Measures	SW	SWN	UK	UKN
MAE %	1.41	1.62	0.46	2.20
RMSE %	1.63	1.80	0.66	2.50
R <sup>2</sup>	0.95	0.94	0.94	0.85

**Note:** SWN and UKN denote the naive models for Sweden and UK.  
R<sup>2</sup> is forming the realisation regression of the actual on the forecast.

**Table 5. Forecasting accuracy housing investment (1991 - 1998)**

Measures	SW	SWN	UK	UKN
MAE %	4.60	6.30	3.02	3.95
RMSE %	6.40	7.90	4.00	5.70
R <sup>2</sup>	0.91	0.88	0.47	0.33

**Note:** SWN and UKN denote the naive models for Sweden and UK.  
R<sup>2</sup> is forming the realisation regression of the actuals on the forecast.

## 8. Granger causality

Economic causality must be based on a theory. One reason why economists and econometricians are faced to tie their concept of causality to time is that there are so many two-way causal relationships in economics. For example price “causes” the quantity demanded but the quantity demanded also causes prices. As the stock-flow model has a supply and demand side its interesting to test for causality using the concept of Granger-causality. Granger causality tests are applied to find out in which direction the predictive causation runs.

The relationships between house prices and determinants can be ambiguous at times. There is an on going debate in the housing literature. Theoretically one would expect that the house price determinants are exogenous (independent variables) and therefore are expected to Granger cause house prices. However a possibility exists that there might be a feedback. In order to test for the direction of causality it we make use of the concept of Granger-causality.

A time series  $Y_t$  Granger causes another time series  $X_t$  if present value of  $X$  can be better predicted by using past values of  $Y$  than by not doing so, considering also that other relevant information (including the past values of  $X$ ) are used in either case. The standard Granger-

causality test can be expressed as in equation (13 ) and (14) below without  $\mu_{t-1}$ . But if the variables are cointegrated,  $\mu_{t-1}$  is necessary. Therefore, more specifically,  $X_t$  is said to cause  $Y_t$  provided some  $\beta_i$  in equation (13) is non-zero. Similarly,  $Y_t$  is causing  $X_t$  if some  $\delta_i$  is not zero in equation (14). If both this feed back effects occur, there is a feedback effect present.

$$\Delta Y_t = \theta_y \mu_{t-1} + \sum_{i=1}^n \alpha_i \Delta Y_{t-i} + \sum_{j=1}^n \beta_j \Delta X_{t-j} + \varepsilon_{1t} \quad (13)$$

$$\Delta X_t = \theta_x \mu_{t-1} + \sum_{i=1}^n \delta_i \Delta Y_{t-i} + \sum_{j=1}^n \Phi_j \Delta X_{t-j} + \varepsilon_{2t} \quad (14)$$

Our null hypothesis is that  $\beta_1 = \beta_2 = \beta_3 = 0$ , in (13). Our alternative hypothesis is that  $\beta_1 = \beta_2 = 0$  and  $\beta_3 \neq 0$ .

In the initial stage we test for co-integration between the bi-variate variables. Having found co-integration, we proceed to test for the direction of Granger causality. The hypothesis is tested using a Wald test for linear restrictions. The number of lags used while conducting the test is between 4 to 7. Looking at Table 6 and Table 7, we see that for Sweden income Granger causes house prices, while for the UK we have feedback from house prices to income.

**Table 6. Granger-Causality tests: Sweden**

Dependent Variable			F-test values
$\Delta PH/P$	←	$\Delta INCOME$	F(5,102) = 5.18 P[0.00]**
$\Delta PH/P$	→	$\Delta FINANCIAL$	F(5,100) = 2.89 P[0.02]*
	←	WEALTH	F(5,100) = 3.03 [0.01]*
$\Delta PH/P$	→	$\Delta DEBT$	F(5,100) = 4.37 P[0.00]**
	←		F(5,100) = 2.77 P[0.02]*
$\Delta PH/P$	←	$\Delta REAL INTEREST$	F(4,100) = 5.91 P[0.00]**
	→	RATE	F(5,100) = 4.62 P[0.00]*
$\Delta PH/P$	→	HOUSING STOCK	F(5,100) = 6.43 [0.00]**
$\Delta IH$	←	TOBINS Q	F(5,100) = 2.77 P[0.02]*

**Note:** ← denotes causes in the Granger sense. Arrows in both the directions implies feedback.

The economic intuition is that increase in disposable income implies that the household feels wealthier. This leads to increase in both demands for housing and house prices. House represents an accumulation of wealth to a household that rises with the appreciation of house prices, which results into capital gains. House prices Granger cause income for UK as persistent increases in house prices result into capital gains (if realised). For Sweden house prices cause financial wealth the intuition been increases in house prices increase financial wealth as homeowners feel richer and diversify their financial portfolios. For Sweden and UK financial wealth Granger causes house prices in the sense that one needs an initial down payment in order to buy a house and hence causing house prices.

Both for Sweden and UK house prices Granger cause debt and there is a feedback from debt (simultaneous). Debt is incurred in order to purchase a house. Hence debt leads to increase in both effective demand for housing and prices. The appreciation in prices can facilitate borrowing i.e. house can be used as a collateral. In the UK an overwhelming proportion of the debt of the personal sector is in the form of mortgages (over 80% at the end of 1992).

**Table 7. Granger-Causality tests: UK**

Dependent Variable			F-test value
$\Delta PH/P$	←	$\Delta INCOME$	$F(5,99) = 3.47 P[0.00]**$
	→		$F(5,99) = 6.31 P[0.00]**$
$\Delta PH/P$	←	$\Delta FINANCIAL WEALTH$	
$\Delta PH/P$	←	$\Delta DEBT$	$F(5,99) = 2.47 P[0.04]*$
	→		$F(5,99) = 2.37 P[0.04]*$
$\Delta PH/P$	←	$\Delta REAL INTEREST RATE$	$F(7,93) = 2.37 P[0.03]*$
	→		$F(5,97) = 2.34 [0.04] *$
$\Delta PH/P$		HOUSING STOCK	
$\Delta IH$	←	TOBINS Q	$F(5,97) = 2.55 P[0.03]*$

In both countries the real interest rates Granger cause house prices. The economic intuition is that the real interest rate is generally believed to act most strongly on the consumer durable component of consumer expenditure, via the user cost. According to the stock flow-model its assumed that in the long run demand equals supply. In the short run an unbalance may exist. Shortage of housing would will cause house prices to increase. Excess supply would reduce prices. One would expect that Tobin's q would Granger cause housing investment. Our test results indicate that both for Sweden and the UK Tobins' q Granger causes housing

investment because the construction industry bases its investment decisions on profitability as reflected by the  $q$  index.

## 9. Conclusions

The main objective of this study has been to econometrically model house prices and housing investment in Sweden and the UK using the stock-flow model and compares the similarities and differences with respect to elasticities, estimates and the speed of adjustment coefficient. The results from the ADF tests indicates that all the variables have unit roots i.e. they are integrated of order  $I$   $I(1)$ . Our cointegration results indicate four cointegrating vectors, two for each country, representing the demand and supply sides.

The results on the demand side indicate that the dynamics of lagged house prices are very similar for both the countries with marginal differences in the magnitude of the estimated coefficients. The change in debt has stronger effects for the UK than Sweden. This is due to the fact that mortgage debt for the UK is more sensitive to house prices than total household debt, which includes debt incurred also in order to buy other durable. Both nominal and real interest rates matter for house prices in Sweden and the UK. However the results indicate that Sweden has stronger interest rate effects both on the short and the long run. In the long-run part of the model the wealth, debt and interest rate effects are stronger for Sweden than the UK. Using household debt as a proxy for mortgage debt implies five times higher elasticities on the debt income ratio compared to UK. The ECM adjustment coefficient for the level of real house prices is indicates that in case of departure from equilibrium, 12% of the shock is corrected within one year for Sweden and 23% for the UK. However it must be pointed out that in ECM, owners of occupied homes are allowed to make mistakes in the short-run which will be corrected in the long-run.

Using gross financial wealth instead of net implies that that we would capture simultaneously the financial assets and liabilities of the households in the estimated coefficients, while when it is decomposed as done in this study, we have two different coefficients for the respective components (net worth and indebtedness). In the household balance sheet, net financial wealth plays an important role in the purchase of new homes, as household has to make a down payment of about 25% percent of the purchase price in Sweden. Usually, increases in debt are considered to be an indicator of consumer optimism and strong demand. People buy houses with debt financing to a large extent, which tells us that real house prices and debt could be positively correlated.

On the other hand, an increase in indebtedness or a drop in holdings of financial assets would raise the risk of financial distress, thus prompting the consumer to shift his demand away from durables and housing thus reducing house prices. Increased inflation changes the time profile of real mortgage payments. Because expectations of rising inflation increase the nominal rate of interest, higher anticipated inflation raises both the mortgage cost and forgone interest cost of homeowner equity. In this study, interest rates are used as a proxy for debt amortisation.

Scrutinising the supply side with almost identical specification for both the countries we find that the Tobins  $q$  variable are significant for both the countries. The Swedish data fits the Tobins  $q$  model better than the UK data. In addition the Swedish supply side has a much more plausible steady state specification and interpretation than the UK. Usually the steady state is defined in ratios and grows at constant growth rates. We have had problems of estimating the steady state in ratio form for the UK. For the UK supply side  $q$  is significant both in the short- and long run. While for Sweden the  $q$  is only significant in the long run. The out of sample forecast is less accurate for the UK supply side, which is mainly due to a wrong specification of the model. However the UK is richer as it includes the interest rate reflecting the cost of financing housing investment. The speed of adjustment on the supply side for Sweden is 6% while it is 48% for the UK. This vast difference may be due to the wrong specification of the supply side for the UK. The forecasting evaluation indicates that both the Swedish and the UK models are more accurate than their naive auto-regressive counterparts with respect to MAE and RMSE.

House prices are commonly derived from an estimated reduced form function founded on the integration of separate housing demand and supply equations. The model has deliberately been kept as simple as possible in order to highlight its salient features of demand and supply. The strategy applied is Hendry's general to specific modelling, applying a sequential testing procedure to error correction dynamics. The fit of the separate demand and supply sides for both Sweden and UK tracks the actual developments in the respective variables well and illustrates how accurate a theoretical model corresponds to statistical data (with the exception of the UK supply side). However it should be noted, that no matter what methods are used to develop economic models, they are unlikely to be taken seriously until they can be shown to be congruent with the available information and in particular with the empirical observations (see Mizon (1989)). Results with respect to Granger causality tests indicate reasonable results and correspond to the applied stock-flow model applied in this study and the economic intuition underlying the housing theory.

## Appendix 1.

**Table A1: Augmented Dickey Fuller Integration test**

Sweden	Constant	Lags	Constant	Lags	UK	Constant	Lags	Constant	Lags
			Trend					Trend	
Variables					Variables				
ln(PH/P)	-2.75	4	-3.17	4	ln(PH/P)	-2.61	5	-3.31	6
ln(Y)	-1.65	4	-2.30	4	ln(RY)	-1.02	5	-2.00	4
ln(POP)	-2.21	4	-1.86	4	ln(UKPOP)	-2.30	4	-0.78	4
ln(E)	-1.24	8	-2.66	4	ln(UNP)	-0.39	4	-1.82	4
ln(HF)	-0.49	4	-3.44	4	ln(HS)	-1.53	4	-0.77	4
ln(DE)	-2.69	6	-1.84	6	ln(RL)	-0.71	5	-1.69	4
ln(H/Y)	-1.69	8	-0.57	8	ln(HS/RY)	-1.80	5	-1.35	4
ln(WF/Y)	-2.74	4	-2.06	4	ln(RW/RY)	-0.29	2	-2.46	4
ln(DE/Y)	-2.05	8	-2.36	8	ln(RL/RY)	-0.24	3	-1.58	4
RG-ln( $\Delta$ P/P)	-2.09	8	-0.37	8	RB -ln( $\Delta$ P/P)	-1.47	4	-2.37	4
ln(IH)	0.57	8	-1.77	8	ln(IH/H)	-2.79	5	-1.77	4
ln(IH/H)	0.49	9	-1.68	8	ln(RL)	-0.79	4	-1.68	4
ln(PH/PB)	-0.94	4	-0.94	4	ln(P)	-2.30	4	-0.94	6
					ln(PH/HB)	-1.69	4	-0.56	5
RG	-1.05	4	-1.20	4	ln(IH)	-1.50	4	-1.20	5
ln(P)	-2.46	5	-0.61	5	AMIH	-2.67	1	-3.30	4
<b>Critical values</b>	-2.89		-3.45			-2.89		-3.45	

**Note:** A constant, a linear and a quadratic trend can be included while conducting the integration test. The constant (intercept) reflects the possibility that under the alternative of stationarity, the intercept is not zero. A further variation introduces a time trend into the equation to allow the alternative to be trend-stationarity. Maximum number of lags is  $l$  up to 9, which pre-whiten the residual. We had to give longer lags for more persistent variables like unemployment, housing stock, and housing investment. Reported critical values are based on a response surface developed by Mackinnon (1991). The test for integration has been carried out in PCGIVE<sup>11</sup>.

### Cointegration

The Johansen procedure makes use of two test statistics for cointegration. The trace tests the hypotheses that are more at most  $r$  cointegrating vectors. The maximum eigenvalue test tests the hypothesis that there are  $r+1$  co-integrating vectors. The test results are presented in Table A2 and Table A3 for Sweden and Table A4 and Table A5 for the UK.

11. See Doornik and Hendry (1992).

**Table A2: Johnson's Cointegration Test for Sweden Demand Side**

Null Hypothesis	Maximal Eigenvalue test	95% Critical value	Trace test	95% Critical value
$r = 0$	74.7**	33.5	153.1**	68.5
$r \leq 1$	57.69**	27.1	78.31**	47.2
$r \leq 2$	13.53	21	20.62	29.7
$r \leq 3$	4.39	14.1	7.09	15.4
$r \leq 4$	2.69	3.8	2.70	3.8

**Notes:** The critical values are at 5% and 1% significance level. The asterisks \* and \*\* denote significance at 95% and 99% significance level. The order of the VAR is 6. We have included a constant term and seasonals in the VAR. Inclusion of trend gives similar type of results. This yielded one significant cointegrating vectors. The first row of standardised eigenvectors can be interpreted as the long run demand relationship. The co-integration relationship as given below, highlights the important determinants of housing demand for Sweden. This long run in equation (13) has coefficients, which are of higher magnitude than in equation (7)

$$\ln \frac{PH}{P} = 0.9 * \ln \frac{WF}{Y} + 2.8 * \ln \frac{DE}{Y} - 3.6 * \ln \frac{H}{Y} - 1.9 * (RG * (1 - M) - \ln \frac{\Delta P}{P}) \quad (15)$$

**Table A3: Johansen's Cointegration Test for Sweden Supply Side**

Null Hypothesis	Maximal Eigenvalue test	95% Critical value	Trace test	95% Critical value
$r = 0$	75.97**	14.1	76.08**	15.4
$r \leq 1$	0.10	3.8	0.10	3.8

**Notes:** The order of the VAR is 4. We have included a constant term and seasonals in the VAR. This yielded only one significant cointegrating vector. The first row of standardised eigenvectors can be interpreted as the long-run Tobins q relationship. The co-integration relationship as given below, highlights the important determinants of housing investment for Sweden.

$$\ln \frac{IH}{H} = 3.92 * \ln \frac{PH}{PB} \quad (16)$$

Analogous to the demand side we obtain a higher value for Tobin's q compared to equation (9).

**Table A4: Johnson's Cointegration Test for UK Demand Side**

Null Hypothesis	Maximal Eigenvalue test	95% Critical value	Trace test	95% Critical value
$r = 0$	28.48	39.4	115.6**	94.2
$r \leq 1$	23.58	33.5	77.7**	68.5
$r \leq 2$	16.91	27.1	46.4	47.2
$r \leq 3$	10.98	21.0	23.97	29.7
$r \leq 4$	6.64	14.1	9.38	15.4
$r \leq 5$	0.41	3.8	0.55	3.8

**Notes:** The order of the VAR is 4. We have included a constant term and seasonals in the VAR. This yielded one significant cointegrating vectors. The first row of standardised eigenvectors can be interpreted as the long run demand relationship. The co-integration relationship as given below, highlights the important determinants of housing demand for UK.

$$\ln \frac{PH}{P} = 0.3 * \ln \frac{RW}{RY} + 0.9 * \ln \frac{RL}{RY} - 2.5 * \ln \frac{HS}{RY} - 5.4 * (RB - \ln \frac{\Delta P}{P}) - 0.2 * UNP \quad (17)$$

The long run has also larger coefficients than in equation (8).

**Table A5: Johnson's Cointegration Test for UK Supply Side**

Null Hypothesis	Maximal Eigenvalue test	95% Critical value	Trace test	95% Critical value
$r = 0$	38.49**	14.1	38.75**	15.4
$r \leq 1$	0.25	3.8	0.26	3.8

**Notes:** The order of the VAR is 4. We have included a constant term and seasonals in the VAR. This yielded only one unique significant cointegrating vector. The first row of standardised eigenvectors can be interpreted as the long-run Tobin's q relationship. The co-integration relationship as given below, highlights the important determinants of housing investment for UK. The Tobin's q for UK is approaching 1 compared to equation (10).

$$IH = 0.96 * \ln \frac{PH}{BH} \quad (18)$$



## Appendix 2.

### Data and data sources for Sweden.

1) **PH** is the nominal house prices.  $PH$  (1991 = 1) is the weighted mean of (fastighetsprisindex) of primary and leisure homes (fritidshus). The market price index covers only direct ownership including second homes, not indirect ownership, Statistics Sweden.

2) **P** denotes the consumption deflator (1991 = 1), Statistics Sweden.

3) **PH/P** is the real house prices.

4) **Y** is real disposable income, Statistics Sweden.

5) **WF** is the households net financial wealth defined as the sum of notes, coins, bank deposits and the National Saving Scheme (Allemanssparande), bonds and treasury discount notes, private insurance savings, listed and non-listed shares and other assets, minus total direct debt, Financial Accounts, Statistics Sweden.

6) **DE** is the household debt. The annual stock figures for household financial assets and liabilities were from Financial Accounts Sweden, (Financial Accounts 1970-1997). Financial Accounts, Statistics Sweden.

7) **H** is the stock of private homes i.e. the sum of stocks of primary and second homes computed according to the stock method approximately equal to Statistics Swedens gross stock. In the perpetual inventory stock, all construction of so called Small homes including secondary homes are treated as owned by households. Apartments (or flats) are regarded as rental Housing, Statistics Sweden.

8) **R** is the long government interest rate (5 years). Central Bank Sweden.

9) **E** is employment rate (regular / labour force inclusive programs), in thousands. **(1-E)** is the unemployment rate, Labour Force Survey, Statistics Sweden.

10) **IH** is the gross investment in private (small) homes in 1991 prices. Statistics Sweden.

- 11) **PB** is the building cost index in 1991 prices. Statistics Sweden.
- 12) **GDP** is gross domestic product in 1991 prices. Statistics Sweden.
- 13) **91 TR** is the 91 Tax Reform Dummy. It is 0 up to 1990 and 1 after.
- 14) **POP** is the total population of Sweden in millions, Statistics Sweden.
- 15) **DREG** is a Dummy for credit deregulation in Sweden in 1986.
- 16) **HF** is the rental stock.
- 17) **USER COST** for Sweden can be calculated using the formula:  $\text{Usercost} = (1-\mathbf{M}) \cdot \mathbf{R} + \mathbf{TFE}$  — capital gains, where **M** is the marginal tax rate, **R** is the long term interest rate, **TFE** is the property tax rate and finally capital gains is defined as the annual change in house prices.
- 18) **M** is the marginal tax rate

### **Data and data sources for the UK**

- 1) **PH** is the index of mixed-adjusted nominal house prices (1995=100), Department of the Environment.
- 2) **PH/P** is Index of mixed adjusted real house prices , Department of the Environment.
- 3) **RY** is real personal disposable income (£m), (Monthly digest of Statistics) Economic Trends.
- 4) **P** is the consumer expenditure deflator (1995=100), Economic Trends.
- 5) **RL** is the outstanding debt in 1995 prices, Financial statistics.
- 6) **RW** is the financial net wealth, deflated by PC in 1995 prices, Financial statistics.

- 7) **HS** is the number of owner-occupied dwellings, (000s), Housing and Construction statistics.
- 8) **RB** is the real building society interest rate, Bank of England.
- 9) **IH** is the private sector investment in dwellings (£mn)-Source national Statistics, UK Economic Trends.
- 10) **BH** is the building cost index is a factor cost index. The quantity weightings for the index were derived for a house and site works by preparing an approximate bill of quantities in the normal way. The bill items were split down into their labour and material contents using constants given in the Measured Rates section. The house used in the index is a two-storey, three bedrooms, and semi-detached house of traditional construction. As such, it's held to be representative of the majority of houses being constructed. For details see Building Cost Information service of the Royal Institution of Chartered Surveyors (RICS ), 7 April, 1978.
- 11) **UNP** is the unemployment rate in UK, Office for National Statistics.
- 12) **POP** is the total population in UK, Economic Trends.
- 13) **AMIH** is the London clearing banks' base rate, Bank of England.
- 14) **GDP** is the gross domestic product in 1995 prices. Economic Trends.

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