# EVALUATION OF HOUSE PRICE MODELS USING AN ECM APPROACH

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# EVALUATION OF HOUSE PRICE MODELS USING AN ECM APPROACH:

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Marc K. Francke*†, Sunčica Vujić* and Gerjan Vos†

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**Ortec Finance**
**Research Center**
P.O. Box 4074, 3006 AB Rotterdam
Max Euwelaan 78, The Netherlands, www.ortec-finance.com

**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, 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; Cointegration; Error Correction Model; Long-run Equilibrium.

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*Authors are member of Ortec Finance Research Center. Please e-mail comments and questions to marc.francke@ortec-finance.com.

†Authors are affiliated at University of Amsterdam Business School, Faculty of Economics and Business, Roetersstraat 11, 1018 WB Amsterdam, the Netherlands.

# 1 Introduction

In this paper we examine 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[1]? 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 house price models. Sections 3 and 4 present estimation results of the Netherlands Bureau for Economic Policy Analysis (CPB) and the OTB Research Institute, respectively, in the period from 1980 to 2007, based on yearly data (CPB) and 1978(1) to 2000(2), based on half-yearly data (OTB). Section 5 presents estimation results of an improved error-correction model (ECM), 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.

[1] According to the economist Jaap van Duijn (NRC Handelsblad, 13 May 2009), Dutch households have one of the highest debts to disposable income ratio in the world, after Denmark, with debts to disposable income ratio of $246\%$. In comparison, the similar number in the US is $135\%$, in Germany $107\%$, and in Italy $59\%$.

# 2 Literature Overview

House price models can be divided into two broad groups: demand and supply-and-demand models. In 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 demand models, the development of house prices is connected to the development of 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 new construction is strongly regulated and undeveloped building land is scarce. New building developments react poorly to demand incentives and supply surplus do not exist. From this point of view, interest rates, disposable income, and borrowing capacity of consumers are the most relevant factors influencing 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 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 usually examined through a macroeconomic housing model, where both supply and demand factors are considered. Next to flow variables, like income and consumption, stock variables are also taken into account, like housing stock, number of households, wealth, etc. In this approach, the impact of supply factors, like 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, new building developments are determined by the production costs and the costs of 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 construction which can 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 predicts the development 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 impact of baby boom and baby bust[2] on house prices. DiPasquale and Wheaton (1994) show that, in the long-run, demographic factors can reduce the

[2]A baby boom is any period of greatly increased birth rate during a certain period, and usually within certain geographical bounds and when the birth rate exceeds 2% of the population. People born during such a period are sometimes called “baby boomers”. Some contest the general conventional wisdom that baby booms signify good times and periods of general economic growth, and stability. The term baby boom most often refers to the dramatic post-World War II baby boom (1946 to 1964). “Baby busters” is a term which is used interchangeably with “Generation X” and “13th Generation” to describe those people born between approximately 1964 and 1977, after a dramatic baby boom.

appreciation of 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 curve 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). Error correction model combines both levels and differences of a series. If we denote log real house prices by $h_t$, the model in the long- (2.1) and short–run (2.2) can be written as follows:

$$h_t^* = \beta_1 x_{1t} + \cdots + \beta_k x_{kt}, \tag{2.1}$$

$$\Delta h_t = \alpha \Delta h_{t-1} + \delta(h_{t-1} - h_{t-1}^*) + \gamma \Delta h_t^* + \varepsilon_t, \tag{2.2}$$

The variables taken into account by this type of model are those which have direct effect on both house demand and supply ($x_{kt}$): long-run interest rate, disposable household income, lagged house prices, housing stock, construction costs, 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.

In the short-run model, $\Delta h_{t-1}$ can be seen as a *bubble builder*: it captures the speculative influences on the market or the market's inefficiency; $\alpha$ measures the degree of serial correlation, whereas the the deviation from the long term equilibrium (error correction term) $(h_t - h_t^*)$ can be interpreted as a *bubble burster*; $\delta$ measures the degree of mean reversion. If $(h_t - h_t^*) > 0$, we say that house prices are overvaluated and if $(h_t - h_t^*) < 0$, the house prices are undervaluated; $\gamma$ measures contemporaneous adjustments of prices to current shocks in the explanatory variables. According to Clark and Coggin (2009), the error correction model (2.1) – (2.2) is typical and representative of many ECM models for house prices found in the literature. Examples of application of an ECM in the literature on house prices are Hort (1998), Malpezzi (1999), Gallin (2006), **?**), and **?**).

There are a number of conditions which the model in 2.1) – (2.2) has to meet in order to be called co-integrated error correction model. If $h_t$ is *non-stationary* or integrated of order one, I(1) (no time invariant first and second moment), then $\varepsilon_t = h_t - h_t^* = h_t - x_t\beta$ (for some $\beta$) has to be *stationary*, in order that a long-run equilibrium relationship $x_t\beta$ is called a *co-integrating relation*. Alternatively, if $\varepsilon_t = h_t - h_t^* = h_t - x_t\beta$ (for some $\beta$) is non-stationary, then the long-run equilibrium relationship $x_t\beta$ is *spurious*: the ECM is not valid, and the usual statistics (standard errors, $R^2$, etc.) do not have their common interpretation.

As an extension of the model 2.1) – (2.2), more lags of $\Delta h_t$ and $\Delta h_t^*$ can be included, as well as an asymmetric error correction term: different coefficients for positive and negative values of error correction term.

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

$$h_t = \alpha_1 h_{t-1} + \alpha_2 h_{t-2} + \sum_{i=1}^{k} \beta_{i0} x_{it} + \sum_{i=1}^{k} \beta_{i1} x_{i,t-1} + \sum_{i=1}^{k} \beta_{i2} x_{i,t-2} + \varepsilon_t. \tag{2.3}$$

The long-run equilibrium is derived from (2.3) by substituting $h_t = h^*$ and $x_{it} = x_i^*$, leading to

$$h^* = \frac{1}{1 - \alpha_1 - \alpha_2} \sum_{i=1}^{k} x_i^* (\beta_{i0} + \beta_{i1} + \beta_{i2}), \tag{2.4}$$

The dynamic model (2.3) can equivalently be written in an error-correction format as

$$\Delta h_t = -\alpha_2 \Delta h_{t-1} - (1 - \alpha_1 - \alpha_2)(h_{t-1} - h_{t-1}^*) + \sum_{i=1}^{k} \beta_{i0} \Delta x_{it} - \sum_{i=1}^{k} \beta_{i2} \Delta x_{i,t-1} + \varepsilon_t \tag{2.5}$$

where

$$h_t^* = \sum_{i=1}^{k} x_{i,t} \frac{\beta_{i0} + \beta_{i1} + \beta_{i2}}{1 - \alpha_1 - \alpha_2}. \tag{2.6}$$

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).

# 3 Results of the Netherlands Bureau for Economic Policy Analysis (CPB)

The Netherlands Bureau for Economic Policy Analysis (CPB) estimated long-run model for 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 could explain 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 reproduce 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[3]. First, we report the estimates of the short-run ECM model, which has not been analyzed by Kranendonk and Verbruggen (2008). Second, we extend their sample size to the period from 1965 to 2009Q1 and we present both static and dynamic long-run models for 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. A description of the variables employed by the CPB can be found in Table 3.1. For a more detailed variable description and a model specification, we refer the reader to Verbruggen et al. (2005) and Kranendonk and Verbruggen (2008).

Table 3.1: Variables employed by the CPB

| Variable | Description |
|---|---|
| $H$ | House price index based on average selling prices of private homes from Kadaster[a] |
| $Y$ | Disposable labor income (aggregate) |
| $I$ | Long-term interest rate (10-year government securities) |
| $W$ | Nominal wealth indicator net other financial assets of households (end of the year) |
| $S$ | Total housing stock (end of the year) |
| $P$ | Consumer price index |

[a]Kadaster collects data on registered real estate objects in the Netherlands, keeps this information in public registers and cadastral maps, and makes it available to private and business parties against an agreed financial compensation.

Table 3.2: 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

[3]We are grateful to Henk Kranendonk and Johan Verbruggen from the CPB for making their data available for the current analysis.

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

The subscript $t$ denotes time and a lower case letter denotes a variable in natural logarithm. A description of variables in this long-term relationship is in Table 3.2. A graphical representation of the scaled variables is shown in Figure 3.1. Apart from the early eighties, real house prices increased over the analyzed 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 3.2.

The estimation of the long-run relation (3.1) assumes that the variables are integrated of order (at most) $1$. By applying an 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 (first order) co-integration. 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, see 3.2) – is not valid in this case.

Nevertheless, we reproduced 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 3.3, 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 3.3 show that all coefficients have the 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[4]. As a result, the impact of new construction on real house prices is relatively small. Finally, the $DW$ statistic is quite low, indicating presence of autocorrelation.

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 3.2.

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 3.4. A graphical representation of the analyzed series is given in Figure 3.2. Note that variables $\Delta h_t$ and $\Delta s_t$ 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.

[4]The CPB uses a series for the housing stock that does not match the series supplied by Statistics Netherlands (CBS). In particular for years 2007 and 2008 the changes in housing stock deviate. The changes reported by CPB for those years are much higher.

Table 3.3: Long-run relationship (1980-2007) from Kranendonk and Verbruggen (2008)

| Variable | Coefficient | Std. Error | $t$-value |
|---|---|---|---|
| Constant | $-6.5986$ | $1.2730$ | $-5.18$ |
| $y_t$ | $1.5336$ | $0.2653$ | $5.78$ |
| $I_t^r$ | $-5.944$ | $1.6900$ | $-3.52$ |
| $w_t$ | $1.6320$ | $0.4201$ | $3.89$ |
| $s_t$ | $-2.8298$ | $0.6032$ | $-4.69$ |

| | |
|---|---|
| Sigma = $0.0703$ | RSS = $0.1136$ |
| $R^2 = 0.9705$ | $F(4, 23) = 189(0.00)$ |
| Log-likelihood = $37.3742$ | DW = $1.11$ |
| No. of observations = $28$ | No. of parameters = $5$ |
| $\bar{h}_t = 4.7725$ | $\sigma^2_{h_t} = 0.1374$ |

Table 3.4: Short-run ECM variables employed by the CPB

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

Table 3.5: Short-run ECM model using the CPB data in the period 1981-2007

| Variable | Coefficient | Std. Error | $t$-value |
|---|---|---|---|
| $\Delta y_t^a$ | $1.4386$ | $0.2225$ | $6.46$ |
| $\Delta I_t^a$ | $-6.3515$ | $1.3530$ | $-4.70$ |
| $\Delta\nabla P_t$ | $1.1015$ | $0.8375$ | $1.32$ |
| $\Delta s_t$ | $-2.0639$ | $0.5536$ | $-3.70$ |
| $d_{2000}$ | $0.1398$ | $0.0358$ | $3.90$ |
| $ecm_{t-1}$ | $-0.2177$ | $0.1852$ | $-1.18$ |
| $ecm_{t-1}^+$ | $0.3238$ | $0.2905$ | $1.11$ |

| | |
|---|---|
| Sigma = $0.0339$ | RSS = $0.0230$ |
| Log-likelihood = $57.1361$ | DW = $1.42$ |
| No. of observations = $27$ | No. of parameters = $7$ |
| $\bar{h}_t = 0.0247$ | $\sigma^2_{h_t} = 0.0054$ |

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 in Table 3.5 using the CPB data.

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 1980–2007 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.

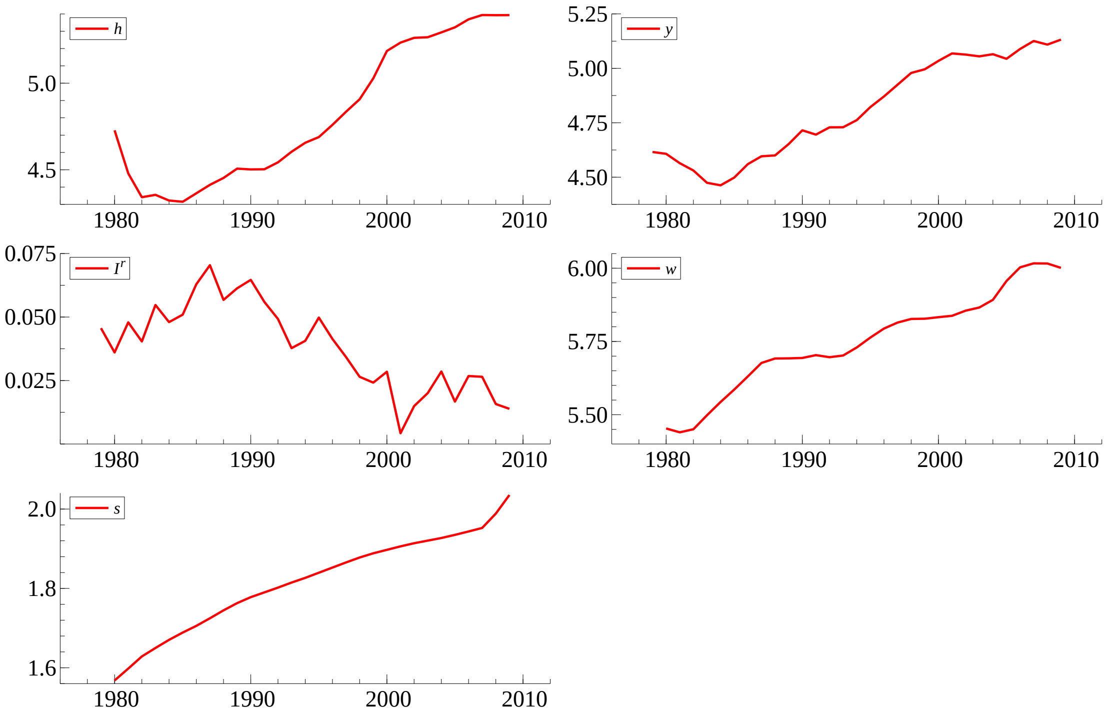


Figure 3.1: Long-run CPB series

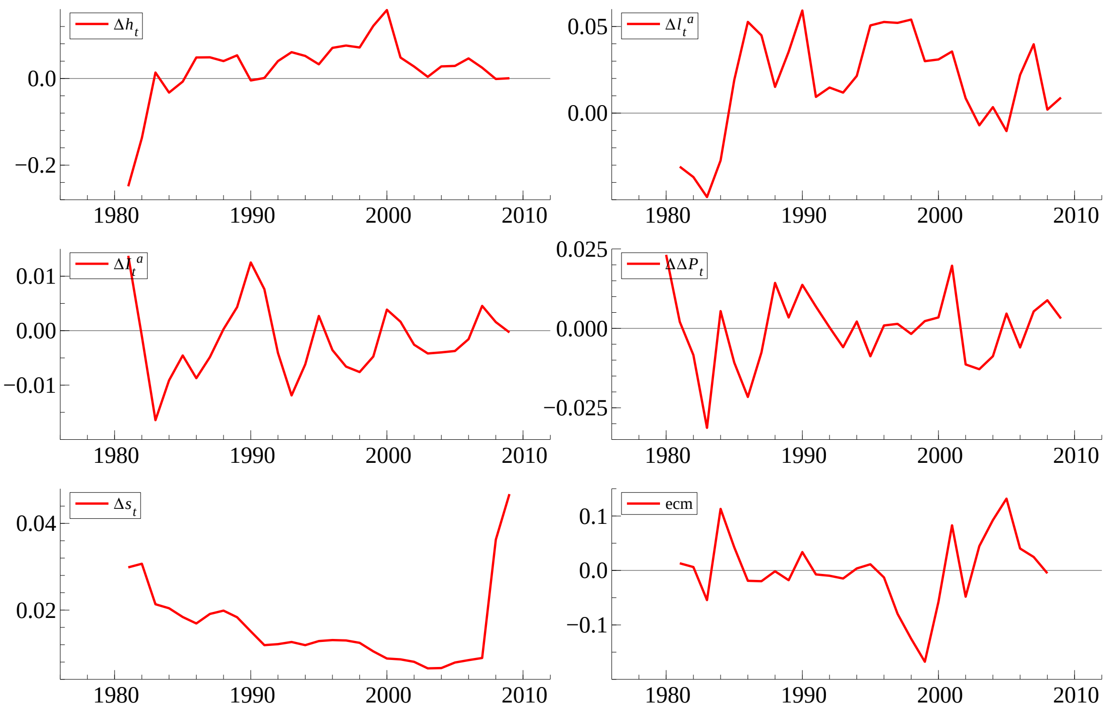


Figure 3.2: Short-run (first-differenced) CPB series

# 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. A description of the variables employed by the OTB is given in Table 4.1. The data are provided in Boelhouwer et al. (2001). A 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 4.1.

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 the after tax interest-to-income ratio 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

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

where $\nabla$ 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 $\gamma_2$ 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 4.2 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 4.2 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 4.2 do not have the usual interpretation.

Comparing the OTB model (4.1) to the CPB model, represented by equations (3.1)– (3.1), reveals a number of differences. First, the CPB model is closer to an co-integrated ECM model than the OTB model; 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 generated 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

Table 4.1: Variables employed by the OTB

| Variable | Description |
| --- | --- |
| $\nabla H_t$ | Percentage change of 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). |
| $\nabla Y_t$ | 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 as nominal interest rate minus realized inflation ($\nabla P_t$), where $P$ is the consumer price index. |

Table 4.2: Estimation results using half-yearly data from the OTB

| Variable | Coefficient | Std. Error | $t$-value |
| --- | --- | --- | --- |
| Constant | $5.2626$ | $1.6240$ | $3.24$ |
| $\nabla H_{t-1}$ | $0.5574$ | $0.0863$ | $6.46$ |
| $IIR_{t-2}$ | $-0.1926$ | $0.0583$ | $-3.30$ |
| $d_t$ | $1.3522$ | $0.3001$ | $4.51$ |
| $\nabla Y_t$ | $0.5657$ | $0.2520$ | $2.24$ |
| $\Delta I_t^r$ | $-2.1252$ | $0.6409$ | $-3.32$ |
| $LRE_t = 5.2626/0.1926 = 27.33$ | | | |
| Sigma = $1.9902$ | | RSS = $158.4371$ | |
| $R^2 = 0.8230$ | | $F(4, 23) = 37.21(0.00)$ | |
| Log-likelihood = $-93.7156$ | | DW = $1.71$ | |
| No. of observations = $46$ | | No. of parameters = $6$ | |
| Mean($\nabla H_t$) = $0.4811$ | | Var($\nabla H_t$) = $19.4641$ | |

uses household income, whereas the CPB model uses disposable (aggregate) labor 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 $\Delta x_t \approx \nabla x_t$[5], Eq. (4.1) can be approximated by

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

where lower-case letter denotes that a variable is in natural logarithms, the time-invariant parameter $f = \ln(1-F)$ is included in $\gamma_0^*$ 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 Hendershott (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.

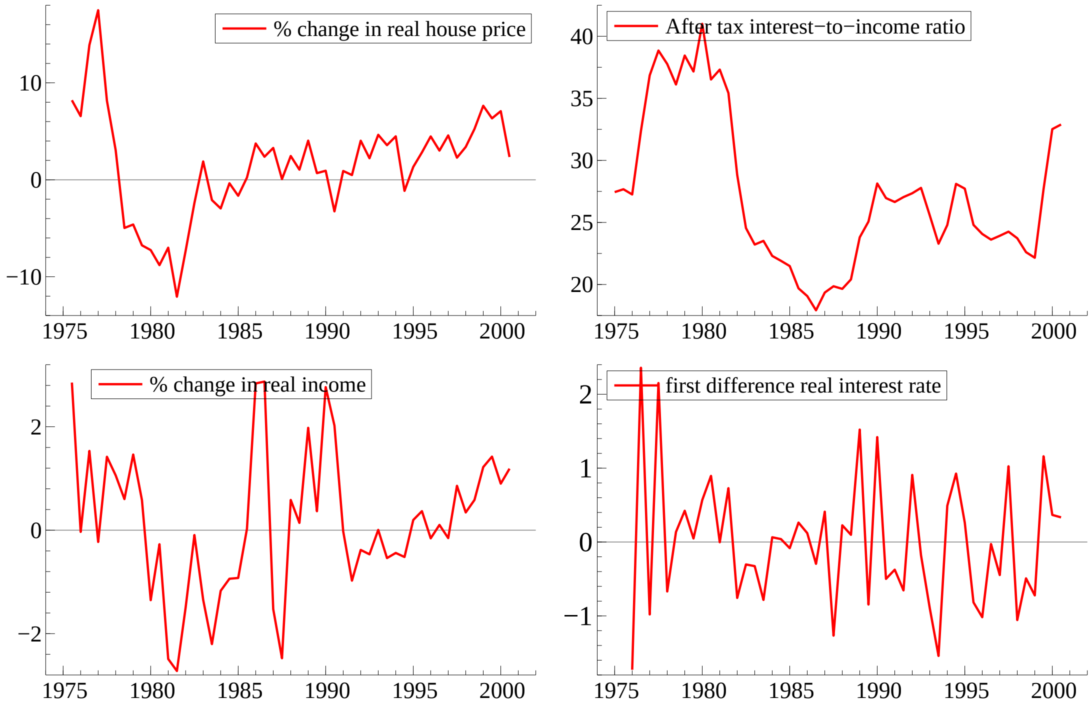


Figure 4.1: OTB series

[5]This approximation can be justified by the following relation: $\ln(1+\varepsilon) \approx \varepsilon$, if $\varepsilon$ is small.

# 5 Unobserved Components 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[6], to estimate different versions of an ECM model. Table 5.1 provides the available variables for the extended sample period. Definitions and sources are provided in Appendix A.1. 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 5.1: Variable Description

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

Figure 5.1 presents the analyzed series in the period from 1965 to 2009Q1. We can see that real house prices increased until the 1980s, when they experienced a sharp fall. From the 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 reduced 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, when it was $8.12$. Its minimum value is $3.32$ in 1985. In the first quarter of 2009 the rate reduced 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 $40.5\%$[7]. The average ratio is $20.3\%$. The 2008 and 2009Q1 rates are $24.0\%$ and $19.5\%$ respectively. From the perspective of the after tax 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 5.1, including a linear trend in the long-run relation. In subsection 5.3 we formulate and estimate ECM models embedded into the unobserved components modeling approach. In this model the linear trend is replaced by a random walk model. Finally, subsection 5.4 compares both models.

[6] The latest available data point is for the first quarter of 2009. Otherwise, the data frequency is yearly.

[7] According to De Vries and Boelhouwer (2009), the after tax interest-to-income ratio (at time of purchase) is calculated as $IIR_t = NIP_t/I_t$, where $NIP_t$ is net interest payments (mortgage debt only), and $I_t$ is household income (per household). The net interest payments is calculated as $NIP_t = P_t \times IR_t \times (1 - F)$, where $P_t$ is house price, $IR_t$ is interest rate, and $F$ is fiscal advantage, which is a constant of $40.5\%$. Due to the fact that fiscal arrangements for house owners in The Netherlands have remained largely unchanged over the past decade, the fiscal benefit (F) can be applied over the entire period. Owners are responsible for $59.5\%$ of the interest liability; the remaining $40.5\%$ is paid by the government. See also Boelhouwer et al. (2004).

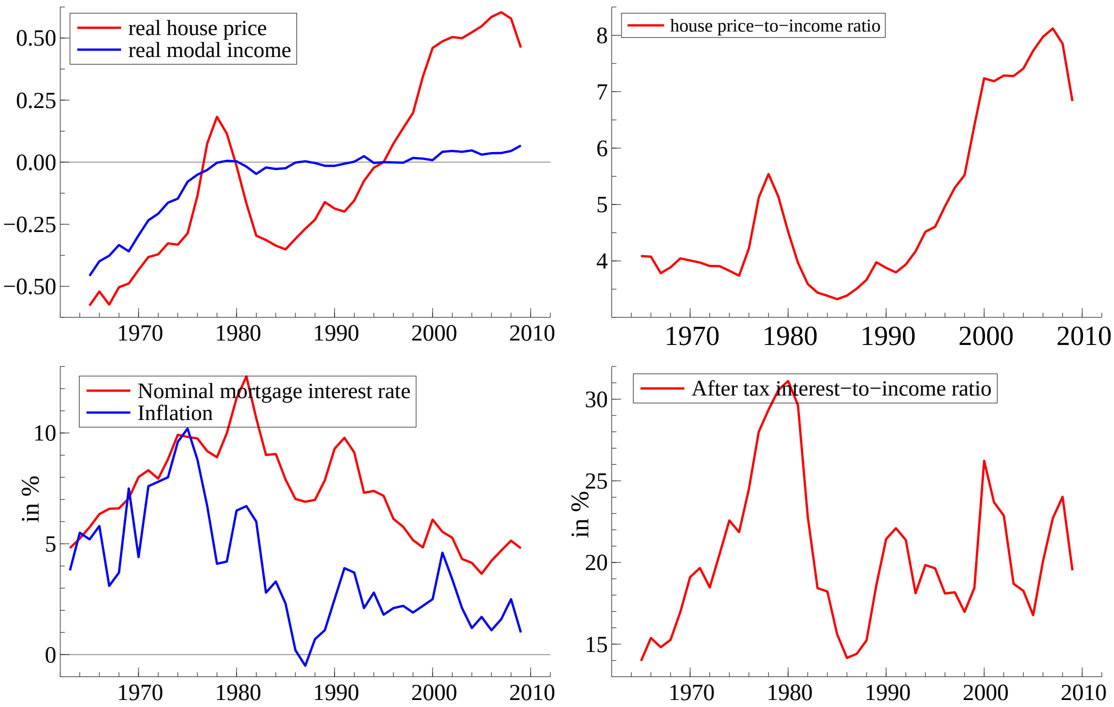


Figure 5.1: analyzed series in the period 1965 – 2009Q1

## 5.2 Error-Correction Model with a Linear Trend

### 5.2.1 Dynamic Model Specification

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

$$h_t = \alpha_1 h_{t-1} + \alpha_2 h_{t-2} + \sum_{i=1}^{k} \beta_{i0} x_{it} + \sum_{i=1}^{k} \beta_{i1} x_{i,t-1} + \sum_{i=1}^{k} \beta_{i2} x_{i,t-2} + \varepsilon_t. \tag{5.1}$$

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 the log of real house prices at time $t$, $\alpha_2$ 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 $\beta$s measure the contemporaneous adjustment of prices to current shocks in the explanatory variables.

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) – (5.3). 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 5.1. Estimation results are presented in Tables 5.2 and 5.3. 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 5.2 and 5.3 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 5.2, 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 5.2 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 $\Delta h_t$, giving[8]

$$\Delta h_t = 0.6142 \Delta h_{t-1} - 0.3149 ECM_{t-1} - 0.3002 \Delta y_{t-1} + 0.0149 \Delta IM_{t-1}. \tag{5.5}$$

The marginal long-run real income elasticity is close to 1. This is much lower than the CPB estimation results in Table 3.3, 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 $\Delta h_{t-1}$ is $0.61$, close to the estimate in the OTB model, where it was $0.56$ (see Table 4.2). The coefficient for the error-correction term is $-0.31$.

Figure 5.2 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 (1965 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 analyzed 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).

[8]There are restrictions imposed on other variables, such as $y_{t-1}$, $y_t$, $IM_t$. XXXXX Marc, could you edit this footnote??

Table 5.2: ECM with linear trend (Eq. 5.1)

| Variable | Coefficient | Std. Error | $t$-value |
|---|---|---|---|
| $h_{t-1}$ | $1.2952$ | $0.1189$ | $10.90$ |
| $h_{t-2}$ | $-0.6100$ | $0.1037$ | $-5.88$ |
| $y_{t-2}$ | $0.3002$ | $0.1110$ | $2.70$ |
| $IM_{t-1}$ | $-0.0122$ | $0.0054$ | $-2.24$ |
| $IM_{t-2}$ | $-0.0149$ | $0.0062$ | $-2.40$ |
| 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 = $43$ | | No. of parameters = $7$ | |
| $\bar{h}_t = -0.0126$ | | $\sigma^2_{h_t} = 0.1261$ | |

Table 5.3: 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 = $0.1393$ | | | |
| $ECM = h_t - 0.9534y_t + 0.0859IM_t - 0.0190Trend + 0.1360$ | | | |

Interpretation of results in Tables 5.2 and 5.3 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.

## 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,

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

where $\mu_t$ denotes the trend component[9]. In case of a random walk, the trend component is given by

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

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 analyzer, Modeler and Predictor (STAMP) software; see Koopman et al. (2007).

In this specification, an alternative test for co-integration is a test that the variance of the random walk trend component is equal to zero, or alternatively that the autoregressive parameter in a first-order

[9] For a more extended model, we refer the reader to Harvey (1989), p. 371-373.

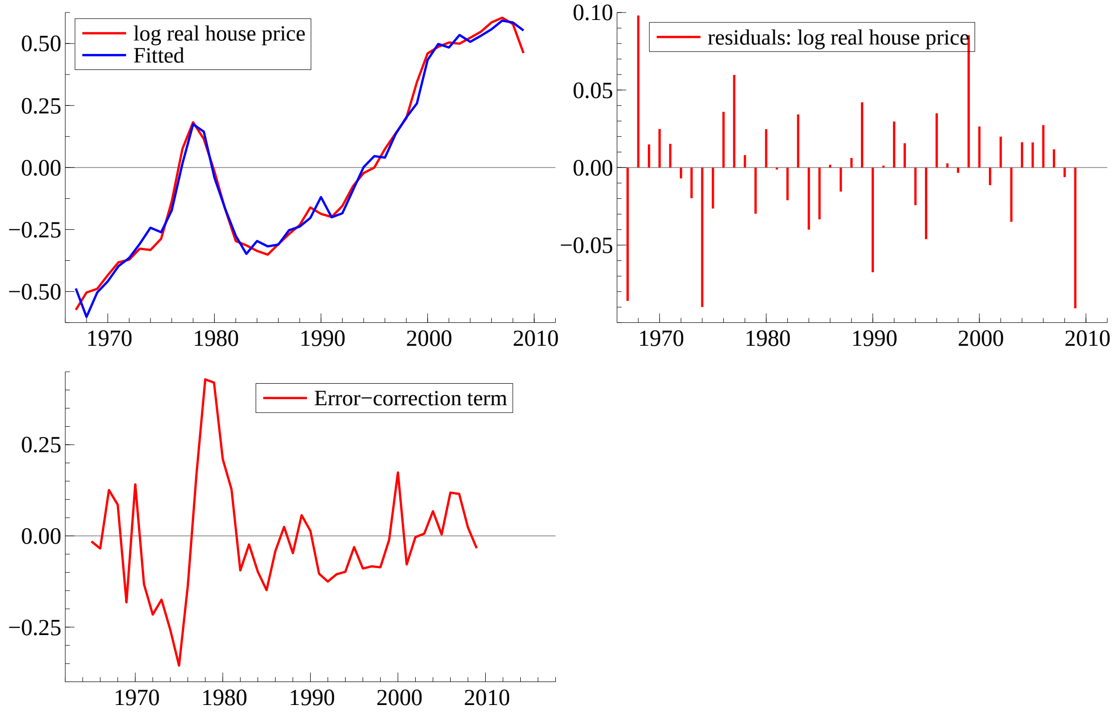


Figure 5.2: Estimation results ECM, with linear trend from 1967 to 2009Q1

autoregressive model is equal to 1. The estimated short-run specification is given by Eq. (5.8), with diagnostics presented in Table 5.4:

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

where

$$ECM_t = h_t - 1.6766 y_t + 0.0681 IM_t - \mu_{t+1}. \quad (5.9)$$

The error correction term, $ECM_{t-1}$, in Table 5.4 is substituted by its elements, $h_{t-1}$, $IM_{t-1}$, and $y_{t-1}$, see Eq. 5.9. Note that the marginal long-run elasticity with respect to real model income is much higher than in the model with linear trend.

Figure 5.3 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 5.2.

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 5.3). For the last decade this would imply that the overvaluation is between $10\%$ and $38\%$ (in logs), see the third column of Table 5.5. 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 5.5. The difference between these two measures is quite high. The question, what a more likely measure of overvaluation is, is hard to answer. One can argue that 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.

We also estimated 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 the authors

Table 5.4: Estimation results ECM with random walk 1967 – 2009Q1

| Variable | Coefficient | Std. Error | $t$-value |
|---|---|---|---|
| $\Delta h_{t-1}$ | $0.4726$ | $0.1391$ | $3.3986$ |
| $\Delta IM_{t-1}$ | $0.0153$ | $0.0065$ | $2.3448$ |
| $\Delta y_{t-1}$ | $-0.5372$ | $0.3739$ | $-1.4367$ |
| $h_{t-1}$ | $-0.3776$ | $0.0943$ | $-4.0035$ |
| $IM_{t-1}$ | $-0.0257$ | $0.0089$ | $-2.8870$ |
| $y_{t-1}$ | $0.6330$ | $0.2952$ | $2.1445$ |
| Disturbances | | | |
| | Variance | Std. Error | |
| Level | $0.0009$ | $0.0300$ | |
| Irregular | $0.0011$ | $0.0330$ | |
| State vector analysis at period 2009 | | | |
| | Value | $p$-value | |
| Level | $0.2020$ | $0.0024$ | |
| Std. error = $0.0473$ | | Log-likelihood = $107.2840$ | |
| No. of observations = $43$ | | p.e.v. = $0.0022$ | |
| $R^2 = 0.6418$ | | DW = $1.7405$ | |

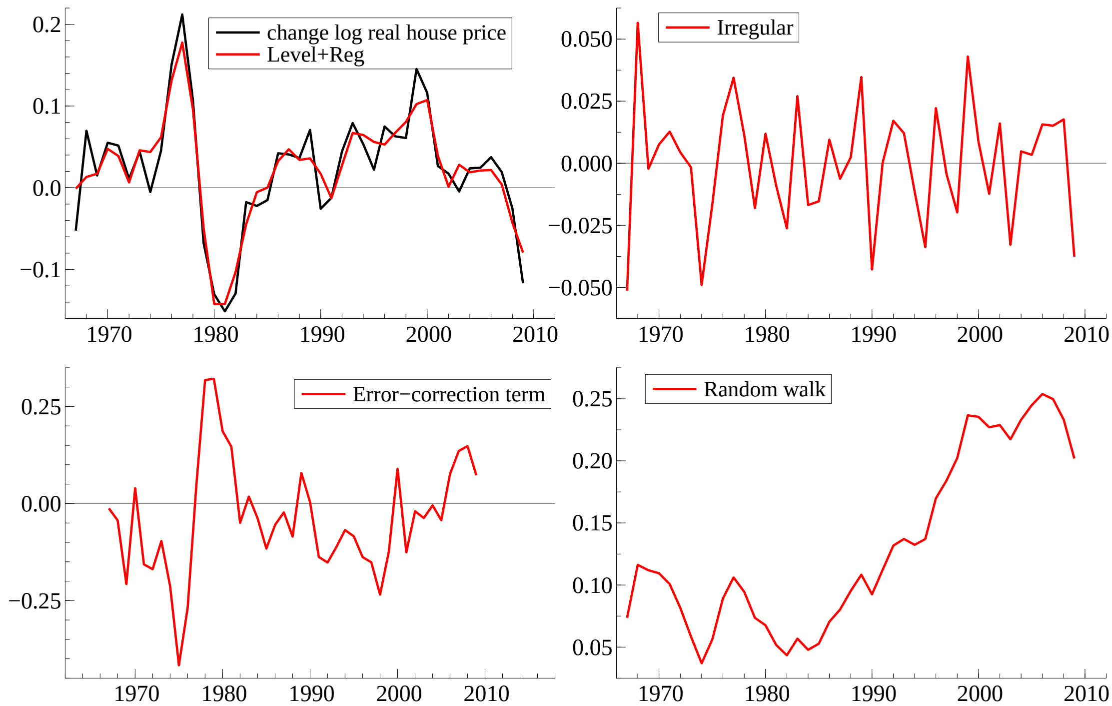


Figure 5.3: Estimation results ECM random walk 1967 – 2009Q1

Table 5.5: Overvaluation of median house prices (in logs)

| | Random walk | | Random walk with drift | |
|---|---|---|---|---|
| Year | $ECM$ | $ECM + \mu_{t+1}$ | $ECM$ | $ECM + \mu_{t+1}$ |
| 2000 | 0.0895 | 0.3249 | 0.1400 | 0.3335 |
| 2001 | −0.1256 | 0.1015 | −0.1118 | 0.0862 |
| 2002 | −0.0200 | 0.2088 | −0.0304 | 0.1727 |
| 2003 | −0.0373 | 0.1801 | −0.0189 | 0.1885 |
| 2004 | −0.0048 | 0.2283 | 0.0467 | 0.2595 |
| 2005 | −0.0430 | 0.2018 | −0.0133 | 0.2045 |
| 2006 | 0.0761 | 0.3299 | 0.1092 | 0.3316 |
| 2007 | 0.1355 | 0.3852 | 0.1136 | 0.3399 |
| 2008 | 0.1479 | 0.3811 | 0.0294 | 0.2592 |
| 2009$Q$1 | 0.0733 | 0.2752 | −0.0255 | 0.2079 |

upon request). Nevertheless, the measures for overvaluation are provided in the fourth and fifth column of Table 5.5. Compared to the random walk ECM model, the overvaluation in recent years is lower.

## 5.4 Comparison of Error-Correction Models

The comparison of goodness-of-fit measures for the estimated error correction models is given in Table 5.6. The models differ in terms of variable specification. Next to real disposable labor 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 labor income, and real mortgage interest rates. The ECM models with random walk and random walk with drift also include the latter two terms.

Table 5.6: 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 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 $10\%$ ($9\%$) 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 house prices in the Netherlands were $14\%$ ($3\%$) above the long-run equilibrium value. The graphical comparison of estimated error-correction terms is given in Figure 5.4. 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 3.1, the models in this section 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, elasticity is estimated to be close to 1, whereas the CPB estimation results and the random walk model estimate a 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.

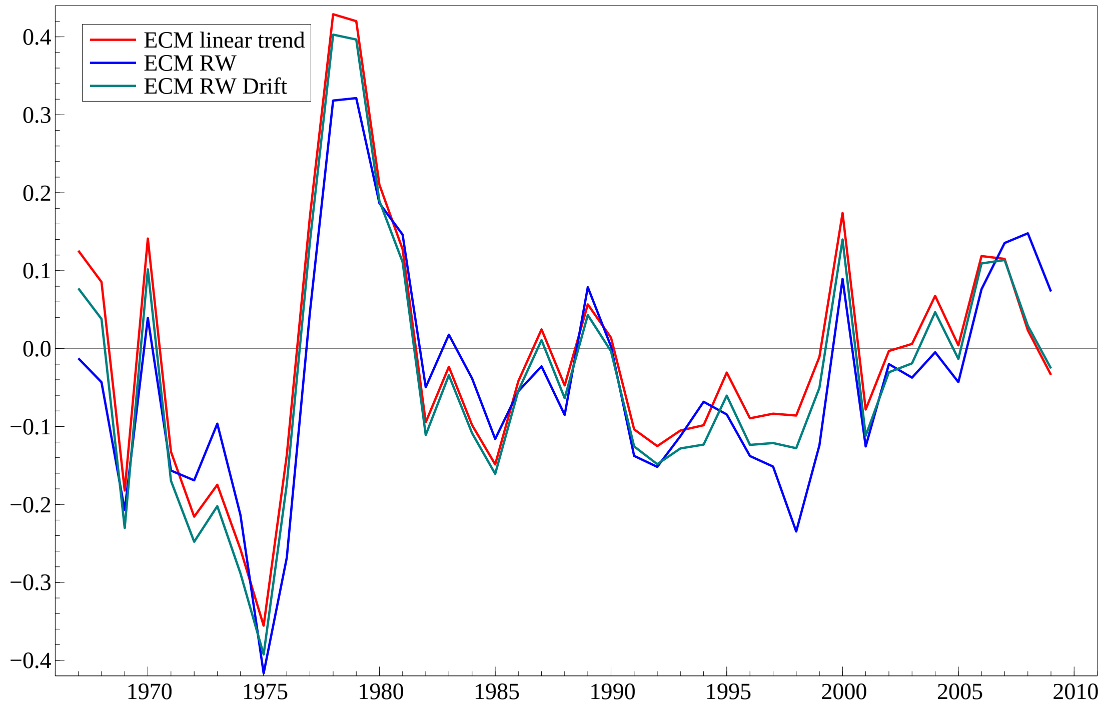


Figure 5.4: The estimated error-correction terms

## 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 6.1.

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 6.1: 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 6.2 in nominal terms. Graphic representation of forecasts in nominal terms is in Figure 6.1. We can see that the linear model predicts the largest increases in house prices over the next 5–6 years, for all three scenarios, in comparison to the random walk and random walk with drift models. Taking 2008 as a benchmark, for 2015 the linear model predicts a nominal increase between $14\%$ and $32\%$, going from recession to quick recovery scenarios. Similar figures are $9\%$ to $27\%$ 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 6.2: Forecasts of house price index in **nominal** terms from the ECM (2010-2015)

| Year | Recession | | | Slow Recovery | | | Quick Recovery | | |
|---|---|---|---|---|---|---|---|---|---|
| Model | Linear | RWD | RW | Linear | RWD | RW | Linear | RWD | 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 |

RW = Random walk; RWD = Random walk with drift

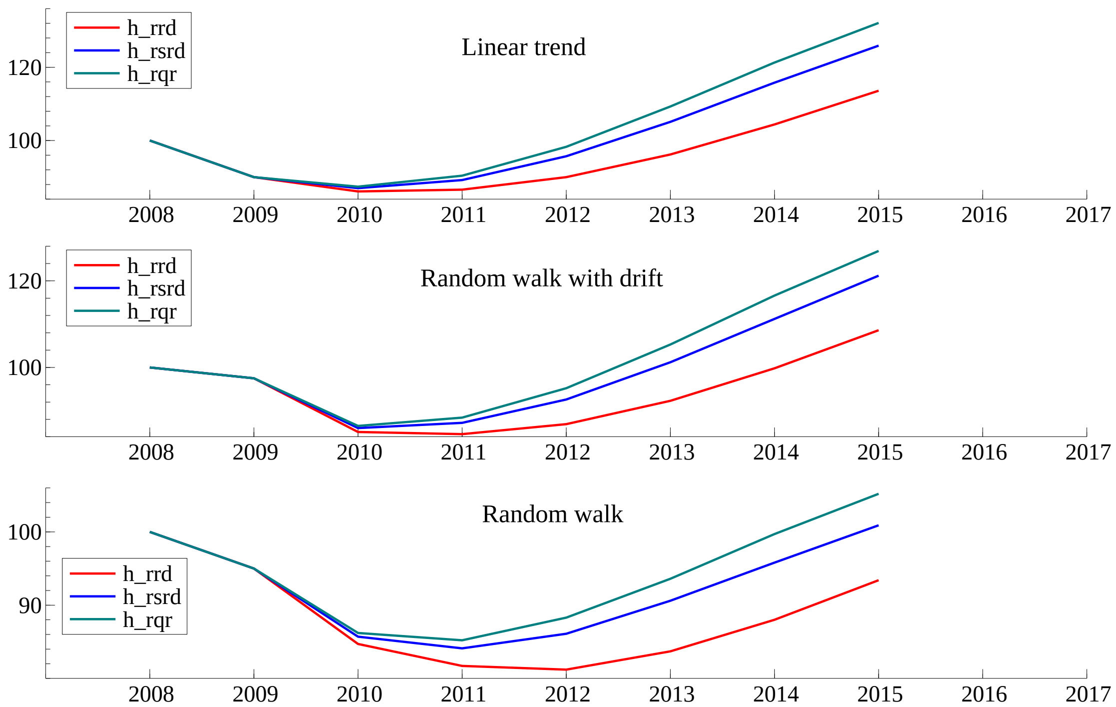


Figure 6.1: Forecasts in nominal terms for 2010 – 2015:
hhrd = recession; hrsrd = slow recovery; hrqrd = quick recovery

# 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 analyzed 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 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 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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# A Appendix

## A.1 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.

**Ortec Finance bv**
Max Euwelaan 78
3062 MA Rotterdam
Nederland
Tel. +31 (0)10 498 66 66
Fax +31 (0)10 498 66 67

**Ortec Finance bv**
Orlyplein 145c
1043 DV Amsterdam
Nederland
Tel. +31 (0)20 436 90 20
Fax +31 (0)20 436 90 21

**Ortec Finance Ltd**
23 Austin Friars
London EC2N 2QP
United Kingdom
Tel. +44 (0)20 3178 3914

**Ortec Finance AG**
Rösslimatte 7
8808 Pfäffikon SZ
Switzerland
Tel. +41 (0)55 410 38 38

ORTEC FINANCE