Elias Oikarinen

Dynamic linkages between housing and lot prices: Empirical evidence from Helsinki

Aboa Centre for Economics

Discussion Paper No. 53
Turku 2009

ISSN 1796-3133

Printed in Uniprint
Turku 2009

Elias Oikarinen

Dynamic linkages between housing and lot prices: Empirical evidence from Helsinki

Aboa Centre for Economics
Discussion Paper No. 53
September 2009

ABSTRACT

The price of vacant land zoned for housing is expected to be tightly linked to housing prices. In informationally efficient markets, vacant lot price movements should not lag changes in housing prices. In practice, however, the leading role of housing appreciation with respect to vacant lot price growth may be caused by factors such as thin trading and lack of publicly available data on transactions in the lot market. Based on a vector error-correction model employing quarterly data from the Helsinki Metropolitan Area over 1988Q1-2008Q2, this study shows that housing price movements lead price changes in the market for vacant lots and housing prices react to shocks in the demand side fundamentals more rapidly than lot prices. Overall, the empirical results give support to the hypothesis that house prices respond to shocks influencing the value of developed land first, after which the price level of vacant lots reacts to the information revealed by housing prices. Hence, the results indicate that the market for lots is more informationally inefficient than the housing market. Furthermore, the empirical findings suggest that construction costs too react to income and interest rate shocks.

JEL Classification: R31; R32; E31

Keywords: Housing, land, lot prices, dynamics, construction costs

Contact information

Elias Oikarinen, Department of Economics, Turku School of Economics, Rehtorinpellonkatu 3, 20500 Turku, Finland. Email: elias.oikarinen@tse.fi

Acknowledgements

The author wishes to thank Luis H. Alvarez, Martin Hoesli, Risto Peltola and the participants at the 25th American Real Estate Society Annual Meeting and at the XXXI Annual Meeting of the Finnish Society for Economic Research for helpful comments. Financial support from the OP Bank Group Research Foundation and the City of Helsinki is gratefully acknowledged.

1 Introduction

It is obvious that the housing price level is dependent on the price of land. Price of a house consists of the replacement cost of the physical structure together with the value of land upon which the house is built.[1] Consequently, the growth rate of the price of a house is the weighted average of growth rates of the value of the structure and of the land upon which the house stands. The price of the structure is typically measured as the replacement cost of the physical building, after accounting for depreciation. Land, in turn, is the factor that makes a house worth more than the cost of putting up a new structure of similar size and quality on a vacant lot. In other words, land is the market value associated with the location, size and attractiveness of the site.

According to theory, also the value of vacant land zoned for housing is tightly linked to housing prices. If the markets were efficient, price changes in the land market should not lag those in the housing market; at least there is no theoretical model suggesting such dynamics. On the contrary, according to the land pricing framework of Titman (1985) price movements of vacant lots should precede housing price movements. Yet, it is possible that housing appreciation leads the price changes perceived in the market for vacant land. The leading role of housing appreciation with respect to price movements of vacant lots may be caused by informational reasons due to factors such as thin trading in the lot market and the lack of publicly available data concerning transactions in the land market. The empirical results by Rosenthal (1999), for example, imply that any inefficiency in the housing market must lie in the market for land.

Lead-lag relations between the housing and lot markets would have implications for the informational efficiency of the lot market and for the predictability of lot prices. Nevertheless, while a number of studies such as Titman (1985), Capozza and Helsley (1989, 1990), Keushnigg and Nielsen (1996), Guntermann (1997), Rosenthal (1999) and Cunningham (2006), just to name a few, have analyzed price determination of vacant land, empirical research on the linkages between the housing market and the market for vacant land is still scarce. There are some previous studies, e.g. Ozanne and Thibodeau (1983), Manning (1988) and Potepan (1996), in which the relationship between housing prices and land prices is studied. None of these studies, however, investigate the potential lead-lag relation between the prices.

This article aims to contribute to filling the gap regarding empirical evidence on the dynamic interaction between housing and land prices. Quarterly data on vacant lot prices and on housing prices over 1988Q1-2008Q2 from the Helsinki Metropolitan Area (HMA) in Finland are employed in the empirical analysis. It is shown based on a vector error-correction model that housing price movements lead price changes in the market for vacant lots. Moreover, vacant land prices appear to be more predictable and to react to demand shocks more sluggishly than housing prices. Overall, the empirical results give support to the

---

[1] Due to the weak demand for housing, in a rapidly declining area the price of a house can be less than the joint value of land and the replacement cost of the structure. At a minimum the price can be the value of the land net of the demolition cost of the structure. In this study, however, it is only housing in non-declining metropolitan areas that is considered.

hypothesis that house prices respond to shocks influencing the value of developed land first, after which the price level of vacant lots reacts to the information revealed by housing appreciation. That is, the results indicate that the market for vacant lots is more informationally inefficient than the housing market.

The results imply that the construction costs too have notably reacted to shocks in the demand side factors. It is claimed that this is mainly due to changes in the profit margins. The fact that a demand shock appears to have a permanent effect on real construction costs implies that the construction sector is not fully competitive; a positive shock to housing demand leads to greater profit margins.

The paper proceeds as follows. The next section discusses the linkages between housing prices and vacant land prices theoretically. The third section presents the data used in the empirical analysis, and the empirical methodology is introduced in section four. The findings from the econometric analysis are presented in the fifth section. In the end, the paper is summarized and conclusions are derived.

2 Theoretical considerations

A simple way to look at the linkage between housing prices and prices of lots zoned for housing is to consider the price level for newly completed dwellings. The selling price of newly built housing can be presented by (1), where H denotes the price of a unit of newly built housing, L is the unit price of land upon which the building is built and C signifies the unit cost of constructing the structure (including developers profit margin). Similarly, the price of a unit of vacant land zoned for housing can be expressed by (2). This way of presenting the dependence between the prices of housing and of vacant land zoned for housing corresponds to the residual value of land view (see e.g. Somerville, 1996; Tse, 1998).

$$H = L + C \tag{1}$$

$$L = H - C \tag{2}$$

Equations (1) and (2) yield the following equations (where w denotes the share of the land value component of the price of housing) for the housing and land price changes:

$$\Delta H = w^*\Delta L + (1\text{-}w)^*\Delta C \tag{3}$$

$$\Delta L = [\Delta H - (1\text{-}w)^*\Delta C]/w \tag{4}$$

Equation (3) states that the growth rate of housing prices is a simple weighted average of the growth rates of the land and structure components of housing. Naturally, (3) and (4) apply also for the old housing stock, H then being the unit price of old dwellings, L the unit value of developed residential land and C the value of the old structure.

As old dwellings and newly built homes within a metropolitan area can be considered to be close substitutes for each other, price growth of existing housing stock implies that higher prices can be charged also for newly built housing. In fact, substitutability between old and new housing implies that in (3) and (4) H can stand for the price of old housing while L can denote the price of vacant land zoned for housing. This fact is utilized in the forthcoming empirical analysis. Empirical support for the hypothesis that the price level of the old housing stock is tightly linked to that of new housing construction in Finland is reported by Suoniemi (1990). Rosenthal (1999), in turn, finds different-vintage buildings to be close substitutes in Vancouver, Canada.

The equilibrium asset price models by Capozza and Helsley (1989, 1990) show that, in equilibrium, in larger cities and in cities with greater growth prospects the value of land is higher. This is because of the positive relationship between city size and scarcity of desirable land and due to the positive effect of growth prospects on the real option value of land. The regional differences in the value of land are of importance, since the higher the land's share of the aggregate home value (or the "land leverage", a phrase introduced by Bostic et al. (2007)) is, the greater is the correlation between housing appreciation and land price movements and the more volatile housing prices are likely to be. This is because construction costs are typically relatively stable whereas land prices are much more volatile.

Since desirable land is largely non-reproducible, changes in the demand for housing are likely to have substantial influence on the price of the land component of housing. By contrast, changes in the demand side are not expected to have much impact on the real price of structures, i.e. on construction costs. That is, when a positive housing demand shock takes place H increases while, due to the restraining influence of competition among housing developers on the growth in C, C is expected to stay constant or at least to grow less than H. This leads to an increase in the price of vacant lots zoned for housing. As construction costs, in general, are stable compared to land prices, it is reasonable to believe that housing price movements usually give information regarding changes in the value of land. Empirical evidence for the high volatility of the value of land compared with the value of physical structure is presented by Somerville (1999) and Davis and Heathcote (2007) utilizing US data. Davis and Heathcote bring evidence also for the demand driven nature of land prices and find the contemporaneous correlation between detrended real land and housing prices to be as high as .92.

Furthermore, since the supply of desirable land is generally fixed and growth in the demand factors such as population and income induce rise in the value of land, in a rapidly growing metropolitan area the value of land is expected to grow faster than the value of the structure (i.e. construction costs). That is, in a growing city the share of land value (structure) of the average home value is expected to increase (decrease). In line with this claim, Davis and Heathcote (2007) find that land's share of aggregate home value has been trending upwards since the 1950s in the U.S. Moreover, according to Davis and Palumbo (2008) the value of land accounted for about 50% of the total market value of housing in large US metro areas in 2004, while the share was only 32% in 1984. Bostic et al. (2007) show that even in a relatively small city with no notable geographical restrictions (Wichita, Kansas) the value of land can grow substantially faster than the value of the structure.

The residual value of land framework considered above is, of course, a simplification of the reality. However, it illustrates the basic idea behind the linkage between housing prices and prices of lots. The price of vacant land can be examined more rigorously by the real option pricing theory.

According to the real option pricing theory, owners of vacant land hold a call option that gives them the right, but not obligation, to develop the land. Due to the real option value, a lot can be more valuable as a potential site for development in the future than it is as an actual construction site at the present moment. It has been shown theoretically that the real option value of land is increased by greater growth prospects of the city and by greater uncertainty about future housing prices or rental prices (e.g. Titman, 1985; Capozza and Schwann, 1989; Capozza and Helsley, 1990; Capozza and Sick, 1994; Capozza and Li, 2002).

Empirical evidence by a number of authors supports the existence of a notable real option value component of vacant land. Quigg (1993) estimates a real option premium of six percent over the deterministic price of vacant land. Guntermann (1997), in turn, finds evidence for the hypothesis according to which land prices in rapidly growing areas include a significant premium based upon expectations of future growth. The estimations of Guntermann suggest that the premium varies from less than 40% of land value during busts to over 70% during booms in the case of Phoenix, Arizona. In a more recent study, Cunningham (2006) finds a standard-deviation rise in uncertainty to increase the price of vacant land by 1.6%.

The real option value capitalizes into the price of developed land and thereby into the price of housing. The real option component of developed land equals the real option value of vacant land at the boundary of the city. However, the relative impact of an increase in uncertainty regarding future rental price growth may not be the same on developed land as it is on vacant land situated outside the boundary of the city (see Capozza and Helsley, 1990). In particular, as vacant lot prices outside the boundary do not include the value of accessibility component, an increase in uncertainty and thus growth in the real option value is likely to lead to a greater relative rise in the prices of lots situated outside the boundary than in the price of developed land, in general. This may results in complications in an empirical analysis, such as the one conducted in this article. Generally, a significant fraction of the vacant lots that are transacted in the market are located outside the boundary. Therefore, due to time variation in uncertainty, the perceived growth rate of price of vacant land zoned for housing may differ somewhat from the appreciation rate of developed land even if old and new dwellings are close substitutes. That is, although Capozza and Helsley (1990) do not consider the potential consequences of higher discount rates due to greater uncertainty in their model (they assume land owners to be risk neutral), it may be necessary to include a proxy for rental price growth uncertainty in an econometric examination to find a stationary long-run relation between housing prices and vacant lot prices.

If the shares of the land value component and structure component of housing prices stay constant over the long run, the following long-run model can be estimated:

$$H_t = \phi + \beta_1 L_t + \beta_2 C_t + \beta_3 U_t + \varepsilon_t. \tag{5}$$

Because of the potential impact of uncertainty discussed above, a measure of uncertainty concerning rental price development (U) is included in equation (5). β_1, β_2 and β_3 are the estimated parameters on the vacant lot price index (L), constructions cost index (C) and U. Since housing price level consists of the two components (land and structure), the theory suggests that $\beta_1>0$, $\beta_2>0$ and $\beta_1 + \beta_2 = 1$. Moreover, since the growth rate of housing price is a simple weighted average of the growth rates of land and structures, β_1 (β_2) should equal the share of the land (structure) value component of housing prices. The coefficient on U, instead, is expected to be negative, since an increase in uncertainty should, in general, result in a greater relative rise in the vacant lots outside the boundary of the city than in the value of developed land. The temporary deviation from the long-run relation is signified by ε. Finally, ϕ is a deterministic constant.

The relation in (5) is expected to be stationary if the growth rate of L equals the growth rate of C over time, i.e. if the shares of land and structure stay constant in the long horizon. However, in a growing metropolitan area it is generally expected that L increases faster than C. Therefore, in the HMA case β_1 is expected to be growing and β_2 decreasing in the long run. Because of this, the long-run model (6), including a time trend (t), is actually estimated in the empirical analysis.

$$H_t = \phi + \beta_1 L_t + \beta_2 C_t + \beta_3 U_t + \delta t + \varepsilon_t. \qquad (6)$$

The trend may be needed to cater for the faster growth of land value than of construction costs. Because the share of the more rapidly growing component increases, δ is expected to be positive. In other words, housing appreciation is expected to be faster over the long horizon than implied by the parameters β_1 and β_2 alone. To preview, the findings reported in section 5 imply that relation (6) is, indeed, stationary over 1988Q1-2008Q2 whereas relation (5) is not. This supports the hypothesis that the deterministic trend term is, at least to a reasonable extent, able to take account of the long-term trends in the shares of the land value and structure value components during the sample period.[2]

If the markets were informationally efficient, price changes in the land market should not lag those in the housing market. At least the theoretical literature does not present any analytical model exhibiting structural relations that would suggest the leading role of housing prices with respect to vacant land prices. On the contrary, according to the land pricing framework of Titman (1985) price movements of vacant lots should precede housing price growth.[3] In practice, however, leading role of housing appreciation with respect to the price movements of vacant lots may be caused by informational reasons due to factors such as thin trading in the lot market and lack of publicly available data concerning transactions in the land market.

The purpose of this paper is to study the dynamic relationship between prices of vacant lots and housing. Of particular interest is to investigate if housing appreciation Granger causes land price growth. As explained above, housing appreciation in a metropolitan area is usually driven by changes in the value of land. Therefore, it is reasonable to assume that, in general, price changes perceived in the housing market reveal information concerning movements in the value of developed land rather than regarding changes in the value of structure. The econometric analysis in this paper suggests that the market for vacant land is inefficient; it appears that the reaction of land prices to demand shocks is delayed and housing price movements lead land price changes.

---

[2] Actually, if the share of the land value component increases over time, there may not be any linear cointegrating vectors between the four variables even if the trend is included. However, it appears that equation (6) is a reasonable approximation for the long-run relationship during the sample period and is therefore employed in the empirical analysis.

[3] Titman (1985) points out that if the sizes of the buildings that can be built on the vacant lots are constrained by zoning regulation, the anticipatory feature of land price movements with respect to housing appreciation is undermined. In Finland, the zoning regulations are typically relatively tight.

3 Data

The real housing price index (*H*) used in this study describes the price development of single-family houses in the Helsinki Metropolitan Area (HMA).[4] The real land price index (*L*), in turn, depicts the evolution of price level of vacant land zoned for single-family houses. Both price indices are quality adjusted. The hedonic housing price index is published by Statistics Finland, while *L* is based on the hedonic model by Peltola and Väänänen (2007). The indices are quarterly and cover a period from 1985Q1 to 2008Q2.

In addition, a number of control variables likely to affect housing prices and land prices significantly are incorporated in the empirical analysis:

- Real construction cost index (*C*)
- Unemployment rate (*U*)
- Real interest rate (*IR*)
- Real aggregate disposable income (*Y*)

The reason for including *C* in the dataset becomes clear in the theoretical discussion above. *Y* and *IR*, in turn, are fundamental factors affecting housing demand and, thereby, housing and land prices. Inclusion of *Y* and *IR* in the econometric model enables a more detailed examination of housing and land price dynamics. In particular, the reactions of *H* and *L* to shocks in the prevailing market conditions (*Y* and *IR*) are investigated in the empirical analysis.

Unlike typically in the empirical literature, the construction cost variable incorporates the developers' profit margin. Hence, *C* corresponds to the theoretical concept of construction costs in equations (1)-(4). The construction cost index is based on tender prices of new housing construction in HMA. The index is reported by Rapal Ltd and is available starting from 1988Q1. *C* approximates the development of the value of physical structure component of housing prices.

The unemployment rate (*U*) reported by Statistics Finland is incorporated to the dataset to approximate the time variation in uncertainty regarding future housing (or rental) price development. It is assumed that people perceive the uncertainty regarding the future particularly high in times of high unemployment. On the other hand, greater uncertainty about the future development of demand side factors may induce higher unemployment rates (see e.g. Jellal et al., 2005). Therefore, the unemployment rate is likely to give information about the uncertainty concerning the future in the economy. The results from the econometric analysis are in line with this assumption. Obviously, unemployment is only a proxy for the uncertainty regarding future housing (or rental) price growth, however. Due to the extreme seasonal variation in the unemployment series, a seasonally adjusted version of the unemployment rate is employed.[5]

---

[4] HMA, as defined here, consists of Helsinki and the three nearest surrounding municipalities Espoo, Kauniainen and Vantaa.

[5] Similar measures of housing price uncertainty to those employed by Cunningham (2006) were also tried in the analysis. Those measures did not yield sensible results.

The market interest rate variable (*IR*), in turn, is the twelve month Helibor until 1998Q4 and the corresponding Euribor after that. This interest rate measure is used in the analysis, since the interest rates of most of the mortgages in the Finnish market are tied to the twelve month Helibor/Euribor. The quarterly values of *IR* are based on arithmetic averages of the daily values.

Finally, the aggregate disposable income (*Y*) caters for both population and income growth in HMA. The disposable income data are available only at an annual level. Thus, the quarterly variation has been estimated based on the quarterly nationwide income level index. This is likely to produce a fairly good approximation for the quarterly aggregate income figures. Also the income data are published by Statistics Finland.

In the econometric analysis, natural logarithms are taken from all the series except for *U* and *IR*. Furthermore, only real values are employed in the study. Nominal values are deflated by the cost of living index to get real variables.

It is reasonable to assume that cross-regional differences in construction costs within a relatively homogenous and small country, such as Finland, are small relative to differences in land prices.[6] Hence, as the housing price level in HMA is substantially greater than in the other areas in Finland, it is can be assumed that the value of land in HMA notably exceeds that in the other Finnish regions. Indeed, this appears to be true according to the vacant lot price statistics reported by Statistics Finland. In 2008Q2 the average square meter price of a dwelling in HMA was more than double that in the rest of Finland. This suggests that the value of developed land may actually account for more than half of the price of a typical dwelling in HMA. Because of the high value of land, housing appreciation in HMA is expected to correlate strongly with land price changes.

Although hedonic price indices are employed, there appears to be substantial short-run measurement error in the house and land price series. That is, the hedonic indices are probably not able to perfectly track the time variation in the quality of the transacted houses and lots. In particular, due to thin trading in the markets the price series are likely to include "noise" in the short run, i.e. the short-run variation of the price series is probably overly large. Since the apparently substantial noise in the price series might disturb the results of the econometric analysis, Hodrick-Prescott (HP) filtered price indices are used in the econometric analysis. To avoid extracting actual short-term dynamics, as small a tuning parameter for HP filter as 1.5 is employed. Even such a small tuning parameter yields notably smoother indices than the original ones (Figure A1 in the Appendix). Figure 1 exhibits the series included in the empirical analysis. Because of the limits set by the construction cost index, the effective sample period in the empirical analysis is 1988Q1-2008Q2.

[Fig. 1 here]

The dramatic rise since 1988 in housing and lot prices was largely a consequence of the financial market liberalization in the late 1980s that was followed by a boom in bank lending. The housing and lot markets finally collapsed at the beginning of the 1990s. The

---

[6] Within a larger and more heterogeneous country there may be more significant differences between regional construction costs (see e.g. Gyourko and Saiz (2006) for differences in construction costs across U.S. housing markets).

drop in housing and land prices as well as in the other asset prices was deepened by the severe recession in Finland in the early and mid 1990s. Also *C* decreased drastically during 1990-1993. This was largely due to a drop in the profit margins. After mid 1990s, housing and lot prices have grown substantially faster than *Y*. This is likely to be, to a great extent, due to the low level of house and lot prices during the slump and because of the significant decrease in the interest rates and loosening in the liquidity constraints (see Oikarinen, 2009). In 2008Q2, the population of HMA reached 1.02 million.

Expectedly, vacant land prices have grown more during the sample period than construction costs and housing prices. Consequently, the share of the land value component of housing prices has most likely notably increased during the sample period. Also in line with the expectations, land prices have been more volatile than housing prices and construction costs. The difference between the volatilities is relatively small, though. However, the divergence between the standard deviations is somewhat greater if longer-horizon price changes are used. Note also that the *L* and *C* series are only approximations of the underlying factors (i.e. developed land value and structure value). This may be a partial reason behind the fact that *H* is below both *L* and *C* for some time during the mid 1990s. Another reason may be the influence of uncertainty. Anyhow, it is reasonable to believe that the employed data describe fairly well the underlying fundamentals.

Table 1 reports some descriptive statistics of the differenced series. Note that all the variables are highly autocorrelated.

[Table 1 here]

Unsurprisingly, the contemporaneous quarterly correlations between the differenced *H*, *L* and *C* series are statistically highly significant (see Table 2). The figure between lot and house appreciation is .77. As expected, the correlation between housing price and construction cost movements is somewhat smaller (.59). The correlations based on the unsmoothed housing and land price series are considerably smaller than those reported in Table 2 because of the substantial noise in the original indices. The correlation between the unsmoothed quarterly changes in *H* and *L* is as low as .12. Naturally, the correlation between the unsmoothed series approaches that between the HP filtered series as the data frequency is decreased.

[Table 2 here]

Cross-autocorrelations show that the interdependence between land and housing price movements is even stronger than implied by the contemporaneous correlation. In particular, current land appreciation correlates highly significantly with past housing price changes. Consequently, annual correlation between ΔL and ΔH is .84 and biannual correlation as high as .88. The growth of the correlation as the horizon is extended indicates that there are some forms of lead-lag relations between the housing and lot markets. Indeed, this is supported by the forthcoming econometric analysis.

4 Econometric methodology

In the empirical section, the dynamic interdependences between the variables are examined econometrically. First, the existence of cointegrating relationships is tested employing the Johansen test. Due to the reasons presented in section 2, the cointegration test is based on a Vector Error-Correction Model (VECM) that includes a deterministic trend (t) in the long-term dynamics:

$$\Delta X_t = \mu + \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \alpha(\beta', \beta_1)(X'_{t-1}, t)' + \varepsilon_t. \quad (7)$$

In (7), ΔX_t is X_t - X_{t-1}, X_t is a four-dimensional vector of the variable values in period t, μ is a four-dimensional vector of drift terms, Γ_i is a 4 x 4 matrix of coefficients for the lagged differences of the variables at lag i, k is the maximum lag, i.e. the number of lags included in the corresponding vector autoregressive (VAR) model and α is a vector of the speed of adjustment parameters. Finally, β' is a four-dimensional vector of the long-run parameters of the stochastic variables, β_1 is the coefficient for the deterministic trend included in the long-run model and ε is a vector of white noise error terms.

The number of lags in the cointegration analysis is selected based on the Hannan-Quinn (HQ) information criteria as suggested by Johansen et al. (2000). Seasonal dummies are not included in the estimated model, since HQ prefers the model without seasonal dummies. Finally, the selection of the number of cointegrating vectors (r) is done by comparing the estimated Trace statistics with the quantiles approximated by the Γ-distribution (see Doornik, 1998). Because asymptotic distributions can be rather bad approximations of the finite sample distributions, the Bartlett small sample corrected values suggested by Johansen (2002) are employed.

After the selection of the number of cointegrating vectors, the need for the trend term in the long-run dynamics as well as the long-run exclusion of the stochastic variables is tested formally by the Bartlett small-sample corrected LR test proposed by Johansen (2000). Furthermore, the LR test (see Johansen, 1996) is used to test for weak exogeneity of the variables.[7] Moreover, the stability of the estimated long-run relation is examined employing a recursive estimation analysis explained in Juselius (2006).

Based on the estimated long-run relation, VECMs are estimated to study the dynamics more carefully. The Akaike Information Criteria (AIC) is used to decide the lag length in the models. Based on the VECMs, Granger causalities are tested by a standard F-test to examine the existence of lead-lag relations between the variables. Furthermore, the Choleski decomposition is conducted to study the impulse responses and forecast error variance decompositions of the model that includes the control variables.

---

[7] Weak exogeneity of a variable indicates that the variable does not react to deviation from the long-run relation (i.e., to disequilibrium). In other words, the speed of adjustment parameter of a weakly exogenous variable is zero.

5 Econometric analysis

In this section, the short- and long-run dynamics between housing prices, vacant lot prices and the control variables are investigated in more detail by estimating a vector error-correction model (VECM). The order of integration of the variables is checked first. Then the existence of cointegrating relationships between *H*, *L* and *C* is tested. Finally, Granger causalities and impulse response functions as well as variance decompositions are examined based on the estimated VECM.

The ADF unit root test indicates that all the variables are I(1). This finding is in line with the majority of previous related empirical work. The unit root test results are reported in Table 3.

[Table 3 here]

With all the variables being I(1), it is sensible to conduct cointegration analysis. The Johansen Trace test results, reported in Table 4, suggest that there is one cointegrating vector in a system including *H*, *L*, *C* and *U*. In line with the theoretical discussion in section 2, neither the trend nor *U* can be excluded from the long-run relation. That is, the analysis gives support to the proposition according to which a deterministic trend and a measure of uncertainty need to be included in the long-term dynamics in order to detect a reasonable long-run relationship. Expectedly, *U* does not appear to adjust towards the long-run relation. P-value in the test for weak exogeneity of *U* is .77. Therefore, the estimated long-run relation shown in Table 4 is based on a VECM where *U* is restricted to be weakly exogenous.

As the model includes the trend in the long-term relation, the long-run coefficients on *L* (.312) and *C* (.643) do not straightforwardly show the relative shares of land value and structure components of the housing price level during a particular time period. This is because the estimated equilibrium housing price level has grown by some .2% per quarter faster than implied by the coefficients on the stochastic variables only. In any case, $\beta_1 + \beta_2$ is close to one as anticipated. Furthermore, in line with the theory, increased uncertainty (unemployment rate) has lowered housing prices, i.e. the value of developed land, relative to vacant lot prices.

[Table 4 here]

The housing price index and the fit from the estimated long-run model are exhibited in Figure 2. The housing price index follows the long-run level closely during the whole sample period. That is, the long-run model appears to work well. Also the recursive test supports the stability of the relation (see Figure A1 in the Appendix).

[Fig. 2 here]

Granger causalities between the four variables are investigated based on a VECM that includes four lags in differences. As can be seen in Table 5, the VECM indicates that *H* Granger causes *L* both in the short run and through the long-run relation. There is also evidence for a short-run feedback effect from land prices to house prices. It appears, however, that the deviation from the long-run relation does not have predictive power with respect to *H*. Anyhow, both housing price and lot price movements are Granger caused by themselves suggesting that past and current housing/lot price growth can be used to predict future housing/lot price development. Furthermore, lagged changes in *C* can be used to predict land price changes. All in all, housing and lot price movements appear to be highly predictable.

Also construction costs adjust towards the long-run relation. This may suggest that, due to imperfect competition, stronger demand for housing enables construction companies to gain greater profit margins. The speeds of adjustment of land prices and construction costs are estimated to be 20% and 46% per quarter. Note also that the results regarding housing price movements do not notably change even if housing prices are assumed to be weakly exogenous (we)

[Table 5 here]

[Table 6 here]

To get some further light to the housing and land price dynamics, a VECM that includes *Y* and *IR* in the short-run dynamics and five lags in differences is estimated. Table 6 confirms most of the findings reported in Table 5. The main difference in the model including the additional control variables compared to the more parsimonious model is that lot prices do not appear to Granger cause housing prices even in the short run. This indicates that feedback from vacant lot prices to housing prices is weak or even negligible.

The estimated adjustment speeds in the six-variable model are 51% and 60% for *L* and *C*, respectively. The fact that the estimated speed of adjustment parameters exceed one in aggregate does not mean that the system ”over adjusts”. Given the parameters of the long-run model and the adjustment speeds, the model implies that some 54% of the equilibrium error vanishes during one quarter due to the adjustment of *L* and *C*. This is substantially faster than implied by the four-variable model (36%).[8]

Finally, innovation accounting employing the estimated six-variable VECM and Choleski decomposition is conducted. Housing prices are assumed to be weakly exogenous in the analysis. The ordering of the variables in the decomposition is the following: *U*, *Y*, *H*, *L*, *C*, *IR*. It is therefore assumed that unemployment does not respond contemporaneously to innovations in any of the other variables, but may affect all the other variables within the quarter. Furthermore, the ordering reflects the common assumption that interest rate changes are transmitted to the economy with lag. In any case, the ordering of the variables does not greatly affect the findings. In particular, changing the ordering between *H* and *L* does not notably alter the results.

Impulse response analysis reveals some interesting observations. Most importantly, as can be seen in Figure 3, the model suggests that vacant lot prices adjust substantially slower than house prices to income and interest rate shocks. While the impulse response curve for *H* peaks five quarters after a shock in *Y*, the curve for *L* peaks at 10 quarters. Within one quarter of the initial shock, the response of *H* is 72% of the eventual long-run effect of the shock. The corresponding figure is only 22% for *L*. There is a similar pattern concerning a shock to *IR*. Both prices react slower to an interest rate shock than to an income shock, though. That is, the impulse responses indicate that informational inefficiencies are greater in the market for vacant lots than in the housing market even though also the adjustment of the

[8] The reported overall adjustment figures are based on models where *H* is weakly exogenous.

house price level to the shocks is sluggish. This is in line with the Granger non-causality tests and prior expectations.

[Fig. 3 here]

The differences between the eventual long-run responses of *H* and *L* are relatively small. It would be expected that the impact of a demand shock is notably greater on land prices than on housing prices, since construction costs are typically assumed to be quite inelastic to demand shocks. However, in the previous literature construction costs without profit margins are usually considered. At least in the HMA case it appears that construction costs (including profit margins) have, in fact, responded to demand side changes.

It is reasonable to assume that the reaction of *C* is, to a great extent, due to variation in the profit margins. To support this claim, construction cost indices both with and without profit margins are pictured in Figure A3 in the Appendix. The fact that a demand shock appears to have a permanent effect on real construction costs implies that the construction sector is not fully competitive; a positive shock to housing demand leads to greater profit margins. Expectedly, the reaction of *C* to demand side shocks appears to be notably smaller than that of *H* and *L*, though.

The response of housing prices to an income shock is of similar magnitude to that reported by Oikarinen (2009) regarding flats in Helsinki. The response to an interest rate shock estimated in this study is notably greater (in absolute value) than that suggested by Oikarinen's results, however. This can probably be attributed to the existence of household loan stock variable in Oikarinen's model. The fact that 1% income shock leads to a greater (1.3%) eventual increase in housing prices, is not surprising in light of numerous previous studies from various markets. Meen (2001, p. 129), for example, reviews a number of studies that report income elasticities of housing prices between 1.9 and 3.8. The liquidity constraints faced by households are often stated to be a major reason for such large income elasticities. Note, however, that because of the endogeneity of the macroeconomic variables in the model, the income elasticity of housing prices cannot be observed from the impulse responses in Figure 3. Anyhow, after a shock in *Y* the eventual growth in *H* is of the same magnitude as that in *Y*. Similarly, the elasticity of *H* with respect to *IR* cannot be seen from the reported impulse curves.

Note that, due to the growing trend of the land price share, the response of housing prices to demand shocks has probably changed somewhat during the sample period. The reported responses are based on a time-invariant parameter estimates, however. The main aim of the impulse response analysis is to study the reaction speeds of housing and land prices to shocks in the fundamentals, and the exact magnitude of housing price reactions are not of major interest in this article.

Variance decomposition, exhibited in Table 7, suggests that *H* is the principal factor driving *L*. In the long horizon some 60% of the forecast error variance of *L* is due to innovations in *H*. By contrast, the significance of land price shocks with respect to the forecast error variance of housing prices is negligible. It is the economic fundamentals that drive housing prices rather than shocks to *L* or *C*. These findings are in line with the hypothesis set earlier according to which housing price movements react to demand side shocks first, revealing information concerning movements in the value of developed land, in general. The driving nature of housing prices with respect to vacant lot prices proposes that this information revealed by housing price movements is then reflected in vacant lot prices with lag. The variance decomposition is also in line with the finding from the Granger causality analysis according to which the feedback from the land market to the housing market is weak.

[Table 7 here]

6 Summary and conclusions

The price of vacant land zoned for housing is expected to be tightly linked to housing prices. In informationally efficient markets, vacant lot price movements should not lag changes in housing prices; at least the theoretical literature does not present any analytical model exhibiting structural relations that would suggest the leading role of housing prices with respect to vacant land prices. On the contrary, according to the land pricing framework of Titman (1985) price movements of vacant lots should precede housing price growth. In practice, however, leading role of housing appreciation with respect to vacant lot price growth may be caused by factors such as thin trading and lack of publicly available data on transactions in the lot market.

In general, volatility in metropolitan housing prices is mainly attributable to demand driven changes in the value of developed land. Hence, housing appreciation typically reveals information regarding land price movements. Even though empirical evidence generally suggests that housing prices adjust sluggishly to changes in the fundamentals, this paper proposes that housing prices respond to demand shocks influencing the value of land first, after which the price level of vacant lots reacts to the information revealed by housing appreciation. Thus, it is hypothesized that housing price movements, typically, lead changes in the prices for vacant land.

Empirical analysis gives support to this hypothesis. Based on quarterly data over 1988Q1-2008Q2 from the Helsinki metropolitan area (HMA), the estimated vector error-correction model (VECM) shows that the real price movements of single-family houses Granger cause real appreciation of vacant lots zoned for single-family houses. According to forecast error variance decomposition, housing appreciation is clearly the principal factor driving vacant land prices. There does not appear to be notable feedback from the lot market to the housing market.

The basis for the estimated VECM lies in a cointegrating long-run relation between real single-family housing prices, real prices of vacant lots zoned for single-family housing and the real construction cost index including profit margins of the construction sector. The unemployment rate, approximating uncertainty, is included in the model as a control variable. The estimated long-run relation is in line with the recent findings by Bostic et al. (2007) and Davis and Palumbo (2008) according to which the land price component of housing is likely to increase through time in a growing metropolitan area.

To study the reaction of housing and land prices to demand side shocks, also real aggregate income and the real interest rate are included in the short-run dynamics of the model. In line with prior expectations, the estimated model indicates that the price of vacant land responds more strongly to interest rate and income shocks than housing prices. The difference between the magnitudes of the reactions is relatively small, though. This appears to be due to the response of construction costs to demand shocks; the econometric analysis suggests that also the value of the physical structure component of housing, i.e. the replacement cost of the physical building proxied by construction costs, notably reacts to shocks in housing demand in HMA. It is claimed that this is due to changes in the construction sector's profit margins.

The pro-cyclical nature of construction costs is likely to have adverse effects on the overall economy by emphasizing housing price cycles. Therefore, policy decision aiming to enhance the competitiveness of the construction sector might smooth housing price cycles and be beneficial to the overall economy. Anyhow, in markets where construction costs are more stable and where the value of land is relatively low, the differences between the reactions of housing prices and land prices to demand side shocks are likely to be greater than those reported in this paper.

All in all, the findings give support to the hypothesis that the market for vacant land is more inefficient informationally than the housing market, even though also the housing price adjustment is sluggish. For one, land price movements appear to be more predictable than housing price changes. Furthermore, land appreciation seems to lag housing price movements and land prices react more sluggishly to shocks in the fundamentals than housing prices.

In the future, it would be interesting to investigate if the results apply to other metropolitan areas with different institutional settings as well. Furthermore, it might be worthwhile to examine the role and adjustment of the developers' profit margins more rigorously in another study.

References

Bostic, R.C., Longhofer, S.D., Redfearn, C.L., 2007. Land leverage: decomposing home price dynamics, Real Estate Economics 35, 183-208.

Capozza, D.R., Helsley, R.W., 1989. The fundamentals of land prices and urban growth, Journal of Urban Economics 26, 295-306.

Capozza, D.R., Helsley, R.W., 1990. The stochastic city, Journal of Urban Economics 28, 187-203.

Capozza, D.R., Li, Y., 2002. Optimal land development decisions, Journal of Urban Economics 51, 123-142.

Capozza, D.R., Schwann, G.M., 1989. The asset approach to pricing urban land: Empirical evidence, Real Estate Economics 17, 161-174.

Capozza, D.R., Sick, G.A., 1994. The risk structure of land markets, Journal of Urban Economics 35, 297-319.

Cunningham, C.R., 2006. House price uncertainty, timing of development, and vacant land prices: Evidence for real options in Seattle, Journal of Urban Economics 59, 1-31.

Davis, M., Heathcote, J., 2007. The price and quantity of residential land in the United States, Journal of Monetary Economics 54, 2595-2620.

Davis, M.A., Palumbo, M.G., 2008. The price of residential land in large US cities, Journal of Urban Economics 63, 352-384.

Doornik, J.A., 1998. Approximations to the asymptotic distributions of cointegration tests, Journal of Economics Surveys 12, 573-593.

Guntermann, K.L., 1997. Residential land prices prior to development, Journal of Real Estate Research 14, 1-17.

Gyourko, J., Saiz, A., 2006. Construction costs and the supply of housing structure, Journal of Regional Science 46, 661-680.

Jellal, M., Thisse, J.-F., Zenou, Y., 2005. Demand uncertainty, mismatch and (un)employment, Economics Letters 89, 248-254.

Johansen, S., 1996. Likelihood-Based Inference in Cointegrated Vector Auto-Regressive Models, Oxford University Press, Oxford.

Johansen, S., 2000. A Bartlett correction factor for tests on the cointegrating relations, Econometric Theory 16, 740–778.

Johansen, S., 2002. A small sample correction of the test for cointegrating rank in the vector autoregressive model, Econometrica 70, 1929–1961.

Johansen, S., Mosconi, R., Nielsen, B., 2000. Cointegration analysis in the presence of structural breaks in the deterministic trend, Econometrics Journal 3, 216-249.

Juselius, K., 2006. The Cointegrated VAR Model: Methodology and Applications, Oxford University Press, Oxford.

Keuschnigg, C., Nielsen, S.B., 1996. Housing markets and vacant land, Journal of Economic Dynamics and Control 20, 1731-1762.

Manning, C.A., 1988. The determinants of intercity home building site price differences, Land Economics 64, 1-14.

Meen, G., 2001. Modelling Spatial Housing Markets: Theory, Analysis and Policy, Kluwer Academic Publishers, Massachusetts, USA.

Ozanne, L., Thibodeau, T., 1983. Explaining metropolitan housing price differences, Journal of Urban Economics 13, 51-66.

Oikarinen, E., 2009. Household borrowing and metropolitan housing price dynamics – empirical evidence from Helsinki, Journal of Housing Economics 18, 126-139.

Peltola, R., Väänänen, J., 2007. Asuntotontin Hinta, Maanmittauslaitoksen julkaisuja nro 105.

Poteban, M.J., 1996, Explaining intermetropolitan variation in housing prices, Real Estate Economics 24, 219-245.

Quigg, L., 1993. Empirical testing of real option-pricing models, Journal of Finance 48, 621-640.

Rosenthal, S.S., 1999. Residential buildings and the cost of construction: new evidence on the efficiency of the housing market, Review of Economics and Statistics 81, 288-302.

Rosenthal, S.S, Helsley, R.W., 1994. Redevelopment and the urban land price gradient, Journal of Urban Economics 35, 182-200.

Somerville, C.T., 1996. The contribution of land and structure to builder profits and house prices, Journal of Housing Research 7, 127-141.

Somerville, C.T., 1999. Residential construction costs and the supply of new housing: Endogeneity and bias in construction cost indexes, Journal of Real Estate Finance and Economics 18, 43-62.

Suoniemi, I., 1990. Uusien ja Vanhojen Asuntojen Hinnat Suomessa: Hintasarjojen trendi- ja kausaaliominaisuudet, Labour Institute of Economic Research Discussion Papers 103.

Titman, S., 1985. Urban land prices under uncertainty, American Economic Review 75, 505-514.

Tse, R.Y.C., 1998. Housing price, land supply and revenue from land sales, Urban Studies 35, 1377-1392.

Table 1 Descriptive statistics of differenced variables over 1988Q1-2008Q2

Variable	**Mean (annualised)**	**Standard deviation (annualised)**	**Jarque-Bera (p-value)**	**Ljung-box test for auto-correlation (p-value, 4 lags)**
Housing price	.022	.079	.05	.00
Land price	.064	.094	.10	.00
Construction costs	-.011	.067	.03	.00
Unemployment rate	.001	.012	.00	.00
Interest rate (level)	.037	.066	.01	.00
Disposable income	.032	.040	.00	.02

Table 2 Contemporaneous quarterly correlations between differenced series over 1988Q1-2008Q2

	H	*L*	*C*	*U*	*Y*	*IR*
H	1					
L	.77**	1				
C	.59**	.45**	1			
U	-.53**	-.59**	-.50**	1		
Y	.32**	.28*	.34	-.15	1	
IR	-.05	-.04	.07	-.00	.07	1

* and ** denote for statistical significance at the 5% and 1% level, respectively. The reported correlations are based on a sample period over 1988Q1-2008Q2.

Table 3 Augmented Dickey-Fuller test results

Variable	**Level (lags)**	**Difference (lags)**
House price	-1.19 (2)^{c}	-3.98** (1)
Land price	-2.40 (3)^{c}	-2.71** (1)
Construction costs	-2.04 (1)^{c}	-5.02** (0)
Unemployment rate	-.67 (5)	-2.22* (4)
Interest rate	-1.81 (4)^{s}	-4.82** (3)^{s}
Aggregate income	-.60 (4)^{c}	-2.51* (3)

* and ** denote for statistical significance at the 5% and 1% level, respectively. Critical values at the 5% and 1% significance levels are -1.95 and -2.60 if constant is not included and -2.89 and -3.51 in the case where constant is present. The number of lags included in the ADF tests is decided based on the general-to-specific method. A constant term (^{c}) is included in the tested model if the series clearly seem to be trending or if the ADF test without the constant term suggests that the series are exploding. In addition, three seasonal dummies (^{s}) are added to the test if recommended by the F-test.

Table 4 Cointegration test statistics

H_0 (rank)	Trace test value (p-value)
r = 0	65.7 (.03)
$r \leq 1$	30.8 (.46)
$r \leq 2$	17.2 (.41)
$r \leq 3$	4.26 (.71)

P-value in the test for exclusion:

Trend	.01
Housing price	.00
Land price	.00
Construction costs	.01
Unemployment rate	.03

Estimated long-run relation (standard errors in parenthesis:

$$H = .337 + .311{*}L + .643{*}C - 1.902{*}U + .002{*}t$$

(.041) (.116) (.493) (.001)

The tested model includes *H*, *L*, *C*, *U*, one lag in differences and a deterministic trend in the long-run dynamics.

Table 5 P-values in the Granger non-causality tests

Dependent variable	Explanatory variable					
	ΔH	ΔL	ΔC	ΔU	eqe	Adj. R^2
Δ Housing	**.00**	**.06**	.68	.19	.50	.83
Δ Land	**.00**	**.00**	**.00**	.37	**.02**	.91
Δ Construction cost	.67	.56	.93	.26	**.01**	.48
Δ Unemployment	.67	.75	.34	**.06**		.49
Δ Housing (we)	**.00**	**.07**	.68	.13		.83

The reported p-values are based on a standard F-test. Statistically significant values at the 10% level are bolded. The model includes four lags in differences.

Table 6 P-values in the Granger non-causality tests including income and interest rate

Dependent Variable	Explanatory variable							
	ΔH	ΔL	ΔC	ΔU	ΔY	ΔIR	eqe	Adj. R^2
Δ Housing	**.00**	.28	.75	.23	.81	.27	.91	.82
Δ Land	**.00**	**.00**	**.00**	**.01**	.21	.51	**.00**	.92
Δ Construction cost	.67	.26	.38	.14	.23	.21	**.02**	.50
Δ Unemployment	.90	.99	.93	**.19**	.33	.56		.46
Δ Income	**.18**	.07	.48	**.01**	.82	.61		.21
Δ Interest rate	**.07**	.21	.19	.30	.39	**.00**		.61
Δ Housing (we)	**.00**	.24	.72	.11	.79	.24		.83

The reported p-values are based on a standard F-test. Statistically significant values at the 10% level are bolded. The model includes five lags in differences.

Table 7 Variance decomposition for H and L based on the six-variable VECM model

Step (quarters)	House price level					
	ΔU	ΔY	ΔH	ΔL	ΔC	ΔIR
1	.008	.139	.852	.000	.000	.000
2	.013	.134	.839	.000	.000	.013
5	.033	.099	.773	.001	.003	.092
10	.151	.070	.612	.008	.010	.150
20	.217	.040	.544	.011	.017	.170
40	.239	.031	.523	.013	.019	.176
Step (quarters)	**Land price level**					
	ΔU	ΔY	ΔH	ΔL	ΔC	ΔIR
1	.062	.005	.155	.778	.000	.000
2	.042	.030	.366	.558	.003	.001
5	.010	.080	.681	.168	.036	.025
10	.060	.079	.699	.046	.016	.099
20	.142	.045	.645	.004	.004	.151
40	.165	.035	.631	.002	.002	.159

Figure 1 Plot of the variables included in the empirical analysis

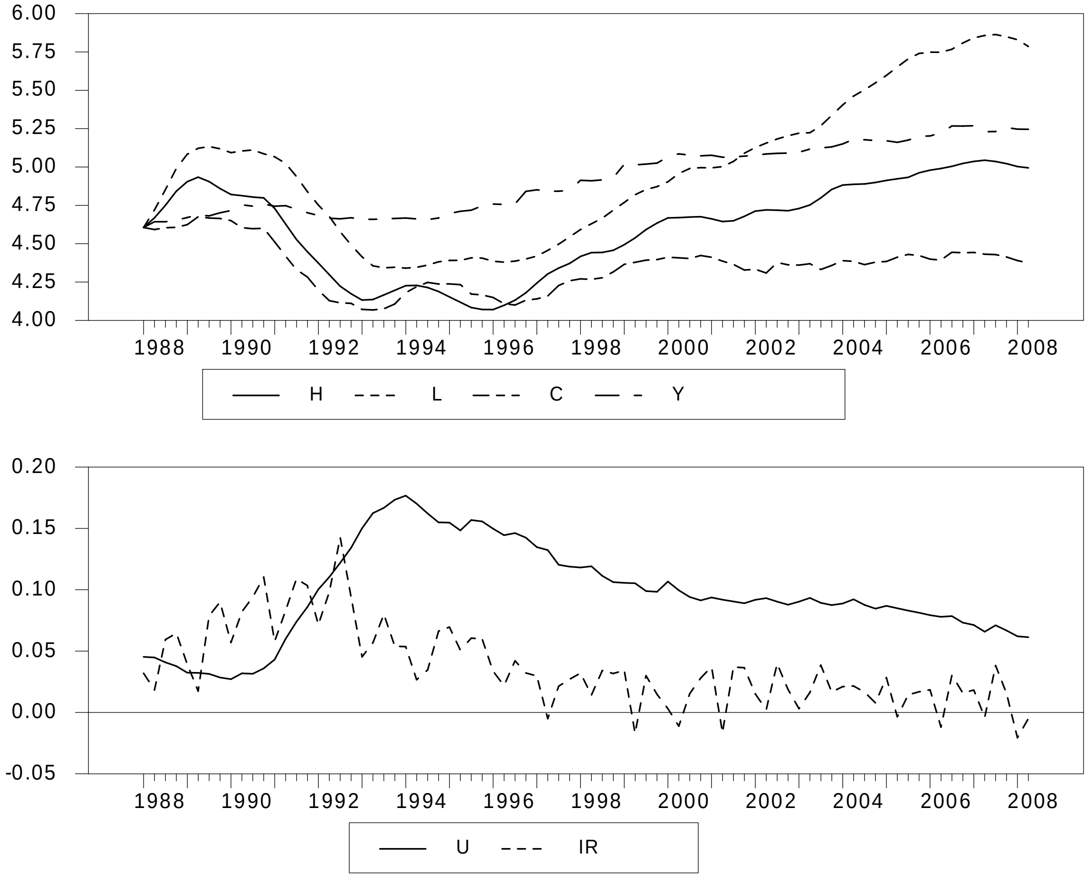


Figure 2 Housing price index (H) and fit from the estimated long-run relation (EQ)

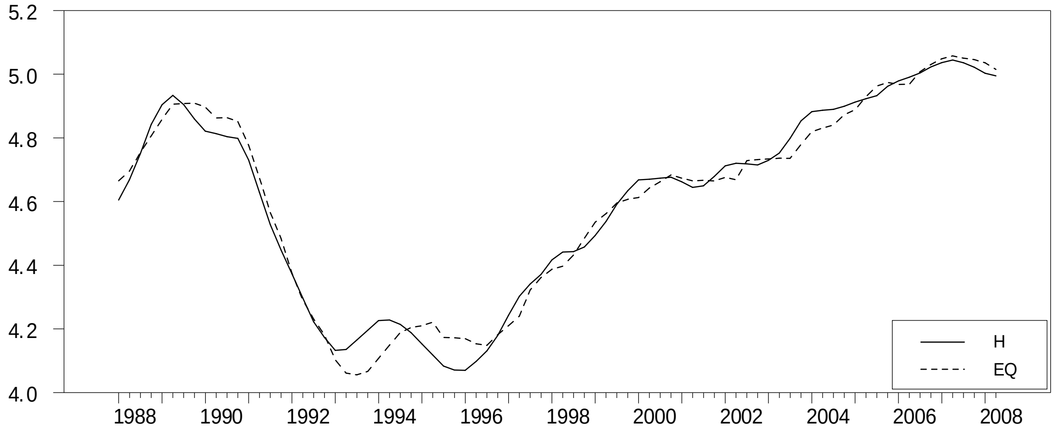


Figure 3 Impulse responses of *H*, *L* and *C* to one unit shocks in *Y* and *IR*

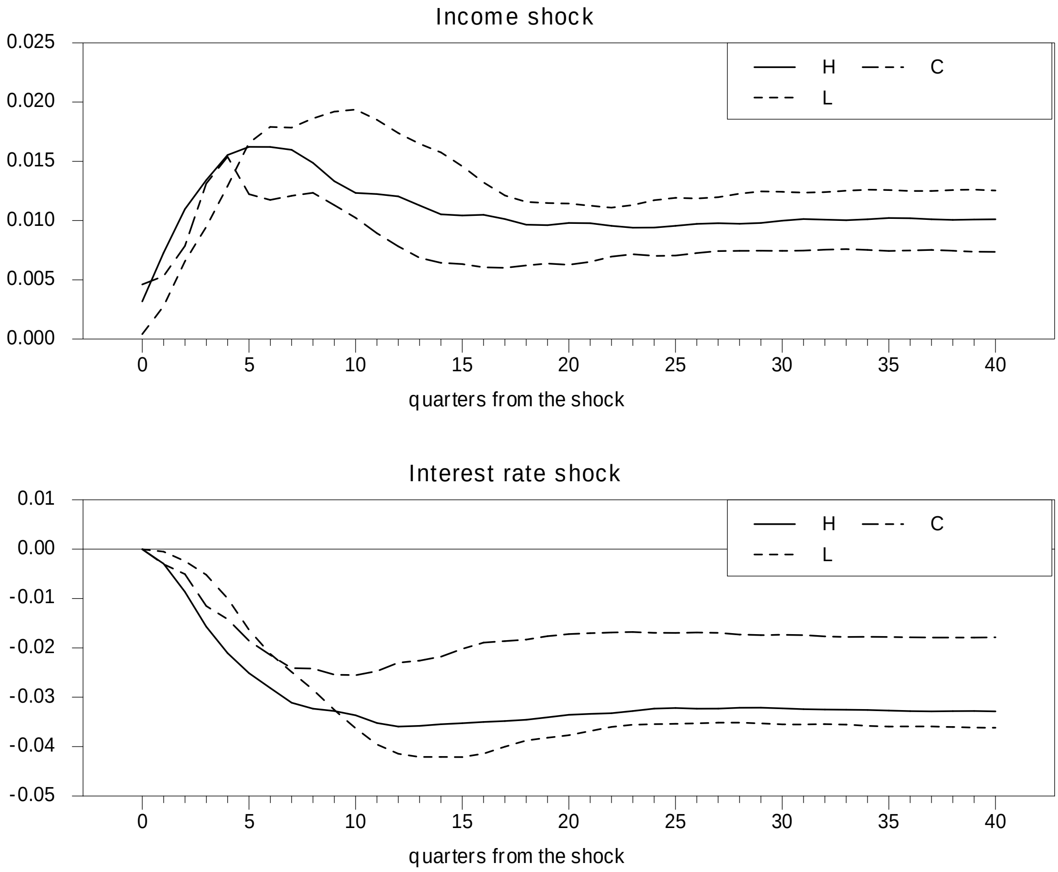


Figure A1 Plot of the unsmoothed and HP filtered housing and land price indices

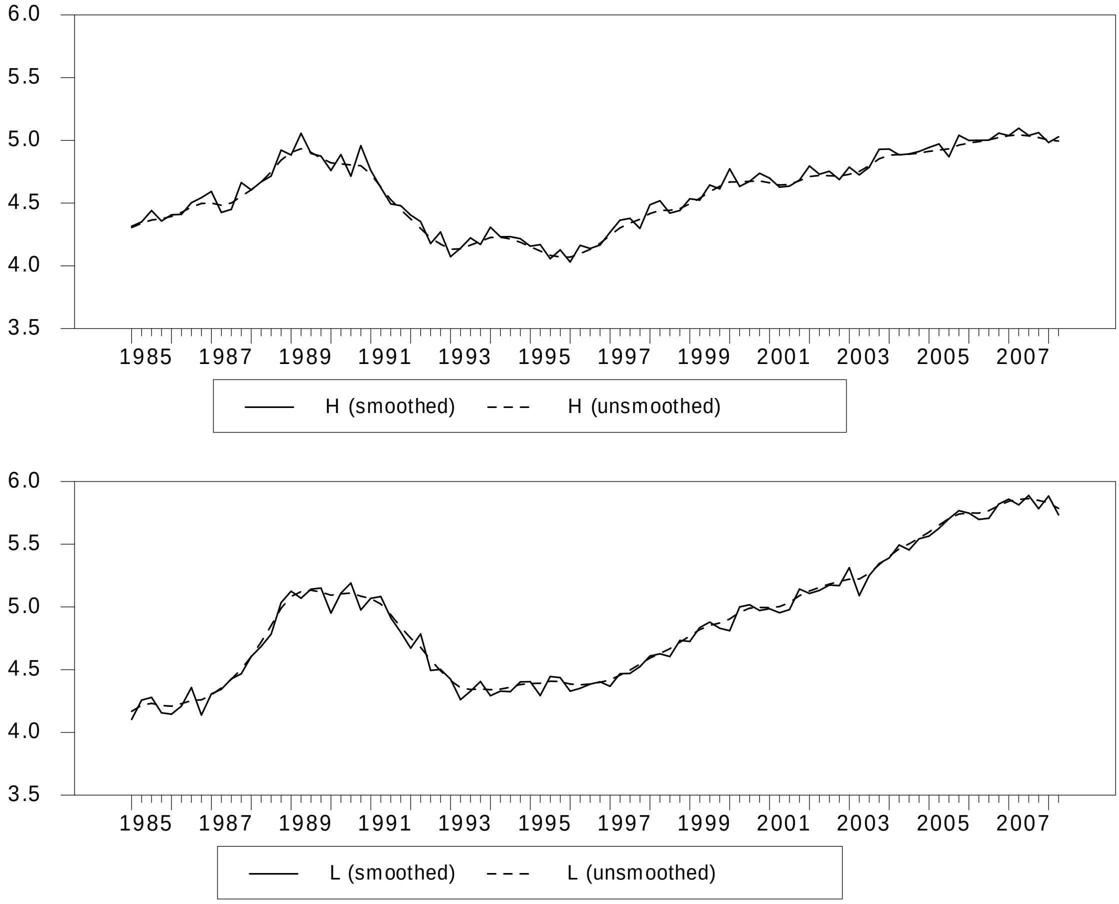


Figure A2 Plot of the recursive and backwards recursive Max Test statistics (in the R-form) of constancy of the estimated long-run relation scaled by the 5% critical value

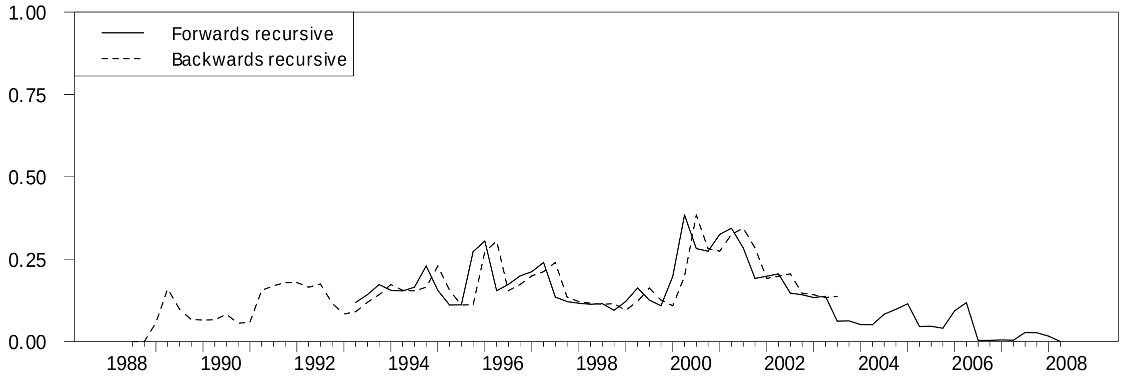
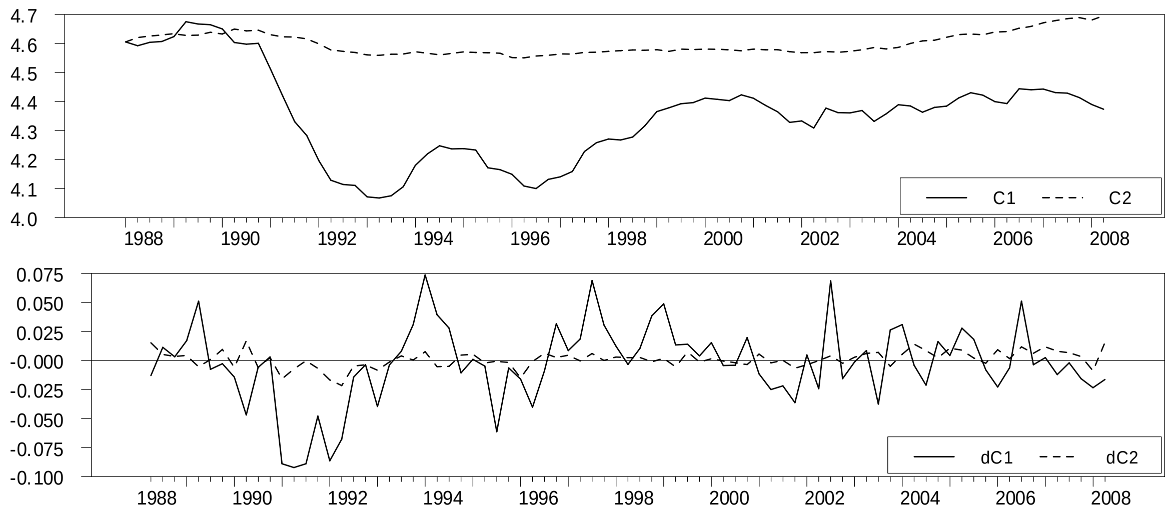


Figure A3 Levels and differences of construction cost index including profit margins (C1, published by Rapal Ltd.) and of construction cost index excluding profit margins (C2, published by Statistics Finland)



Aboa Centre for Economics (ACE) was founded in 1998 by the departments of economics at the Turku School of Economics, Åbo Akademi University and University of Turku. The aim of the Centre is to coordinate research and education related to economics in the three universities.

Contact information: Aboa Centre for Economics, Turku School of Economics, Rehtorinpellonkatu 3, 20500 Turku, Finland.

Aboa Centre for Economics (ACE) on Turun kolmen yliopiston vuonna 1998 perustama yhteistyöelin. Sen osapuolet ovat Turun kauppakorkeakoulun kansantaloustieteen oppiaine, Åbo Akademin nationalekonomi-oppiaine ja Turun yliopiston taloustieteen laitos. ACEn toiminta-ajatuksena on koordinoida kansantaloustieteen tutkimusta ja opetusta Turun kolmessa yliopistossa.

Yhteystiedot: Aboa Centre for Economics, Kansantaloustiede, Turun kauppakorkeakoulu, 20500 Turku.

www.ace-economics.fi

ISSN 1796-3133