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Short-run and Long-run Determinants of House Prices in Eastern and Western European Countries

RESEARCH PAPER

Maruška Vizek*

Abstract

This paper uses cointegration and error-correction models to examine the long-run and short-run behavior of house prices in Eastern and Western European countries. Four post-transition (Bulgaria, Croatia, the Czech Republic, and Estonia) and three developed EU countries (Ireland, Spain, and the U.K.) are included in the sample. House price behavior for each country is modeled separately as a function of income, interest rates, credit, construction activity, and employment. The results of the empirical analysis suggest that, in the long run, interest rate changes explain house price behavior in both groups of countries, while income changes are only relevant for Western European countries. Along with interest rates and income, house prices in both groups of countries react in the short run to changes in the construction activity. Moreover, house price persistence is important for short-run house price changes in both groups of countries. Housing loan changes also affect the short-run house price behavior, but this effect is limited to Eastern European countries.

Keywords: determinants of house prices, housing markets, cointegration, Central and Eastern Europe, Western Europe

JEL classification: C22, R21, R31

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1 Introduction¹

House prices and their links to macroeconomics in developed countries have been the subject of an increasing body of empirical work. In the last few years research interest in housing markets has intensified because of the role that housing markets have played in the global economic crisis. However, the boom-bust cycle in house prices is not unique to developed countries, as similar or even more pronounced house price developments have been observed in the countries of the former Soviet Union (Stepanyan, Poghosyan and Bibolov, 2010), Eastern Europe (Posedel and Vizek, 2009), and the Middle East (Beidas-Strom, Weicheng and Maseeh, 2009).

The last decade has witnessed increased interest in analyzing house price determinants from country-by-country or cross-country perspectives in emerging economies in general, and in Eastern European countries in particular. Several studies also compare house price behavior in these countries to that in developed economies. This paper contributes to the literature by conducting a country-by-country analysis with a comparison of results across countries. We ask the following question: What are the most important house price drivers in Eastern European countries? How does house price behavior in the short run differ from the long run? What are the key similarities and differences between Eastern European and developed European Union countries when it comes to house price drivers?

In order to obtain answers to these questions, this paper uses Johansen cointegration and vector error-correction models. To the best of the author's knowledge, there are no empirical papers which model house prices on a country-by-country basis using the cointegration and error-correction models. A total of seven countries are included in the sample: four transition economies (Bulgaria, Croatia, the Czech Republic, and Estonia) and three developed EU economies (Ireland, Spain, and the U.K.). The data

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prices (Abelson et al., 2005; Sutton, 2002), and house price persistence (Hort, 1998; Annett, 2005) could be the relevant house price determinants in developed countries.

Unlike developed countries, house prices in European transition countries have been less extensively researched.² Papers like Egert and Mihaljek (2007), Posedel and Vizek (2009; 2010), Stepanyan, Poghosyan and Bibolov (2010), Zemčík (2010), and Hlaváček and Komárek (2009) studied house price determinants in the region. The first empirical study of house prices in European transition countries was done by Egert and Mihaljek (2007). The authors estimated panels composed of eight transition and 19 developed OECD economies. Given the limited data availability, their modeling strategy consisted of reserving two explanatory variables for income and interest rates, while the third explanatory variable was varied. The results of their empirical exercise indicated that per capita GDP, real interest rates, credit growth, demographic factors, and indicators of institutional development of housing markets and housing finance were important house price drivers.

Posedel and Vizek (2009) applied the SVAR and multiple regression models and analyzed house price determinants in three EU-15 countries and three Eastern European countries. Besides house price persistence, which prevails in Croatia, Ireland, Poland, and Spain, interest rates accounted for the largest portion of the house price variance in the U.K. and Estonia. Moreover, house prices in the three EU-15 countries accounted for a significant fraction of the GDP, construction activity, and interest rates variance. However, this was not the case for the Eastern European countries. In both groups of countries supply-side factors did not determine house prices in the short run.

Stepanyan, Poghosyan and Bibolov (2010) used a panel data approach to model house price behavior in the former Soviet Union countries (FSU countries). Given that the Central Asian FSU economies experienced

² Palacin and Shelburne (2005) provide a detailed description of the housing markets and their fundamentals in Central and Eastern Europe.

3 Data and Methodology

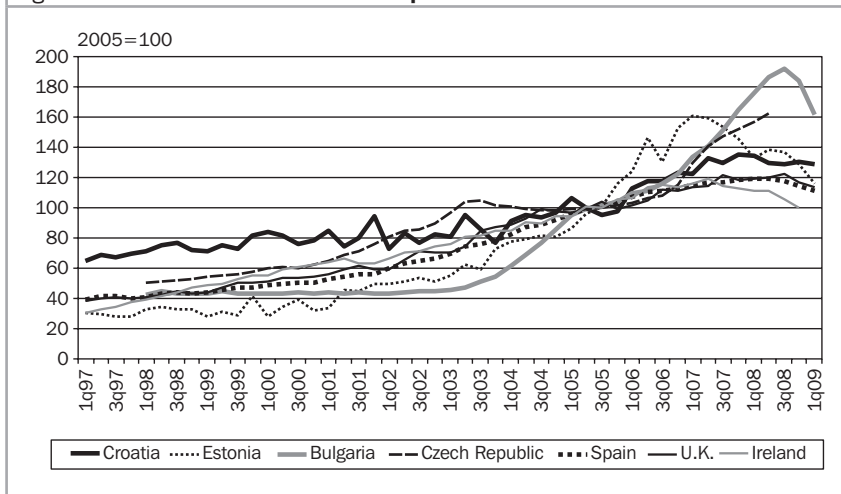
3.1 Data

In this section we briefly describe the methodology and the data. As stated earlier, the sample includes three developed EU countries (Ireland, Spain, and the U.K.) and four Eastern European transition countries (Bulgaria, Croatia, the Czech Republic, and Estonia). The Eastern European countries included in the sample are the only countries for which the author could obtain longer house price series from official, non-commercial sources. In the case of Croatia, data are provided by a commercial database also used by the Croatian National Bank for calculation of the hedonic house price index (Kunovac et al., 2008). Data for developed countries start from 1995:Q1. The last observation available for Ireland is 2009:Q1. For the other three countries data extend to 2009:Q2. As house price data for the U.K. are available from 1969, we estimated cointegration and error-correction models for the U.K. on shorter and longer samples.

The longest sample for transition countries is available for Croatia (from 1996:Q4). Data for Estonia start in 1997:Q1, while for Bulgaria and the Czech Republic the starting observation is 1998:Q1. Data series for all transition countries end with 2009:Q2 (for the Czech Republic 2008:Q4). As evident in Appendix I, where details on all series used in the analysis are displayed, house price data are not homogenous across countries. House price series for Estonia, the Czech Republic, and Spain encompass new and used apartments, while series for the United Kingdom and Ireland contain only new and used house prices and new house prices, respectively. House price series for Bulgaria and Croatia encompass both types of dwellings, but in the Bulgarian case only used dwellings are included, while in the Croatian case both new and used dwellings are included. For all countries except Estonia, a national house price series is available. In the Estonian case, a house price series for the capital city is used.³ Given the observed heterogeneity of house price data for countries in the sample, which in

³ *The house price series for the capital city for the period 2002–2009 is highly correlated with the national series both in levels and annual growth rates.*

Figure 1 Nominal House Price Developments



Sources: *Burza nekretnina (Croatia)*, *Statistics Estonia*, *National Statistical Institute (Bulgaria)*, *Czech Statistical Office*, *Department for Communities and Local Government (U.K.)*, *National Statistics Institute (Spain)*, and *Department of the Environment, Heritage and Local Government (Ireland)*.

In order to get a better grasp of the intensity of house price appreciation and subsequent correction, Table 1 displays cumulative increases and decreases of house prices. One can notice that there are substantial differences in both cumulative house price appreciation and the correction that followed. The highest house price increase was recorded in Estonia and Bulgaria, where prices rose by 394 and 355 percent over a nine- and ten-year period, respectively. On the other hand, the house price increase in the Czech Republic seems in line with those developed countries that experienced house price booms, while the house price increase in Croatia seems comparatively modest. As against the Eastern European countries, house price inflation in the three Western European countries followed a similar path: in all three countries prices have tripled in approximately eleven years.

As far as house price deflation is concerned, the biggest cumulative drop so far has been recorded in Estonia and Bulgaria, which seems logical given that in those two countries house prices have appreciated the most.

	Bulgaria	Croatia	Czech Republic	Estonia	Ireland	Spain	U.K.
Cumulative appreciation (in %)	355	89	221	394	205	193	199
House price peak	2008:Q3	2007:Q4	-	2007:Q1	2007:Q2	2008:Q1	2007:Q3
Cumulative correction (in %)	19	5	-	39	19	7	7

Sources: *Burza nekretnina (Croatia)*, *Statistics Estonia*, *National Statistical Institute (Bulgaria)*, *Czech Statistical Office*, *Department for Communities and Local Government (U.K.)*, *National Statistics Institute (Spain)*, and *Department of the Environment, Heritage and Local Government (Ireland)*.

Before turning to the empirical analysis, it is useful to take a look at housing affordability indices. OECD (2005) and IMF (2004) use housing affordability indices as indicators of over- or under-valuation of housing, under the condition that these indicators are available for longer time periods.⁵

Looking at housing affordability is useful because the index compares house price to household income which is a macroeconomic fundamental. If their relationship is not mean reverting over time, this might suggest that house prices do not reflect the changes in fundamentals well. In Figure 2 we present housing affordability indices calculated according to the so-called “shelter first approach” (Robinson, Scobie and Hallinan, 2006) which assumes that outlays for housing are always paid first, while the residual part of income is used for other types of consumption and/or savings. As a measure of income we used official GDP per capita in euros that includes a correction for the unofficial economy. House prices refer to the price of a square meter of housing (also expressed in euros). When interpreting the indices, one has to keep in mind that GDP per capita is not an ideal choice for measuring household income, which in turn may blur the results of the analysis. One interprets the affordability index in the following way: the higher the value of the index, the lower the housing affordability. Moreover, if the value of the index is higher than its long-run average, it may indicate that house prices are overvalued.

⁵ For the same purpose one could analyze price-to-rent ratios, but unfortunately data on rents for three out of four transition countries are not available.

We begin the cointegration analysis by estimating a VAR in the form of Equation 1. In it, k represents country, and $Y_{k,t}$ is a (6x1) vector containing the values that six variables assume at time t . $Y_{k,t}$ consists of six variables representing the demand side and the supply side of the housing market, as well as the financing conditions, i.e., real house price, real GDP, employment, real volume of housing loans, real interest rate on housing loan, and construction output index.

$$Y_{k,t} = c_k + \sum_{j=1}^p \Phi_{k,j} Y_{k,t-j} + \varepsilon_{k,t} \quad (1)$$

The dynamics of $Y_{k,t}$ is presumed to be governed by a p^{th} -order Gaussian vector autoregression, where p represents the lag length, $Y_{k,t}$ (6x1) vector contains the constant terms of the VAR, matrices $\Phi_{k,1}, \dots, \Phi_{k,p}$ contain the autoregressive coefficients, and $\varepsilon_{k,t}$ is an i.i.d. $N(0, \Sigma)$ process.

If no cointegration vector was found, we reduced VAR by one variable – employment. If still no cointegration vector was detected, we continued the analysis by excluding housing loans. If the remaining four variables did not form a long-run relationship, we excluded the construction output index from the VAR, leaving just three variables: real house price, real GDP and real interest rates on housing loans. These three variables are most often used in empirical studies of the determinants of house prices. Moreover, these variables were the key variables Egert and Mihaljek (2007) used in their analysis of house price determinants in Central and Eastern European countries. We believe that it is appropriate to exclude employment and housing loans from the analysis because the remaining variables partially represent the excluded variables – GDP can be thought of as a proxy for employment, while interest rates on housing loans proxy for the availability of financing. In this way we obtained cointegration vectors for all the countries.

After we derived the long-run relationships, we estimated an error-correction model of house prices for each country. We followed a general-to-specific approach, instead of the standard vector error-correction model (VECM), mainly because VECM is very inflexible in terms of its lag

This leads to the derivation of the final error-correction model, which must satisfy all standard diagnostic tests.

3.3 Results

Finite sample corrections of trace and max statistics suggested that in the case of all countries except Ireland one cointegrating vector could be found, which enabled us to determine long-run parameters directly. The details on trace and max statistics can be found in Appendix II. In the case of Ireland, two cointegrating vectors were found, which required the imposition of at least four restrictions on the cointegrating space in order to identify the long-run parameters. These restrictions and the corresponding coefficients are presented in Table A5a.

Table 2 displays the long-run elasticities of house prices with respect to other variables, along with the results of the zero restrictions test (calculated as Chi^2 statistics) on each individual long-run elasticity. This table thus indicates which variables were used in order to obtain a cointegrating relationship, while Chi^2 statistics and corresponding p-values suggest which of the variables entailing the long-run relationship are not statistically significant. One can notice that in the case of Croatia, Bulgaria, the U.K., and Spain, house prices seem to form a relationship with GDP (which proxies both income and overall economic activity) and interest rates (which represent the financing conditions and the monetary policy stance). In Estonia, house prices also react to changes in the construction activity, while in Ireland and the Czech Republic they react both to changes in the construction activity and housing loans.

One can observe from Table 2 that although the GDP and interest rates are relevant for house price behavior in the long run, the GDP coefficient is statistically significant only in the case of Spain and the U.K. (1995 sample), while the interest rate is significant for all countries except Spain. Long-run elasticities of house prices with respect to interest rate changes have the expected sign, but vary considerably across countries (from 0.01 for the

Table 2 Long-run Elasticities of House Prices and Corresponding Zero Restrictions

Variable	House price		Constant		GDP		Construction		Housing loans		Interest rates (housing loans)	
	β	$\beta=0$ []	β	$\beta=0$ []	β	$\beta=0$ []	β	$\beta=0$ []	β	$\beta=0$ []	β	$\beta=0$ []
Bulgaria	1.0	4.35* [0.04]	-	-	0.591	0.244 [0.62]	-	-	-	-	-2.8	5.82* [0.015]
Croatia	1.0	11.01** [0.001]	2.93	10.21** [0.001]	0.037	0.038 [0.84]	-	-	-	-	-2.1	11.92** [0.001]
Czech Rep.	1.0	8.75** [0.003]	3.80	1.15 [0.28]	0.749	0.594 [0.44]	-0.24	0.28 [0.59]	-0.27	0.013 [0.91]	-0.09	8.93** [0.003]
Estonia	1.0	10.62** [0.001]	-	-	1.835	1.77 [0.18]	-0.39	0.17 [0.68]	-	-	-4.0	5.04* [0.03]
Ireland	1.0	18.7** [0.00]	-	-	0.781	0.05 [0.81]	-0.781	7.4** [0.006]	0.67	1.65 [0.19]	-1.1	4.62* [0.04]
Spain	1.0	5.41* [0.03]	1.027	0.0004 [0.98]	1.076	4.87* [0.03]	-	-	-	-	-3.2	0.167 [0.73]
U.K. (1995)	1.0	22.9** [0.00]	-11.5	12.83** [0.00]	2.97	16.1** [0.0001]	-	-	-	-	-2.9	4.97* [0.03]
U.K. (1969)	1.0	4.3* [0.04]	0.233	1.35 [0.24]	1.364	0.005 [0.94]	-	-	-	-	-0.1	15.2** [0.001]

Notes: **Significant at 1 percent level; *significant at 5 percent level; zero restriction on long-run elasticities is tested using the likelihood ratio test of restriction with Chi² statistics; numbers in brackets denote the p-values.
Source: Author's calculations.

Table 3 Adjustment Coefficients and Weak Exogeneity Tests

Variable	House price		GDP		Construction		Housing loans		Interest rates (housing loans)	
	α	$\alpha=0$ []	α	$\alpha=0$ []	α	$\alpha=0$ []	α	$\alpha=0$ []	α	$\alpha=0$ []
Country										
Bulgaria	-0.042	1.61 [0.20]	0.004	0.209 [0.65]	-	-	-	-	-17.0	8.71** [0.003]
Croatia	-0.377	6.36* [0.011]	0.100	4.17** [0.041]	-	-	-	-	-9.01	6.64** [0.01]
Czech Rep.	-0.087	5.7* [0.02]	-0.05	10.5** [0.001]	0.01	0.01 [0.91]	-0.01	0.002 [0.96]	-4.71	0.90 [0.34]
Estonia	-0.115	1.528 [0.21]	0.033	4.20* [0.04]	-0.04	0.405 [0.52]	-	-	-5.28	4.34* [0.04]
Ireland	0.0201	8.41** [0.003]	0.016	6.67** [0.009]	-0.01	0.22 [0.63]	0.026	19.6** [0.00]	0.090	0.06 [0.80]
Spain	0.0009	0.43 [0.50]	0.003	6.21* [0.012]	-	-	-	-	-0.75	11.8** [0.001]
U.K. (1995)	0.127	16.09** [0.0001]	0.041	45.98** [0.00]	-	-	-	-	-0.90	1.55 [0.21]
U.K. (1969)	-0.057	7.96** [0.005]	-0.04	28.4** [0.00]	-	-	-	-	-0.47	0.08 [0.77]

Notes: **Significant at 1 percent level; *significant at 5 percent level; zero restriction on adjustment coefficients is tested using the likelihood ratio test of restriction with Chi^2 statistics; numbers in brackets denote the p-values.
Source: Author's calculations.

Table 4 Error-correction Model: Summary of Estimation Results

Explanatory variables	Bulgaria	Croatia	Czech Republic	Estonia	Ireland	Spain	U.K. (1995)	U.K. (1969)
Error-correction term	0.45* (1) -0.46* (2)	-0.53* (4)	-0.09*(2)	0.10 (1)	-0.38** (1)	-0.03** (1)	0.16* (3)	-0.29** (3)
House price persistence	-0.42** (4)	-0.68** (1) -0.86** (2) -0.70** (3)	0.73** (1)	-0.42** (1) -0.28* (2)	-	0.58** (1) 0.36** (3)	0.55** (1) -0.35* (4)	-0.20*(2)
GDP	1.06* (1) 1.36* (4)	1.28** (1)	1.11* (3)	2.27** (1)	0.26* (2)	0.41* (1)	1.26* (1)	1.63** (1)
Interest rate	-1.71** (1)	-1.31* (2) 1.41** (3)	0.25* (4)	-	-0.4* (4)	-	-0.97*(4)	-0.30*(4)
Housing loans	0.48** (1)	0.47* (3)	-	0.79* (2)	-	-	-	-
Employment	-	5.09** (2)	-	-	-	-	-	1.12*(3)
Construction output	-	-0.81** (2)	-	-0.72** (3)	-0.22** (1)	-0.10** (1) -0.09** (2)	-	0.24*(1)
Adj. R ²	0.76	0.59	0.67	0.54	0.71	0.76	0.49	0.63
RSS	0.0033	0.018	0.0019	0.049	0.002	0.0006	0.0095	0.013
AR test	0.38 [0.82]	2.11 [0.12]	0.342 [0.79]	0.11 [0.97]	0.55 [0.70]	0.75 [0.56]	0.56 [0.69]	1.45 [0.25]
ARCH test	1.07 [0.39]	0.42 [0.79]	0.53 [0.66]	0.85 [0.50]	0.53 [0.74]	1.99 [0.12]	1.68 [0.17]	0.923 [0.35]
Normality test	1.72 [0.42]	0.67 [0.74]	4.04 [0.13]	0.93 [0.62]	0.73 [0.65]	3.01 [0.22]	0.23 [0.89]	0.267 [0.87]
RESET test	1.35 [0.25]	0.77 [0.39]	0.078 [0.78]	0.097 [0.76]	0.33 [0.57]	0.83 [0.37]	0.21 [0.65]	2.74 [0.11]

Notes: **Significant at 1 percent level; *Significant at 5 percent level; numbers in parentheses denote the time lag; numbers in brackets denote the p-value. Source: Author's calculations.

key similarities and differences between Eastern and Western European countries.

The results of this study suggest that both income and interest rates enter into a long-run cointegration relationship with house prices, thus supporting the findings of earlier papers written by Egert and Mihaljek (2007), Posedel and Vizek (2009), and Hlaváček and Komárek (2009). However, in the majority of cases interest rates cannot be excluded from the model, while income can. Thus, only interest rate changes explain house price behavior in the majority of the countries in the long run, while income changes are only relevant for two developed countries (Spain and the U.K.). The prevalence of financing conditions for determining the house price was not remarked in earlier analyses of house price determinants in transition countries, but was indicated as important in industrialized countries by Tsatsaronis and Zhu (2004) and Annett (2005).

The supply of new housing, proxied by the construction activity index, enters into a long-run relationship in the case of the Czech Republic, Estonia, and Ireland, but only in the Irish case it cannot be restricted to zero. Housing loans are statistically insignificant in those cases where they entered the cointegrating relationship. This finding suggests that, in the long run, financing conditions matter more for determining house prices than income developments. Comparing the results for the U.K. on a longer (1969) and shorter (1995) sample corroborates this conclusion. Namely, both income and interest rate elasticities in the 1969 model are much smaller in magnitude when compared to the 1995 model. This difference is particularly evident for the interest rate elasticity, which increased from 0.1 to 2.9. This may suggest that financial sector developments, in both Eastern and Western Europe, matter significantly for house price changes in the long run, and that their influence on house prices has increased over time.

Error-correction model estimates also suggest that income and interest rates significantly affect the behavior of house prices. Its estimates suggest that house prices in all countries except Estonia correct for deviations from

Appendix I

Description and Sources of Data

Country: **Bulgaria**

Data range: 1998:Q1–2009:Q2

House price	National Statistical Institute	Average market prices of used dwellings in Bulgaria, in EUR.
Gross domestic product	Eurostat	Gross domestic product, in million EUR, chain-linked volumes, reference year 2000 (at 2000 exchange rates).
Construction production index	Eurostat	Construction production index, 2005=100.
Number of employed persons	Eurostat	Total employment, national concept, in '000.
Housing loans	Bulgarian National Bank	Loans for house purchase, in million EUR.
Interest rate on housing loans	Bulgarian National Bank	Average interest rate on EUR loan for house purchase.
CPI deflator	International Financial Statistics	Calculated by using quarterly base index of consumer prices.

Note: All data for Bulgaria from domestic sources are originally denominated in domestic currency, but for the purpose of analysis are recalculated to euro values.

Country: **Croatia**

Data range: 1996:Q4–2009:Q2

House price	Real Estate Exchange Database (<i>Burza nekretnina</i>)*	Average sale price of all housing units (houses and apartments, new and used) in Croatia, in EUR.
Gross domestic product	Eurostat	Gross domestic product, in million EUR, chain-linked volumes, reference year 2000 (at 2000 exchange rates).
Construction production index	Croatian Bureau of Statistics	Volume of construction work undertaken by legal entities with 25 or more employees, 2000=100.
Number of employed persons	Croatian Bureau of Statistics	Total number of employed persons in legal entities, crafts, and free-lance activities, in '000.
Housing loans	Croatian National Bank	Housing loans series is available from July 1999; before July 1999 the series is compiled using growth rates of total loans to households, in million EUR.
Interest rate on housing loans	Croatian National Bank	Average annual interest rates on housing loans are available since January 2002; before 2002 average annual interest rate for long-term housing loans with currency clause.
CPI deflator	International Financial Statistics	Calculated by using quarterly base index of consumer prices.

*Notes: * Burza nekretnina is a commercial database containing all details on real estate sale transactions conducted by real estate agencies; all data for Croatia from domestic sources are originally denominated in domestic currency, but for the purpose of analysis are recalculated to euro values.*

Country: **Ireland**

Data range: 1995:Q1–2009:Q1

House price	Department of the Environment, Heritage and Local Government	Average price of new houses in Ireland, in EUR.
Gross domestic product	Central Statistics Office	Gross domestic product, in million EUR, chain-linked volumes, reference year 2000 (at 2000 exchange rates). The data for period 1995:Q1–1996:Q4 are compiled using quarterly growth rates of industrial production volume.
House completion index	Central Statistics Office	Calculated using the quarterly series of house completion number in all local authorities, 2000=100.
Number of employed persons	Central Statistics Office	Persons aged 15 years and over in employment, in '000.
Housing loans	Department of the Environment, Heritage and Local Government	Total housing loan payments, banks and building societies, in million EUR.
Interest rate on housing loans	Department of the Environment, Heritage and Local Government	Average annual building society mortgage interest rate.
CPI deflator	International Financial Statistics	Calculated by using quarterly base index of consumer prices, 2000=100.

Country: **Spain**

Data range: 1995:Q1–2009:Q2

House price	National Statistics Institute	Average price per square meter of new and used apartments for Spain, in EUR.
Gross domestic product	Eurostat	Gross domestic product, in million EUR, chain-linked volumes, reference year 2000 (at 2000 exchange rates).
Construction production index	Eurostat	Construction production index, 2005=100.
Number of employed persons	Eurostat	Total employment, national concept, in '000.
Housing loans	Bank of Spain	Total housing loans, in million EUR.
Interest rate on housing loans	Eurostat, Bank of Spain	For the period 1995:Q1–2003:Q1 average annual interest rate on housing loans for households; from 2003:Q2 onwards, average interest rate on housing loans over 5-year maturity, outstanding amount.
CPI deflator	International Financial Statistics	Calculated by using quarterly base index of consumer prices, 2000=100.

Appendix II

Estimation Results

Table A1 Johansen Cointegration: Bulgaria

Rank	Eigenvalue	Trace test	Max test	Trace test (T-nm)	Max test (T-nm)
0	-	40.00 [0.002]	22.74 [0.027]	30.77 [0.038]	17.49 [0.155]
1	0.441	17.26 [0.025]	13.91 [0.055]	13.27 [0.105]	10.70 [0.172]
2	0.300	3.34 [0.068]	3.34 [0.068]	2.57 [0.109]	2.57 [0.109]
3	0.082	-	-	-	-

Notes: *p*-values in brackets; VAR includes 3 lags. Lag length chosen according to SBIC. VAR residuals satisfy all diagnostic tests.

Source: Author's calculation.

Table A2 Johansen Cointegration: Croatia

Rank	Eigenvalue	Trace test	Max test	Trace test (T-nm)	Max test (T-nm)
0	-	41.54 [0.008]	25.46 [0.015]	39.00 [0.017]	23.90 [0.027]
1	0.405	16.08 [0.174]	11.07 [0.255]	15.09 [0.226]	10.39 [0.311]
2	0.202	5.01 [0.293]	5.01 [0.292]	4.70 [0.329]	4.70 [0.328]
3	0.097	-	-	-	-

Notes: *p*-values in brackets; VAR includes 1 lag and a restricted constant. Lag length chosen according to SBIC. VAR residuals satisfy all diagnostic tests except normality.

Source: Author's calculation.

Table A3 Johansen Cointegration: Czech Republic

Rank	Eigenvalue	Trace test	Max test	Trace test (T-nm)	Max test (T-nm)
0	-	102.6 [0.000]	43.52 [0.002]	77.01 [0.048]	32.64 [0.087]
1	0.66	59.16 [0.015]	30.25 [0.027]	44.37 [0.277]	22.68 [0.245]
2	0.53	28.91 [0.205]	14.24 [0.454]	21.68 [0.619]	10.68 [0.777]
3	0.299	14.68 [0.251]	10.57 [0.295]	11.01 [0.549]	7.93 [0.566]
4	0.2322	4.10 [0.409]	4.10 [0.408]	3.08 [0.575]	3.08 [0.574]
5	0.097	-	-	-	-

Notes: *p*-values in brackets; VAR includes 2 lags and a restricted constant. Lag length chosen according to SBIC. VAR residuals satisfy all diagnostic tests except normality.

Source: Author's calculation.

Rank	Eigenvalue	Trace test	Max test	Trace test (T-nm)	Max test (T-nm)
0	-	58.61 [0.003]	27.58 [0.047]	48.63 [0.040]	22.89 [0.183]
1	0.443	31.03 [0.036]	20.99 [0.051]	25.74 [0.140]	17.41 [0.158]
2	0.360	10.04 [0.283]	7.72 [0.417]	8.33 [0.438]	6.40 [0.569]
3	0.151	2.32 [0.127]	2.32 [0.127]	1.93 [0.165]	1.93 [0.165]
4	0.048	-	-	-	-

Notes: *p*-values in brackets; VAR includes 2 lags. Lag length chosen according to SBIC. VAR residuals satisfy all diagnostic tests except normality.
Source: Author's calculation.

Rank	Eigenvalue	Trace test	Max test	Trace test (T-nm)	Max test (T-nm)
0	-	135.24 [0.000]	63.20 [0.000]	110.19 [0.000]	51.50 [0.000]
1	0.689	72.03 [0.000]	42.40 [0.000]	58.69 [0.017]	34.55 [0.006]
2	0.544	29.63 [0.178]	14.40 [0.439]	24.14 [0.459]	11.74 [0.685]
3	0.234	15.22 [0.218]	9.54 [0.391]	12.40 [0.422]	7.77 [0.585]
4	0.161	5.69 [0.224]	5.69 [0.224]	4.63 [0.337]	4.63 [0.336]
5	0.099	-	-	-	-

Notes: *p*-values in brackets; VAR includes 2 lags and a restricted constant. Lag length chosen according to SBIC. VAR residuals satisfy all diagnostic tests.
Source: Author's calculation.

Variables	Long-run		Short-run		Joint restrictions Chi ² (5)= 1.11 [0.95]	
	β coefficients	St. errors	α coefficients	St. errors		
House price	1.00	0.00	0.054	0.00	$\beta=1$	$\alpha_{\text{house price}} = \alpha_{\text{GDP}}$
Constant	0.00	0.00	-	-	$\beta=0$	-
GDP	-0.781	0.00	0.054	0.0096	$\beta_{\text{GDP}} = -\beta_{\text{constr}}$	-
Construction	0.781	0.038	0.00	0.00	-	$\alpha=0$
Housing loans	-0.674	0.0384	0.077	0.0096	-	-
Interest rate on a housing loan	0.011	0.007	0.00	0.00	-	$\alpha=0$

Note: β coefficients are written in vector form.
Source: Author's calculation.

Rank	Eigenvalue	Trace test	Max test	Trace test (T-nm)	Max test (T-nm)
0	-	54.37 [0.000]	29.89 [0.002]	38.69 [0.019]	21.27 [0.068]
1	0.437	24.48 [0.011]	15.32 [0.060]	17.42 [0.118]	10.90 [0.268]
2	0.255	9.16 [0.050]	9.16 [0.050]	6.52 [0.159]	6.52 [0.159]
3	0.161	-	-	-	-

Notes: *p*-values in brackets; VAR includes 5 lags and a restricted constant. Lag length chosen according to SBIC. VAR residuals satisfy all diagnostic tests.
Source: Author's calculation.

Rank	Eigenvalue	Trace test	Max test	Trace test (T-nm)	Max test (T-nm)
0	-	71.93 [0.000]	59.71 [0.000]	68.08 [0.000]	56.51 [0.000]
1	0.655	12.23 [0.437]	7.22 [0.649]	11.57 [0.496]	6.83 [0.693]
2	0.120	5.01 [0.293]	5.01 [0.292]	4.74 [0.324]	4.74 [0.323]
3	0.085	-	-	-	-

Notes: *p*-values in brackets; VAR includes 2 lags and a restricted constant. Lag length chosen according to SBIC. VAR residuals satisfy all diagnostic tests.
Source: Author's calculation.

Rank	Eigenvalue	Trace test	Max test	Trace test (T-nm)	Max test (T-nm)
0	-	68.16 [0.000]	46.59 [0.000]	62.92 [0.000]	43.00 [0.000]
1	0.70	21.58 [0.031]	18.09 [0.020]	19.92 [0.054]	16.70 [0.075]
2	0.37	3.49 [0.505]	3.49 [0.504]	3.22 [0.550]	3.22 [0.549]
3	0.085	-	-	-	-

Notes: *p*-values in brackets; VAR includes 1 lag and a restricted constant. Lag length chosen according to SBIC. VAR residuals satisfy all diagnostic tests.
Source: Author's calculation.

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