Evaluation of House Prices Models Using an ECM Approach: The Case of the Netherlands

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Abstract

The research question of this paper is whether the Dutch housing market is overvalued or not. This is investigated by using different types of error correction models and by examining the impact of different variables that can explain house price changes in the Netherlands. The current financial crisis confirms the notion that developments in the residential property sector are important for the economy as a whole. For that reason it is important to fully understand the factors that affect the housing market. Therefore we need a long-run model approach that relates house prices to fundamentals. However the model should also be able to detect bubbles in the short run. As a first step, we look at the affordability of house prices and mortgage payments in order to check how well the housing market performs in the short run. In the medium to long-run run, we estimate an error correction model relating prices to fundamentals, using variables like interest rate, labour income, financial assets of households, and household stock. The error correction model tests whether prices tend to revert to some equilibrium price level. We evaluate existing house price models for the Netherlands, which we use as a benchmark for comparison to our improved model. Finally, we try to forecast housing prices based on a few simple economic scenarios.

Keywords: Bubble, Co-integration, Error-Correction Model, Long-run Equilibrium.

1 Introduction

In this paper we examine the short-run and long-run price developments of the Dutch housing market. This subject is also looked upon from the perspective of the current financial crisis, which is a hotly debated topic in the Netherlands and abroad (IMF, Economist, etc.). It can be concluded that not only is economic growth important for the housing market, but also that developments in the real estate sector are important for the economy as a whole. It is then of paramount importance to fully understand the factors that affect the housing market and the house price developments. Some of the questions that we want to answer are as follows. Is, or was, the Dutch housing market overvalued? In which capacity can our model predict the house price developments? How do housing markets react to economic growth and decline? Do prices increase smoothly or unevenly during a period of adjustment to an exogenous shock? Are households financially vulnerable through, for example, too high mortgage debts in comparison to disposable income? We evaluate existing house price models for the Netherlands, which we use as a benchmark for comparison with our improved model. Finally, we try to forecast housing prices based on a few simple economic scenarios.

The outline of the paper is as follows. Section 2 summarizes existing theoretical and empirical literature on the house price models. Sections 3 and 4 present estimations results of the OTB Research Institute and the Netherlands Bureau for Economic Policy Analysis (CPB), respectively, in the period from 1978(1) to 2000(2), based on half-yearly data (OTB) and 1980 to 2007 (CPB), based on yearly data. Section 5 presents improved error-correction model (ECM) estimation results, for an extended sample from 1965 to 2009Q1, including ECM estimation results embedded into the unobserved components modelling approach. Section 6 gives forecasts until 2015 for the three possible economic scenarios: recession, slow, and quick recovery. Section 7 concludes.

2 Literature Overview

The house price models can be divided into two broad groups: demand and supply-and-demand models. In the demand models, the house supply is fixed and house price changes are predominantly a function of demand variables such as housing expenses, disposable income, borrowing capacity of a consumer, etc. These models do not say anything about the impact of new building developments on house prices. In the supply-and-demand models, both demand and supply factors are important. Example of supply factors are the housing stock and new construction.

2.1 Demand Models

In the demand models, the development of the house prices is coupled with the development of the demand in the housing market. In these models, in the short-run, the housing market is treated as a housing stock market (De Vries and Boelhouwer, 2005), particularly in countries where the new building complexes are strongly regulated and undeveloped building land is scarce. New building developments react poorly on demand incentives and supply surplus does not exist. From this point of view, interest rates, disposable income, and borrowing capacity of the consumers are most relevant for the house price developments. In this context house prices can be examined by a simple *affordability model*. An affordability index reflects how attractive it is for a consumer to buy a house or not. If it is attractive for a consumer to buy a house, it may be expected that the demand for owner-occupied homes rises as a result, which makes it likely for prices to rise, and vice versa. Therefore, an important source of information for the housing market is the affordability of the average priced house. In the affordability model, the focus is on the relationship between house prices and a number of demand factors, such as, price/income ratio or mortgage-payments/income ratio. Use of these models should answer the following question: What is the relationship between the house price changes and the ability of a consumer to pay the average mortgage payments from her/his income? Calibration through the affordability model gives a prognosis of the house price growth in the short-run. For an application, see Vos (2002).

2.2 Supply-And-Demand Models

In the long-run (>10 years), the house price growth is examined through a macroeconomic housing model, where both supply and demand factors are considered. Next to the flow variables, like income and consumption, the stock variables are also taken into account, like housing stock, number of households, wealth, etc. In this approach, the effect of supply factors, like the new building developments, on demand factors can be examined (and vice versa). The equilibrium in the market is determined by supply and demand. In the long-run equilibrium, the new building developments are determined through the production costs and the costs of the land use. When prices go up, because of a temporary shortage of houses, the building entrepreneurs will use this opportunity to buy land and build new complexes which could be sold at attractive prices. The supply of these houses will bring the house prices down to a new equilibrium.

An application of this approach is the *stock-flow model* which gives predictions of new construction as well as house prices through time (DiPasquale and Wheaton, 1994). The model is based on the stock-flow theory of highly durable goods. The stock-flow approach holds that in the short run, house prices adjust quickly to equate housing demand to the existing stock of units. By contrast, adjustments to the stock of housing (such as new construction) occur only slowly over time, and often with lags. Such stock adjustments respond to the prices determined by the market's short-run equilibrium. The stock-flow model can be used, for example, to encompass the effects of baby boom and baby bust on the house prices. DiPasquale and Wheaton (1994) show that, in the long-run, demographic factors can reduce the appreciation of the house prices. However, an important result of their model is that in case of price elastic construction in the short run and the rising long run supply schedule for the stock of housing, it is impossible for prices to undergo any sustained decline.

2.3 Error-Correction Model

Both types of housing models (demand and supply-and-demand models) can empirically be represented by the *error-correction model* (ECM). The variables taken into account by this type of models are those which have direct effect on both house demand and supply: long-run interest rate, disposable household income, lagged house prices, housing stock, number of households, wealth and the error-correction term (deviation from the long-run relationship). The error-correction term secures that the house prices are, in the long-run, at their equilibrium level which is determined by economic fundamentals.

3 Results of the Netherlands Bureau for Economic Policy Analysis

The Netherlands Bureau for Policy Analysis (CPB) estimated the long-run model of the development of house prices in the Netherlands (Verbruggen et al., 2005; Kranendonk and Verbruggen, 2008), where they focused on to what extent the fundamentals of the housing market were responsible for the observed movements in house prices. By estimating a long-run co-integration relationship in the period from 1980 to 2007, the authors showed that the index of house prices in the Netherlands responded well to the housing market supply and demand factors and did not suffer from 'substantial overvaluation', as reported in the IMF (2008) World Economic Outlook.

In what follows, we report the analysis done by Kranendonk and Verbruggen (2008), which we use as a benchmark for comparison purposes with own results in Sections 5. Our contributions to the existing estimation results are two-fold. First, we report the estimates of the short-run ECM model, which has not been analysed by Kranendonk and Verbruggen. Second, we extend their sample size to the period from 1965 to 2009Q1 and we present both static and dynamic long-run models for the real house prices using an alternative dataset and a more general model specification.

3.1 Yearly Data from the CPB

Kranendonk and Verbruggen (2008) estimate the long-term co-integrating relation using yearly data in the period from 1980 to 2007, where the real house prices are explained using disposable income, interest rates, other financial assets of households, and total housing stock. Description of variables employed by the CPB is in Table 1. For a more detailed variable description and a particular model specification, we refer the reader to Verbruggen et al. (2005) and Kranendonk and Verbruggen (2008).

Table 1. Variables employed by the CPB

Variable	Description
H	House price index based on average selling prices of private homes from Kadaster
Y	Disposable labour income (aggregate)
I	Long-term interest rate (10-year government securities)
W	Nominal net other financial assets of households (end of year): wealth indication
S	Housing stock (end of the year)
P	Consumer price index

Table 2. Variables employed by the CPB

Variable
$h_t = \ln(H_t / P_t)$
$y_t = \ln(Y_t / P_t)$
$I_t^r = I_t - \nabla P_t$
$w_t = \ln((W_t + W_{t-1}) / 2 / P_t)$
$s_t = \ln((S_t + S_{t-1}) / 2)$
$\nabla P_t = P_t / P_{t-1} - 1$

3.2 The Co-Integrated Error-Correction Model

The long-term co-integrating relationship estimated by Kranendonk and Verbruggen (2008) is given by

$$h_t = \alpha_0 + \alpha_1 y_t + \alpha_2 I_t^r + \alpha_3 w_t + \alpha_4 s_t + \varepsilon_t, \text{ for } t = 1980, \dots, 2007. \tag{3.1}$$

The subscript t denotes time and lower case letter denotes a variable in natural logarithm. Description of variables in this long-term relationship is in Table 2. The graphical representation of variables is shown in Figure 1. Apart from the early eighties, real house prices increased over the analysed period. The remaining variables are upward-trending, except for the real interest rates. The changes in housing stock for the years 2006 and 2007 are relatively high, see also Figure 2.

The estimation of the long-run relation (3.1) assumes that the variables are integrated of order (at most) 1. By applying augmented Dickey-Fuller test, the null hypothesis of a unit root cannot be rejected for all except for the stationary wealth variable w. However, the differenced log real house price series is not stationary, violating the assumptions of co-integration (first order). The t-values are -2.38 and -2.31, including constant and constant and trend, respectively. The corresponding 5% critical values are -3.00 and -3.62. It also holds that the differenced log house size is non-stationary due, perhaps, to incorrect data points for 2006 and 2007. This implies that the standard two step co-integration estimation approach – first applying ordinary least squares to the long term specification (in levels) and using the residuals from the long term model for the short term relation (in first differences) – is not valid in this case.

Nevertheless, we reproduce the ordinary least squares (OLS) estimation results for the long-run relationship as presented in Kranendonk and Verbruggen (2008). Estimation results of this exercise, together with more detailed goodness-of-fit measures are shown in Table 3, identical to those presented by Kranendonk and Verbruggen (2008).

Applying the augmented Dickey-Fuller test on the residuals of Eq. (3.1) reveals that the null hypothesis of no co-integration is not rejected. In other words, there is no evidence for a co-integrating relation. The t-value is -2.47 and the 5% critical value is -4.78. This critical value is derived from MacKinnon (1991). This implies that the standard interpretation of test statistics, like standard errors, p-values, t-values and R^2, is not valid. However, our findings are in contrast with the Johansen test for co-integration that has been applied by Kranendonk and Verbruggen (2008).

The estimation results in Table 3 show that all coefficients have expected sign. The real house price is more than proportional to real income (y): the marginal long-run real income elasticity is 1.5. An increase in the real interest rate of 1% point results in a 6% decrease of real house prices. The marginal long-run elasticity with respect to wealth (w) is 1.6. The long-run elasticity with respect to the housing stock (s) is very high, approximately -3. However, in practice the percentage change in housing stock is small, ranging from 2% in the eighties to less than 1% in recent years. As a result, the effect of new construction on real house prices is relatively small. Finally, the DW statistic is quite low, indicating presence of autocorrelation.

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The residual of the regression can be interpreted as a degree of overvaluation or undervaluation of the actual real houses prices. According to this measure the overvaluation in 2007 was approximately zero, whereas it was +14% in 2004, see graph 6 in Figure 2.

Table 3. Long-run relationship (1980-2007) from Kranendonk and Verbruggen (2008)

Variable	Coefficient	Std. Error	*t*-value
Constant	-6.5986	1.2730	-5.18
y_t	1.5336	0.2653	5.78
I_t^r	-5.9440	1.6900	-3.52
w_t	1.6320	0.4201	3.89
s_t	-2.8298	0.6032	-4.69

Sigma = 0.0703	RSS = 0.1136
R^2 = 0.9705	$F(4,23)$ = 189 (0.0000)
Log-likelihood = 37.3742	DW = 1.11
No. of observations = 28 (1980 – 2007)	No. of parameters = 5
Mean (h_t) = 4.7725	Var (h_t) = 0.1374

Table 4. Short-run ECM variables

Δh_t	=	$h_t - h_{t-1}$
Δy_t^a	=	$0.65\Delta y_t + 0.35\Delta y_{t-1}$
ΔI_t^a	=	$0.5\Delta I_t + 0.5\Delta I_{t-1}$
$\Delta\nabla P_t$	=	$\nabla P_t - \nabla P_{t-1}$
Δs_t	=	$s_t - s_{t-1}$

Table 5. Short-run ECM model using the CPB data in the period 1981-2007

Variable	Coefficient	Std. Error	*t*-value
Δy_t^a	1.4386	0.2225	6.46
ΔI_t^a	-6.3515	1.3530	-4.70
$\Delta\nabla P_t$	1.1015	0.8375	1.32
Δs_t	-2.0639	0.5536	-3.73
d_{2000}	0.1398	0.0358	3.90
ecm_{t-1}	-0.2177	0.1852	-1.18
ecm^+_{t-1}	0.3238	0.2905	1.11

Sigma = 0.0339	RSS = 0.0230
Log-likelihood = 57.1361	DW = 1.42
No. of observations = 27 (1981 - 2007)	No. of parameters = 7
Mean (Δh_t) = 0.0247	Var (Δh_t) = 0.0054

The short-term error-correction relationship estimated by Verbruggen et al. (2005) is given by

$$\Delta h_t = \beta_1 \Delta y_t^a + \beta_2 \Delta I_t^a + \beta_3 \Delta\nabla P_t + \beta_4 \Delta s_t + \beta_5 d_{2000} + \beta_6 ecm_{t-1} + \beta_7 ecm_{t-1}^+ + \varepsilon_t , \tag{3.2}$$

where ecm is the error-correction term (residual from the long-run co-integrating relationship), ecm^{+} is the positive residual, and d_{2000} is a dummy variable, equal to 1 for $t = 2000$, and 0 otherwise. This dummy variable has been included to capture the relatively large price increase in 2000. Other variables employed in the short-run relationship are described in Table 4. Graphical representation of the analysed series is given in Figure 2. Note that variables Δh_t and Δs_t are non-stationary.

This particular specification of the short-term error-correction relationship has been used in the analysis of Verbruggen et al. (2005). They estimate and report this ECM model for the sample from 1980 to 2003. However, the results of the ECM model are not discussed in Kranendonk and Verbruggen (2008), for the sample from 1980 to 2008. We report the missing results using the CPB data in Table 5.

Verbruggen et al. (2005) report that adjustment of the actual price level to the long-term level occurs asymmetrically, such that an undervaluation of the house prices adjusts more quickly to the long-term level than an overvaluation (downward price rigidity). Re-estimating the ECM model on the sample from 1981 to 2007, we do not find that the two error-correction terms are significant. The coefficients for changes in real income, real interest and housing stock have the right sign and magnitude.

It can be concluded that the model employed by the CPB leads to reasonable and interpretable results, although it is formally violating the assumptions of co-integration. From the long-run relation it can be concluded that in 2007 the overvaluation is approximately zero, whereas it was +14% in 2004. Re-estimating the short-term relationship (3.2) for the period 1981–2007 reveals that the estimation results are not stable. They differ from the results from the period 1980 to 2003: the (asymmetric) error terms and the differenced inflation have t-values less than 2. Another weak point of the short-term specification is the somewhat *ad hoc* chosen dummy variable for the year 2000, which picks up the enormous price increase in this year.

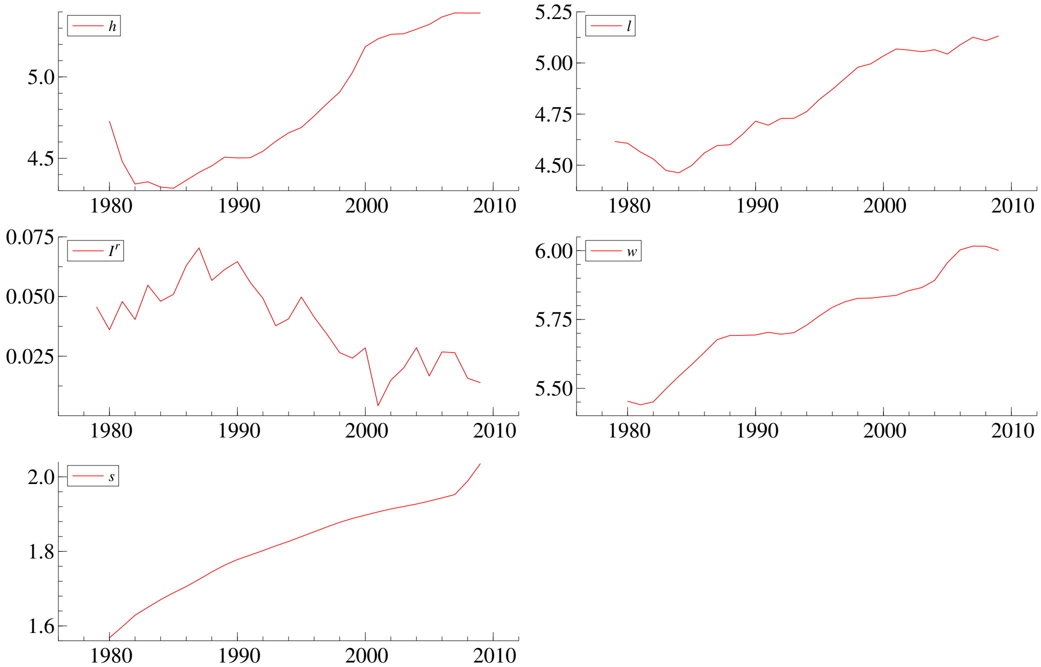

Figure 1. Long-run CPB series

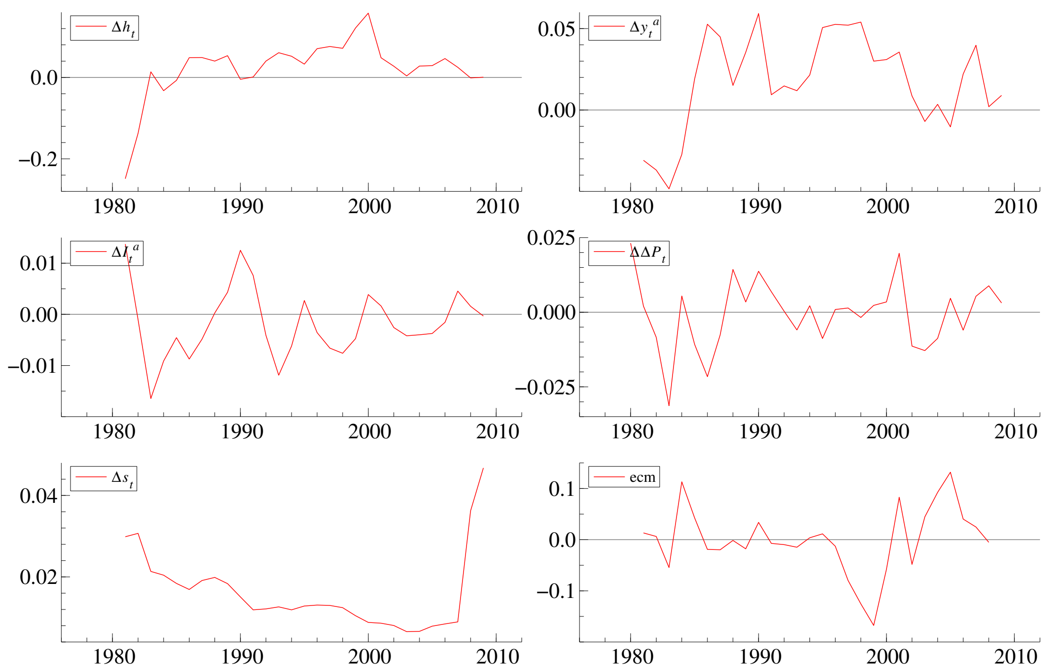

Figure 2. Short-run (first-differenced) CPB series

4 Results of the OTB Research Institute

4.1 Half-Yearly Data from the OTB

The OTB research institute also estimated a house price model for the Netherlands (Boelhouwer et al., 2001), using half-yearly data in the period from 1978 to 2000. It is an ECM model, where short-run price movements are explained by lagged short-run price changes, seasonal effects, changes in the disposable household income, real mortgage interest rate, and an after-tax (mortgage) interest-to-income ratio. Description of the variables employed by the OTB is given in Table 6. The data are provided in Boelhouwer et al. (2001). More detailed variable description (in English) can be found in Boelhouwer et al. (2004) and De Vries and Boelhouwer (2009). A graphical representation of the variables is shown in Figure 3.

All variables are stationary, except for the after tax interest-to-income ratio, which is I(1) (integrated of order 1). The augmented Dickey-Fuller unit root test does not reject the presence of a unit root: for the model including a constant, the t-value and the 5% critical value are -2.16 and -2.93, respectively. However, it can be argued that in the long run it must be stationary as it is bounded between 0 and 1.

4.2 The Restricted Error-Correction Model

The OTB research institute estimates the following model

$$\nabla H_t = \gamma_0 + \gamma_1 \nabla H_{t-1} + \gamma_2 IIR_{t-2} + \gamma_3 d_t + \gamma_4 \nabla Y_t + \gamma_5 \Delta I_t^r + \varepsilon_t , \qquad (4.1)$$

where ∇ represents the percentage change, such that $\nabla x_t = x_t / x_{t-1} - 1$. Boelhouwer et al. (2004) and De Vries and Boelhouwer (2009) define $-\gamma_0 / \gamma_2$ as the constant long-run equilibrium (LRE_t). That is, the regression coefficient of the constant term is divided by the regression coefficient of the interest-to-income ratio (IIR_t). Hence, the difference between the actual interest-to-income ratio (IIR_t) and the constant equilibrium (LRE_t) represents a deviation from the long-run equilibrium term: $ECM_t = IIR_t - LRE_t$. The interpretation is that if the interest-to-income ratio (IIR_t) is higher than the market long-run equilibrium (LRE_t), house prices will adjust, and vice versa. The coefficient γ_2 is expected to lie between -1 and 0, which implies that the equilibrium between housing costs and income is restored in the long term. The lagged dependent variable accounts for speculative and psychological factors, as well as house supply limitations in the short-run. Its coefficient is expected to be less than 1. The seasonal variable corrects for semi-annual effects.

Table 7 presents our OLS re-estimation results of the OTB model specification. The results slightly differ from Boelhouwer et al. (2004). According to the OTB report, the estimated model in Table 7 explains well the house price movements in the Netherlands (R^2= 0.82), using only a few explanatory variables. The long-run equilibrium value is 27.33. All coefficients have the expected sign and magnitude. The lagged dependent variable has a coefficient 0.55 and the effect of interest-to-income ratio is -0.19. A 1% point increase in real interest rate leads to a reduction of the real house price of 2.1% point. A 1% point increase in real income leads to an increase of the real house price of 0.56% point. Prices in the first half-year are 2.7% higher compared to the second half-year.

As mentioned earlier, the interest-to-income ratio series is non-stationary. This implies that the OLS estimation procedure is not valid and that the reported statistics in Table 7 do not have usual interpretation.

Table 6. Variables employed by the OTB

Variable	Description
∇H_t	Percentage change of the real house prices (nominal house prices deflated by the consumer price index (*P*)).
IIR_t	After tax Interest-to-income ratio defined by $H_t I_t (1-F)/Y_t$, where *F*=0.405 is the fiscal advantage.
d_t	Dummy variable that takes into account half-year seasonal effects (equal to 1 in the first half-year, and equal to -1 in the second half-year).
∇Y_t	Percentage change of the real household income.
$\Delta I_t^r = I_t^r - I_{t-1}^r$	Absolute change in the real interest rate, defined by nominal interest minus realized inflation (∇P_t), where *P* is the consumer price index.

Table 7. Estimation results using half-yearly data from the OTB

Variable	Coefficient	Std. Error	*t*-value
Constant	5.2626	1.6240	3.24
∇H_{t-1}	0.5574	0.0863	6.46
IIR_{t-2}	-0.1926	0.0583	-3.30
d_t	1.3522	0.3001	4.51
∇Y_t	0.5657	0.2520	2.24

The long-run equilibrium value is: LRE_t = 5.2626/0.1926 = 27.33

Sigma = 1.9902	RSS = 158.4371
R^2 = 0.8230	$F(5,40)$ = 37.21 (0.0000)
Log-likelihood = -93.7156	DW = 1.71
No. of observations = 46 (1978.1 – 2000.2)	No. of parameters = 6
Mean (∇H_t) = 0.4811	Var (∇H_t) = 19.4641

Comparing the OTB model (4.1) to the CPB model (3.1) – (3.2) reveals a number of differences. First, the CPB model is a co-integrated ECM model, the OTB model is not; all variables in the OTB model are assumed to be stationary. Next, the OTB model does not include private wealth and housing stock as variables determining the long-run equilibrium. The latter choice is motivated by De Vries and Boelhouwer (2009), stating that in the Dutch context house prices are formulated primarily within the existing stock of houses, since the house-building market is strongly regulated and building land is scarce. Another difference with the CPB model is that the OTB model uses household income, whereas the CPB model uses disposable (aggregate) labour income. The OTB model includes the lagged real house price changes as an explanatory variable in contrast to the CPB model. Finally, note that Eq. (4.1) is formulated in percentage changes instead of log differences.

Using, $IIR_t \approx h_t + i_t + \ln(1-F) - y_t - 1$ and $\Delta x_t \approx \nabla x_t$, Eq. (4.1) can be approximated by

$$\Delta h_t = \gamma_1 \Delta h_{t-1} + \gamma_2 (h_{t-2} - (y_{t-2} - i_{t-2}) + \gamma_0^*) + \gamma_3 d_t + \gamma_4 \Delta y_t + \gamma_5 \Delta I_t^r + \varepsilon_t, \tag{4.2}$$

where lower-case letter denotes that a variable is in natural logarithms, the time-invariant parameter $f = \ln(1-F)$ is included in γ_0^* and $(h_t - (y_t - i_t) + \gamma_0^*)$ is the error-correction term. This specification comes close to the CPB model as specified in (3.1) and (3.2). An important difference is that the coefficients of the co-integrating vector in Eq. (4.2) are imposed to be –1 and +1 for y_t and i_t respectively, and in (3.1) they are unrestricted. As a consequence Eq. (4.1) can be interpreted as a restricted version of error correction models provided by, among others, Abraham and Hendershot (1996), Malpezzi (1999), Hort (1998), Meen (2002), and Gallin (2006). In all these models the coefficients for the variables real income and interest variables (user costs) are unrestricted.

The non-stationarity of the interest-to-income ratio series suggests that the null hypothesis of no co-integration in the restricted model (4.2) can not be rejected in favour of an unrestricted version of (3.1).

It can be concluded that the model employed by the OTB leads to reasonable and interpretable results, although it is formally violating the assumptions of a linear regression. The model can easily be generalized by relaxing the implicit restrictions in the error-correction term in Eq. (4.2), possibly leading to a co-integrated relation. Compared to the CPB model, the OTB model incorporates the significant lagged real house price change variable.

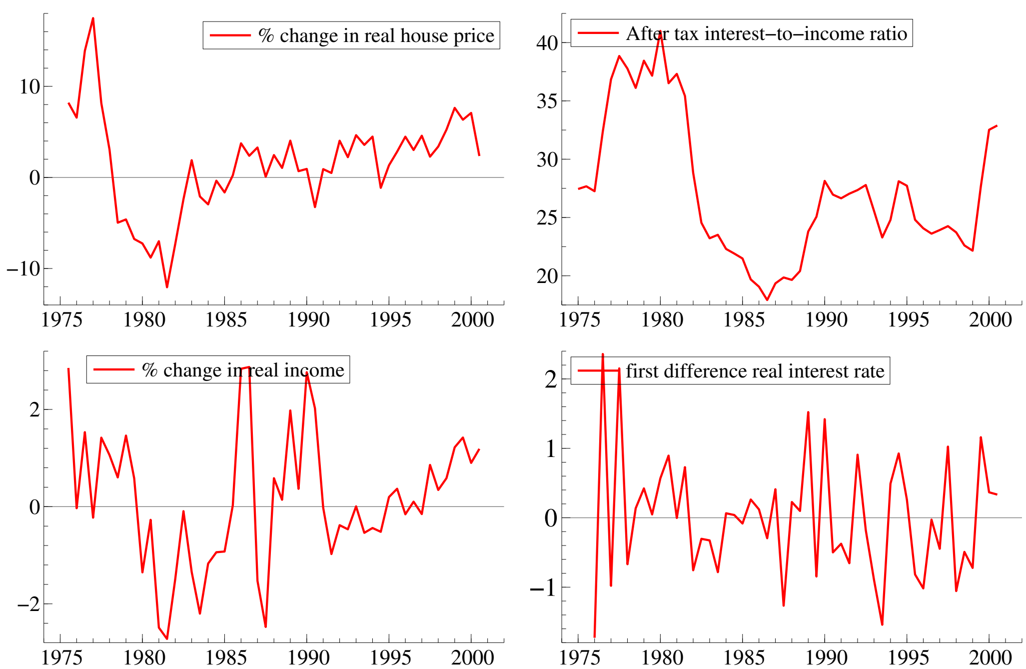

Figure 3. OTB series

5 Unobserved Component ECM Using Extended Sample

5.1 Extended Sample from 1965 to 2009Q1

In this section we use an extended sample (1965–2009Q1), at a yearly frequency level, to estimate different versions of an ECM model. Table 8 provides the available variables for the extended sample period. Definitions and sources are provided in Appendix A. At a later stage, we wish to extend the analysis by including supply side variables like housing stock, construction costs, and number of households.

Table 8. Variable Description

Variable	Description
h_t	Real log house price
y_t	Log real modal labour income per employee
IM_t	Mortgage interest rate minus inflation (not in logs)

Figure 4 presents the analysed series in the period from 1965 to 2009Q1. We can see that real house prices increased until 1980s, when they experienced a sharp fall. From mid-1980s until early 2000s, the real house prices exhibited a sharp increase. The most recent period, the late 2000s, which coincides with the global financial crisis, witnesses a decline in the real house prices.

The nominal mortgage interest rate had a peak in 1981 (12.55%). It gradually reduces to approximately 5% in 2008. In the sixties and seventies the inflation was relatively high, 10.2% in 1975. In 1987 the inflation was –0.5%. The mean inflation rate over the whole period is 3.5%. In recent years the inflation is 1 to 2% below this average.

The house price-to-income ratio shows almost the same pattern as the real house price figures. It only significantly differs in the first period from 1965 to 1975. The average house price-to-income ratio is 4.19. Its maximum was in 2007, where it was 8.12. Its minimum value is 3.32 in 1985. In the first quarter of 2009 the rate reduces to 6.8, far above the average value.

The after tax interest-to-income ratio is somewhat more stable than the price-to-income ratio, it varies from 14% in 1965 to 31% in 1980, using a marginal income tax rate of 40.5%. The average ratio is 20.3%. The 2008 and 2009Q1 rates are 24.0% and 19.5% respectively. From the perspective of the interest-to-income ratio it can be concluded that houses were 18% overvalued in 2008 compared to the long-run average. For the first quarter of 2009 it holds that houses are 4% undervalued.

From the augmented Dickey-Fuller tests it can be concluded, using 5% critical values, that the real log house price and real interest series are integrated of order 1 and that the log real modal income is stationary.

In subsection 5.2 we first estimate a standard ECM model based on the extended sample and the variables provided in Table 8, including a linear trend in the long-run relation. In subsection 5.3 we formulate and estimate an ECM models embedded into the unobserved components modelling approach. In this model the linear trend is replaced by a random walk model. Finally, subsection 5.4 compares both models.

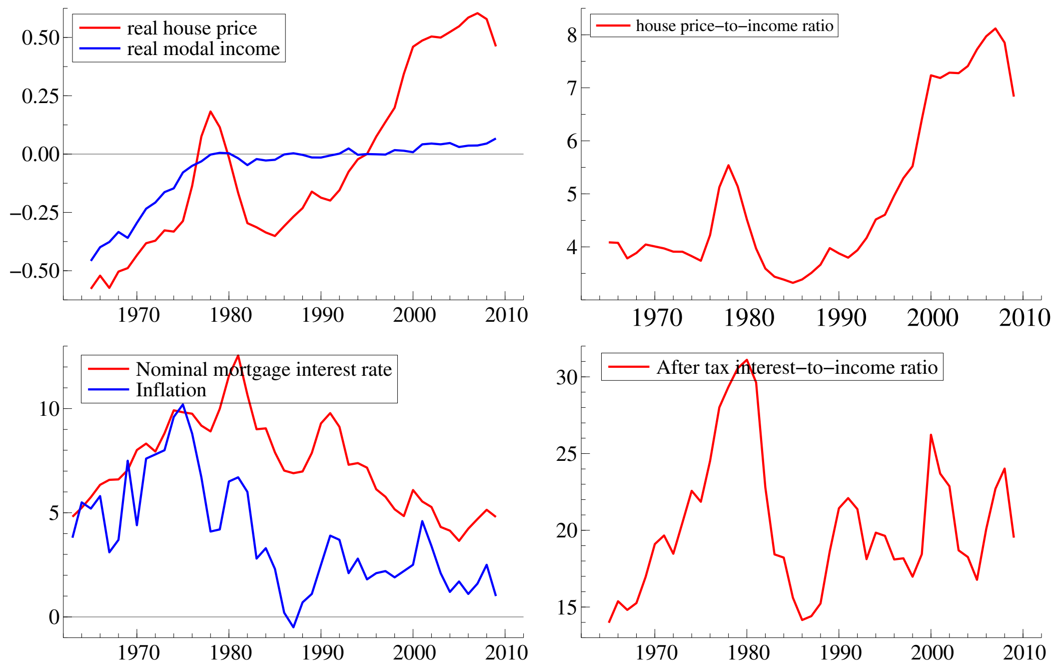

Figure 4. Analysed series in the period 1965 – 2009Q1

5.2 Error-Correction Model with a Linear Trend

5.2.1 Dynamic Model Specification

We use general-to-specific modelling approach to come to the following dynamic model, with two lags of dependent variable h_t and exogenous explanatory variables x_t, provided by

$$h_t = \alpha_1 h_{t-1} + h_2 y_{t-2} + \sum_{i=1}^{k} \beta_{i0} x_{it} + \sum_{i=1}^{k} \beta_{i1} x_{i,t-1} + \sum_{i=1}^{k} \beta_{i2} x_{i,t-2} + \varepsilon_t \ . \tag{5.1}$$

The long-run equilibrium is derived from (5.1) by substituting $h_t = h^*$ and $x_{it} = x_i^*$, leading to

$$h^* = \frac{1}{1-\alpha_1-\alpha_2} \sum_{i=1}^{k} x_i^* (\beta_{i0} + \beta_{i1} + \beta_{i2}), \tag{5.2}$$

The dynamic model (5.1) can equivalently be written in an error-correction format as

$$\Delta h_t = -\alpha_2 \Delta h_{t-1} - (1-\alpha_1-\alpha_2)(h_{t-1} - h_{t-1}^*) + \sum_{i=1}^{k} \beta_{i0} \Delta x_{it} - \sum_{i=1}^{k} \beta_{i2} \Delta x_{i,t-1} + \varepsilon_t \tag{5.3}$$

where

$$h_t^* = \sum_{i=1}^{k} x_{i,t} \frac{\beta_{i0} + \beta_{i1} + \beta_{i2}}{1-\alpha_1-\alpha_2}. \tag{5.4}$$

This is the static long-run solution, provided by PcGive (Doornik and Hendry, 2007), as a combination of short-run and long-run relationships. If the series $(h_{t-1} - h^*_{t-1})$ is stationary, then $(h_{t-1} - h^*_{t-1})$ is the co-integrating relation. The null hypothesis of no co-integration can be tested using the (augmented) Dickey-Fuller (ADF) test and the co-integrated regression Durbin-Watson (CRDW) test, see Engle and Granger (1987). The critical values are provided by MacKinnon (1991), see also Table 6.3 in Maddala and Kim (2004).

According to Clark and Coggin (2009), the model (5.3) is typical and representative of many ECM models for house prices found in the literature. In Eq. (5.3), h_t denotes log of real housing price at time *t*, α_2 denotes a degree of serial correlation, $1-\alpha_1-\alpha_2$ denotes a degree of mean reversion, h^*_t denotes the fundamental value determined by economic conditions, and βs measure the contemporaneous adjustment of prices to current shocks in the explanatory variable.

Eq. (5.1) could easily be extended to include more lags for the dependent variable, as well as the exogenous explanatory variables, leading to generalizations of Eq. (5.2) – (5.4). In our empirical results we will only use two lags.

5.2.2 Estimation Results

In order to estimate the dynamic model in Eq. (5.1), we employ the variables described in Table 8. Estimation results are presented in Table 9 and 10. Applying the ADF test on the error correction term reveals that the null hypothesis of no co-integration can not be rejected. However, the value of t-statistic is -4.15, which is close to the 5% critical value of -4.42. This implies that all statistics in the Tables 9 and 10 should be considered with 'a pinch of salt'. Assuming stationarity of the error-correction term, all parameter estimates are significant. Measures of goodness-of-fit, reported at the bottom of Table 9, are also satisfactory. The Durbin-Watson statistic is 1.88, not far away from 2. The residuals are small; the standard error of regression (Sigma) is equal to 0.04. Figure 5 shows that the fitted values are close to the observed values.

The solved static long-run equation corresponds to Eq. (5.2). The results can also be expressed in terms of the ECM model specification (5.3), where the dependent variable is Δh_t, giving

$$\Delta h_t = 0.6142\Delta h_{t-1}\text{-}0.3149E\mathrm{CM}_{\mathrm{t\text{-}1}} - 0.3002\Delta y_{t-1} + 0.0149\Delta IM_{t-1}. \tag{5.5}$$

The marginal long-run real income elasticity is close to 1. This is much lower than the CPB estimation results in Table 3, where it was 1.5. However, the CPB model also includes the housing stock. These findings are in line with Meen (2002). In a study for the US and the UK, he shows that omitting the housing stock variable from a regression leads to a dramatic fall of the income coefficient, from 2.51 to 1.18 for the UK and from 2.71 to -0.53 for the US. For the Netherlands these differences are much smaller. An increase of 1% point in real interest leads to a reduction in real house prices of 8.6%. A linear trend is included to capture the absence of other important variables like demographics and house supply. The coefficient for the linear trend is 0.019, leading to a yearly real house price increase of approximately 2%. The coefficient for Δh_{t-1} is 0.61, close to the estimate in the OTB model, where it was 0.56 (see Table 7). The coefficient for the error-correction term is -0.31.

Table 9. ECM with linear trend (Eq. 5.1)

Variable	Coefficient	Std. Error	t-value
h_{t-1}	1.2952	0.1189	10.9
h_{t-2}	-0.6100	0.1037	-5.88
y_{t-2}	0.3002	0.1110	2.70
IM_{t-1}	-0.0122	0.0054	-2.24
IM_{t-2}	-0.0149	0.0062	-2.40
Trend	0.0060	0.0015	4.08
Constant	-0.0428	0.0417	-1.03

Sigma = 0.0439	RSS = 0.0692
R^2 = 0.9872	$F(6,36)$ = 463.9 (0.0000)
Log-likelihood = 77.2615	DW = 1.88
No. of observations = 43 (1967 – 2009Q1)	No. of parameters = 7
Mean (h_t) = -0.0126	Var (h_t) = 0.1261

Table 10. Static long-run equation for log of real house prices (Eq. 5.2)

Variable	Coefficient	Std. Error	t-value
y_t	0.9534	0.3156	3.02
IM_t	-0.0859	0.0131	-6.57
Trend	0.0190	0.0032	6.04
Constant	-0.1360	0.1274	-1.07

Long-run sigma = 0.139278

$ECM = h_t - 0.9534 y_t + 0.0859 IM_t - 0.0190 Trend + 0.1360$

Figure 5 also plots residuals from the dynamic model in Eq. (5.1) and the error-correction term. If we interpret the error-correction term as a deviation from the long-run equilibrium, we can see that house prices were severely undervalued in 1975 (-35.6%), followed by a period of extreme overvaluation in 1978 (42.9%). During the 2000s, house prices in the Netherlands were also overvalued (2006: 11.9%; 2007: 11.5%; 2008: 2.4%). In the first quarter of 2009, we witness an undervaluation of -3.4%, according to the ECM model. However, the model includes a linear trend, which can also capture overvaluation.

In comparison to the specifications estimated by the CPB and the OTB, we present here estimation results for a much longer sample (1967 to 2009Q1), whereas the CPB and the OTB samples are from 1980 to 2007 and 1978 to 2000, respectively. It is important to stress that our approach models nicely the house price movements from 1970 to 1980, the period not analysed by the two above mentioned research institutes. Further, comparing to the CPB specification, we also include changes in lagged log real house prices. In contrast to the OTB approach, we present results of an unrestricted model (5.1) – (5.4).

Interpretation of results in Tables 9 and 10 from an error-correction point of view can only be done if the error-correction term is stationary, which is not the case. Hence, in the next step, in the unobserved component ECM model, we replace the linear trend in the error-correction term in Eq. (5.5) by a (non-stationary) random walk.

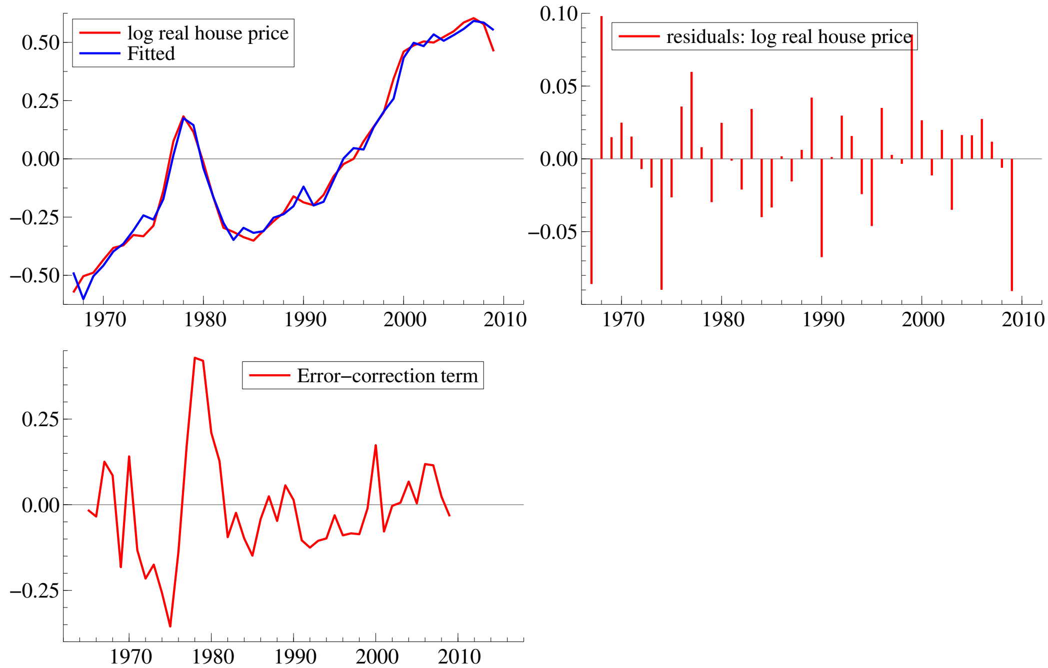

Figure 5. Estimation results ECM, with linear trend from 1967 to 2009Q1

5.3 Local Level Model (Random Walk)

In the unobserved component ECM model we replace the linear trend in the error-correction term in Eq. (5.5) by a random walk. A general specification of the unobserved component ECM model is given by,

$$\Delta h_t = \sum_{j=1}^{r} \varphi_j \Delta h_{t-j} + \sum_{i=1}^{k} \beta_{i0} \Delta x_{i,t} + \sum_{j=1}^{s-1} \sum_{i=1}^{k} \beta_{ij} \Delta x_{i,t-j} + (\varphi - 1)(h_{t-1} - \mu_t - \sum_{i=1}^{k} \delta_i x_{it-1}) + \varepsilon_t, \qquad (5.6)$$

where μ_t denotes the trend component. In case of a random walk, the trend component is given by

$$\mu_{t+1} = \mu_t + \eta_t. \qquad (5.7)$$

The model can be formulated in state-space form and estimated by the Kalman filter; see Harvey (1989). Estimation results are generated using the Structural Time Series Analyser, Modeller and Predictor (STAMP) software; see Koopman et al. (2007).

In this specification, an alternative test for co-integration is a test that variance of the random walk trend component is equal to zero, or alternatively that the autoregressive parameter in a first-order autoregressive model is equal to 1. The estimated short-run specification is given by Eq. (5.8), with diagnostics presented in Table 11:

$$\Delta h_t = 0.4726 \Delta h_{t-1} - 0.3776 ECM_{t-1} + 0.01534 \Delta IM_{t-1} - 0.5372 \Delta y_{t-1} \qquad (5.8)$$

where

$$ECM_t = h_t - 1.6766 y_t + 0.0681 IM_t - \mu_{t+1}.$$

Note that the marginal long-run elasticity with respect to real model income is much higher than in the model with linear trend.

Table 11. Estimation results ECM with random walk 1967 – 2009Q1

Variable	Coefficient	RMSE	*t*-value
Δh_{t-1}	0.47257	0.13905	3.39862
ΔIM_{t-1}	0.01534	0.00654	2.34476
Δy_{t-1}	-0.5372	0.37391	-1.43671
h_{t-1}	-0.37756	0.09431	-4.0035
IM_{t-1}	-0.0257	0.0089	-2.88697
y_{t-1}	0.63302	0.29519	2.14447
Disturbances			
	Variance	Standard error	
Level	0.0009	0.030	
Irregular	0.0011	0.033	
State vector analysis at period 2009			
	Value	*p*-value	
Level	0.202	0.0024	
Std. error = 0.0473		Log-likelihood = 107.284	
No. of observations = 43		p.e.v. 0.00224	
R^2 = 0.6418		DW = 1.7405	

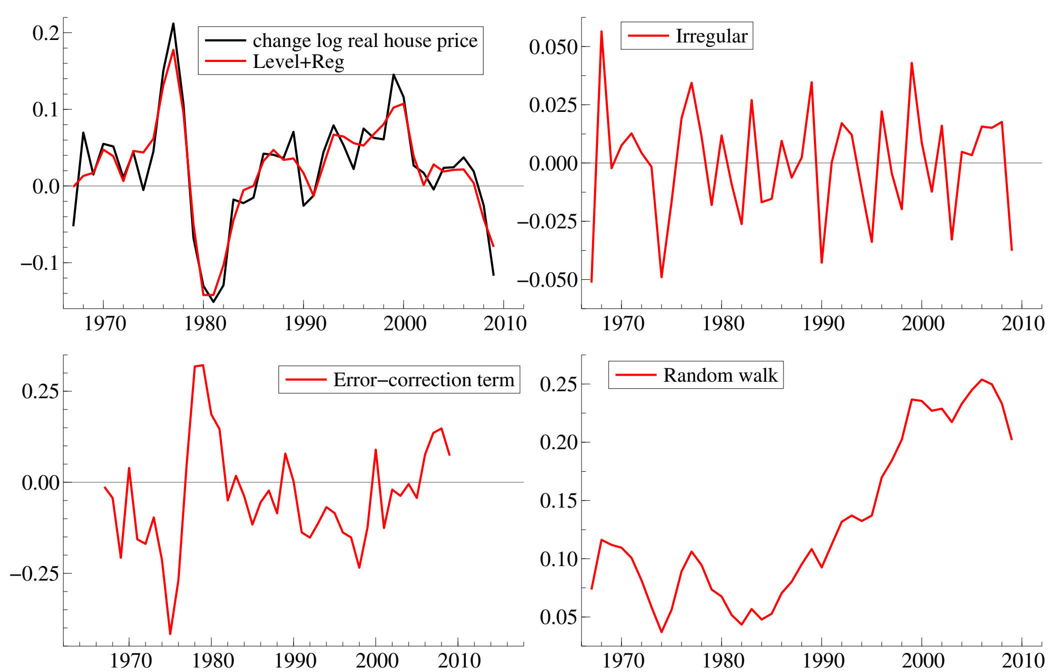

Figure 6. Estimation results ECM random walk 1967 – 2009Q1

Figure 6 shows the estimated short-run movements in the house prices – the fitted values follow closely the observed values. The movements and the magnitude of the error-correction term are very similar to Figure 5.

The random walk contains, like the linear trend in the previous subsection, the non-stationary unexplained part of the long-run equilibrium. This term can also incorporate overvaluation. In that case, the overvaluation is the sum of the error-correction term and the random walk component (lower two graphs in Figure 6). For the last decade this would imply that the overvaluation is between 18% and 38% (in logs), see the third column of Table 12. If it is assumed that only the error-correction term measures overvaluation, the overvaluation in the last decade is between -13% and +15% (in logs), see the second column of Table 12. The difference between two measures is quite high. The question what a more likely measure of overvaluation is, is hard to answer. One can argue that a part of the random walk component captures some omitted variables in the long-term relationship. In that case only a fraction of the random walk can be interpreted as an overvaluation. Therefore, the *ECM* and $ECM + \mu_{t+1}$ can be regarded as boundary values for overvaluation.

Table 12. Overvaluation of median house prices (in logs)
Unobserved components ECM 1967 – 2009Q1

	random walk		random walk with drift	
Year	ECM	ECM + μ_{t+1}	ECM	ECM + μ_{t+1}
2000	0.08947	0.324917	0.140023	0.333532
2001	-0.12558	0.101451	-0.11185	0.086203
2002	-0.01998	0.208844	-0.03040	0.172666
2003	-0.03726	0.180067	-0.01893	0.188501
2004	-0.00475	0.228317	0.046703	0.259499
2005	-0.04299	0.201839	-0.01330	0.204510
2006	0.076123	0.329901	0.109247	0.331645
2007	0.135512	0.385247	0.113592	0.339899
2008	0.147949	0.381090	0.029391	0.259210
2009Q1	0.073292	0.275178	-0.02547	0.207869

We also estimates an ECM model where the random walk is replaced by a random walk with drift, given by $\mu_{t+1} = \mu_t + \beta + \eta_t$. We do not provide here detailed estimation results (available from authors upon request). Nevertheless, the measures for overvaluation are provided in the fourth and fifth column of Table 12. Compared to the random walk ECM model, the overvaluation in recent years is lower.

5.5 Comparison of Error-Correction Models

The comparison of goodness-of-fit measures for the estimated error correction models is given in Table 13. The models differ in terms of variable specification. Next to real disposable labour income, long-term real interest rates, and the housing stock, the CPB model also includes the asymmetric error-correction terms and a dummy for the year 2000. The linear trend model includes, next to a linear trend, lags of house prices, real modal labour income, and real mortgage interest rates. The ECM models with random walk and random walk with drift also include the latter two terms.

Table 13. Comparison of ECM models

	Sigma	Durbin-Watson	Observations	Parameters
CPB	0.0339	1.42	27	11
Linear trend	0.0439	1.88	43	7
Random walk	0.0300	1.74	43	7
Random walk with drift	0.0434	1.78	43	8

The models differently estimate the overvaluation of the Dutch house prices. From the CPB long-run relation it can be concluded that in 2007 the overvaluation was approximately zero, whereas it was +14% in 2004.

The ECM model with a linear trend estimates that the Dutch house prices were severely undervalued in 1975 (-35.6%), followed by a period of extreme overvaluation in 1978 (42.9%). During the 2000s, house prices in the Netherlands were also overvalued (2006: 11.9%; 2007: 11.5%; 2008: 2.4%).

The random walk (with drift) component indicates that a substantial part of house prices could not be explained by fundamental economic factors. If we interpret the random walk (with drift) term together with the error-correction term as measuring overvaluation in the Dutch housing market, they indicate that Dutch house prices were 18% (9%) to 38% (34%) overvalued in the period between 2000 and 2009Q1, (the figures for the random walk with drift are provided between brackets). In contrast, if overvaluation is measured by the error-correction term only, in 2008 were house prices in the Netherlands 14% (3%) above the long-run equilibrium value. The graphical comparison of estimated error-correction terms is given in Figure 7. The three error-correction terms look very similar, with a through and a subsequent peak between 1975 and 1980.

Between each other and in comparison to the CPB estimation results in subsection 3.2, they mostly differ with respect to the estimated marginal long-run real income elasticity. In the ECM model with linear trend and random walk with drift, it is estimated to be close to 1, whereas the CPB estimation results and the random walk model estimate the marginal long-run real income elasticity of 1.5 and 1.7, respectively. An explanation for the higher marginal long-run real income elasticity in the CPB model is inclusion of the housing stock.

Our most preferred model is the error-correction with random walk model, which has the lowest standard error. This model can be seen as the most ‘pessimistic’ one, considering the forecasting scenarios in the next section and the overvaluation estimates.

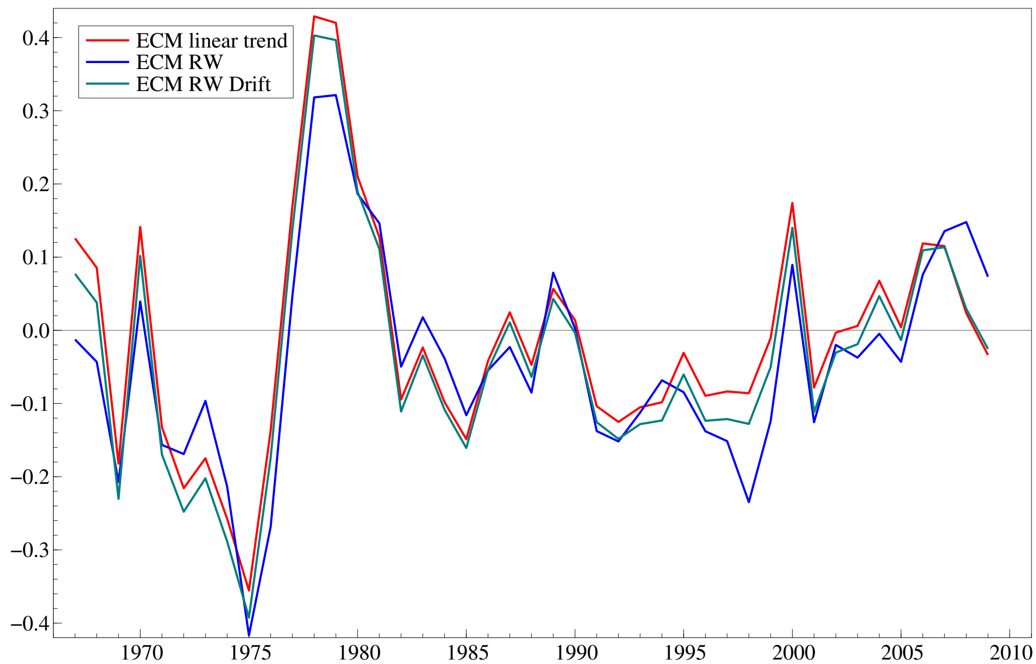

Figure 7. Three estimated error-correction terms

6 Predictions

Forecasts of house prices are generated using three different economic scenarios in the period 2010-2015. The three scenarios are provided in Table 14.

The first, *the recession scenario*, assumes that the national economy stays unchanged with hardly any economic growth during the forecast period, except for a negative growth in 2009Q1. Real income growth of households is close to zero, except in election years 2011 and 2015. The real interest rate on the 10-year state bond is relatively high (close to 3%). Inflation and mortgage rates are set below the averages of the last 10-year country figures, except for the final year (2015) where inflation and mortgage rate increase.

The second, *the slow recovery scenario*, assumes that the national economy stabilises in 2010 and slowly grows to the historic average levels in 2015. Inflation and mortgage rates also slowly grow to the historic average levels in 2015. Real income growth of households stays close to zero, with slow growth in nominal terms, due to rising inflation. The real interest rate on the 10-year state bond returns slowly to average level around 2 %.

The third, *the quick recovery scenario*, assumes that the national economy stabilises in 2010 and returns quickly to the historic average levels. Inflation, mortgage rates and nominal income growth of households also return to levels characteristic of the historic periods. However, real income growth of households only slowly recovers due to the fiscal shortages of the national government budget during this period and higher inflation. The real interest rate on the 10-year state bond stabilises at a level below 2 %.

Table 14. Description of the three economic scenarios (nominal values)

	Recession			**Slow Recovery**			**Quick Recovery**		
Year	Inflation	Mortgage rate	Income	Inflation	Mortgage rate	Income	Inflation	Mortgage rate	Income
2010	0.00	4.50	32,000	1.0	4.70	32,400	1.5	4.80	32,500
2011	0.50	4.60	32,500	1.5	4.90	33,000	1.8	4.90	33,200
2012	1.00	4.80	32,900	1.8	4.90	33,600	2.2	5.00	34,000
2013	1.20	4.80	33,700	1.9	5.00	34,500	2.2	5.00	35,000
2014	1.50	4.90	34,500	2.0	5.00	35,000	2.3	5.20	36,200
2015	1.70	4.90	35,500	2.2	5.00	36,600	2.5	5.20	37,500

We present forecasts for the three estimated models in Table 15 in nominal terms. Graphic representation of forecasts in nominal terms is in Figure 9. We can see that the linear model predicts largest increases in house prices over the next 5–6 years, for all three scenarios, in compare to random walk and random walk with drift models. Taking 2008 as a benchmark, for 2015 linear model predicts a nominal increase between 14% and 32%, going from recession to quick recovery scenarios. Similar figures are 9% to 27% percent in a random walk with drift model and –7% to +7% for a random walk model. Looking at the diagnostics from subsection 5.3, the random walk model is our most preferred model, although it might also be the most pessimistic representation of the housing market reality.

Table 15. Forecasts of house price index in **nominal** terms from the ECM (2010-2015).

Year	Recession			Slow Recovery			Quick Recovery		
Model	Linear	RW drift	RW	Linear	RW drift	RW	Linear	RW drift	RW
2008	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*
2009	*90.0*	*97.5*	*95.0*	*90.0*	*97.5*	*95.0*	*90.0*	*97.5*	*95.0*
2010	86.1	85.1	84.7	87.0	86.0	85.7	87.4	86.5	86.2
2011	86.6	84.6	81.7	89.2	87.2	84.1	90.4	88.4	85.2
2012	90.0	86.9	81.2	95.7	92.6	86.1	98.3	95.2	88.3
2013	96.2	92.3	83.7	105.1	101.2	90.6	109.3	105.3	93.6
2014	104.4	99.8	88.0	115.8	111.2	95.8	121.3	116.6	99.7
2015	113.6	108.6	93.4	125.9	121.2	100.9	132.1	126.9	105.2

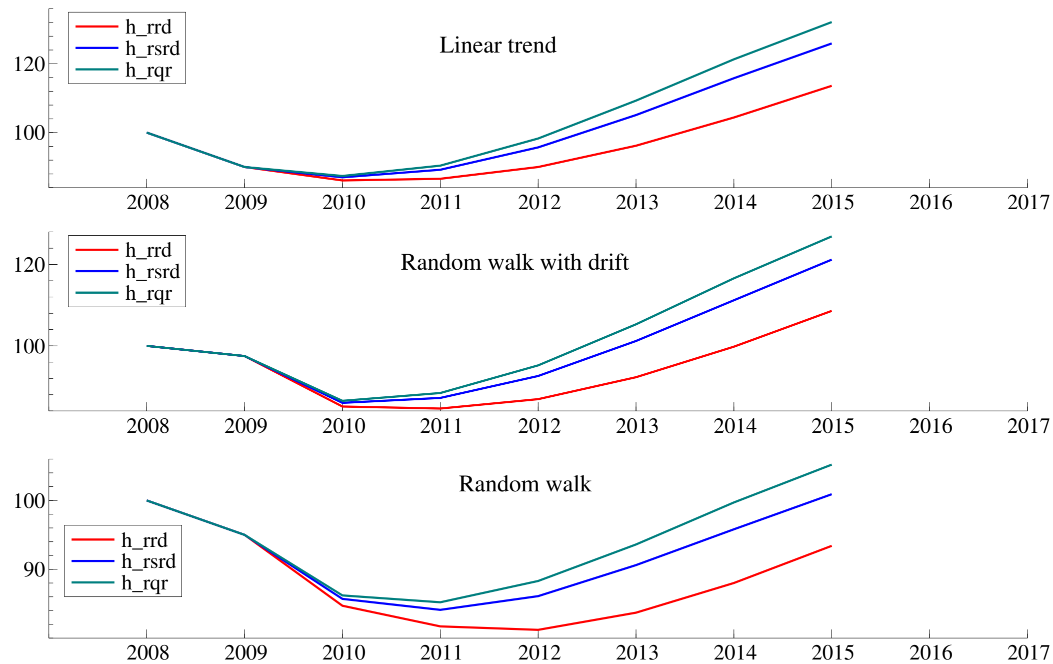

Figure 8. Forecasts in nominal terms for 2010 – 2015:
hhrd = recession; hrsrd = slow recovery; hrqrd = quick recovery

7 Conclusions

The current financial crisis in the Netherlands did not start with problems in the residential property market, but on the contrary, the global financial and economic crisis has affected the housing market. Based on a simple affordability approach analysis, from the perspective of the mortgage interest-to-income ratio it can be concluded that house prices in 2007-2008 were around 18% overvalued compared to the long-run average ratio. However, at this moment, due to the price fall of around 8% and the lower mortgage interest rate in the first half year of 2009, average median mortgage payments as a share of the income of the median employee is broadly in line with its historic average (the median price level is not overvalued anymore).

In comparison with the specifications estimated by the Dutch research institutes CPB and OTB, this research presents estimation results for a much longer sample (1967 to 2009), whereas the CPB and the OTB samples range from 1980 to 2007 and 1978 to 2000, respectively. It is important to stress that our approach nicely models the house price movements from 1970 to 1980, the period not analysed by the two above mentioned research institutes. Other differences with the CPB specification are that we also include changes in lagged log real house prices. With respect to the OTB approach, our model differs in that we present results based on an unrestricted model.

The models estimate differently the overvaluation of the Dutch house prices. According to the IMF (2008) World Economic Outlook, the house price increase between 1997 and 2007 in the Netherlands suffered from a ‘substantial overvaluation’ of approximately 30%. From the CPB long-run relation it can be concluded that in 2007 the overvaluation was approximately zero, whereas it was +14% in 2004. Our ECM model with linear trend estimates that the Dutch house prices were severely undervalued in 1975 (-35.6%), followed by a period of extreme overvaluation in 1978 (42.9%). During the 2000s, house prices in the Netherlands were also overvalued (2006: 11.9%; 2007: 11.5%; 2008: 2.4%).

The random walk (with drift) component indicates that a substantial part of house prices cannot be explained by fundamental economic factors. If we interpret the random walk (with drift) term together with the error-correction term as measuring an overvaluation in the Dutch housing market, they both indicate that Dutch house prices were substantially overvalued in the last decade. In contrast, if overvaluation is measured by the error-correction term only, house prices were moderately above the long-run equilibrium value. One can argue that a part of the random walk component captures some omitted variables in the long-term relationship. In that case, only a fraction of the random walk (with drift) component can be interpreted as an overvaluation.

Our most preferred model is the error-correction with random walk model, which has the lowest standard error. This model can be seen as the most ‘pessimistic’ one, considering the forecasting scenarios and the overvaluation estimates. Forecasting house prices with this approach shows a recovery of prices to the level of 2008 no sooner than 2015 in all scenarios, except for the recession scenario.

Further research should encompass several extensions of the current model. First, the real interest rate should be based on expected inflation, in order to account for real user costs. Second, among the set of explanatory variables we would also like to include housing stock and construction costs, thereby accounting for the supply side of the market. Third, we want to present estimation results on a more disaggregate level, such as regions or the largest cities in the Netherlands.

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Appendix

A1 Data Sources and Definitions

- Annual data, national level.
- Median weighted sales price of existing homes (1985-2009.Q1), Dutch Association of Realtors and Property Consultants (NVM).
- Average weighted sales price of existing homes (1965-1984), Statistics Netherlands (CBS), except for 1975 which is an extrapolation of the NVM figures.
- Nominal gross income of the median employee (1965-2009), The Netherlands Bureau for Economic Policy Analysis (CPB), CEP/MEV.
- Mortgage interest rate, 1973-2009.Q1, average 5-year rate on repayment loans with national mortgage guarantee, De Hypotheekshop, NHG.
- Mortgage interest rate (average), 1965-1972, Statistics Netherlands (CBS), average interest rate for granted mortgage loans on residential houses.
- Inflation rate, 1965-2009.Q1, Statistics Netherlands (CBS), Consumer price index (CPI), 1990=100.