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Long-Run Movements in House Prices

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This study analyzes the housing market by using four key ratios: price-rent, price-building cost, price-land cost and price-wage. We attempt to determine how they work together in order to explain the housing market. A unique dataset from Norway is used to investigate the long-run movements of the variables. In order to analyze these, we have created Norwegian hedonic indices for building and land costs. The cointegration tests confirm that there are long-term relationships between these ratios. The results show that these ratios affect future movement in house prices, rents, and building and land costs. Wages are weakly exogenous in the system and therefore drive house prices, rents, and building and land costs in the long run.

Keywords

House Prices, Rents, Construction Costs, Wages, VECM, Cointegration

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1. Introduction

The idea that house prices tend to move back to construction costs is widespread in the literature. It is often hard to formally test this statement because of the limited availability of data. However, Krakstad and Oust (2013) find that house prices and construction costs have a long-run equilibrium by using an average construction cost index. Studies in the U.S. often utilize construction wage in order to obtain a long enough time series. Likewise, it is normal to assume that there is a link between affordability/income and house prices in the long run. By thinking of land as a scarce or restricted resource, it is quite easy to explain the link between income and land cost. However, as Shiller (2009) argues, we are not running out of land. Regulatory barriers “tend to be thwarted in the long run if economic incentives to work around them become sufficiently powerful”. It becomes difficult to explain the link between income and the house prices in the long run by the change in land cost alone. For the price-construction cost ratio to be constant in the long run, income needs to be linked to building cost. To be able to test the link between building cost and income as well as the link between land cost and income, we split the construction costs into building and land costs. We are not aware of any paper that tests the link between land and building costs with other fundamental variables such as house prices, rents and income. Due to data limitations, there has been a lack of research on land and building costs. However, data are available for countries other than Norway. Chang and Chen (2012) create land and building cost indices for six metropolitian areas in the U.S. for the period between 1997 and 2009. This paper creates three new Norwegian hedonic indices for construction, building and land costs for the period between 1970 and 2012. In addition, we use these data to investigate the long-term relationship in the Norwegian housing market by using a vector error correction model (VECM).

Price-rent, price-construction cost and price-income ratios are commonly used to explain over- or undervaluation of the housing market, either by studying the development in these ratios or through a more formal analysis by using a VECM. Since we have decomposed the construction costs, we use the two following ratios instead of the price-construction cost ratio: price-building cost and price-land cost. We restrict our long-term (cointegration) matrix by using economically reasonable price-rent, price-building cost, price-land cost and price-income ratios.

In the literature, researchers have investigated the link between house prices and rents because owning or renting an apartment provides approximately the same service flow. Gallin (2008) finds a long-term relationship between house prices and rents in the U.S. and uses this price-rent ratio to predict house prices. Similar to this service flow argument, there is a strong theoretical link between housing supply function and construction costs. House prices tend to converge towards construction costs in the long run (Glaeser et al. (2008)). By using aggregated quarterly U.S. data from 1980 to 2008, Mikhed and Zemcik (2009) find that house prices, construction costs and income are cointegrated. As they show, the use of different subsamples of their time period (1980–2008) leads to different conclusions as to whether a long-term relationship exists between house prices, construction costs and income. However, Gallin (2006) does not find that U.S. house prices and income show a long-term relationship between 1975 and 2002. U.S. income did not increase as much as house prices, especially in the last part of his sample period. This could explain why no cointegration between these two variables is found by Gallin (2006), although another reason could be misspecification of the long-term cointegration matrix. Contrary to his findings, however, several other studies find a long-term relationship between house prices and income (cf. Abraham and Hendershott (1996), Capozza et al. (2002) and Meen (2002)).

To address some of the typical complications of housing price dynamics, we use a new and unique dataset from Norway. Our time series consist of 43 years of data for house prices, rents, building and land costs, and wage (wage is a proxy for income). We find that there is a long-term relationship, and that this relationship can be used to estimate changes in house prices, rents, and building and land costs. In a VECM, wages are found to be weakly exogenous, which implies that the wage process drives the four other variables in the long run. House prices will converge towards building and land costs in the long run. As building cost and not only land cost are driven by wage in the long run, our study improves the understanding of the connection between the construction cost and the affordability theories of explaining house prices and allows both theories to be used side by side, thus bridging some of the gap between the two. For the literature review on the construction cost and affordability theories, we recommend Mayer (2011). In addition, house prices and rents have a long-term equilibrium, which means that the user cost of renting and owning will be the same in the long run. The dataset and methodology that we use should give us advantages over previous studies. Often construction costs are excluded from long-term analyses of the housing market, probably on account of the limited availability of data in some of the countries. Including only some of these variables, however, can create a misspecified model and lead to incorrect conclusions.

The remainder of this paper is organized as follows: we start by explaining the housing market in Section 2, and a description of the Norwegian house market is given in Section 3. The data are described in Section 4, model is presented in Section 5, empirical results are presented in Section 6, and Section 7 concludes.

2. The Housing Market

This section first gives a brief discussion of long-term relationships in the housing market. Thereafter, the life cycle model is introduced.

2.1 Discussion of Long-Term Relationships

Like other free market prices, house prices are a result of supply and demand. The housing market has, however, a number of special properties. First, the supply of dwellings is fixed in the short term. Hence, the microeconomic theory of the housing market predicts a strong relationship between the variables of the housing demand function and the real price of housing in the short term (Kenny (1999)). The determinants of housing demand that are typically used are wages, unemployment ratio, interest rates, GDP, inflation, consumption, immigration and performance of the stock market. The supply of dwellings becomes more elastic as the time horizon becomes longer. In the long run, supply is typically determined by construction costs. Following a sudden increase in housing demand and house prices, construction firms will find it profitable to supply more units to the market. The price of a house can be divided into two main components, the price of the building and the price of the land. The price of a dwelling can be expected to converge towards building costs plus the cost of the land since the supply of workers and materials is elastic in the long run. Furthermore, building costs are likely to be correlated with the wage level since both the wages of construction workers and the price of materials should to some extent follow general changes in the wage level.

Household income and wealth are important when households determine the level of housing services that they can consume (Hansen et al. (1996)). Unlike many other products, dwellings are not homogenous. When a household buys a home, many factors are considered. Households can choose between a large variety of technical standards and locations. When households become richer, they typically want better homes. Technical house quality is heterogeneous across markets and time because higher real wages and wealth will change the preferences of a population and requirements for dwellings.

To determine how the price of land converges is somewhat harder, since location may be a scarce resource. Starting with von Thunen (1966) in 1826,[2] the literature has mostly focused on the cost of travel. All households spend time on traveling from their home to work, school, kindergarten, stores, etc. Different locations impose different travel times (Sheppard (1999)). Furthermore, travel time creates a difference in willingness to pay for different city locations. When the average wage level increases, travel becomes relatively more expensive, thus driving up the average house price. In addition, the willingness to pay for other utilities that are associated with location, such as good schools, a safe neighborhood, nice views, and area status, is dependent on wage level when there is a scarcity of dwellings with these utilities.

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[2] Originally published in 1826 as *Der isolierte Staat Beziebung auf Landwirtschaft and Nationalokonomie*, translated into English in 1966 as *Von Thunen's Isolated State.*

It is also common to assume that the price-rent ratio has an impact on house prices in the short and medium term. In principle, an agent could either buy or rent a house to receive the same service flow (Brunnermeier and Julliard (2008)). In the literature, it is normal to assume that long-term changes in rent level should capture long-term changes in the service flows of owning dwellings. Since households receive almost the same service flow from the two alternatives, the user costs should not move too far apart, and in the long run, the costs should converge.

2.2 Life Cycle Model

A normal starting point of the life cycle model is (cf. Anundsen and Heebøll (2013), Buckley and Ermisch (1983), Meen (2001) and Muellbauer and Murphy (1997)):

$$p_h = \alpha_1 y + \alpha_2 h + \alpha_3 uc \tag{1}$$

where p_h is house price, y is income, h is housing stock and uc is user costs. All variables are logarithms.

In this section, we derive another version of the life cycle model which states that the price is equal to a function of income, rent and construction costs (land and building costs).

The following equation shows the user cost (UC) formula:

$$\frac{R}{P_t} = UC \tag{2}$$

The housing stock (H) can be identified with the following equation (housing stock is equal to the previous period housing stock minus depreciation (δ) plus new investment (I)):

$$H_t = H_{(t-1)}(1-\delta) + I \tag{3}$$

In equilibrium, the solution of housing stock is:

$$H = \frac{I}{\delta} \tag{4}$$

Profit-maximizing construction firms will push construction activity towards a level where the marginal construction cost equals the market price of a unit of housing. By using Tobin's q-theory, we have:

$$I = \frac{p_h}{p_{CC}} \tag{5}$$

where p_{CC} is the price of construction costs.

Equation 5 is put into Equation 4, and then into Equation 3. Thereafter, we take logarithms of this equation (where lower cased letters indicate that the variables are transformed into logarithms):

$$h = (1 - \delta) + (p_h - p_{CC}) \tag{6}$$

Equations 6 and 2 are placed into the life cycle model, Equation 1:

$$p_h = \alpha_1 y + \alpha_2\big((1 - \delta) + (p_h - p_{CC})\big) + \alpha_3(p_h - r) \tag{7}$$

$$p_h = \alpha_0 + \alpha_1 y + \alpha_2 p_{CC} + \alpha_3 r \tag{8}$$

Next, we assume that construction costs can be split into:

$$p_{CC} = \gamma_1 bc + \gamma_2 lc \tag{9}$$

The replacing of p_{CC} with the above formula gives:

$$p_h = c_0 + c_1 y + c_2 bc + c_3 lc + c_4 r \tag{10}$$

The last equation states that the house prices are determined by the long-term movement in income, building and land costs, and rent.

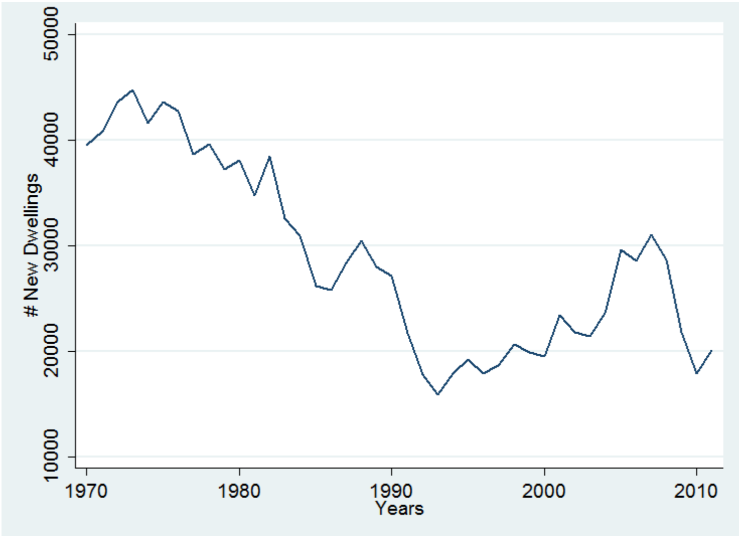
3. The Norwegian Housing Market, 1970-2012

Since data from Norway are used in this study, we will provide a short introduction on the housing market and the general economic development of Norway.

In the early post-war decades, local authorities provided a large number of building sites, primarily to co-operatives, to meet housing shortages. Sites were also provided for self-builders, thus ensuring a strong increase in the supply of new dwellings. In the first part of the 1970s, there was essentially no housing shortage in Norway. From the middle of the decade, construction activity fell for almost 20 years before a new growth period started in 1993 (see Figure 1). The supply of new buildings increased until the financial crisis of 2008, and afterwards, fell to a very low level. Norway had a population of 3,900,000 in 1970 and 5,000,000 in 2012 (see Figure 2).

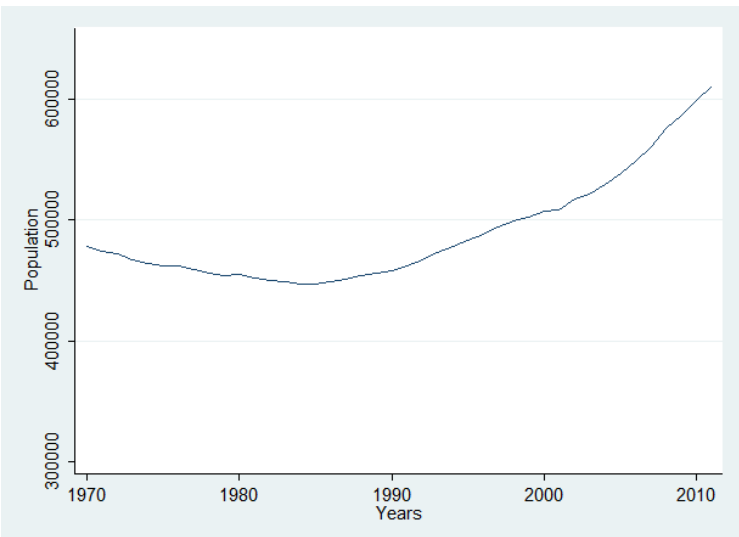
In the 1970s, the Norwegian economy was influenced by large investments in the petroleum sector. The prospect of substantial future income from petroleum increased public spending, and several attempts were made to help industries in the trading sector get through the international recession. Economic indicators showed that Norway was performing rather well, despite high inflation and problems abroad. High oil prices after the oil price shock of 1979/80 resulted in high optimism. At the same time, Norway deregulated its financial market, which created a boom cycle from 1984 to 1987, and house prices strongly increased. In addition, rent control was removed in 1982 for all new contracts. Both before and after the removal of rent control, it was common to convert rental dwellings into owner-occupied properties. The share of owner-occupied dwellings increased from around 50% in 1970 to around 71% in 2001 (Langsether et al. (2003)). The boom ended on Black Monday, October 19, 1987.

Figure 1 Development of Finished New Dwellings 1970-2012



Note: The figure shows the number of new dwellings that was completed from 1970 to 2012 in Norway. Data are collected from Statistics Norway.

Figure 2 Population in Norway between 1970 and 2012



Note: The figure shows the number of inhabitants in Norway for each year from 1970 to 2012. Data are collected from Statistics Norway.

Norway's economic problems had already started in 1986 when the negative oil price shock brought high public spending to an end. Simultaneously, there were large cuts in private spending. This led to a large negative demand shock that reduced economic growth and increased unemployment. House prices and rents fell in this period. The problems in the housing market were compounded by the Norwegian banking crisis from 1988 to 1993 (Vale (2004)).

In the banking crisis, the banks which accounted for almost 60% of the lending to the non-financial domestic sector were in financial distress. From 1988 until 1990, the most severely affected were mainly local or regional banks. The early part of the banking crisis coincided with the deepest post-World War II recession in Norway. The crisis peaked in the autumn of 1991 with the second and fourth largest banks in Norway (with a combined market share of 24%) losing all of their regulatory and share capital, and the largest bank also facing serious difficulties.[3] Problems in the banking sector and high interest rates (due to a weak currency) meant a difficult lending market, and house prices fell. By late 1993, the crisis was effectively over (Vale (2004)).

After several years of problems, the housing and rental market started to improve after 1992, and Norway experienced a period of strong recovery. Political reforms and increasing influence from the petroleum sector produced higher economic growth, house prices and rents. The consumer price index, however, did not increase at the same speed as it had before 1987. In 2001, the Norwegian Central Bank officially changed its regime for setting the interest rate, from a fixed-exchange rate to inflation targeting, although this had already unofficially been in place since 1999 (NOU (2003)).

Real rents reached a new peak in 2001, before decreasing in 2002 to 2004. This time, the reduction was not followed by a fall in house prices (see Figure 3). Several years with a strong increase in real wages, a strong currency and high interest rates meant lower profitability, especially in the trade sector. In order to reduce unemployment, the interest rate was lowered. In 2004, the Norwegian Central Bank regarded the economic problems in Norway as so severe that the key policy interest rate was set as low as 1.75%. This crisis, however, was not as fundamental as the previous one. Unemployment did not increase much, economic growth did not fall too much, and the lower interest rates made it easier for households to keep their homes.

After more than two decades of strong increases in real terms, Norwegian house prices started to fall at the end of 2007, a process accelerated by the international financial crisis of 2008. Backed by Norway's large money reserves, the government guaranteed bank liquidity. The fall in house prices was only temporary, and prices started to grow again in 2009 (see Figure 3).

[3] Kredittkassen, Fokus Bank, and DNB, respectively.

4. Data

Our house price, rent, construction cost, and building and land cost indices are all adjusted for quality, but not for standard. Quality here is defined as type of dwelling, size and location. Standard is defined as everything else, e.g. more expensive kitchen and bathroom, better isolation, higher use of energy-efficient solutions, etc. The indices are not based on a fixed standard, and all will therefore be affected by an increase in standard. The controlling of each time series for standard could lead to higher measurement errors since it is difficult to control for the true standard effect.

Gallin (2008) illustrates this point. When he compares his rent index that is adjusted for standard with a house price index that is not, he first adjusts the growth rate before 1988 by 0.3% to undo the adjustment made to the time series by the Bureau of Labor Statistics. Second, the growth rate each year is increased by 0.2% because many researchers argue that the age adjustment is overestimated. Our unique indices offer the possibility of new insights. They are neither estimates nor subject to adjustments of standard because they are based on observations of the market in each time period.

We use the same house price, rent and wage data as Krakstad and Oust (2013), but the construction, building and land cost indices have never been presented before and can be found in Appendix.

4.1 House Price Index

Norwegian real estate prices are collected from two price indices. From 1970 to 1985, a repeat sale index from the Norwegian Central Bank is used (Eitrheim and Erlandsen (2004)). From 1985 to 2012, a hedonic house price index from the Norwegian Association of Real Estate Agents (NEF) is used. Eitrheim and Erlandsen (2004) use the same time series from NEF from 1985 to 2003. The Norwegian Central Bank posts updates of the complete index annually. NEF constructs their hedonic price index weighted by the dwelling sold.

4.2 Rent Index

Since a national rent index does not exist, we use a local rent index from Oslo constructed by Oust (2013). The index is based on data from advertisements in *Aftenposten* for August of every year from 1970 until 2008. (Oust collected observations for August since it is the most liquid month for renting an apartment.) For the years 2009 to 2012, we use a survey conducted by Opinion Perduco for Boligbygg Oslo KF. Their hedonic method is based on *FINN.no* advertisement data. The method and data used in our work are very similar to the methodology of Oust (2013), thus making the indices compatible.

4.3 Wage Index

We construct a national wage index that starts in 1970. The real wage increase (from Statistics Norway) is used to construct the index for each year until 2012. Household income could be an alternative variable because it would capture some of the same effects. However, since this time series is not available for our period, and the household income time series is highly correlated with our constructed wage index, the general real wage increase is chosen.

4.4 The Building and Land Cost Indices

Before we describe the method that we have employed to create three new hedonic indices for construction, building and land costs, we will give a brief overview of the data source used to make these indices.

Our indices are based on information (about 4000 observations) issued by the Norwegian State Housing Bank (Husbanken). The bank implements the state’s housing policy and assists municipalities in increasing the supply of dwellings. In its annual reports, it publishes the construction costs of dwellings built with its financial aid. The largest group of applicants for financial aid were private developers, followed by co-operatives and private households. Dwellings constructed for groups with special needs are excluded. The share of houses constructed with financial aid from Husbanken has fallen from around 70% in the 1970s to around 20% today. This is the result of policy changes in which the commercial banks were given a more central role in housing finance. The indices include all the costs incurred by the construction companies in building the dwellings, including material, labor, machines, transportation, energy, value-added tax (VAT), land, profit margins of subcontractors, architect fees, processing costs to local authorities and so on. In order to capture the cost variations in all these components, it is important to understand how overall building costs have changed, for instance through several alterations in the VAT rules, which add up to a total effect on building costs of (somewhere) between 5% and 10%. The way that costs are reported introduces some weaknesses into the indices. First, there is no revision of the numbers that the construction companies report. Second, the location variable covers quite large areas, which implies the possibility that land cost may vary from one year to the next because of an unobserved variable.

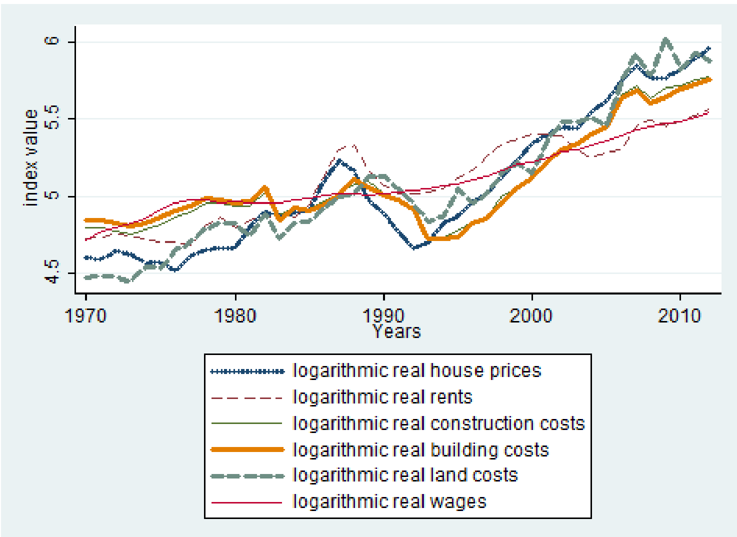
In order to create the hedonic indices, we follow the method used in Oust (2013); that is, the time dummy variable method. This method is a widely used technique to control for the heterogeneous nature of properties when constructing house price indices. Since each house building project has special characteristics, we control for location, square meters and type of housing. The estimated hedonic equation is:

$$r_{it} = \gamma_0 + \delta_t + \alpha_k c_{kit} + e_{it} \qquad (11)$$

where r equals the natural logarithm of construction, building or land costs. c is a set of explanatory variables for the presence of certain characteristics, (t={1,2,...,T}) and i denote the period and the dwelling, respectively. The dummy variables that we use in our regression are dwelling size and location. δ_t represent the time dummy coefficients.

The hedonic indices for construction, building and land costs are presented in Appendix, see Table A1.

Figure 3 Development of the Logarithm of Real Prices, Rents, Construction, Building and Land Costs, and Wages from 1970 to 2012



Note: The figure shows the development of the natural logarithm of real house prices, rents, construction, building and land costs, and wages. Norwegian house prices are downloaded from the Norwegian Central Bank. Rent data from Oslo are taken from Oust (2013) and Opinion Perduco. The data from Oslo are used as a proxy variable for the national rent index. Construction, building and land costs are hedonic indices created in this paper which utilize data from the National State Housing Bank (Husbanken). The wage index is also created in this paper by using the real annual and national wage increases as the proxy variable for real wage increase. Data are collected from Statistics Norway.

4.5 Short-term Variables

We include relevant short-term variables that can help to predict future changes in house prices, rents, building and land costs, and wages. The following exogenous variables are used:

- inflation (CPI) 1970-2012 (from Statistics Norway),
- GDP growth per capita 1970-2012 (from Statistics Norway),*
- 10-year government bond interest rate, 1970-2012 (from the Norwegian Central Bank),*
- MSCI Norway Price Index 1970-2012 (Datastream),*
- unemployment rate 1970-2012 in Norway (from Statistics Norway),*
- household consumption data 1970-2012 (Statistics Norway),*
- number of completed homes 1970-2012 (from Statistics Norway),
- population 1970-2012 (from Statistics Norway), and
- net immigration 1970-2012 (from Statistics Norway).

*All variables are deflated by using the consumer price index (CPI) (Statistics Norway).

The summary statistics and correlation matrix for these exogenous variables and the long-term variables can be found in Tables A2 and A3 in Appendix, respectively.

In addition to controlling for short-term variables, we include dummy variables to improve the precision of our estimation. In 1982, the rent market was deregulated, and hence, for this event, we include a dummy variable (d1982) that is 1 from 1982 and 0 before. The next dummy variable (d1999) that we use is 1 from 1999 when the Central Bank started to use the new inflation goal in setting the interest rate (0 before).

5. Method

This section presents the model used, which is the VECM. The VECM is commonly used in the housing literature (c.f. Gallin (2008) and Malpezzi (1999)).

5.1 Model Framework

Assume that there exist g numbers of level variables in the matrix Z, and all variables are non-stationary with one unit root ($I(1)$ processes). The following VECM is used:

$$Z_t = \Gamma_0 + \sum_{i=1}^{m-1} \Gamma_{t-i} + \Pi Z_{t-1} + \varepsilon_t \tag{12}$$

where Γ_i is a constant, i={0,1,…,$m-1$}, m is the number of lags, Π is the long-term cointegration matrix and ε_t is the error term.

Before this model is used, the rank of the Π matrix needs to be determined. The method, derived by Johansen and Juselius (1990), is used because it is more flexible than many of the alternatives (cf. Hamilton (1994)). The matrix Π can be split into a short-term matrix (α) and a long-term matrix (β):

$$\Pi = \alpha\beta' \tag{13}$$

Both α and β are (g×r) matrices, where g is the number of level variables, and r is the number of cointegration vectors. α is also called the speed of adjustment towards the long-run equilibrium. βZ_{t-1} is the component that provides the cointegrating relationship. To test for the number of cointegrating vectors is equivalent to determining the number of eigenvalues that are different from zero, or the rank of the cointegration matrix. The β matrix is not identified before rank squared restrictions are imposed onto the β and α matrices.

Variables in Z can be weakly exogenous for β (e.g. if a row in α is zero). If a variable in Z is weakly exogenous, the error correction terms will not affect the marginal process of this variable (Johansen (1995)). If this is the case, we do not need to consider the marginal process of the weakly exogenous variable when estimating the long-term relationships. The LR-test of restrictions can be used to test if one or more of the variables in Z are weakly exogenous, but at least one of the variables must be endogenous.

5.2 Our Model

In our analysis, Z contains house price, rent, building and land costs, and wage. These variables have been discussed in the section on the housing market, where it was argued that the variables should be linked in the long run. These include exogenous variables, which are not related to the cointegration relationships: 10-year government bond interest rate, inflation rate, GDP per capita, number of new buildings, unemployment rate, household consumption per capita, net immigration, stock exchange returns and population. These variables are chosen because it is reasonable that they could affect the short-term dynamics of the variables in Z, and it is common to include all of the relevant control variables in estimations to take account for possible misspecification of the model. In addition, we test whether the exogenous variables are stationary (contain one or more unit roots), and if not, the variables are differentiated. To determine the number of unit roots of the exogenous and the long-term variables, Dickey-Fuller unit root tests are performed.

6. Results

In this section, we provide evidence that there are long-term relationships in the housing market. First, the order of integration in each variable is determined by using unit root tests. Second, to detect whether long-term relationships exist in the housing market, cointegration tests are run.

Dickey-Fuller unit root tests are performed in order to quantify the order of integration ($I(d)$). All variables have one unit root, except population, which has two unit roots (see Table 1). The Dickey-Fuller tests for unemployment rate show that this variable has more than two unit roots, but if we add 1 lag (in order to fulfill the white noise assumptions better), the variable has only one unit root.

Table 1 Dickey-Fuller Tests for Unit Root of All Variables

	Level	First Difference	Second Difference
Variable	**Test stat.**	**Test stat.**	**Test stat.**
ln(real house prices)	0.62	-4.16	
ln(real rents)	-0.61	-3.78	
ln(real construction costs)	0.86	-5.24	
ln(real building costs)	0.64	-5.31	
ln(real land costs)	-0.38	-8.69	
ln(real wages)	0.46	-3.80	
ln(real GDP per capita)	-0.48	-3.32	
ln(real household consum per capita)	0.73	-5.43	
ln(real price index MSCI Norway)	-1.71	-6.92	
ln(new finished buildings in Norway)	-1.53	-4.57	
ln(population in Oslo)	7.05	0.05	-5.08
ln(1+national unemployment rate)	-1.39	-1.93*	-2.52
ln(1+inflation rate)	-1.77	-7.17	
Net immigration in Norway	-0.57	-7.70	
Critical Value	-2.96	-2.96	-2.96

*with 1 lag, the test statistic and critical value are -3.74 and -2.96 respectively.

Note: This table shows the unit root tests performed of all variables. The 5% interpolated Dickey-Fuller critical values are used. No lags are included in the test (if nothing else is specified). All variables except for new buildings, population, net immigration and inflation have been deflated by using the CPI. ln is short for natural logarithm.

As a generalization of Equation 10, we allow the rank to be greater than 1. The number of cointegration vectors in the system is determined by using the Johansen and Juselius (1990) cointegration rank test without exogenous variables. Based on the Schwarz criterion (BIC), the number of lags is set to 1. In the cointegration literature, it is common to take out the mean of the cointegration relationships, which follows the seminal paper of Engle and Granger (1987); a good discussion can also be found in MacKinnon (1996).

We have applied this transformation to our paper. Therefore, there are no constants in our vector autoregressive (VAR) model.

According to the cointegration test, the rank of the matrix Π is 4 for Equation 10 (see Table 2). In order to improve the estimation of the β , two dummy variables (defined in Section 4.5) are introduced for the deregulation of the rent market in 1982 and the new inflation goal in 1999. The α and β matrices are not identified, and therefore, the unrestricted matrices need to be restricted with rank squared restrictions (4^2=16). In order to obtain exact identification, the following restrictions are imposed: $\beta_{11} = \beta_{21} = \beta_{31} = \beta_{41} = 1$ (just a normalization) and $\beta_{13} = \beta_{14} = \beta_{15} = \beta_{22} = \beta_{24} = \beta_{25} = \beta_{32} = \beta_{33} = \beta_{35} = \beta_{42} = \beta_{43} = \beta_{44} = 0$. Alternatively, some of the restrictions could be imposed onto the α matrix.

Table 2 Johansen and Juselius (1990) Cointegration Rank Test

r	Eigenvalue	Trace-test	Critical value
0	0.9997	554.63	59.46
1	0.9400	212.10	39.89
2	0.8248	94.05	24.31
3	0.3919	20.90	12.53
4	0.0002	0.01	3.84
Obs.	43		

Note: The rank of the cointegration matrix is tested by using the Johansen and Juselius method. Endogenous variables: natural logarithm of real house price, rent, building and land costs or trend in wage. The critical values (95% interval) are derived per Osterwald-Lenum (1992) with no intercept in the cointegration vectors and the VAR. The number of lags is one.

These restrictions have been chosen because economists often use ratios between price-rent, price-construction cost and price-wage to say something about over- or undervaluation in the housing market. Since construction costs are decomposited into building and land costs, we use these ratios instead of the price-construction cost ratio: price-building cost and price-land cost. In addition, the bivariate cointegration tests of these ratios show that the variables have a long-term relationship.[4] By using these restrictions, the β and α matrices can be estimated under the assumption of exact identification. The 10-year government bond interest rate, number of new finished buildings, unemployment rate, population, GDP per capita, household consumption per capita and net immigration are used as exogenous variables because they significantly affect changes in house prices, rents, building and land costs, and wages after controlling for the error correction terms in the VECM. Estimation of the α and β matrices are shown in Table 3

[4] If the reader would like to see the cointegration tests, please email the authors of this paper.

Table 3 Estimation of the α and β Matrices

β matrix								
	CV1		CV2		CV3		CV4	
Variable	β	St.Err.	β	St.Err.	β	St.Err.	β	St.Err.
ln(real house prices)	1	0	1	0	1	0	1	0
ln(real rents)	-0.98	0.03	0	0	0	0	0	0
ln(real building costs)	0	0	-0.95	0.02	0	0	0	0
ln(real land costs)	0	0	0	0	-1.00	0.03	0	0
ln(real wages)	0	0	0	0	0	0	-0.97	0.04
d1982 (1 if year > 1981)	0.19	0.14	-0.34	0.09	0.05	0.15	-0.08	0.19
d1999 (1 if year > 1998)	-0.55	0.11	-0.36	0.08	-0.32	0.13	-0.96	0.16
α matrix								
	CV1		CV2		CV3		CV4	
Variable	α	St.Err.	α	St.Err.	α	St.Err.	α	St.Err.
ln(real house prices)	0.09	0.09	0.06	0.17	0.18	0.11	-0.21	0.10
ln(real rents)	0.17	0.06	0.10	0.12	0.07	0.08	-0.09	0.07
ln(real building costs)	0.21	0.14	0.51	0.14	0.18	0.09	-0.40	0.08
ln(real land costs)	0.19	0.12	0.01	0.23	0.50	0.15	-0.34	0.14
ln(real wages)	0.01	0.02	-0.02	0.04	-0.01	0.02	-0.01	0.02

Diagnostic tests	Test-stat	p-val
Normality ($\chi^2(10)$)	8.91	0.54
Heteroskedasticity(F(130,54))	1.12	0.33

Beta is identified.

Eigenvalues of companion matrix

real	1	0.96	0.85	0.65	0.53
modul	1	0.96	0.85	0.65	0.53

Note: This table shows the estimation of the α and β matrices by using the VECM. The following restrictions are imposed in order to estimate the β matrix under the assumption of exact identification: $\beta_{11} = \beta_{21} = \beta_{31} = \beta_{41} = 1$and $\beta_{13} = \beta_{14} = \beta_{15} = \beta_{22} = \beta_{24} = \beta_{25} = \beta_{32} = \beta_{33} = \beta_{35} = \beta_{42} = \beta_{43} = \beta_{44} = 0$. CV1 is the first cointegration vector (CV), CV2 the second CV, and so on. The number of lags is one. Endogenous variables: ln(real house prices), ln(real rents), ln(real building costs), ln(real land costs) and ln(real wages). Stationary exogenous variables lagged once: first differences of ln(real GDP per capita), ln(real consumption per capita), ln(1+ national unemployment rate), ln(1+ real 10 year Norwegian government bond interest rate), net immigration, ln(number of new finished dwellings) and second differences of ln(population in Oslo).

The next step is to test for over-identifying restrictions. First, whether some of the long-term variables in Z are weakly stationary, is tested by using LR-tests of restrictions (see Table 4). These tests reject the possibility that house prices, rents, and building and land costs are weakly exogenous, but wages are marginally weakly exogenous (based on a 7% significance level). However, as a contrast to the other endogenous variables, the wage index does not have any significant α values when t-tests are used. Hence, the stochastic process that drives wages also drives house prices, rents, and building and land costs in the long-run.

Table 4 Weakly Exogeneity Tests

α restriction	LR-test $\chi^2(4)$	p-value
$\alpha_{11} = \alpha_{21} = \alpha_{31} = \alpha_{41} = 0$	9.93	0.04
$\alpha_{12} = \alpha_{22} = \alpha_{32} = \alpha_{42} = 0$	11.22	0.02
$\alpha_{13} = \alpha_{23} = \alpha_{33} = \alpha_{43} = 0$	21.51	0.00
$\alpha_{14} = \alpha_{24} = \alpha_{34} = \alpha_{44} = 0$	14.34	0.01
$\alpha_{15} = \alpha_{25} = \alpha_{35} = \alpha_{45} = 0$	8.65	0.07

Note: The table shows whether some of the endogenous variables tested are weakly exogenous by imposing restrictions onto the α coefficients in the VECM. The LR-test of over-identified restrictions is used. The following restrictions are imposed in order to estimate the β matrix under the assumption of exact identification: $\beta_{11} = \beta_{21} = \beta_{31} = \beta_{41} = 1$ and $\beta_{13} = \beta_{14} = \beta_{15} = \beta_{22} = \beta_{24} = \beta_{25} = \beta_{32} = \beta_{33} = \beta_{35} = \beta_{42} = \beta_{43} = \beta_{44} = 0$. The number of lags is one. Endogenous variables: ln(real house prices), ln(real rents), ln(real building costs), ln(real land costs) and ln(real wages). Stationary exogenous variables lagged once: first differences of ln(real GDP per capita), ln(real household consumption per capita), ln(1+ national unemployment rate), ln(1+ real 10 year Norwegian government bond interest rate), net immigration, ln(number of new finished dwellings) and second differences of ln(population in Oslo).

Next, we test whether $\beta_{12} = \beta_{23} = \beta_{34} = \beta_{45} = -1$. The LR-test of restrictions rejects this hypothesis with a significant level of 1%, but we are nonetheless unable to reject it, mainly on account of the estimation of β_{32}, which has a value of -0.95. Naturally, we test whether that $\beta_{12} = \beta_{34} = \beta_{45} = -1$ where β_{32} is freely estimated. The LR-test of restriction now shows a p-value of 15%. Therefore, we accept this hypothesis and restrict these βs to -1.

In addition to the above restrictions, we can restrict more insignificant variables to be equal to 0. By doing this stepwise, we end up with the model in Table 5. After all of these restrictions are imposed, it can be shown that we cannot reject that β_{32} is different from -1 when using an LR-test of restrictions, which shows a p-value of 7%.

Our results that regard the importance of the price-rent ratio supports the results of Gallin (2008) who finds a long-run relationship between rents and prices in the U.S. housing market. However, this paper deviates from Krakstad and Oust (2013) by finding an explicit instead of an implicit long-term relationship between house prices and rents (the α values are positive).

Table 5 α and β Estimations with Over-identifying Restrictions

β matrix								
	CV1		CV2		CV3		CV4	
Variable	β	St.Err.	β	St.Err.	β	St.Err.	β	St.Err.
ln(real house prices)	1	0	1	0	1	0	1	0
ln(real rents)	-1	0	0	0	0	0	0	0
ln(real building costs)	0	0	-0.96	0.01	0	0	0	0
ln(real land costs)	0	0	0	0	-1	0	0	0
ln(real wages)	0	0	0	0	0	0	-1	0
d1982 (1 if year > 1981)	0.35	0.08	-0.34	0.04	0	0	0	0
d1999 (1 if year > 1998)	-0.48	0.12	-0.18	0.05	0	0	-0.60	0.08

α matrix								
	CV1		CV2		CV3		CV4	
Variable	α	St.Err.	α	St.Err.	α	St.Err.	α	St.Err.
ln(real house prices)	0.11	0.05	0	0	0.15	0.09	-0.22	0.06
ln(real rents)	0.11	0.03	0	0	0	0	0	0
ln(real building costs)	0.19	0.12	0.48	0.12	0.18	0.08	-0.36	0.07
ln(real land costs)	0.19	0.08	0	0	0.48	0.13	-0.27	0.08
ln(real wages)	0	0	0	0	0	0	0	0

Diagnostic tests	**Test-stat**	**p-val**
Normality ($\chi^2(10)$)	12.57	0.25
Heteroskedasticity(F(130,54))	1.13	0.30
Restriction LR-test ($\chi^2(16)$)	14.93	0.46

Eigenvalues of companion matrix

real	1	0.96	0.85	0.65	0.53
modul	1	0.96	0.85	0.65	0.53

Note: This table shows the estimation of the α and β matrices by using the VECM. The following restrictions are imposed in order to estimate the β matrix under the assumption of exact identification: $\beta_{11} = \beta_{21} = \beta_{31} = \beta_{41} = 1$and $\beta_{13} = \beta_{14} = \beta_{15} = \beta_{22} = \beta_{24} = \beta_{25} = \beta_{32} = \beta_{33} = \beta_{35} = \beta_{42} = \beta_{43} = \beta_{44} = 0$. CV1 is the first cointegration vector (CV), CV2 the second CV, and so on. The number of lags is one. Endogenous variables: ln(real house prices), ln(real rents), ln(real building costs), ln(real land costs) and ln(real wages). Stationary exogenous variables lagged once: first differences of ln(real GDP per capita), ln(real consumption per capita), ln(1+ national unemployment rate), ln(1+ real 10 year Norwegian government bond interest rate), net immigration, ln(number of new finished dwellings) and second differences of ln(population in Oslo). Additional restrictions have been imposed when the coefficients have a value of exactly 0 or -1.

There is evidence of a long-term relationship between house prices and wages in the literature, but the results are mixed. Kenny (1999) finds cointegration between Irish prices, income, housing stock, and interest rate. With the use of panel data of U.S. cities (1979–1996), Malpezzi (1999) estimates that house prices and income are cointegrated. Gallin (2006) uses 27 years of national U.S. panel data (1975–2002). He does not find cointegration between real prices and income. He argues that cointegration tests have low power in small samples, and that it is therefore better to use a panel test for unit roots and cointegration. However, according to Holly et al. (2010), the bootstrap panel unit root tests reported by Gallin (2006) can be subject to large size distortions. They conclude that the logarithm of real house price and real disposable income are cointegrated. By using the 100 largest metropolitan statistical areas in the U.S., Anundsen and Heebøll (2013) find that around 75% of those areas have a meaningful long-term relationship, thus indicating that the use of panel data may average out cointegration. Our procedure differs from other approaches since we include more stationary exogenous variables, and our time series are longer (going back to 1970). This paper gives evidence that there is an empirical long-term relationship between house prices and income.

Few papers have been able to address the long-term relationship between house prices and construction costs due to data limitations worldwide. With regard to the long-term relationship between house prices, and building and land costs, this paper is the first to use building and land costs in a cointegration test. This gives us an advantage because the movement in building and land costs may deviate. By using construction wage as a proxy variable for construction costs, Mikhed and Zemcik (2009) find that U.S. house prices are cointegrated with construction costs and income in the period between 1980 and 2008. Our findings are also consistent with those of Krakstad and Oust (2013) because Oslo house prices are cointegrated with construction costs.

7. Concluding Remarks

Through the use of a unique dataset which includes the first Norwegian hedonic building and land cost indices, we find a long-term relationship between house prices, rents, building and land costs, and wages. This paper is the first to look at how these five variables interact in the long run. Since indices for building and land costs in Norway do not exist, we create and present hedonic indices for these two variables. In our analysis, we restrict the long-term cointegration matrix by using the economically reasonable and stationary price-rent, price-building cost, price-land cost and price-wage ratios because of identification issues. A VECM is estimated with these five variables. The error correction terms proved important for estimating changes in house prices, rents, and building and land costs, but wages are found to be weakly exogenous in our house market system. In the long run, wages therefore drive house prices, rents, and building and land costs.

As not only land cost but building cost is driven by wage in the long run, our study improves the understanding of the connection between the construction cost theory and the affordability theory of explaining house prices, and allows both theories to be used side by side, thus bridging some of the gap between the two.

In Norway, house prices are high relative to the development in rents, construction costs and wages for the last 40 years. Our findings confirm that building and land costs are important for house price changes. A reduction in the costs associated with them by, for example, having fewer regulations, should increase the supply of new dwellings in Norway. Fewer regulations could reduce the cost of new dwellings and the financial risk for Norway as a whole.

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Appendix

Table A1 Construction, Building and Land Cost Indices

Year	Construction Costs	Building Costs	Land Costs
1970	100.00	100.00	100.00
1971	109.53	108.40	117.10
1972	113.22	112.08	120.81
1973	119.36	118.53	124.87
1974	136.81	134.97	149.04
1975	156.41	154.05	172.11
1976	177.38	172.74	208.25
1977	197.85	193.92	223.96
1978	228.04	220.00	281.54
1979	239.97	230.60	302.26
1980	260.67	248.88	339.03
1981	292.41	284.33	346.14
1982	352.93	332.76	426.74
1983	332.73	320.16	372.81
1984	366.77	351.22	406.87
1985	398.80	376.99	491.26
1986	434.59	401.21	576.00
1987	491.53	459.19	556.22
1988	567.64	540.58	659.03
1989	596.15	555.94	801.62
1990	601.28	554.42	849.65
1991	571.74	514.29	887.15
1992	543.69	494.80	818.31
1993	470.72	426.41	726.73
1994	469.82	429.77	682.36
1995	520.13	453.37	902.93
1996	533.98	503.47	736.79
1997	536.35	490.54	840.83
1998	681.53	592.42	1149.39
1999	674.01	618.93	1129.12
2000	763.57	696.12	1117.01
2001	863.72	787.96	1353.33
2002	959.79	892.02	1401.60
2003	1011.44	926.59	1590.95
2004	1081.45	1007.73	1592.77
2005	1102.83	1085.39	1218.75
2006	1222.75	1193.05	1420.20
2007	1725.05	1511.65	3143.77

(Continued…)

(Table A1 Continued)

Year	Construction Costs	Building Costs	Land Costs
2008	1585.65	1414.66	2722.42
2009	1689.09	1429.10	3417.58
2010	1547.28	1354.15	2831.28
2011	1786.98	1604.93	2997.26
2012	1982.44	1844.49	2899.58

Note: The table shows three Norwegian hedonic indices for construction, building and land costs. The indices have been created by using 4000 observations collected from a database in the Norwegian State Housing Bank (Husbanken). The time dummy method has been used to make the indices. The estimated equation is: $r_{it} = \gamma_0 + \delta_t + \alpha_k c_{kit} + e_{it}$ where r equals the natural logarithm of construction, building or land costs. c is a set of explanatory variables for the presence of certain characteristics, t = {1, 2, ..., T } and i denote the period and the dwelling, respectively. The dummy variables that we use in our regression are dwelling size and location. δ_t represents the time dummy coefficients.

Table A2 Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Real house prices	43	100	49	52	219
Real rents	43	100	28	63	153
Real construction costs	43	100	37	65	187
Real building costs	43	100	36	65	184
Real land costs	43	100	50	48	233
Real wages	43	100	23	66	152
Real price index MSCI Norway	43	184	103	50	490
Real GDP per capita	43	174	52	100	273
Real household consumption per capita	43	5671	1386	3983	8401
Population	43	4339517	306704	3888305	5051275
Net immigration	43	2041	2629	-189	10023
Finished new buildings	43	28723	8811	15897	44714
Inflation rate	43	0.05	0.03	0.01	0.13
Unemployment rate	42	0.01	0.01	0.00	0.03
Real 10 year government bond interest rate	43	0.03	0.03	-0.04	0.07

Note: This table gives the summary statistics of the variables that we have used. The number of observations, mean values, standard deviation, and minimum and maximum values are shown.

Table A3 Correlation Matrix for All Stationary Variables

	drlnP	drlnR	drlnCC	drlnBC	rlnLC	rlnw	drloanint	MSCI	dinflation	drlnGDP	buildg	dunempl	drlnC	d2pop
drlnR	0.62	1												
drlnCC	0.46	0.22	1											
drlnBC	0.47	0.24	0.95	1										
rlnLC	0.22	0.10	0.72	0.58	1									
rlnw	0.21	0.11	0.35	0.34	0.24	1								
drloanint	0.05	0.07	0.23	0.19	0.32	0.05	1							
drlnMSCI	0.03	-0.11	0.08	0.07	0.07	-0.02	-0.03	1						
dinflation	0.13	0.08	-0.06	-0.02	-0.20	-0.06	-0.86	0.06	1					
drlnGDP	0.52	0.47	0.32	0.32	0.20	0.59	-0.01	0.32	0.08	1				
buildg	0.40	0.26	0.37	0.37	0.26	0.28	0.01	0.23	0.04	0.32	1			
dunempl	-0.51	-0.51	-0.23	-0.25	-0.17	-0.39	0.10	-0.39	-0.22	-0.75	-0.34	1		
drlnC	0.17	0.14	0.02	0.07	-0.12	0.18	-0.04	0.34	0.02	0.45	-0.14	-0.43	1	
d2pop	0.28	0.41	0.11	0.19	0.08	0.23	0.00	0.07	0.07	0.31	0.04	-0.44	0.29	1
dNetIm	0.13	0.35	-0.04	0.02	-0.11	0.30	-0.08	0.17	0.14	0.34	0.17	-0.46	0.36	0.73

Note: rlnP = ln(real house price), rlnR = ln(real rent), rlnCC = ln(real construction cost), rlnBC = ln(real building cost), rlnLC = ln(real land cost), rlnW = ln(real wage). The letter d in front of these variables means that they are differentiated once. drloanint = 1.diff. real 10-year government bond interest rate, dinflation=1.diff.inflation, drlnGDP=1.diff. logarithm of the real GDP per capita, buildg= percentage increase of new dwellings, dunempl=1.diff. unemployment ratio, drlnC=1.diff. logarithm of the real household consumption per capita, MSCI=1.diff.real price index of MSCI Norway, d2pop = 2.diff. population Oslo, dNetIm=1. diff. of net immigration.